ATTACHMENT 1

Survival of Juvenile Fall-Run Chinook Salmon through the San Joaquin River Delta, 2010–2015

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Running Head: Juvenile Salmon Survival through the San Joaquin River Delta

Abstract

Survival of juvenile fall-run Chinook Salmon *Oncorhynchus tshawytscha* through the San Joaquin River Delta of California, USA, has been low for most estimates since 2002, and has been consistently low since 2010. From 2010 through 2015, annual estimates of the probability of surviving through the Delta (from Mossdale to Chipps Island, approximately 92 rkm) ranged from 0

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to 0.05, based on acoustic-telemetry data from smolt-sized hatchery Chinook Salmon. River conditions were poor in most of these years; average daily river discharge into the Delta from the San Joaquin River was <40 m^3/s in four of the six study years. In the high flow year of 2011 (average daily river discharge = 278–308 m^3/s), the juvenile survival probability through the Delta was estimated at only 0.02 (SE < 0.01), suggesting increased flows alone may not resolve the low survival through the Delta. The low survival in this short portion of the life history makes achieving a minimal smolt-to-adult ratio (SAR) of ≥2% nearly impossible for this fish stock. Over half of the fish surviving through the Delta during six years of study were salvaged at the Central Valley Project's water export facility and transported for release just upstream of Chipps Island.

<A>Introduction

Historically, the Central Valley (CV) of California (USA) hosted one of the most diverse populations of Chinook Salmon *Oncorhynchus tshawytscha*, including four distinct runs, adults returning during every month of the year, and spawning occurring in every accessible stream (Yoshiyama et al. 1998). The winter and late-fall runs were restricted to the Sacramento River basin, while the fall and spring runs were present throughout both the Sacramento and the San Joaquin river basins (Yoshiyama et al. 1998). Both river basins drain into the California Delta, and eventually into the San Francisco Bay. The largest of these runs is the fall run, which forms the basis of the California and southern Oregon ocean salmon fishery (Williams 2006). The CV fall-run Chinook Salmon (FRCS) population consists predominantly of hatchery-reared fish from the Sacramento River basin (Williams 2006, Barnett-Johnson et al. 2007). However, the San Joaquin River basin has two FRCS hatcheries on the Merced River and Mokelumne River, and both basins produce naturally reared fish. Although naturally produced FRCS in the San Joaquin River basin have been restricted to the tributaries since the 1940s (Fisher 1994), there is currently an effort to return a self-sustaining population to the San Joaquin River main stem (www.restoresjr.net; accessed 7/6/17).

Central Valley FRCS have been listed as a "species of concern" by NOAA Fisheries (NOAA 2010), and in 2008 and 2009, low anticipated adult returns resulted in closure of the ocean fishery south of Cape Falcon, Oregon (NOAA 2008, 2009). Efforts to understand the causes of low survival of FRCS have included measuring juvenile survival through the California Delta, which forms the tidally influenced freshwater portion of the San Francisco estuary (Figure 1). Early coded-wire-tag (CWT) studies, 1994–2006, provided monitoring of Chinook Salmon survival through the Delta to Jersey Point for stocks originating in the San Joaquin basin (Brandes and McLain 2001, SJRGA 2007,

2013). Partly in response to low adult returns of FRCS in the mid-2000s, researchers switched to acoustic telemetry (AT) because of the smaller sample sizes required and the ability to provide more detailed spatial and temporal information on migration through the Delta. Acoustic-telemetry studies of juvenile hatchery-reared FRCS in the San Joaquin Delta were implemented starting in 2006 as part of the multiyear Vernalis Adaptive Management Plan (VAMP), and continued after the VAMP study ended in 2011 (SJRGA 2013). In this paper, we present survival results from six years of AT studies from 2010 through 2015, and discuss ramifications of the consistently low Delta passage survival.

<A>Methods

<B>Study area

The Sacramento–San Joaquin Delta is an area of nearly 3,000 square km located in the Central Valley of California. It extends from the City of Sacramento on the Sacramento River (SR), and the area near Mossdale Bridge on the San Joaquin River (SJR), downstream to the confluence of the SR and SJR at the entrance to Suisun Bay at rkm 64, measured from the Golden Gate Bridge (at the exit of the San Francisco Bay) (Figure 1). For the purpose of this paper, we use the term "Delta" to refer to the portion of the overall Sacramento–San Joaquin estuary that is dominated by the SJR as it approaches Suisun Bay from the east and south (Figure 1). The Delta is a complex network of natural rivers, natural or man-made cuts, islands, and levees, and contains some of California's most fertile agricultural land. The SJR skirts the majority of the Delta to the east. Old River (OR) originates (rkm 170) from the SJR downstream of Mossdale Bridge, and moves west and north near the western Delta edge until it reconnects with the SJR (rkm 122) upstream of the confluence with the SR. Middle River (MR) originates (rkm 158) from OR in the south and moves north until it connects with the SJR (rkm 126) just upstream of the confluence of SJR and OR (Figure 1).

The region of focus in this paper extends from just downstream of the Mossdale Bridge (*Mossdale*; rkm 174), located on the SJR approximately 3.8 rkm upstream of where OR leaves west from the SJR (*head of Old River*), to Chipps Island (rkm 77), which is legally considered the downstream boundary of the Delta and is located near the entrance to Suisun Bay (Figure 1). Within this study area are several routes that fish may take to get from Mossdale to Chipps Island. The simplest (approximately 92 km) is to remain in the SJR throughout the Delta, passing the City of Stockton, MacDonald and Medford islands, and Jersey Point. An alternative is to leave the SJR at the head of OR. Fish using the *Old River route* may either move through the interior Delta via OR and

MR until they rejoin the SJR just upstream of Jersey Point, or enter one of two *water export facilities* where Delta water is actively pumped for export to water users in central and southern California. The entrances to these facilities are located in the southwestern region of the Delta off of OR. The Central Valley Project (CVP) is located approximately 2 rkm south of the State Water Project (SWP), which is accessed via the Clifton Court Forebay (CCFB) reservoir. Fish that enter these facilities are captured and considered *salvaged*; salvaged fish are then transported by truck to the northwestern Delta, and released in the SJR or SR approximately 20 rkm upstream of Chipps Island. Fish that remain in the SJR past the head of OR (*San Joaquin River route*) may either remain in the SJR all the way to Chipps Island, or they may leave the SJR for the interior Delta at various points downstream, including Turner Cut, Columbia Cut, and the MR mouth. Once fish enter the interior Delta, they may move to Chipps Island either in-river (i.e., swimming through Delta waters), or by salvage and trucking from one of the export facilities. Survival was monitored through both the OR and SJR routes. Additionally, survival was monitored through the region (*Southern Delta*) that extended from Mossdale to the Turner Cut junction in the SJR route (37 rkm), and to the water export facilities or Highway 4 in the OR route (29 to 38 rkm).

<B>Tagging, fish health, and release methods

Juvenile FRCS used in these annual studies came from either the Merced River Fish Hatchery (2010–2013) or the Mokelumne River Fish Hatchery (2014, 2015) (Table 1). All fish were surgically implanted with microacoustic tags. The 2010 and 2011 studies used the Hydroacoustic Technology, Inc. (HTI) Model 795 microacoustic tag (diameter = 6.7 mm, length = 16.3-16.4 mm, average weight in air = 0.65 g); each HTI tag transmitted a pulse every 4–11 seconds, depending on the unique settings of the tag. The 2012 and 2013 studies used the VEMCO V5-180 kHz tag (width = 5.6 mm, length = 12.7 mm, average weight in air = 0.66–0.67 g), and the 2014 and 2015 studies used the VEMCO V4-180 kHz tag (width = 5.7 mm, length = 11.0 mm, averaged weight in air = 0.41-0.42 g). The VEMCO tags transmitted the tag identification codes every 25-35 seconds.

In each study year, between two and seven groups of 133–647 juvenile Chinook Salmon were tagged and released in April, May, or June; total sample sizes each year ranged from 950 to 1,918 (Table 1). The tagging team included three to four surgeons each year; all surgeons received either new-surgeon training or refresher training annually. The average fork length at tagging (FL) ranged between 98 mm and 115 mm across years, and was highest for 2012 and 2013, and lowest for 2014 and 2015 (Table 1). Tag burden (i.e., the ratio of tag weight to body weight) averaged

between 3.7% and 4.2% each year (Table 1). Tag burdens ≥ 5% body weight occurred in 4% to 11% of the fish released in the 2010–2012 studies, and 0% to 1.3% of the fish released in the 2013–2015 studies. The maximum tag burden (6.5%) was observed in 2011 (Table 1); no more than 2% of fish in any year had tag burden > 5.4%.

Tagging was performed at the Tracy Fish Collection Facility in 2010–2012, located at the CVP approximately 40 km by truck from the primary release site (Durham Ferry), at Merced River Hatchery in 2013, and at Mokelumne River Hatchery in 2014 and 2015. The Merced River Hatchery and Mokelumne River Hatchery are located on the Merced and Mokelumne rivers approximately 100 km and 80 km from Durham Ferry, respectively. In 2010–2013, fish were anesthetized in a 70-mg·L^{-1} tricaine methanesulfonate (MS-222) solution, buffered with sodium bicarbonate; in 2014 and 2015, a 0.03% AQUI-S 20E solution was used as an anesthetic. Tagging procedures followed those outlined in Adams et al. (1998) and Martinelli et al. (1998) in 2010–2012, and were updated to the standard operating procedures outlined in Liedtke et al. (2012) in 2013–2015. After surgery, fish were transported to the release site in trucks outfitted with tanks designed for dissolved oxygen control and structural stability during transport. A maximum temperature differential between the transport tank and the river water of 5° C was targeted by adding non-chlorinated ice to transport tanks or tempering fish after arrival at the release site (Wedemeyer 1996, Iwama et al. 1997).

In 2011–2014, all fish were released in the San Joaquin River at Durham Ferry (DF), located approximately 21 rkm upstream of Mossdale, and 113 rkm from Chipps Island (Figure 1). The release site was located upstream of the study area boundary (Mossdale) to allow fish to distribute naturally in the river, recover from handling and release, and express any handling effects before entering the study area. In 2010, fish were released at DF and paired with supplemental releases in upper OR and in the SJR near Stockton (STK) (Table 2). In 2015, the April release group was released at DF, and the May release group was split between DF and a release site in the SJR near Medford Island (MF; 50 rkm upstream of Chipps Island).

At the release site, fish were held in the river for approximately 24 hours in 19-L perforated garbage cans to allow them to acclimate to the river water and recover from surgery. The exception was in 2015, when fish released at MF were held at the hatchery 24 hours after surgery, rather than at the release site. A total of 4 tagged Chinook Salmon died during transport or during holding in the river before release in 2010–2014 (0.06% of those transported). In 2015, 2 fish (0.15%) died during transport, and 12 (0.92%) died during holding before release at DF. Most of those mortalities in 2015 occurred in late April and early May, when river temperatures were especially high (21.9° C to 24.7° C at beginning of the holding period). Pre-release mortalities were removed from the release

groups and from data analysis. An exception was in 2015, when the tag could not be recovered from five of the pre-release mortalities; however, because the study area began approximately 21 rkm downstream of the release site, those unknown mortalities did not bias Delta survival estimates.

Each year, between 119 and 227 fish were tagged with inactive tags (*dummy tags*) and transported to the release site using identical procedures as the active-tagged fish, held for 48 hours at the release site, and then examined for mortality and condition. In 2015, dummy-tagged fish associated with the MF release were held for 24 hours at the tagging facility before being transported and assessed at the release site. Of the total number of dummy-tagged fish transported and held, 30 to 90 *control* fish were examined each year for pathogens, physiological condition, and surgical complications (i.e., loose sutures, open or partially closed incisions, and minor to severe inflammation) in a fish health study performed by the United States Fish and Wildlife Service California/Nevada Fish Health Center; 60 to 154 additional untagged control fish were examined for fish health at the hatchery in 2010 and 2011. The fish health assessments occurred after fish were held 29–32 days in 2011, after 72 hours in 2015, and immediately after the 48-hour holding period in all other years. In addition, tag retention studies in 2012–2015 held between 39 and 75 dummy-tagged fish for 5 to 33 days for assessment of long-term mortality and tag retention. Tag retention fish were examined for mortality and tag loss at days 5 (in 2012) and 30–33 (2012, 2014, 2015). In 2014 and 2015, 75 untagged fish were also held for mortality controls and examined at days 31–33. Tag retention fish and untagged fish were held in 2013 as well, but faulty mortality reporting made results unusable.

For each study year, in-tank tag-life studies were performed to measure the failure rate of the tags used in the study. Between 50 and 102 tags were sampled across manufacturing lots each year using either systematic or stratified random sampling. Tag-life studies typically began several weeks after tagged fish were released to the river. Tank water temperature was maintained with chillers in 2010 (average = 17° C) and with river water pumped from Old River in 2011–2015, in order to maintain temperatures similar to the Delta environment when tagged fish were migrating.

<B>Acoustic hydrophone and receiver placement

Between 38 and 166 acoustic hydrophones and their associated receivers were deployed at 22 to 43 locations throughout the SJR and Delta for the 2010–2015 studies. Each hydrophone was connected to a receiver or data logger (*receiver*) that either stored data for download or connected remotely to online data storage. HTI technology (receiver models 290 ATR, 291 ATR; data logger models 295-X, 295-I; hydrophone model 590; operating frequency 307 kHz) was used in 2010 and

2011. VEMCO technology (receiver models VR2W, VR2C, and HR1; 180 kHz; hydrophone was embedded in the receiver) was used in 2012–2015. Each receiver location was composed of 1 to 18 hydrophones to achieve complete coverage of the river channel. Hydrophone spacing across the river channel was based on range tests; at Chipps Island, HTI hydrophone spacing was approximately 150 m to 300 m, and VEMCO receiver spacing was approximately 100 m to 150 m.

Receiver locations throughout the Delta were determined by the possible routes of juvenile passage and the requirements of the multistate release-recapture model to distinguish and estimate movement, survival, and detection processes, described below. Although the technology changed from HTI to VEMCO in 2012, and additional receivers were installed in new locations in later years, the locations of the key receivers remained constant (Figure 1, Table 2). At a minimum, to estimate through-Delta survival from Mossdale (MOS) to Chipps Island (CHP) required receivers at Mossdale and a dual line of receivers (*dual array*) at Chipps Island. Additional receiver locations provided estimation of route selection, route-specific survival, and survival in key river reaches (e.g., past the City of Stockton). Dual arrays were placed in both branches downstream of key river distributary points (*junctions*), in particular the head of OR (SJL, ORE) and Turner Cut (MAC, TRN) off the SJR (Figure 1, Table 2). Receivers were also installed at the trash racks and in the holding tank at the CVP water export facility, and at the entrance to the CCFB outside the SWP. The Chipps Island receivers were located approximately 20 rkm downstream of the post-salvage release locations for fish that were recovered and trucked from the water export facilities, ensuring that all surviving migrants were required to pass the CHP receivers. Starting in 2011, receivers were placed in the SJR at Jersey Point (JPT), located 26 rkm upstream of Chipps Island; Jersey Point had been used as the downstream survival point in 20 years of CWT studies (Brandes and McLain 2001, SJRGA 2013). In 2014 and 2015, receivers were installed at Benicia Bridge (BBR), 19 rkm downstream of Chipps Island, to provide better estimates of detection probabilities at Chipps Island (Figure 1, Table 2).

<B>Statistical methods

The raw detection data were processed into detection events for each tag by the U.S. Geological Survey (USGS) lab in Cook, WA, for the 2010 and 2011 studies, and by the USGS lab in Sacramento, CA, for the 2012–2015 studies. The processed detection event data were transferred to the University of Washington, where the data were further processed into chronological detection histories identifying the receivers and dates where each tag was detected. Although the study fish were expected to be migrating and therefore to be moving consistently in a downstream

(seaward) direction, the tidal nature of the Delta environment means that migrating fish may move upstream temporarily on reverse flows. If such flows expose them to river junctions multiple times, their final route selection may differ from their initial selection at the junction (Perry et al. 2010). Thus, detection histories used the final pass of the tag past a detection site or junction, to best represent fish fate.

The possibility of a predatory fish eating a tagged study fish and then passing a receiver with the still active acoustic tag in its gut raised the potential for biased survival estimates. Detection data were passed through a *predator filter* to identify and remove likely predator detections. The predator filter was based on assumed behavioral differences between migrating Chinook Salmon smolts and predators such as Striped Bass *Morone saxatilis*, including differences in residence time in the vicinity of a receiver, travel rate between receivers, and movements against river flow. More information on the predator filter can be found in Buchanan et al. (2013, 2015, 2016) and SJRGA (2011, 2013).

The filtered detection history data were analyzed using a multinomial, multistate release–recapture model to estimate the probabilities of detection (*P*), reach-specific survival (*S*), and route selection (ψ; i.e., "route entrainment") (Buchanan and Skalski 2010, Perry et al. 2010, Buchanan et al. 2013). Different model states were used to represent the different routes through the Delta. Smolt survival was estimated for various regions in the Delta, including a) through-Delta survival (i.e., MOS to CHP), and b) survival through the Southern Delta (i.e., MOS to MAC/TRN in the SJR route, and MOS to CVP/SWP/OR4/MR4 in the OR route (Figure 1, Table 2). The multistate release–recapture model accounts for imperfect detection probabilities (i.e., efficiencies) in estimating survival. An example of the 2010 model can be found in Buchanan et al. (2013), and a schematic of the model common to all study years (DF releases) is presented in Figure 2. Pope (2014) includes the likelihood equation for the 2011 study year. For MF releases, survival downstream to Chipps Island was estimated with the single-release Cormack–Jolly–Seber model (Skalski et al. 1998).

For the 2010 study year, the multistate model was fit separately for each of seven release groups, and averages of parameter estimates weighted by release size were reported. Sparse detections at downstream sites in the 2011–2015 study years required pooling the data from individual releases in those years for fitting the model. The multistate models were fit to the data for each year using maximum likelihood estimation in the software Program USER (Lady and Skalski 2009). On occasion, the full model had to be simplified to account for sparse data through certain routes, resulting in loss of some route-specific information but not affecting the estimate of overall through-Delta survival. For some study years, only 0 or 1 tag was detected at CHP, which prevented

estimation of survival to Chipps Island separately from the detection probability. These cases were noted in the results, and the survival estimate was reported under the assumption of 100% detection probability. The 95% upper bound on survival to Chipps Island in these cases was estimated using a binomial error structure (Louis 1981) and an assumed travel time of 7 days.

Each year, potential surgeon effects on survival of tagged fish were assessed by testing for persistent differences between surgeons in survival through multiple reaches, using the nonparametric Kruskal–Wallis test (Sokal and Rohlf 1995). In the event that a surgeon was observed to have consistently lower survival than the rest of the surgical team, the release-recapture model was refit to the data without that surgeon's tags.

Survival estimates in the SJR route and OR route were compared using a two-sized Z-test on the log scale and significance level set at $\alpha = 0.05$. Survival estimates were tested for heterogeneity among years with an F-test (Skalski et al. 2014). The hypothesis that survival was higher in the Southern Delta (i.e., through the upstream reaches of the Delta) than through the lower (i.e., downstream) reaches of the Delta was tested by comparing the estimates of through-Delta survival to the square of Southern Delta survival: $\delta =$ (survival through Southern Delta^2)/(through-Delta survival). If Southern Delta survival is comparable to survival in the downstream reaches, then the ratio δ should be approximately 1. A one-sample t-test was used to compare the ratio δ to 1 on the log scale. Only years with tag detections at Chipps Island were included for the regional comparison.

Tag life and travel time.—Tag life was measured as the time between tag activation and failure time in the in-tank studies. In some cases, malfunctioning hydrophones in the tag-life studies required right-censoring the failure-time data. Observed tag survival was modeled separately each year using the 4-parameter vitality curve (Li and Anderson 2009). Within each study year, possible stratification of tag survival by activation date was assessed using the Akaike information criterion (AIC; Burnham and Anderson 2002), with the exception of the April tag-life study from 2014; homogeneity (i.e., no stratification) of tag survival was concluded in all years except 2014. In 2014, the earliest (i.e., mid-April) release group and April tag-life study both suffered from a manufacturing defect that turned the tags off prematurely; the defect was corrected for later release groups, resulting in a separate tag-survival model for the mid-April release for that year.

The fitted tag-survival models were used to adjust the estimated fish survival probabilities for tag failure using methods adapted from Townsend et al. (2006). In this study, travel time and the probability of tag survival to Chipps Island were estimated separately for the different routes (e.g., San Joaquin route and Old River route). Standard errors of the tag-life-adjusted fish survival and

transition probabilities were estimated using the inverse Hessian matrix of the fitted joint fish-tag survival model. The additional uncertainty introduced by variability in tag survival was not incorporated into the estimated standard errors of the survival estimates. In previous studies, however, variability in tag-life parameters was observed to contribute little to the overall uncertainty in the fish survival estimates (Townsend et al. 2006); thus, the resulting bias in the standard errors was expected to be small. Because of the high rate of premature tag failure experienced by the mid-April release group in 2014, no attempt was made to adjust the survival estimates for tag failure for that release group. Thus, estimates from the 2014 mid-April release group represent minimum fish survival (Holbrook et al. 2009).

Results

Delta conditions

Delta inflow from the SJR is measured at the Vernalis river-gaging station, located approximately 3 rkm upstream of the DF release site. River discharge (*flow*) at this station was considerably higher in 2011 than in the other years. Average daily flows at Vernalis during 2011 ranged from 278–308 m^3/s over the course of the study, whereas average daily flows for the other study years ranged from 11 m^3/s in 2015 to 161 m^3/s in 2010. Daily total water export rates from the Delta (i.e., from CVP, SWP) varied throughout the season, especially in 2011. The average daily export rate during the release periods ranged from 42 m^3/s in 2014 to 277 m^3/s in 2011. Mean daily water temperature in the SJR near the City of Lathrop (near the head of OR) varied between years (ANOVA; P = 0.0155) and tended to increase throughout each season. Average daily water temperature during the release periods ranged from 15.1° C in 2010 and 2011, to 22.2° C in 2015; the maximum temperature observed at the release site was 24.7° C at Durham Ferry in 2015. The temperature differential between salmon transport tank and river water was <5° C for 96% of transport trips of tagged fish to the release site (maximum = 6.7° C).

Fish health and Tag Retention

The 24–72 h mortality rate of dummy-tagged fish ranged from 0% to 2% in all study years. Fish condition after tagging was generally good; however, examination of control fish in the fish health studies found surgical complications (e.g., loose sutures) in some years. Incidence of such complications ranged from 0% to 10% per year, except in 2012 (18%). High rates of *Aeromonas-*

Pseudomonas infection were found in some years (20% in 2015, and 37% in 2012), but may have been due to environmental contamination during sampling (Nichols 2015). Health assessments for control fish in 2010–2013 consistently found evidence of the myxozoan parasite *Tetracapsuloides bryosalmonae*, the causative agent of proliferative kidney disease (PKD). Clinical incidence of PKD in control fish ranged up to 93% (2012); no PKD was detected in sampled fish from 2014 and 2015. For more details on fish health results, see SJRGA (2011, 2013); Foott (2012); Nichols (2014, 2015); Buchanan et al. (2015, 2016).

Tag retention studies found no tag loss within 30–33 days except in 2015, when 1 of 75 tags (1.3%) was found expelled upon examination on day 31. The mortality rate among dummy-tagged fish used in the tag retention studies and held 30–33 days in 2014 and 2015 was 0% to 2.4%, and similar mortality rates were observed among untagged control fish. In 2012, 3 of 39 (7.7%) dummy-tagged fish died by day 5; no other dummy-tagged fish died by the study's end on day 30, and no untagged fish were available for comparison in 2012.

<B>Tag life and travel time

Mean tag life was approximately 12 days in the April 2014 tag-life study, which reflected a manufacturing defect. For all other tag-life studies, mean tag life varied from 27 days in 2010 to approximately 50 days for both the 2013 study and the May 2014 tag-life study (Figure 3).

Median travel time from Mossdale to Chipps Island was approximately 3 to 4 days in 2010, 2011, and 2013, and 5.2 days in 2012 (Table 3). The single tag detected at Chipps Island in 2014 was detected there 4.9 days after detection at Mossdale, but came from the faulty tag group and may not represent average travel time of the group. No tags passing Mossdale in 2015 were detected at Chipps Island. Both the shortest (1.1 days) and the longest (12.4 days) travel times through the study area to Chipps Island occurred in 2011. Travel time through the Delta (i.e., Mossdale to Chipps Island) was significantly longer on average in 2012 than in the other three years with estimates (t_{70} = 2.937, P = 0.0045). Median travel time from Mossdale through the Southern Delta to the Turner Cut junction (i.e., to the TRN or MAC receivers) ranged from 1.3 days in 2014 (3 fish) to 3.7 days in 2013 (2 fish) (Table 3). Travel times from Mossdale through the Southern Delta to either the water export facilities (CVP, SWP) or the Highway 4 receivers (OR4, MR4) tended to be slightly shorter, with median travel times ranging from 0.8 days in 2011 to 1.9 days in 2012 (4 fish) and 2013 (Table 3). Tags from the 2015 MF release were detected at Chipps Island 2.1 to 8.9 days after release (median = 3.7 days; Table 3).

Survival estimates

Annual estimates of the total probability of surviving from Mossdale to Chipps Island (*through-Delta survival*) based on acoustic-telemetry data were all ≤0.05 (SE ≤ 0.01) for the six years of study (Table 4); there was no significant difference in survival between years ($F_{4,\infty}$ = 1.668, P = 0.1542). Considering the length of the primary SJR route through the Delta, 92 km, a total survival probability of 0.05 translates to a survival probability of 0.97 per km (i.e., 0.03 probability of mortality per km). Nearly half (7 of 17) of the release groups yielded through-Delta survival estimates ≤ 0.01, although two 2010 release groups had estimates of 0.10 (SE = 0.03) (Figure 4). During the drought years of 2014 and 2015, only one fish was detected at Chipps Island out of 2,719 released at Mossdale; that single fish came from the April 2014 release group that had defective tags, and represents the joint probability of fish and tag survival and detection. Under the assumption of 100% detection probability at Chipps Island, survival from Mossdale to Chipps Island was 0 for fish released with non-defective tags in 2014 and 2015. Also assuming a binomial error structure, the 95% upper bound on survival was 0.01 in 2014, and 0.13 in 2015; the relatively high upper bound in 2015 reflects the low survival from the DF release site to Mossdale that year (0.03; Table 5). In the extreme drought year of 2015, survival from the MF release site to Chipps Island was estimated at 0.08 (SE = 0.01); only one fish released at DF was detected as far downstream as MF that year. No persistent surgeon effects were detected through multiple reaches in any year ($P \geq$ 0.3679 each year).

Of the acoustic tags released at DF and detected at CHP since 2010, the majority of the fish passed through the CVP *en route* to Chipps Island; the exception was in 2012, when a temporary rock barrier blocked most access to OR and the direct route to the CVP was closed (Table 4). The barrier was also installed at the head of OR in 2014 and 2015, and the large majority of fish used the SJR route in those years (Table 5). In years without the rock barrier, the probability of selecting the SJR route ranged from 0.23 (SE = 0.02) in 2014, to 0.58 (SE = 0.01) in 2011 (Table 5). Survival from Mossdale to Chipps Island was low through both the SJR route and the OR route in all years. In the two years in which there was a statistically significant difference ($P \leq 0.0267$) in route-specific survival, the OR route had the higher survival when combined across release groups (Table 5). When compared on the scale of the individual release groups, only three releases showed survival differences between routes: the OR route had the higher survival for the two June releases in 2011, and the SJR route had the higher survival for the late April release in 2010 (SJGRA 2011, 2013). Estimated survival through the Southern Delta (i.e., through the upstream region of the Delta) tended to be considerably higher than through-Delta survival (Table 4). Survival was also higher in

the Southern Delta than in the lower (i.e., downstream) reaches of the Delta (t_3 = 3.670, P = 0.0350). Nevertheless, even the upstream region of the Delta had low survival in recent years. Estimated survival to the Turner Cut junction was only 0.02 (SE = 0.01) in 2013, 0.01 (SE ≤ 0.01) in 2014, and 0.05 (SE = 0.05) in 2015, compared to 0.24 to 0.48 (SE = 0.02) in 2010-2012 (Table 4); the annual differences were highly significant ($F_{5,\infty}$ = 58.237, P < 0.0001).

<A>Discussion

The annual through-Delta survival estimates from 2010–2015 obtained from these acoustic-tag studies were ≤0.05, and some were 0; release-level estimates were ≤0.10. These acoustic-tag survival estimates continue a pattern of declining survival observed in CWT studies dating back to 2002 (Figure 4). However, low survival was observed in earlier years, as well (e.g., 1994; Figure 4). Obvious questions arise in response to these low survival estimates. How do these levels of survival compare to salmonid survival through similar environments in other river systems? What are the possible causes and population effects of low survival? How representative and reliable are the survival estimates, and what are the implications for managers?

Direct comparison of these survival results to other river systems is challenging because of structural differences between the Delta environment and other riverine systems. However, comparisons can be made using survival estimates scaled by migration distance and translated to the length of the Delta, i.e., approximately 92 rkm along the SJR from Mossdale to Chipps Island (Buchanan et al. 2013). Many acoustic-telemetry studies have estimated survival of yearling Chinook Salmon in the lower river and estuary of the Columbia River, reviewed in Dietrich et al. (2016): scaled to the length of the Delta, the Columbia River survival probability estimates averaged 0.84, and ranged from 0.23 to 1.0 (see Dietrich et al. 2016 for data). Thus, the studies of yearling Chinook Salmon in the Columbia River show considerably higher survival through the lower river and estuary than is observed for subyearling fall-run Chinook Salmon (FRCS) through the Delta. For subyearling FRCS from the Columbia River basin, lower river and estuary survival estimates are available from 2002 and 2003 (Clemens et al. 2009) and from 2009 and 2010 (McMichael et al. 2010, 2011; Harnish et al. 2012); translated to the length of the Delta, the Columbia River subyearling FRCS estimates ranged from 0.61 to 0.88. Welch et al. (2008) reported survival of out-migrating yearling Chinook Salmon from 2004 to 2006 through 330 to 395 km of the Thompson–Fraser River system and estuary which, when scaled to the length of the Delta, ranged from 0.37 to 0.74. Thus, there is evidence that

survival of juvenile Chinook Salmon into and through estuaries from two other large river systems on the West Coast of North America have considerably higher survival rates than FRCS from the SJR system, despite the fact that five Chinook Salmon populations in the Columbia River basin have warranted listing as endangered under the federal Endangered Species Act (50 CFR § 223-224).

In the Columbia River basin, a minimum smolt–adult return ratio (SAR) of 2% (0.02) has been recommended for population sustainability (NPCC 2014). The release-specific Delta survival estimates for the SJR FRCS had a maximum of 0.10 and averaged approximately 0.025 (Figure 4). If SAR ≥ 0.02 is required for population persistence, then a minimum survival probability of 0.02/0.10 = 0.2 is required through the remainder of the life history until adult return. Using a low-end Delta juvenile survival value of 0.025, SAR of 0.02 requires post-Delta survival of 0.80. These calculations assume juvenile survival from the tributaries to the Delta is 1.0, which is not the case (Brandes and McLain 2001, Zeug et al. 2014). Additionally, survival through the bays has been found to be lower than survival through the Delta itself for late-fall-run Chinook Salmon (Michel et al. 2015), and Lindley et al. (2009) concluded that ocean conditions contributed heavily to the fall-run salmon fishery collapse in 2007 and 2008. Thus, Delta survival as low as 0.025 to 0.10 is likely not being compensated by higher survival in other life stages. At current Delta survival rates, the SJR component of the CV FRCS population may not persist.

The potential for low Delta survival of SJR FRCS to affect the persistence of the overall CV FRCS population is also a concern. There is little or no genetic distinction among naturally spawning populations of FRCS in the CV, or among the individuals spawned at different hatcheries (Williamson and May 2005, Lindley et al. 2009). The common hatchery practice of trucking juveniles around the Delta may contribute to adult straying, and eggs are sometimes moved from one hatchery to another between basins (Williams 2006, 2012). Furthermore, most existing estimates of Delta survival of SR FRCS are considerably higher than those for SJR FRCS: estimates of SR FRCS survival from Freeport (on the SR) to Benicia Bridge have ranged from 0.26 to 0.39 in 2012 to 2014 and 2016, although an estimate as low as 0.05 was observed in 2014 (A. Ammann, NOAA Fisheries; G. Singer, UC Davis; S. Zeug, Cramer Fish Sciences; personal communication). These observations suggest that the SJR basin may be a sink for the SR component of the overall CV population, rather than a self-sustaining subpopulation (e.g., Johnson et al. 2012). If so, then persistently low survival of the smolt-migrant component of the SJR population puts further strain on the CV population as a whole, and reduces total escapement and harvest.

The reasons behind the low Delta survival of SJR FRCS are varied and speculative. Historically, the population decline of Chinook Salmon from the mid-1800s was caused by overfishing, mining, damming, and water diversions (Yoshiyama et al. 1998). Since then, the Delta environment has been heavily modified from a combination of saltwater, brackish, and freshwater marshes to a complex system of river channels maintained by levees that protect agricultural, industrial, and residential land (Nichols et al. 1986). Additionally, a large proportion of the fresh water entering the Delta is extracted for municipal and agricultural use. A multiyear drought likely contributed to the estimate of 0 survival in 2014 and the high mortality before even reaching the Delta in 2015 (Table 5). Survival estimates from Durham Ferry to Mossdale varied significantly between years ($F_{5,\infty}$ = 708.563, P < 0.0001), and the point estimates for this reach declined for all years of the study except one (Table 5), consistent with the expected drought effects. The prospects of climate change makes such extreme drought events more likely in the future (Cvijanovic et al. 2017).

Nevertheless, high river flows alone do not guarantee high survival (e.g., Romer et al. 2013). In particular, 2011 was a wet year, yet total through-Delta survival was low (0.02). The 2011 study fish were released in mid-May through mid-June that year, which coincided with captures of wild Chinook Salmon in the Mossdale trawl (SJRGA 2013), but also occurred just after the end of peak river flow at Vernalis; thus, it is possible that the study fish in 2011 missed the period of primary benefit of high flows for Delta survival. It is notable, however, that survival through the upstream reaches of the Delta was higher in 2011 (e.g., 0.48 from MOS to the Turner Cut junction) than in other years, as expected for a high flow year, whereas survival through the downstream reaches of the Delta was ≤0.06 (e.g., approximately 0.05 probability of mortality per km from the Turner Cut junction to Chipps Island). This pattern of higher mortality in the downstream vs upstream Delta reaches was also observed for late-fall-run Chinook Salmon from the SR in 2011 (Michel et al. 2015), and suggests spatial variability in mortality factors within the Delta. This possibility is supported by the observation that the majority of tagged SJR FRCS detected at CHP when all routes were available (i.e., no rock barrier at the head of Old River) came through salvage at the CVP rather than migrating entirely through Delta waters, because it is the downstream reaches of the Delta that salvaged fish avoid.

Fish condition may also account for some of the results observed in these studies. In particular, the high incidence of PKD observed in the Merced River Hatchery fish used in 2010–2013 may have contributed to high mortality in those years. PKD is a progressive and potentially fatal disease that progresses faster at higher water temperatures (Ferguson 1981), and is common in fish

from the Merced River Fish Hatchery (Foott et al. 2007) and also prevalent among the natural-spawning population (Nichols and Foott 2002). However, no PKD was observed in the study fish from the Mokelumne River Hatchery in the drought years of 2014–2015, when survival was particularly low.

The observed decline in salmon survival coincides with a well-documented decline in populations of many Delta organisms (Sommer et al. 2007). Referred to as the Pelagic Organism Decline (POD), this phenomenon indicates an ecosystem-wide shift in the ecological community of the Delta. Non-native species such as Largemouth Bass *Micropterus salmoides*, the aquatic weed *Egeria densa*, and the overbite clam *Corbula amurensis* have become well-established in the Delta, and have altered the food web (Kimmerer et al. 1994, Sommer et al. 2007, Healey et al. 2008). Striped Bass and Largemouth Bass are known predators of juvenile salmonids and also support a popular sport fishery in the Delta (Nobriga and Feyrer 2007, Cavallo et al 2013). In the 2010-2015 studies, the predator filter identified a minimum of 20% to 64% of the tagged FRCS detected between Mossdale and Chipps Island as being predated upon. Because the predator filter identifies only those predation events that were followed by movement past an acoustic receiver, the actual predation rate within this region was likely even higher. The hypothesis that faster moving fish have reduced exposure time to predators and consequently higher survival (e.g., Anderson et al. 2005) was not supported here on the scale of the entire Delta, where travel time varied between years (longest in 2012) but total Delta survival did not (Table 3, 4); further investigation of a predator exposure or travel time hypothesis is warranted on smaller spatial scales.

The extent to which the AT study results represent the SJR FRCS population depends on the composition of the study fish, release timing, and fish condition. The fish used in the AT studies were all smolt-sized subyearlings reared at state-run hatcheries on the Merced or Mokelumne rivers, tributaries to the SJR. They were expected to pass quickly through the Delta to San Francisco Bay and the near ocean, and return to the CV to spawn as adults approximately 2.5 years later. The majority of salmon in the CV are hatchery-reared (Barnett-Johnson et al. 2007), but fish from the state-run hatcheries are sometimes trucked around the Delta as juveniles and thus avoid within-Delta mortality (Miller et al. 2010). The natural-spawned population from the San Joaquin basin is not trucked, and includes fish that migrate as smolt-sized fish, as well as those that migrate from the tributaries to the SJR or Delta as either fry- or parr-sized fish (Miller et al. 2010). Recent chemical analysis of otoliths from returning adult wild FRCS from the Stanislaus River in the SJR basin suggest that fish that exit the Stanislaus as parr (i.e., rear in the lower SJR or Delta) sometimes have higher survival to adult return than fish that exit the Stanislaus as smolts, which are expected to be better

represented by the AT study fish (Sturrock et al. 2015). However, trawl sampling at Mossdale concurrent with the AT studies in 2010 and 2011 found Chinook Salmon of comparable length to our study fish, suggesting that our studies effectively represented a detectable component of run-of-river fish in timing and fish size (SJRGA 2011, 2013). Thus, the low survival estimates observed in the AT studies may be considered to represent the Delta survival of the smolt-sized migrant component of the natural-spawned population, to the extent to which hatchery fish may represent natural fish. Introgression of genes from the hatchery population into the natural population may limit the actual differences in survival between the wild and hatchery populations, but there remain questions of surrogacy assumptions in applying results from hatchery fish to the wild population (Murphy et al. 2011). In particular, hatchery fish have been found to have different survival estimates than naturally produced fish by a number of authors (e.g., Berejikian et al. 1999, Buchanan et al. 2010). Even allowing for differences between study fish and the wild population, the low survival observed for the hatchery-reared release groups suggests that Delta conditions are poor, and that a sizeable component of the natural-spawned population from the SJR basin may also experience low Delta survival. A loss of this population component would contribute to the loss of diversity and resilience overall in CV FRCS, and put the population and ocean fisheries at added risk of collapse (Lindley et al. 2009, Carlson and Satterthwaite 2011).

The reliability of the low survival estimates observed here depends on detection probabilities (efficiencies) at Chipps Island, the predator filter, and tagging and handling effects. These survival estimates were generated using a release-recapture model that separates survival from detection processes; in particular, the dual receiver array at Chipps Island, either alone or combined with the Benicia Bridge receivers (if present), provided the data structure necessary to estimate the detection probability at that site. Thus, the efficiency of the detection process does not confound the survival probability estimates. Detection probabilities at Chipps Island were estimated to be high (>0.90) for all years with estimates (Table 4). The lack of detections in 2014 prevented estimation of the detection probability for that year; however, the very low survival (0.01) estimated to the Turner Cut junction in 2014 suggests that the lack of Chipps Island detections was caused by low survival rather than failure of the detection system.

The survival estimates reported reflect detection data after filtering for likely predator detections. Without implementing the predator filter, the only year with a different Delta survival estimate was 2010, when the unfiltered survival estimate was 0.11 instead of 0.05 (SE = 0.01; Buchanan et al. 2013, 2015, 2016; SJRGA 2011, 2013). The possibility that the low survival estimated for the high flow year of 2011 was a result of positively biased detection probabilities or inaccuracies

in the predator filter was explored and discounted; even assuming a Chipps Island detection probability as low as 0.75 and omitting the predator filter, the estimated survival from Mossdale to Chipps Island in 2011 would have been 0.03 instead of 0.02.

Possible tagging and handling effects are of concern in any tagging study. In the six years of this study, tag burden, tagging and handling procedures, and temperature controls during fish handling were within recommended guidelines (e.g., Wedemeyer 1996, Iwama et al. 1997, Anglea et al. 2004, Brown et al. 2006). The possibility of acute mortality effects due to surgery or transport conditions was assessed by examining dummy-tagged fish after being held at least 48 h at the DF release site after transport. The 48-h mortality rate of these dummy-tagged fish was <2% for all years. Additionally, the mortality rate of active-tagged fish during transport and holding prior to release was minimal in 2010–2014 (0.06% of all tagged fish transported). Together, these results suggest that surgery, handling, and transport caused minimal acute mortality. There was higher mortality during holding at the DF release site in 2015 (0.92%). However, river temperatures were abnormally high (≤24.7° C) during the holding period, and may account for the pre-release mortality in that year even in the absence of additional stress from surgery or handling (Marine and Cech 2004). Furthermore, the 21 rkm between the primary release site at DF and the upstream boundary of the study area (MOS) allowed any acute mortality effects of handling to be expressed outside the study area. Survival estimates from DF to MOS ranged from 0.03 (SE < 0.01) in 2015, to 0.94 (SE = 0.01) in 2010 (Table 5). Although these estimates reflect possible handling effects, they also reflect river conditions such as low flows and high temperatures that affect both tagged and untagged fish. These considerations suggest that any acute mortality effects of surgery and handling were not reflected in survival estimates in the study area.

The possibility of chronic mortality effects due to surgical errors or variation in surgeon skill was examined by testing for differences in survival estimates among surgeons each year. Although estimated survival was sometimes lower for a particular surgeon in a given reach and year (e.g., from Stockton to Turner Cut in 2012), there was no indication that any surgeon had consistently lower survival through multiple reaches in any year. The potential impact of surgical complications (e.g., loose sutures) on estimates of total Delta survival was investigated by adjusting observed estimates of survival to Chipps Island (Table 4) by the rate of surgical complications identified from dummy-tagged fish. Such adjustment depended on the conservative assumption that all fish that had surgical complications died within the study area (i.e., neither during the 24-h holding period at the release site nor in the 21 rkm between Durham Ferry and Mossdale), and would not have died without the surgical complications. Even using the maximum observed rate of surgical complications

(18% in 2012), the adjusted annual estimates of total Delta survival increased by only 0.01, e.g., from 0.03 to 0.04 in 2012. The mortality and tag loss rates observed from the tag retention studies produced similar results. Thus, the low survival estimates found in these six years of study are unlikely to have been an artifact of the tagging process, and are more likely to reflect the Delta environment. Similarly, the fact that survival estimates were ≤0.05 regardless of changes in tag and acoustic receiver technology, fish source, and tagging location suggest that low survival is a persistent and pervasive characteristic of this population under current Delta conditions.

<B>Management Implications

Given the complex host of factors contributing to low salmon survival in the Delta and the concurrent needs of other California residents, both aquatic and terrestrial, piscine and human, the actions required to improve survival will not be simple. Uncertainty about the minimum Delta survival necessary for population persistence complicates assessment of management action potential and performance; for example, a hypothetical target survival as high as 0.50 would likely prompt different approaches than a lower hypothetical target of 0.10. A more comprehensive understanding of the structure of the CV metapopulation generally, and specifically the SJR salmon population structure, performance, and requirements, as well as spatially explicit knowledge of regions and causes of high mortality, will be necessary to develop effective recommendations. However, the removal of up to 60% of the river water either upstream or in the Delta (Nichols et al. 1986) may limit any benefits of additional management actions on salmon survival. Managers should be careful to consider the survival both of salmon that use the Delta primarily as migrants, and of population components that may rear in the Delta, in order to promote diversity of life histories in the FRCS population and the buffering benefit of the "portfolio effect" (Miller et al. 2010, Schindler et al. 2010, Carlson and Satterthwaite 2011, Sturrock et al. 2015). A priority on habitat quality within the Delta, combined with efforts to improve survival through all portions of the salmon life history, is likely to be required if this population is to persist.

<A>Acknowledgments

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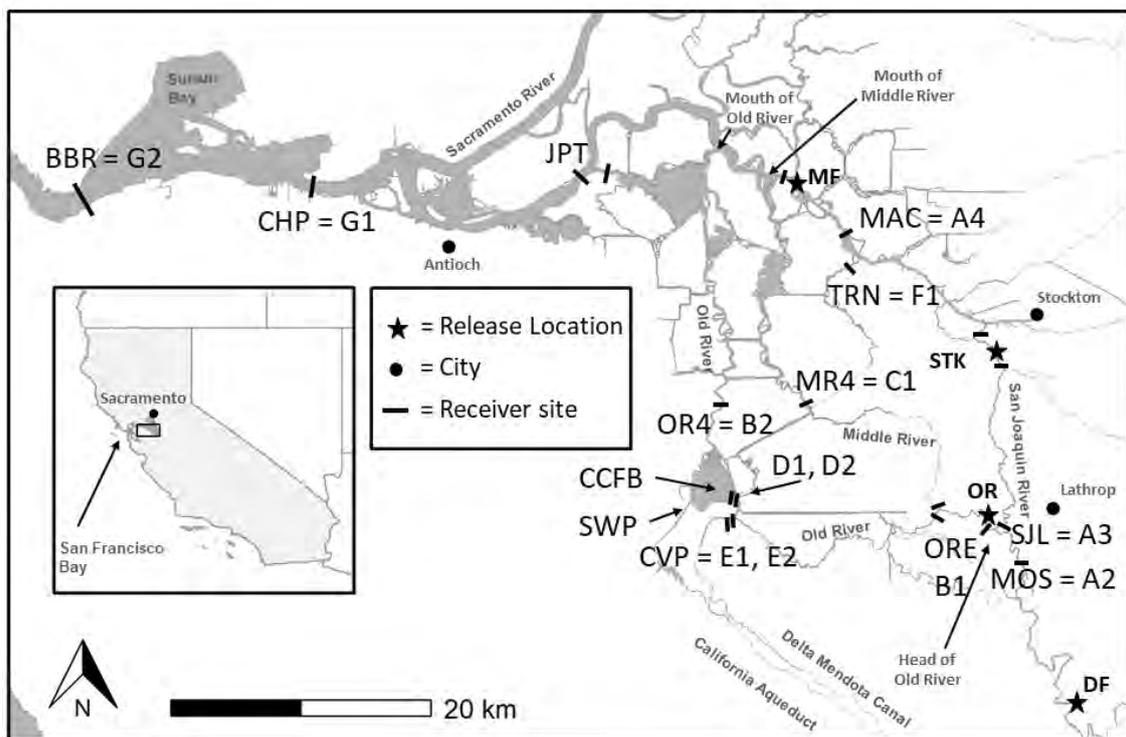
FIGURE 1.—The portion of the Sacramento-San Joaquin River delta that was studied, including acoustic-telemetry receiver sites common to the 2010–2015 studies, and key receiver sites added in later years. Inset map shows state of California, USA, (light shading) and the Delta and San Francisco Bay (dark shading); detailed area is marked with rectangle. The study area extended from Mossdale (MOS) to Chipps Island (CHP). Acoustic-tagged salmon were released at Durham Ferry (DF), Old River (OR), and Stockton (STK) in 2010; DF in 2011–2014, and DF and Medford Island (MF) in 2015. Key sites are DF, MOS, and CHP. Receiver sites with alphanumeric codes (e.g., A2) are used in the model schematic in Figure 2. Site JPT was added in 2011. Site BBR (G2) was added in 2014. Water export facilities are CVP and SWP; CCFB = Clifton Court Forebay. Highway 4 receivers are OR4 and MR4. The CHP site used a dual array of receivers.
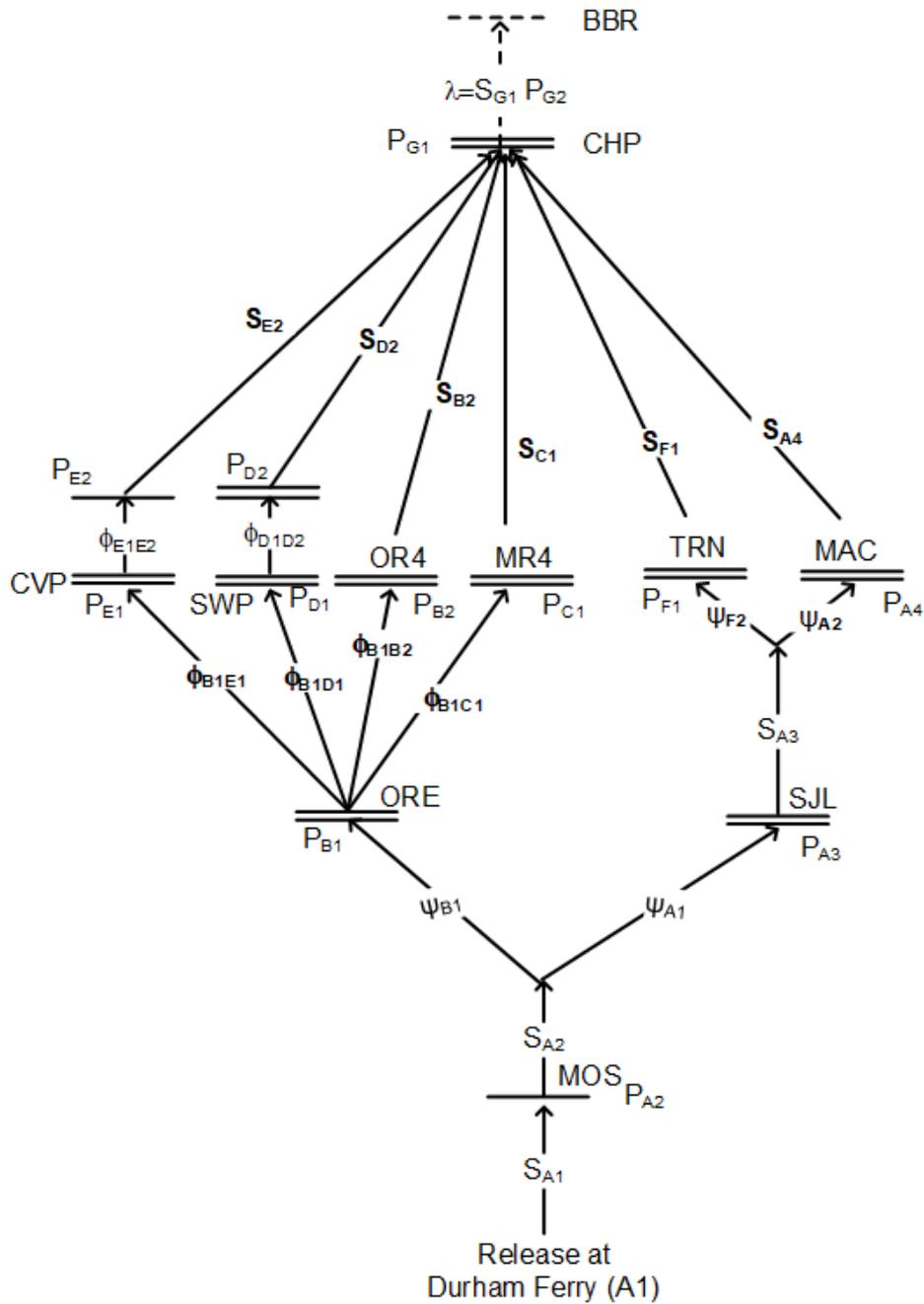
FIGURE 2.—Schematic of multistate release-recapture model to estimate survival from Mossdale (MOS) through the Delta to Chipps Island (CHP). The downstream boundaries of the Southern Delta are: MacDonald Island (MAC) and Turner Cut (TRN) in the San Joaquin River route, and the water export facilities (CVP, SWP) and Highway 4 receivers (OR4, MR4) in the Old River route. Horizontal lines indicate acoustic receivers; parallel lines indicate dual receiver array. Model parameters are probabilities of salmon reach survival (S), detection (P), route selection (ψ), and transition ($\Phi = \psi S$), and the last reach parameter $\lambda = SP$. Site BBR was available only in 2014 and 2015 (dashed lines).
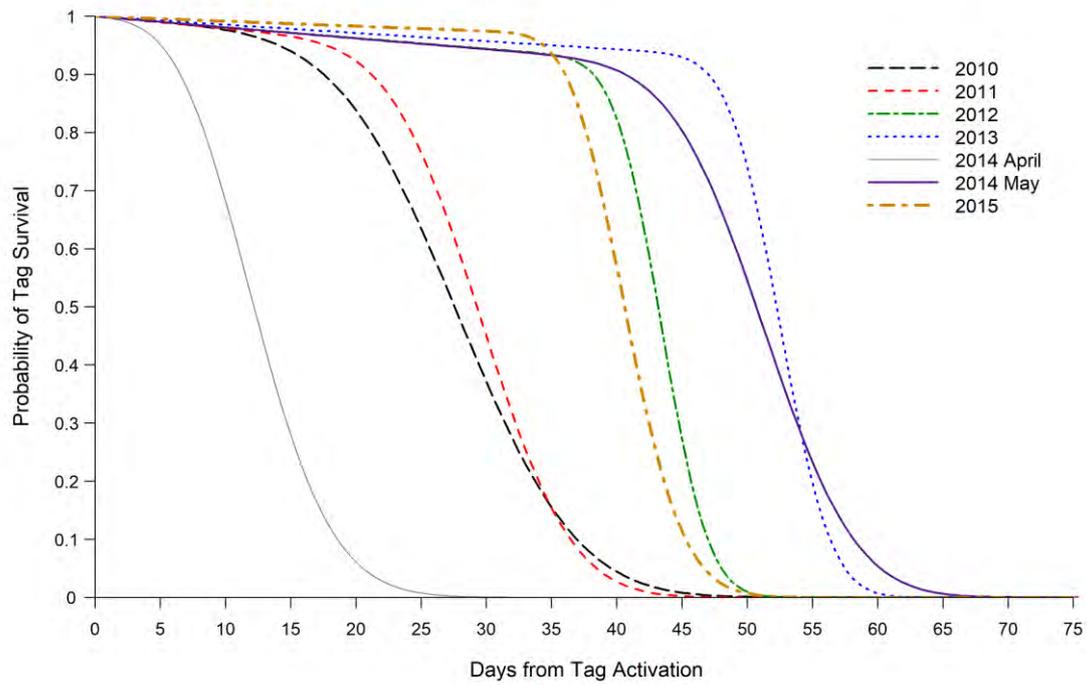
FIGURE 3.— Fitted tag survival curves for each year and/or release group. The 2010 and 2011 studies used HTI tags, and the 2012–2015 studies used VEMCO tags.
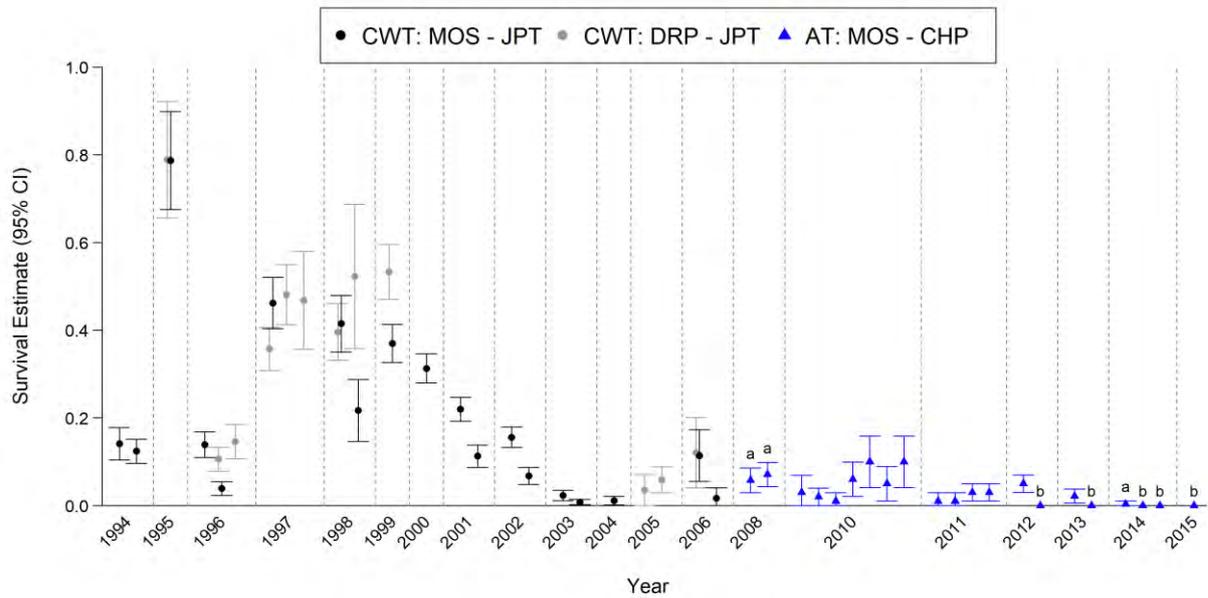
FIGURE 4.—Estimated survival of release groups of juvenile hatchery fall-run Chinook Salmon from Mossdale (MOS) or Dos Reis Park (DRP, 3.7 rkm downstream of SJL receivers) to either Jersey Point (JPT) or Chipps Island (CHP) from coded-wire-tag (CWT) and acoustic-telemetry (AT) studies. Intervals are 95% confidence intervals, truncated to 0 if necessary. a = estimates represent minimum survival because of premature tag failure (Holbrook et al. 2009); b = no detections at Chipps Island; Delta survival was not estimated in 2009 (SJRGA 2010). Adapted from Figure 5-1 in SJRGA 2013.

TABLE 1.—Release year, hatchery source of study fish, sample size (*N*), release dates, mean (range) fork length at tagging, transmitter type (manufacturer and model), mean (range) tag burden (= tag weight/fish weight), and mean estimated tag life (SE; days) for release groups of juvenile Chinook Salmon smolts used in the 2010–2015 South Delta tagging studies.

Year	Hatchery	*N*	Release Dates	Fork length (mm)	Tag type	Tag burden (%)	Tag life
2010	Merced	993	April 27–May 20	110 (99–121)	HTI 795 Lm	4.2 (2.8-5.8)	27.3 (7.8)
2011	Merced	1,895	May 17–June 19	111 (94–140)	HTI 795 Lm	4.1 (2.0-6.5)	28.8 (6.7)
2012	Merced	959	May 2–May 22	113 (100–135)	VEMCO V5	3.8 (2.0-5.4)	41.7 (7.5)
2013	Merced	950	May 1–May 19	115 (101–135)	VEMCO V5	3.8 (2.4-5.2)	50.6 (8.6)
2014	Mokelumne	1,918	April 16–May 19	98 (80–119)	VEMCO V4	3.8 (2.0-5.4)	48.9 (10.4)[a]
2015	Mokelumne	1,290	April 15–May 2	98 (83–119)	VEMCO V4	3.7 (1.9-4.8)	40.2 (5.5)

a = Results are given for May 2014 tag-life study. Mean estimated tag life for April 2014 tag-life study was 12.4 days (SE = 4.7 days)

TABLE 2.—Site acronyms, types, and locations in river km (rkm) measured from the Golden Gate Bridge. Distances to sites on the San Joaquin River are measured along the main stem of the river.

Site	Site type	Description	River km
DF	Primary release site	Durham Ferry	195
STK	Release site	Stockton	151
OR	Release site	Old River	164
MF	Release site	Medford Island	128
MOS	Receiver site	Mossdale	174
SJL	Receiver site	San Joaquin at Lathrop	170
ORE	Receiver site	Old River near head	164
TRN	Receiver site	Turner Cut	138
MAC	Receiver site	MacDonald Island	134
CVP	Receiver site, Water export facility	Central Valley Project	144
SWP	Receiver site, Water export facility	State Water Project	142
OR4	Receiver site	Old River at Highway 4	134
MR4	Receiver site	Middle River at Highway 4	137
JPT	Receiver site	Jersey Point	103
CHP	Receiver site	Chipps Island	77
BBR	Receiver site	Benicia Bridge	57

TABLE 3.—Estimated (median, range in parentheses) travel time (days) through the Southern Delta and to Chipps Island for study years 2010–2015; number after semi-colon = number of observations. Travel times are from Mossdale and are for Durham Ferry (DF) releases unless otherwise noted (MF = Medford Island release). Turner Cut Junction = TRN and MAC acoustic receivers (Figure 1).

Year	Turner Cut Junction	Water Export Facilities/Highway 4	Chipps Island (from Mossdale)	Chipps Island (from release)
2010	2.5 (1.3–3.7); 81	1.1 (0.5–5.8); 162	3.4 (1.3–7.2); 29	3.8 (1.6–7.6); 29
2011	1.6 (0.7–10.2); 404	0.8 (0.3–10.3); 378	2.9 (1.1–12.4); 27	3.3 (1.4–12.7); 33
2012	2.2 (1.0–7.3); 109	1.9 (1.2–3.9); 4	5.2 (3.7–10.0); 15	5.6 (4.1–10.4); 15
2013	3.7 (3.0–4.3); 2	1.9 (0.4–6.1); 95	3.6 (3.3–7.6); 3	4.0 (3.8–8.1); 3
2014[a]	1.3 (0.9–1.6); 3	1.8 (1.7–1.9); 2	NA; 0	NA; 0
2015 (DF)	2.4; 1	NA; 0	NA; 0	NA; 0
2015 (MF)	NA	NA	NA	3.7 (2.1–8.9); 35

a = Estimates omitted mid-April release group because of tag programming error

TABLE 4.—Estimates (standard errors in parentheses) of (1) probabilities of survival from Mossdale to the Turner Cut Junction, the Water Export Facilities/Highway 4 receivers, through the entire Southern Delta, and through the Delta to Chipps Island, (2) detection probability at Chipps Island (conditional on presence), and (3) the percentage of tags released at Durham Ferry (DF) and detected at Chipps Island that came through the CVP; MF = Medford Island release. Estimates are weighted averages for 2010, and estimated from pooled release groups for 2011–2015. When provided, n = number of tags detected at downstream boundary of reach. Turner Cut Junction = TRN and MAC acoustic receivers (Figure 1).

Year	Turner Cut Junction	Water Export Facilities/Highway 4	Total Southern Delta	Chipps Island	Detection at Chipps Island	CVP detection percentage (%)
2010	0.32 (0.02)	0.77 (0.05)	0.56 (0.03)	0.05 (0.01)	1.00 (0.00)	65.5
2011	0.48 (0.02)	0.66 (0.02)	0.56 (0.01)	0.02 (<0.01)	0.99 (0.01)	63.6
2012	0.24 (0.02)	0.42 (0.16)	0.24 (0.02)	0.03 (0.01)	1.00 (0.00)	6.7
2013	0.02 (0.01)	0.27 (0.02)	0.21 (0.02)	0.01 (0.01)	1.00 (0.00)	66.7
2014[a]	0.01 (<0.01)	0.12 (0.05)	0.02 (0.01)	0.00 ($n = 0$)	NA	NA
2015 (DF)	0.05 (0.05; $n = 1$)	0.00 ($n = 0$)	0.05 (0.05)	0.00 ($n = 0$)	NA	NA
2015 (MF)	NA	NA	NA	0.08 (0.01)[b]	0.93 (0.05)	NA

a = Estimates omitted mid-April release group because of tag programming error

b = Survival estimate from release at Medford Island

TABLE 5.—Estimates of the probability of survival from the Durham Ferry (DF) release site to Mossdale (MOS), the probability of selecting the San Joaquin River (SJR) route at the head of Old River (OR), and the probability of survival in the two major routes from Mossdale to Chipps Island (SJR route and OR route); and P-value from the two-sided Z-test on the log scale for the hypothesis of equal survival in the two routes. Estimates are weighted averages for 2010, and estimated from pooled release groups for 2011–2015.

Year	DF to MOS	Select SJR route	SJR route	OR route	P
2010	0.94 (0.01)	0.47 (0.02)	0.04 (0.01)	0.07 (0.01)	0.0267
2011	0.87 (0.01)	0.58 (0.01)	0.01 (<0.01)	0.04 (0.01)	0.0001
2012	0.50 (0.02)	0.98 (0.01)	0.03 (0.01)	0.11 (0.10)	0.2000
2013	0.50 (0.02)	0.23 (0.02)	0.01 (0.01)	0.01 (0.01)	0.8120
2014[a]	0.16 (0.01)	0.92 (0.02)	0.00 ($n = 0$)	0.00 ($n = 0$)	NA
2015	0.03 (<0.01)	0.92 (0.08)[b]	0.00 ($n = 0$)	0.00 ($n = 0$)	NA

a = Estimates omitted mid-April release group because of tag programming error

b = Assumption of 100% detection probability in Old River Route ($n = 1$)

ATTACHMENT 2

June 16, 2015

VIA COURIER

Ms. Katherine Mrowka
Enforcement Program, Manager
State Water Resources Control Board
1001 I Street, 14th Floor
Sacramento, California, 95814

Re: State Water Contractors' complaint against unlawful diversion of State Water Project stored water supplies.

Dear Ms. Mrowka:

This is a complaint against the unlawful diversion of stored State Water Project ("SWP") water. The State Water Contractors,[1] on behalf of itself and its member agencies, (herein "SWC") bring this complaint against diverters in the Delta located south of the San Joaquin River unlawfully diverting stored water from numerous points of diversion in excess of their water rights (herein "South-of-San Joaquin Diverters").[2] The South-of-San Joaquin Diverters are diverting water that they have no right to divert: SWP stored water supplies. This complaint does not challenge South-of-San Joaquin Diverters underlying water rights, rather this complaint assumes senior water rights can be substantiated, and the analyses contained herein informs when those with senior water rights are unlawfully diverting stored water supplies and should be curtailed.

Collectively, these South-of-San Joaquin Diverters are pumping approximately 100,000 to 300,000 acre-feet[3] more than they are entitled to in summer and fall of dry and critical years. The SWC are injured by the South-of-San Joaquin Diverters because approximately 100,000-300,000 acre-feet of their unlawful diversion causes the jointly operated State Water Project ("SWP") and the Central Valley Water Project ("CVP") to make additional stored water releases to satisfy Water Quality Control Plan ("WQCP") requirements. A 100,000 to 300,000 acre-feet unlawful diversion is significant. To put in context, 200,000 acre-feet equals the total amount of water that the SWC received in 2014. A 100,000 to 300,000 acre-feet increase in upstream storage would also significantly increase the ability of the SWP-CVP to maximize operational

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[1] The SWC are a non-profit mutual benefit corporation representing 27 public water agencies that contract with the State of California through the Department of Water Resources ("DWR") for water from the SWP. The SWC was formed in 1982 to represent the interests of public water suppliers that hold contracts with the State of California for the delivery of water from the SWP. Pursuant to its powers and authorities, the SWC represents the interests of its Member Agencies in proceedings that affect the water supplies made available from the SWP. (List of Member Agencies, Attachment 1.) Collectively, the SWC Member Agencies serve water to more than 25 million persons, roughly two thirds of California's population, over a geographic area that extends from Butte County in the Sacramento Valley, through the San Francisco Bay Area and San Joaquin Valley to the California Central Coast and Southern California. The SWC Member Agencies also serve water to over 750,000 acres of irrigated farmland. The SWC is not required to file statements of diversion and use. (23 CCR § 820(d)).

[2] See map identifying location of South-of-San Joaquin Diverters, Attachment 2.

[3] This range reflects the two different approaches to calculating unlawful diversions. Once an approach is adopted, the predicted range of the potential impact will narrow.

flexibility in managing the system in dry and critical years. If this stored water were not being unlawfully diverted, it would be available to satisfy legally established project purposes.

The SWC are requesting that the State Water Resources Control Board ("Water Board") issue an order that requires the South-of-San Joaquin Diverters to cease and desist their excess diversions, as well as set forth standards under which the South-of-San Joaquin Diverters would be subject to an enforcement order. This request is further explained in subsequent sections of this complaint.

In this complaint, the SWC are presenting a new approach by providing information to estimate the timing and magnitude of the unlawful diversions, taking into account inflows and outflows, as well as antecedent conditions in the Delta. This approach is a way to move beyond historic arguments and present an analytical means to achieve resolution. Through modeling, the SWC have tested old assumptions and developed new modeling approaches to analyze in-Delta diversions. This complaint describes two methods for estimating the magnitude of unlawful diversions. The first method is an inflow criterion that is similar to what the Water Board has developed and is an method the SWC have previously presented to the Water Board. The second method is a salinity criterion that models water quality (salinity) without the SWP-CVP, which accounts for antecedent conditions, or the time history of flow, which is related to tidal conditions. The salinity criterion accounts for the relatively fresh conditions that remain in the Delta for a period of time after inflows diminish.

I.   The Water Board Must Uphold the Water Right Priority System.

The Water Board should take immediate action to prevent the unlawful diversion of water pursuant to Water Code § 1831, and the SWC request that the Water Board use its authority to prevent unlawful diversions, waste, and unreasonable use of water.[4] The SWC have the right to file this complaint pursuant to Cal. Code of Regs. § 820, *et seq.*

The SWC are seeking immediate enforcement against all South-of-San Joaquin Diverters with post-1914 appropriative, pre-1914 appropriative and riparian water rights in 2015, as well as a standing order that describes conditions under which future enforcement is appropriate. The SWC seek a standing order that states:

- Delta diverters located south of the San Joaquin River with pre-1914 appropriative water rights, post-1914 appropriative water rights and/or riparian water rights have no right to divert SWP-CVP stored water supplies pursuant to their water rights.

- Delta diverters located south of the San Joaquin River with post-1914 appropriative water rights, pre-1914 appropriative water rights and/or riparian water rights shall be curtailed according to water right priority once in-Delta use exceeds Delta inflows in the without SWP-CVP scenario.

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[4] Cal. Water Code §§ 100, 275; California Constitution, Article X, section 2; *California Farm Bureau Federation v. SWRCB* (2011) 51 Cal. 4th 421, 429 [while the Water Board "…has no permitting or licensing authority over riparian or pueblo rights, or over appropriative rights acquired before 1914. The SWRCB does have authority to prevent illegal diversions and to prevent waste or unreasonable use of water, regardless of the basis under which the right is held]; *United States v. SWRCB*, 182 Cal.App3d. 82 (1986); *Young v. SWRCB*, 219 Cal.App.4th 397, 404 (2013).

- Delta diverters located south of the San Joaquin River with post-1914 appropriative water rights, pre-1914 appropriative water rights and/or riparian water rights do not have the right to divert when Delta salinity (measured as specific conductance) in the without the SWP-CVP scenario is at least 2.0 mS/cm[5] or greater.

The findings to support this standing order should include the following:

- The WQCP, the area of origin statutes, and the Delta Protection Act did not expand the rights of diverters with pre-1914 appropriative water rights, post-1914 appropriative water rights and/or riparian water rights to include the right to divert SWP stored water supplies.[6]

- Delta diverters with pre-1914 appropriative water rights, post-1914 appropriative water rights and/or riparian rights cannot divert foreign water, which includes stored reservoir releases that have not been abandoned.

- Without SWP-CVP operations, water quality in the Delta south of the San Joaquin River would degrade significantly and for prolonged periods of time with limited potential for salinity flushing and drainage, which impact the ability to reasonably and beneficially use water with elevated salinity for agricultural purposes.

- The proper modeling baseline for determining when water is available for diverters with pre-1914 appropriative water rights, post-1914 appropriative water rights, and/or riparian water rights is the current channel configuration without the operation of the SWP-CVP as Delta vested water right holders are entitled to no more water supply than without project flows and the resulting salinity conditions.[7]

- Since Delta diverters south of the San Joaquin River do not actually experience without SWP-CVP flow and salinity conditions, it is appropriate to model without project conditions to capture the points in time when Delta diverters would not otherwise be able to put available supplies to reasonable and beneficial use, which is the maximum extent of their alleged water rights.

- Physical conditions in the Delta south of the San Joaquin River impact the ability to reasonably and beneficially use water with elevated salinity for agricultural purposes.

- Due to physical conditions in the Delta south of the San Joaquin River both currently and if the SWP-CVP were not operated, diverters with pre-1914 appropriative water rights, post-1914 appropriative water rights and/or riparian water rights cannot put

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[5] The justification for a 2.0 mS/cm standard is provided in section II(b), below.

[6] *See e.g.*, Cal. Water Code §11462; *El Dorado Irrigation District v. State Water Resources Control Board*, 142 Cal. App.4th 937, 967, 976 (2016) *Phelps v. SWRCB*, 157 Cal.App.4th 89, 110 (2007). The co-mingling rules apply only if the South-of-San Joaquin Diverters could have otherwise diverted absent the existence of the SWP-CVP.

[7] *See e.g.*, *In the Matter of Administrative Civil Liability Complaints for Violations of Licenses 13444 and 13274 of Lloyd L. Phelps, Jr.; License 1319 of Joey P. Ratto, Jr.; License 13315 of Ronald D. Conn and Ron Silva et al.* State Water Resources Control Board. Order WRO 2004-004, p. 12 (2004 Cal. ENV.LEXIS 104); *In the Matter of Permit 12720 (Application 5625) and Other Permits of the U.S. Bureau of Reclamation for the Federal Central Valley Project and of California Department of Water Resources for the State Water Project. State Water Resources Control Board.* Order WR 78-17 at 23 (1978 Cal. ENV LEXIS 35.)

water with salinity greater than 2.0 mS/cm to reasonable and beneficial agricultural use.

- Based on evidence presented to the Water Board, 2.0 mS/cm is a conservative and reasonable estimate of when a salt tolerant crop grown in the Delta would experience decreased yield.

The standing order is necessary to protect the SWP-CVP water supplies from unlawful diversions, thereby making those supplies unavailable to satisfy multiple legally established project purposes.

II. Evidence of Unlawful Diversions of SWP Stored Water Supplies Supports Swift Enforcement by the Water Board.

In this complaint, the SWC present two approaches to calculating the magnitude of the unlawful diversions: an inflow criterion and a salinity criterion. Regardless of which method is used for the calculation (or to the extent both are used), the magnitude of the South-of-San Joaquin Diverters' unlawful diversion is 100,000 to 300,000 acre-feet this year, with similar losses of stored water supplies in future years during summer and fall, particularly in drier years.

a. Unlawful diversions are occurring when in-Delta use exceeds inflows; SWP stored water supplies require protection.

The inflow criterion takes available inflow coming into the Delta from the Sacramento and San Joaquin River watersheds and subtracts in-Delta water use. When in-Delta use exceeds available inflow curtailments are triggered.

As Figure A illustrates, when outflow (green) crosses zero (gray dash), the curtailment is triggered. The magnitude of the curtailment is the extent that in-Delta use (blue) exceeds inflow (red). The curtailment would end when outflows (green) increase and are once again above zero (gray dash) or when inflow (red) exceeds in-Delta use (blue). Figure B further illustrates the relative magnitude and timing of curtailments using this approach. Curtailments would begin with post-1914 appropriators and pre-1914 appropriators according to water right priority; and after all of the senior appropriators are curtailed, the riparian water users would be curtailed correlatively, based on percent reductions in water use.

The SWC's inflow analysis shows that the curtailment pattern would be centered in the summer (June-August). Using this approach, curtailments would occur in a large number of years, including some normal water years. Using this approach, the in-Delta water use exceeds available inflows from the combined Sacramento and San Joaquin River watersheds 20% of the time in June, 50% of the time in July, and 40% of the time in August. (See Table V.2, p. 11, Attachment 3.)[8] These percentages reflect the percentage of years when curtailments would be triggered using

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[8] The assumption that water from both the Sacramento and San Joaquin River watersheds could be used in an inflow analysis may overestimate the quantity of water available to the area of the Delta south of the San Joaquin River because this area (or portions of this area) do not appear to be riparian to the Sacramento River, and it is therefore also unlikely that the South-of-San Joaquin Diverters could be appropriating water from the Sacramento River under a senior water right. The area south of the San Joaquin River does not appear to be riparian to the Sacramento River for the following reasons: 1.) the properties are located upstream of the confluence of the Sacramento and San Joaquin Rivers, 2.) none of the properties have frontage on the Sacramento River, and 3.) it would not appear that rain water draining from these areas would drain into the Sacramento River which suggests they are

this approach. The diverters Delta-wide are pumping approximately 600,000 acre-feet in excess of available inflows in extreme dry years, with approximately 300,000 acre-feet of this unlawful use attributed to the South-of-San Joaquin Diverters. (See Tables V.3-V.4, p. 12, Attachment 3.)
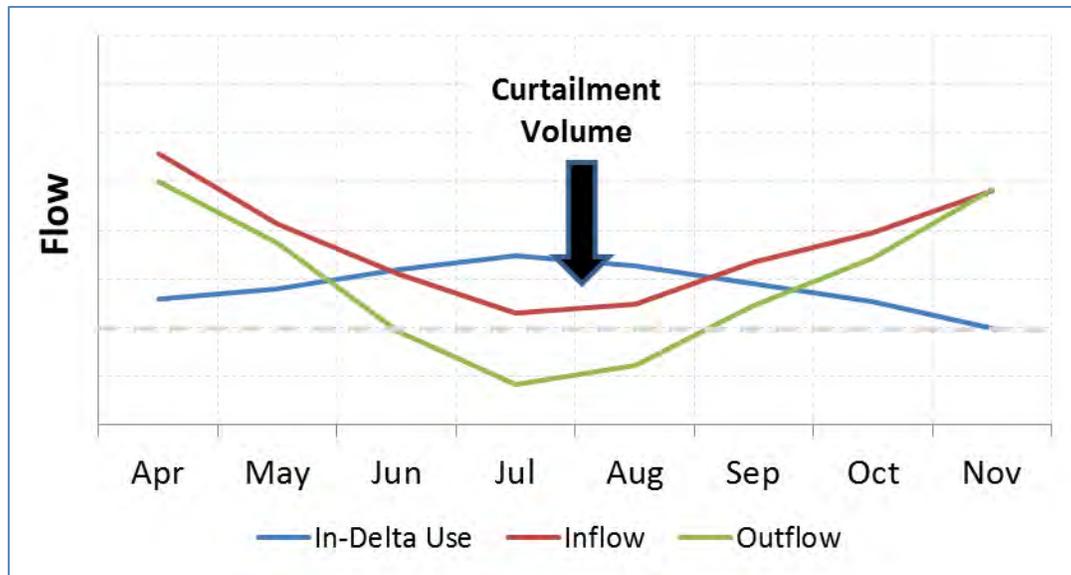
Figure A. Inflow Criterion. Conceptual inflow trigger illustration.
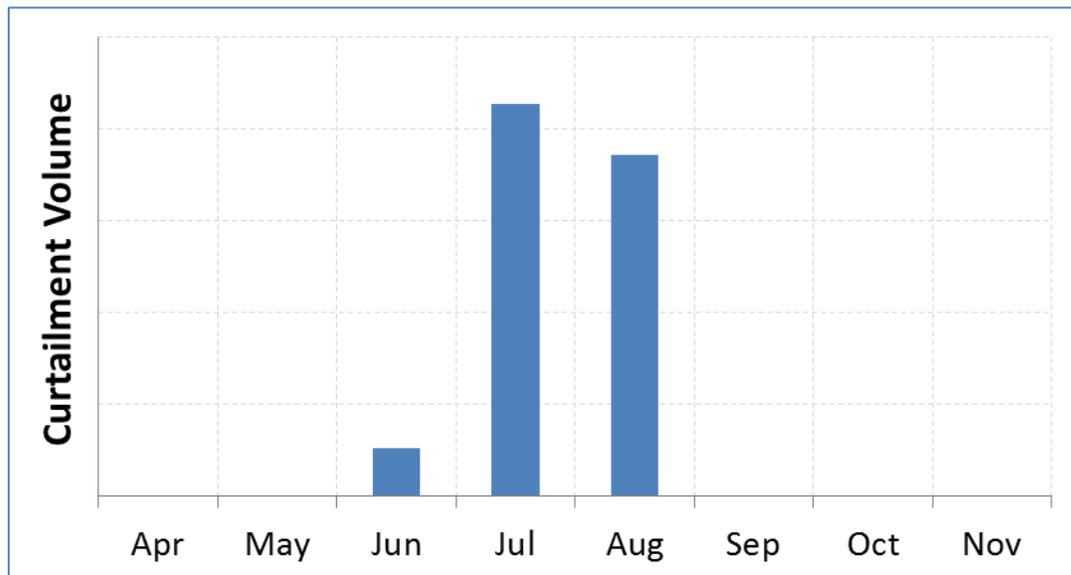
Figure B. Conceptual magnitude and timing of unlawful diversion of stored water supplies using inflow criterion.

The inflow approach does not account for antecedent conditions, or the time history of flow, which is related to tidal conditions in the Delta. The SWC salinity analysis is a means by which the Water Board could trigger curtailments while accounting for both inflow and antecedent conditions.

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not in the Sacramento River watershed. The percentage of the time that in-Delta use south of the San Joaquin River exceeds available inflow from only the San Joaquin River watershed would be even greater than the percentages identified above.

b. Unlawful diversions are occurring when salinity is too high to support reasonable and beneficial use; SWP stored water supplies require protection.

The salinity criterion considers the water available to the South-of-San Joaquin Diverters at their points of diversion absent the existence of the SWP-CVP. This approach provides information about when the South-of-San Joaquin Diverters would be able to beneficially use Delta water if the SWP-CVP neither operated facilities in the Delta nor stored water upstream of the Delta. This approach shows that if the SWP-CVP did not exist, the South-of-San Joaquin Diverters would frequently be unable to divert in dry and critical years because the water quality would be too poor for reasonable and beneficial use. When water quality without the SWP-CVP is too poor for reasonable and beneficial use at all points of diversion within a region, the affected South-of-San Joaquin Diverters have no water right that can be exercised, and thus would be completely curtailed.[9] Using this approach, all South-of-San Joaquin Diverters would not be curtailed at the same time. As salinity increases generally start downstream, the downstream areas would be curtailed first. See Figure C.

As Figure C illustrates, in the without SWP-CVP scenario, salinity moves into the Delta starting in the north and west, ultimately moving further south and east into the Delta as outflow decreases. Based on a salinity trigger of 2.0 mS/cm, Figure C illustrates the curtailment progression.

Salinity and antecedent outflow (which accounts for the time history of flows from prior months) have an inverse relationship, because salinity increases as antecedent outflow decreases. See Figure D. In Figure D, the increasing size of the region subject to curtailment tracks the trajectory of salinity (orange). A salinity trigger would result in a curtailment pattern that occurs over a greater period of time within a year but it would not be triggered in as many years as the inflow trigger. See Figure E.

Figure C. Conceptual illustration of salinity criterion

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[9] Cal. Const., Art. X, Sec. 2; *See e.g.*, *Peabody v. City of Vallejo*, 2 Cal.2d. 351, 383 (1935) ["The rule of reasonable use…applies to all water rights enjoyed or asserted in this state, whether the same be grounded on the riparian right or the right, analogous to the riparian right, of the overlying land owner, or the percolating water right, or the appropriative right."]
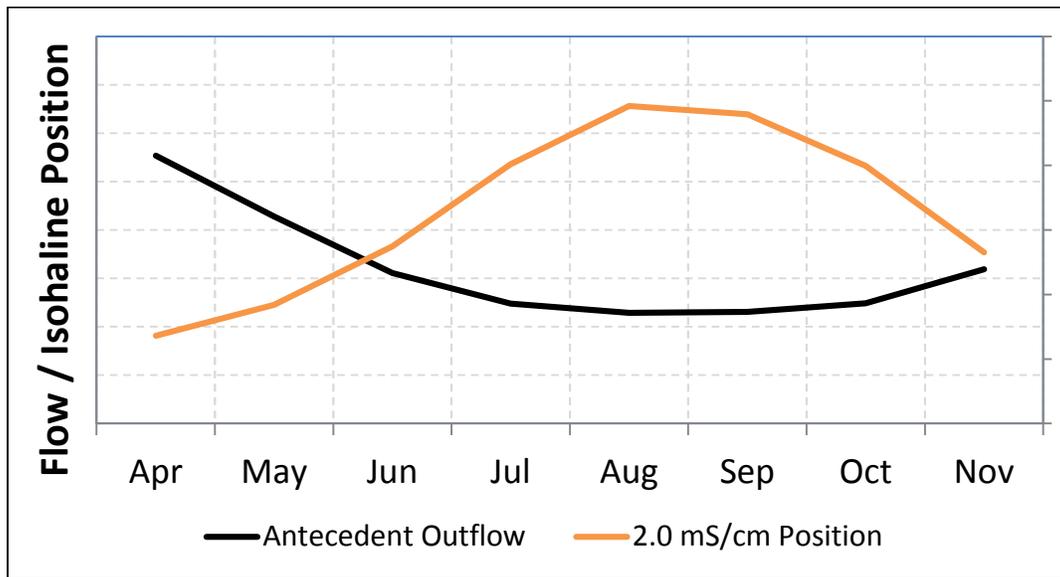
Figure D. Conceptual relationship between antecedent outflow and salinity.
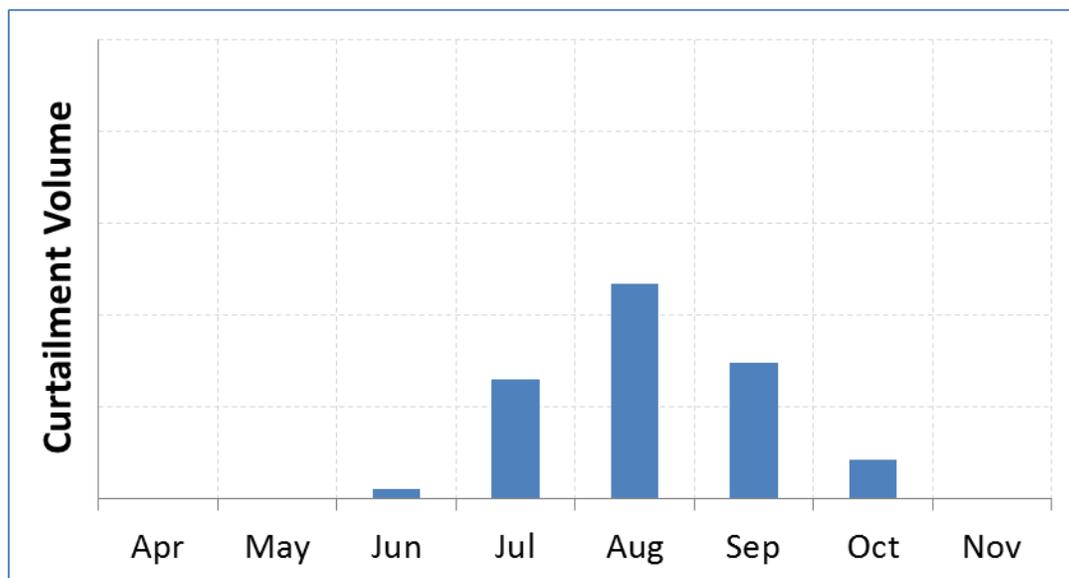
Figure E. Conceptual magnitude and timing of unlawful diversion of stored water supplies using the salinity criterion.

The salinity criterion would likely be triggered only in dry and critical years.

Salinity in Delta channels south of the San Joaquin River is often 2.0 mS/cm or greater during the irrigation season of dry and critical years under without project conditions, which is more than twice the 0.7 mS/cm April-August southern Delta agricultural salinity standard. (See, Attachment 5, Figures 5-52, pp.7-56.) For example, salinity south of the San Joaquin River ranged from 2.0 mS/cm to over 10 mS/cm in August 2014 (a critically dry year) under without project conditions. See Figure F below. This year (2015) is comparable to 2014 under without project conditions, with salinity between 2.0 mS/cm to over 10 mS/cm throughout the area south of the San Joaquin River. (See, Attachment 5, Figures 50-52, pp. 54-56.) In both years, salinity remains high throughout the fall into November and December, illustrating how long seawater intrusion can

linger in the Delta during critical years. See Figure G below. In years like 2014, the South-of-San Joaquin Diverters should be curtailed in the summer and throughout the fall.
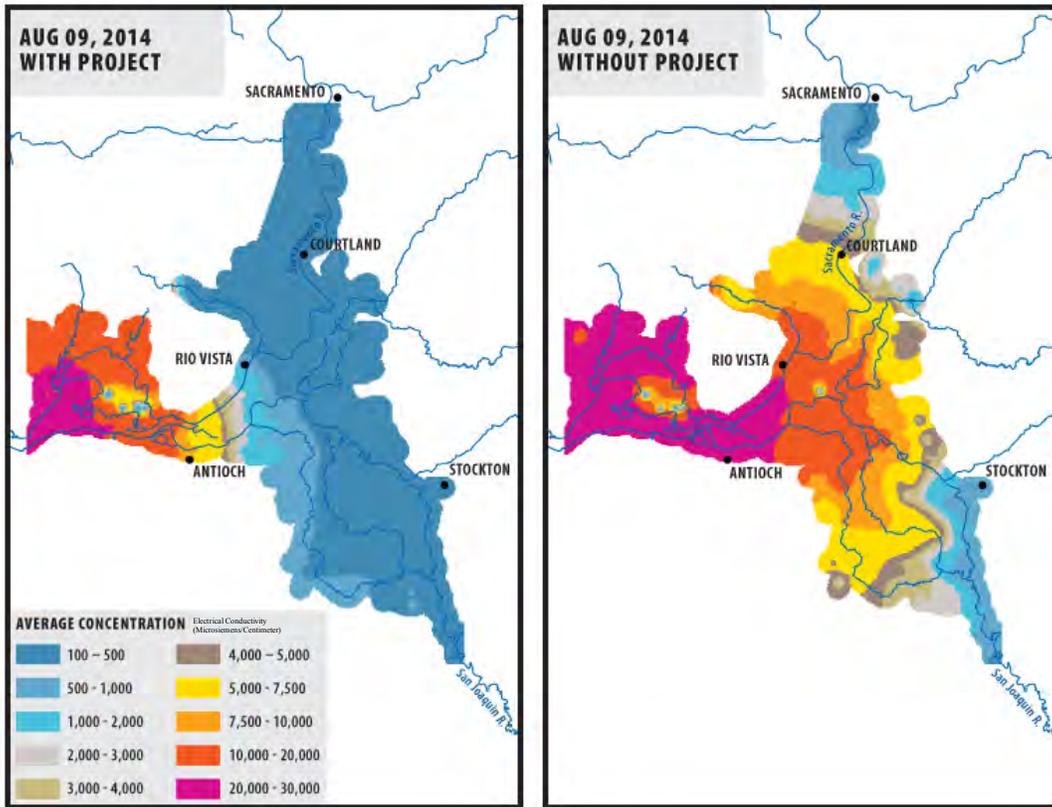
Figure F. Delta salinity comparison of with and without project scenario, August 2014. See Attachment 5, p. 42, supporting documentation for salinity comparison.
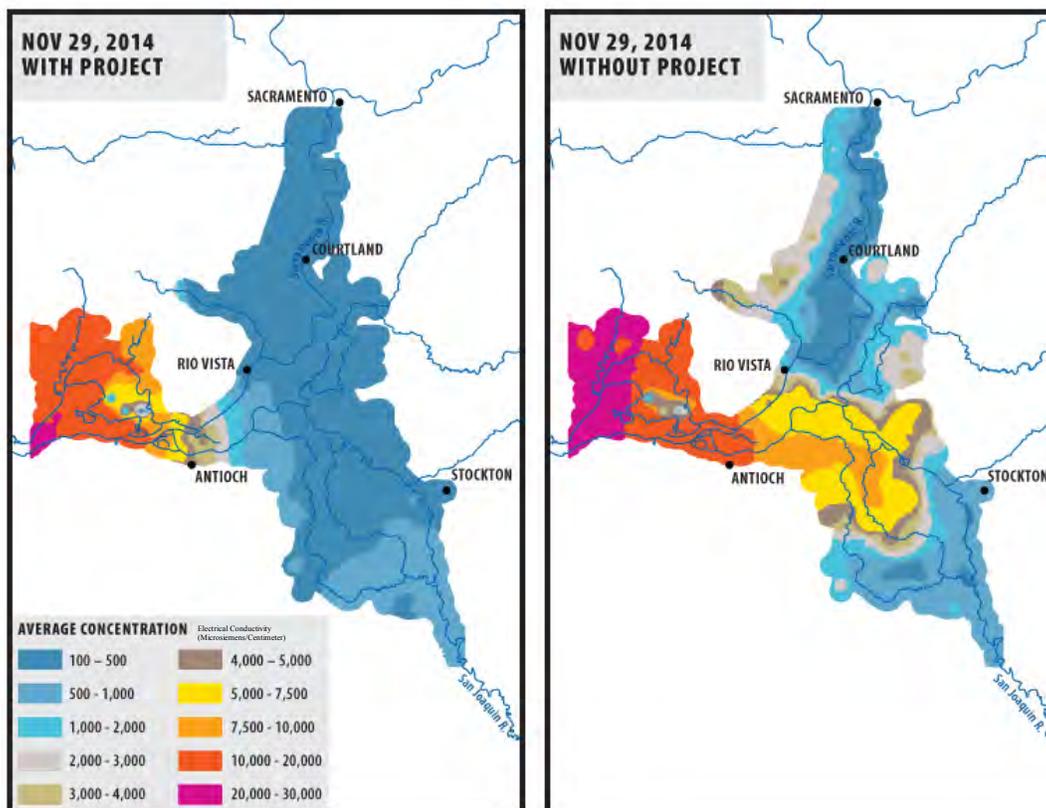
Figure G. Delta salinity comparison of with and without project scenario, November 2014. See Attachment 5, p. 45, supporting documentation for salinity comparison.

It is reasonable to use 2.0 mS/cm as the salinity criterion, which is more than double the current 0.7 mS/cm irrigation season agricultural salinity standard for determining reasonable and beneficial use based on water quality. The Hoffman (2010) [10] report used a modeling approach in an effort to account for the South Delta Water Agency's ("SDWA") ongoing criticisms about the need to consider leaching fractions, and the inability to apply laboratory experiments to determine salinity tolerance. Hoffman (2010) [11] generally concluded that an agricultural salinity standard around 1.0 mS/cm (0.7 - 1.4 mS/cm) was sufficiently protective. Hoffman (2010) did not consider the issue being posed in this complaint, that being what is the maximum salinity tolerance of the most salt tolerant crops being grown in the Delta? Even so, the South-of-San Joaquin Diverters (through the SDWA) have argued before the Water Board on multiple occasions that the current 0.7 mS/cm (April-August) agricultural standard is insufficiently protective, and in fact even at 0.7 mS/cm the South-of-San Joaquin Diverters have previously testified that they experience injury to their farming viability, arguing against raising the WQCP standard to 1.0 mS/cm. [12] If the SDWA is correct and the South-of-San Joaquin Diverters would be experiencing

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[10] Hoffman, G., (2010) *Salt Tolerance of Crops in the Southern Sacramento-San Joaquin Delta*, Final Report, for the California Environmental Protection Agency, State Water Resources Control Board.

[11] *Id.* at p. 98.

[12] *See e.g.*, South Delta Water Agency, Power Point titled "Water Quality Objectives for Agricultural Beneficial Uses in the Southern Delta," presented during public hearing on the adequacy of the substitute environmental documents (Phase I), March 20-21, 2013 ["Hoffman Report are not supported [by] any, much less substantial evidence…Hoffman didn't know: The amount of salts in the soil; The amount of salt applied; The amount of water or salt that passed through the root zone; The amount of ground water/salts in the drainage; The amount of salt remaining in the root zone; All of which prevent him [Hoffman] from calculating the leaching fraction," and Hoffman did not account for the salty groundwater as, "Most of the Southern Delta ag land is between

crop losses at 0.7mS/cm or 1.0 mS/cm, then doubling that salinity level would be expected to cause significant impairment and loss of agricultural viability to the extent water quality of 2.0 mS/cm could not be put to reasonable and beneficial agricultural use.

When salinity would have been too high to support the water rights absent the SWP-CVP operations, the South-of-San Joaquin Diverters have no right to divert and should be curtailed. Using the conservative 2.0 mS/cm salinity trigger, the South-of-San Joaquin Diverters are pumping approximately 100,000 – 300,000 acre-feet in excess of their alleged water rights.

IV.   Conclusion

The SWC are seeking immediate enforcement this year, and a standing order for future dry and critical water-years. The Water Board should take immediate action to protect 100,000 to 300,000 acre-feet of stored water supplies.

Sincerely,

Stefanie D. Morris
General Counsel

Attachments

-5 to +10 feet compared to sea level. The shallow ground water in the area is directly linked to the channel water and thus rises and falls twice daily with the tides. That shallow ground water contains the accumulation of 50+ years of CVP salts. Thus, when the tides rise and fall, the salty ground water rises and falls entering or approaching the root zone. This means any salts which are leached do not go anywhere!" [*emph. in original*).]

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San Gabriel Valley Municipal Water District
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San Gorgonio Pass Water Agency
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Beaumont, CA 92223

San Luis Obispo County Flood Control and
Water Conservation District
County Government Center, Room 207
San Luis Obispo, CA 93408

Santa Clara Valley Water District
5750 Almaden Expressway
San Jose, CA   95118

Solano County Water Agency
810 Vaca Valley Parkway
Vacaville, CA 95688

Tulare Lake Basin Water Storage District
1001 Chase Avenue
Corcoran, CA 93212

The South of San Joaquin River Diverters have points of diversions at numerous locations south of the San Joaquin River within the legal Delta (marked in yellow).

SOUTH DELTA WATER USE ANALYSIS

A Technical Appendix Supporting a Water Rights Complaint
against Delta Diverters South of the San Joaquin River
For Unauthorized Diversions of Stored Project Water

Paul H. Hutton, Ph.D., P.E.

Metropolitan Water District of Southern California

May 2015

Table of Contents

I.   Executive Summary

The State Water Contractors have undertaken several technical studies to evaluate the extent that unauthorized diversions of stored water from the State Water Project (SWP) and Central Valley Project (CVP) are occurring in the Delta south of the San Joaquin River. This document provides a brief summary of these technical studies. These technical studies assume that riparian water rights and pre-1914 appropriative water rights are senior to those of the SWP and CVP. These technical studies also assume that those currently diverting pursuant to a claimed senior water right would be able to prove the existence of such a right. The senior water rights are associated with water that would have been available in the system absent the operation of SWP-CVP upstream storage and in-Delta facilities, a hypothetical "without project" condition.

Two approaches are presented for estimating the availability of water for in-Delta agricultural users; these approaches are applied to the study area south of the San Joaquin River under the without project condition. The first approach, an inflow criterion, assumes at one bound that when Delta inflow approaches zero, no water is available in the study area and curtailment of all water use is warranted. At the other bound, the criterion assumes that if Delta outflow is positive, i.e. Delta inflow exceeds full in-Delta water use, water is available for all in-Delta use and no curtailment is warranted. Between these bounds, the inflow criterion assumes that study area water use is curtailed such that it does not exceed Delta inflow. The second approach, a salinity criterion, assumes that water is available for use within the study area provided that water is of adequate quality for beneficial use. This approach requires the use of Delta salinity models and specification of a salinity "trigger" to estimate water availability. Given that extremely low outflow conditions characteristic of the "without project" hydrology are outside the calibration range of available Delta salinity models, data collected in the 1920s and 1930s before construction of Shasta Dam were examined to assess the validity of the proposed modeling approach. Two key conclusions were drawn from this data examination: (1) the study area was subject to severe seawater intrusion before construction and operation of the SWP-CVP and (2) the use of DSM2 and DSM2-calibrated flow-salinity models allow for a reasonable and conservative method of evaluating water supply availability in the study area as part of the salinity criterion.

The inflow criterion analysis suggests that unauthorized diversions are taking place in the study area, these diversions are centered in the April through August period, and excess diversions are in the range of 300,000 acre-feet in dry and critical water years. The inflow criterion suggests that excess diversions take place in most years, but in smaller volumes under wetter hydrologic conditions. The salinity criterion analysis also suggests that unauthorized diversions are taking place in the study area. However, these diversions are later in the season (typically June through November) with lower volumes in the range of 100,000 to 200,000 acre-feet in dry and critical water years. The salinity criterion suggests that excess diversions are of little consequence under wetter hydrologic conditions.

II.   List of Tables

III. List of Figures

IV.   Introduction

The State Water Contractors have undertaken several technical studies to evaluate the extent that unauthorized diversions of stored water from the State Water Project (SWP) and Central Valley Project (CVP) are occurring in the Delta south of the San Joaquin River. This document provides a brief summary of these technical studies. Detailed findings are documented in individual project reports; these reports are listed in the References section of this document.

These technical studies assume that riparian water rights and pre-1914 appropriative water rights are senior to those of the SWP and CVP. These technical studies also assume that those currently diverting pursuant to a claimed senior water right would be able to prove the existence of such a right. The senior water rights are associated with water that would have been available in the system absent the operation of the SWP-CVP facilities in the Delta (i.e. no pumping facilities and no Delta cross channel with gates) and absent stored water upstream of the Delta (referred to herein as the "without project conditions"). Therefore, many of these technical studies define and utilize a hypothetical hydrology to represent flows and salinity that would exist without the SWP-CVP.

Section V summarizes a simple inflow analysis that was conducted to estimate the availability of surface water in the Delta for agricultural use. This analysis, which was conducted over the entire Delta as well as the area south of the San Joaquin River (herein referred to as the "study area", identifies without project conditions when (1) monthly Delta inflow is positive and (2) monthly Delta outflow is positive. This classification is used to assess the availability of water for assumed senior water rights under a wide range of hydrologic conditions and is used to estimate the extent that water use in the study area has exceeded available inflow historically using the historical 91-year hydrologic record spanning water years 1922-2012 (October 1921 through September 2012). This analysis is referred to herein as the "inflow criterion".

Section VI, building on the findings of Section V, summarizes an evaluation of surface water availability in the study area under without project conditions that is of adequate quality to meet agricultural beneficial uses. This analysis utilizes the DSM2 model to simulate water quality under without project conditions using an 82-year hydrologic record (water years 1922-2003) that represents current land use in the Sacramento and San Joaquin River basins. Utilizing these modeling results, a conceptual approach to trigger water use curtailments based on available water quality (referred to herein as the "salinity criterion") is presented. This section also summarizes an analysis of historical water quality measurements, prior to construction of the SWP-CVP, to provide a quasi-validation of the modeling results.

Additional technical studies that build on the analyses contained herein were undertaken by the State Water Contractors and are presented in separate documents. One such study utilizes the DSM2 model to extend the without project conditions salinity analysis to water years 2012-15. Another technical study analyzes Delta island water use, including: (1) possible water

management scenarios that result from water curtailment on Delta islands; (2) consequences of possible curtailment of Delta diversions in the study area, (3) the response of key water budget components and Delta island water budgets to curtailment and alternative land and water management strategies, (4) uncertainty in the estimation of water budget components, and (5) the response of salinity on Delta islands to water curtailment and different land and water management practices. A third study utilizes the C2VSim integrated groundwater surface water model to evaluate the viability of current land use practices in the Sacramento River basin absent the SWP-CVP.

V.   Analysis of Surface Water Availability (Inflow Criterion)

The availability of surface water for agricultural use in the study area was evaluated through a simple inflow approach or criterion. This approach estimates water availability on an average monthly basis by removing the effects of SWP-CVP reservoirs and Delta facilities (i.e. without project conditions) from the historical record of Delta hydrology. This hypothetical hydrology is then used to evaluate water availability by identifying when (1) monthly Delta inflow is positive and (2) monthly Delta outflow is positive. It is assumed that when monthly Delta inflow approaches zero, no water is available for in-Delta agricultural use and curtailment of all water use in the study area is warranted. Furthermore, it is assumed that if monthly Delta outflow is positive, i.e. Delta inflow exceeds full in-Delta water use, water is available for all in-Delta use and no curtailment is warranted. This latter assumption ignores circumstances when Delta outflow is positive but sufficiently small such that seawater intrusion impairs the beneficial use of water in the study area, thereby limiting water availability for diversion. These circumstances are evaluated and discussed in Section VI. The methods and results for the surface water availability analysis are described below.

A.   Methods

The methods used to evaluate the availability of surface water for agricultural use in the study area are described below. The data used for the analysis are identified and the calculation approach is defined.

1.   Data

Monthly average data spanning the period October 1921 through September 2012 were assembled into an electronic spreadsheet file from a variety of sources. Data and sources are summarized in Table V.1.

2.   Delta Inflow and Outflow Calculations

Historical total Delta inflow, by definition, was calculated by summing the various Delta inflows as follows:

$$Historical\ Total\ Delta\ Inflow = Q_{freeport} + Q_{yolo} + Q_{east} + Q_{vernalis} \dots\dots\dots\dots\dots (V.1)$$

where $Q_{freeport}$ is Sacramento River inflow at Freeport; Q_{yolo} is Yolo Bypass inflow; Q_{east} is inflow from the Cosumnes, Mokelumne and Calaveras Rivers; and $Q_{vernalis}$ is San Joaquin River inflow at Vernalis.

Historical Sacramento River inflow at Freeport was adjusted to remove the effects of upstream SWP-CVP storage operations through the following calculation:

$$Q_{freeport\ w.o.\ project} = Q_{freeport} - Q_{trinity} + \sum Q_{sac\ storage} \dots\dots\dots\dots\dots\dots\dots\dots\dots. (V.2)$$

where $Q_{trinity}$ is import from the Trinity River watershed and $\Sigma\, Q_{sac\ storage}$ is the flow associated with removing storage operations at Shasta, Oroville and Folsom. Historical storage increases are added to the without project river flows; historical storage releases are subtracted from the without project river flows. This calculation results in a long-term balance between storage increases and storage releases and ignores small losses associated with evaporation from the reservoirs and local withdrawals. The adjusted Freeport inflow is constrained to always be ≥ 0.

Data Type	Data Source	Comments
Delta Inflow: October 1921 – September 1929	Joint Hydrology Study (DWR & USBR 1958)	---
Delta Inflow: October 1929 – September 2012	DAYFLOW Database (DWR 2012a)	---
CCWD Diversions	DAYFLOW Database (DWR 2012a)	---
Delta Net Channel Depletions: October 1921 – September 1929	Joint Hydrology Study (DWR & USBR 1958)	---
Delta Net Channel Depletions: October 1929 – September 2012	DAYFLOW Database (DWR 2012a)	---
Trinity Imports	USGS Website	---
Reservoir Storage	CDEC (DWR 2012b)	Shasta, Oroville, Folsom, New Melones
Millerton Lake Inflow: October 1921 – September 1994	Provided by Andy Draper (MWH) 1/27/15	CalSim II input data
Millerton Lake Inflow: October 1994 – September 2012	Provided by Andy Draper (MWH) 1/27/15	USACE Website
Millerton Lake Outflow	Provided by Andy Draper (MWH) 1/27/15	USGS Website
SJR Exchange Contractor Diversions & Return Flows: D607B; R619H; R614J	Provided by Sujoy Roy (Tetra Tech) 1/27/15	CalSim II input data

Table V.1 Data Summary for Surface Water Availability Analysis

Similarly, historical San Joaquin River inflow was adjusted to remove the effects of upstream CVP storage operations through the following calculation:

$$Q_{vernalis\ w.o.project} = Q_{vernalis} + Q_{inM} - Q_{outM} - Q_{dep} - Q_{exc} + \sum Q_{nm\ storage} \dots\dots\dots (V.3)$$

where Q_{inM} and Q_{outM} are Millerton Reservoir inflow and outflow, respectively; Q_{dep} is channel depletion to groundwater between Millerton Reservoir and Mendota Pool (assumed equal to zero in this analysis); Q_{exc} is water use by the San Joaquin River Exchange Contractors; and $\Sigma\, Q_{nm\ storage}$ is the flow associated with removing storage operations at New Melones. Without project Vernalis flow was set equal to historical Vernalis flow prior to October 1941, the date of initial Friant Dam operation. To account for periods when the full consumptive demand of the San Joaquin River Exchange Contractors was not available in the river, the following calculation was made:

$$Q_{exc} = MIN\big(D607B - R619H - R614J, Q_{inM} - Q_{dep}\big) \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots. (V.4)$$

where D607B is Exchange Contractor diversion and R619H and R614J are Exchange Contractor return flows as defined in CalSim II input data. The adjusted Vernalis inflow is constrained to always be ≥ 0.

Given the above calculations, without project total Delta inflow is calculated as follows:

$$Without\ Project\ Total\ Delta\ Inflow = Q_{freeport\ w.o.project} + Q_{yolo} + Q_{east} + Q_{vernalis\ w.o\ project} \dots\dots\dots (V.5)$$

and without project Delta outflow is calculated as follows:

$$Without\ Project\ Delta\ Outflow = Without\ Project\ Total\ Delta\ Inflow - Q_{ccwd} - Q_{ncd} \dots\dots\dots\dots\dots (V.6)$$

where Q_{ccwd} is historical Contra Costa Water District diversion and Q_{ncd} is historical agricultural net channel depletion.

3. Estimating Full Water Use in Study Area

The following reconnaissance-level calculation was used to estimate full or unrestricted water use in the study area:

$$Full\ Water\ Use = Q_{ncd} * \frac{A_{south}}{A_{Delta}} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (V.7)$$

where Q_{ncd} was previously defined as historical agricultural net channel depletion, A_{south} is the irrigated area in the study area and A_{Delta} is the irrigated area in the Delta. This analysis assumed A_{south} = 186,700 acres and A_{Delta} = 393,400 acres (Tetra Tech Inc. 2015a). This estimate could be refined through modeling analysis using the Delta Island Consumptive Use (DICU) model.

B. Results

Using the methods described above, Delta inflow and outflow under without project conditions were calculated for every month over the period October 1921 through September 2012. The availability of surface water for agricultural use in the study area was then evaluated by identifying when (1) monthly Delta inflow is positive and (2) monthly Delta outflow is positive. It is assumed that when monthly Delta inflow approaches zero, no water is available for in-Delta agricultural use and curtailment of all use in the study area is warranted[1]. Furthermore, it is assumed that if monthly Delta outflow is positive, i.e. Delta inflow exceeds full in-Delta water use, water is available for all use in the study area and no curtailment is warranted. This latter assumption ignores circumstances when Delta outflow is positive but sufficiently small such that seawater intrusion impairs water quality to the extent that the available supply could not be put to reasonable and beneficial use.

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[1] As described previously under Methods, Freeport and Vernalis inflows under without project conditions are constrained such that they are always ≥ 0. Therefore, by definition, without project Delta inflow is always positive. However, for purposes of illustrating the bounds of water availability, it is assumed that without project Delta inflow "approaches zero" when without project Freeport inflow is zero.

Outside the typical irrigation season of April through August, without project Delta inflow was always positive. The frequency of water not being available for use in the study area during the irrigation season, i.e. without project Delta inflow approaches zero, is summarized in the second column of Table V.2. Without project Delta inflow is always positive in the months of April and May except in April 1977. The frequency of near-zero inflow in June, July and August is 10%, 25% and 5%, respectively.

Month	No Availability	Limited Availability	Unlimited Availability
April	<1	<1	>99
May	0	1	99
June	10	10	80
July	25	25	50
August	5	40	55

Table V.2. Frequency (%) of Water Availability for In-Delta Agriculture

Similar to Delta inflow, without project Delta outflow was always positive outside the typical irrigation season of April through August. The frequency of unlimited water availability for use in the study area during the irrigation season, i.e. without project Delta outflow is greater than or equal to zero, is summarized in the fourth column of Table V.2. Without project Delta outflow is always positive in the months of April and May except in April 1977, May 1976 and May 1992. The frequency of positive outflow in June, July and August is 80%, 50% and 55%, respectively.

The third column of Table V.2 provides an estimate of the frequency of limited water availability in the study area. This frequency is estimated such that the sum of columns 2, 3 and 4 equal 100%. As discussed in the previous paragraph, April and May is generally characterized by unlimited water availability. The frequency of limited availability in the months of June, July and August is 10%, 25% and 40%, respectively.

Frequency of water availability in the month of August is shown as an exceedance probability in Figure V.1. The top blue line shows the exceedance probability of without project Delta inflow. This line shows that the probability of inflow exceeding 0 cfs is 95%, i.e. inflow is near zero 5% of the time. This compares with the second column of Table V.2. Other values can be estimated from this figure. For example, the probability of inflow exceeding 5,000 cfs is 40%, i.e. inflow is less than 5,000 cfs 60% of the time. The bottom black line shows the exceedance probability of without project Delta outflow. This line shows that the probability of outflow exceeding 0 cfs is 55%. This compares with the fourth column of Table V.2.

The difference between water use and water availability in the study area was calculated on a monthly basis and averaged by month and 40-30-30 water year type. Results for the full period October 1921 through September 2012 are provided in Table V.3. These values are reported as a volume in thousand acre-ft per year and represent water use that exceeded water availability. The full period of record does not reflect the extent of excess water use under current conditions,

given that the early period of record is characterized by lower upstream water use and higher without project Delta inflow. Therefore, results are also provided in Table V.4 and Figure V.2 for the more recent period October 1967 through September 2012.

WY Type	April	May	June	July	August	Total
Wet	0	0	0	5	0	6
Above Normal	0	0	0	48	17	65
Below Normal	0	0	18	65	45	128
Dry	0	0	36	95	65	196
Critical	4	3	54	101	83	244

Table V.3 Study Area Excess Use Using Inflow Criterion:
Water Years 1922-2012 Averages by Month and 40-30:30 Water Year Type (TAF)

WY Type	April	May	June	July	August	Total
Wet	0	0	0	9	0	9
Above Normal	0	0	0	48	0	48
Below Normal	0	0	40	101	18	159
Dry	0	0	90	126	85	300
Critical	6	4	78	126	106	320

Table V.4 Study Area Excess Use Using Inflow Criterion:
Water Years 1968-2012 Averages by Month and 40-30:30 Water Year Type (TAF)
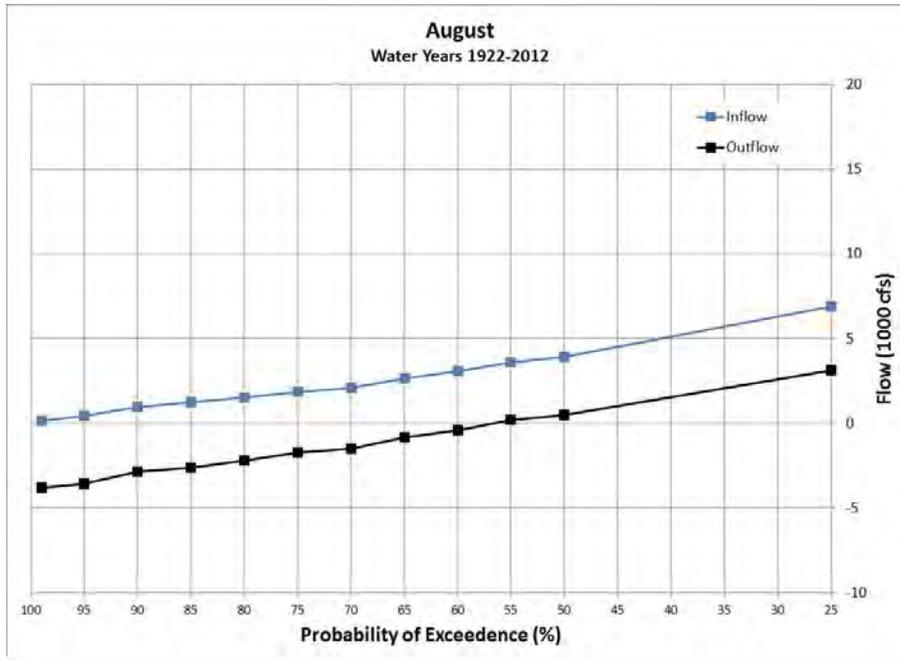
Figure V.1. Without Project Delta Inflow and Outflow Frequency During August:
Water Years 1922-2012
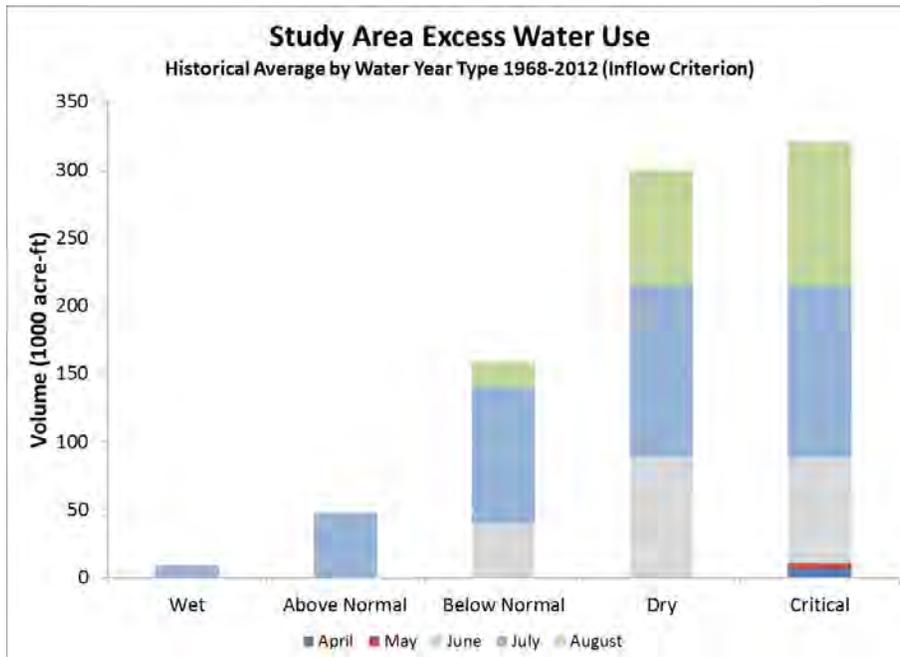
Figure V.2. Study Area Excess Diversion Using Inflow Criterion:
Water Years 1968-2012 Averages by Month and 40-30-30 Water Year Type (TAF)

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VI.   Analysis of Delta Water Quality (Salinity Criterion)

The previous section (Section V) evaluates the availability of surface water for agricultural use in the study area (i.e. south of the San Joaquin River) through a simple inflow approach or criterion. The evaluation assumes that when monthly Delta inflow approaches zero under a without project scenario, no water is available for in-Delta agricultural use and curtailment of all use in the study area is warranted. Furthermore, the evaluation assumes that if monthly Delta outflow is positive under a without project scenario, i.e. Delta inflow exceeds full in-Delta water use, water is available for all use in the study area and no curtailment is warranted. This latter assumption ignores circumstances when Delta outflow is positive but sufficiently small such that seawater intrusion impairs the beneficial use of water.

The purpose of this section is to evaluate the availability of surface water in the study area under without project conditions that is of adequate quality to meet agricultural beneficial uses. A water quality modeling analysis was conducted and is discussed below. An analysis of historical water quality measurements, prior to construction of the CVP and SWP projects, is summarized to provide a quasi-validation of the modeling results. Based on flow-salinity relationships suggested by the water quality modeling analysis, a conceptual approach to trigger water use curtailments as a function of hydrologic conditions is presented, i.e. the salinity criterion.

A.   Water Quality Modeling Analysis

The availability of surface water in the study area under without project conditions that is of adequate quality to meet agricultural beneficial uses was evaluated through a water quality modeling analysis. This section summarizes the methods that were used to conduct the analysis and presents results from the modeling studies. Details on the modeling analysis are presented elsewhere (Tetra Tech Inc. 2015a).

1.   Methods

The DSM2 model (Version 8.0.6) was used to simulate water quality in the study area under current and without project conditions. These scenarios were compared to assess how operation of the SWP and CVP influences salinity in the study area. Modeling assumptions associated with the scenarios are described below.

The current conditions scenario assumes an 82-year sequence (water years 1922-2003) of hydrology and operations provided in a recent SWP Delivery Reliability Report (DWR 2014). The without project scenario assumes no SWP-CVP Delta facilities (i.e. no export facilities and no Delta Cross Channel) and generally assumes the same upstream hydrology as the current conditions scenario; however, upstream hydrology is modified to remove SWP-CVP reservoirs. The method used to adjust upstream hydrology is similar to that described in Section V.

Note that the without project scenario assumes that upstream water use is identical to the current conditions scenario. In other words, the modeling assumption is that irrigated agriculture in the Sacramento Valley (and San Joaquin Valley) would have developed to the same level even if the SWP and CVP were unavailable to provide additional surface water supplies. The validity of this assumption is being tested through a separate C2VSim modeling study. The study will evaluate the physical and economic viability of utilizing groundwater when surface water is unavailable for irrigation, assuming historical development patterns absent the SWP-CVP projects.

The current conditions scenario assumes Vernalis salinity as characterized in the recent SWP Delivery Reliability Report (DWR 2014). It is recognized that current inflow to the Delta from the San Joaquin River is generally of higher salinity than during the era prior to construction of Friant Dam in the 1940s. While development impacts in the San Joaquin River basin are associated with several non-project facilities as well as CVP facilities, for purposes of this analysis it is assumed that water quality observed during the pre-Friant period is representative of the without project scenario. Thus, salinity in the San Joaquin River at Vernalis for this scenario is based on the report "Effects of the CVP upon the Southern Delta Water Supply" (USBR & SDWA 1980). Mathematical relationships developed in the 1980 report were used to (1) calculate salt load based on Vernalis flow, (2) convert salt load to chloride concentrations, and (3) convert chloride concentration to specific conductance or EC. These equations are provided in Appendix A for reference. Relative to current salinity conditions at Vernalis, this characterization results in fresher flow entering the Delta throughout the year except in the summer months and in the late spring of drier years (see Table VI.1).

Month	Monthly Average Salinity (mS/cm)									
	Wet		Above Normal		Below Normal		Dry		Critical	
	Current	w/o Projects	Current	w/o Projects	Current	w/o Projects	Current	w/o Projects	Current	w/o Projects
January	0.40	0.20	0.51	0.23	0.58	0.25	0.66	0.31	0.75	0.37
February	0.31	0.21	0.41	0.24	0.43	0.28	0.58	0.33	0.65	0.45
March	0.27	0.15	0.37	0.17	0.46	0.18	0.61	0.21	0.73	0.31
April	0.21	0.12	0.26	0.13	0.28	0.15	0.36	0.20	0.49	0.41
May	0.22	0.16	0.28	0.20	0.29	0.27	0.37	0.43	0.47	0.72
June	0.26	0.36	0.32	0.51	0.42	0.62	0.53	0.82	0.65	0.82
July	0.32	0.52	0.42	0.59	0.49	0.64	0.58	0.69	0.70	0.75
August	0.38	0.50	0.46	0.53	0.49	0.54	0.56	0.56	0.68	0.58
September	0.37	0.43	0.42	0.46	0.45	0.46	0.48	0.51	0.57	0.57
October	0.54	0.36	0.64	0.40	0.58	0.39	0.59	0.40	0.66	0.42
November	0.60	0.32	0.68	0.37	0.64	0.36	0.65	0.39	0.69	0.42
December	0.52	0.22	0.65	0.25	0.61	0.28	0.66	0.32	0.74	0.35

Table VI.1 Comparison of Vernalis Salinity under Current and Without Project Scenarios
by Month and Water Year Type: Water Years 1922-2002

2. Results

The Delta cannot be treated uniformly when evaluating responses to different impulses such as seawater intrusion, SWP-CVP project operations and Vernalis salinity boundary conditions. For example, water quality in the Old and Middle River corridors downstream of Clifton Court Forebay and Jones Pumping Plant are strongly influenced by project operations. In contrast, water quality in the remaining parts of the south Delta is primarily influenced by water quality at Vernalis and local groundwater and agricultural drainage (DWR 2005). Furthermore, the effect of seawater intrusion is not uniform throughout the Delta but is dictated to a large degree by a location's distance from Golden Gate.

Three stations in the study area were selected to illustrate salinity differences between the current condition and without project scenarios: (1) Old River @ Bacon Island (ROLD024), San Joaquin River @ Stockton (RSAC063), and Grant Line Canal @ Tracy Road Bridge. The Old River station, located along the Old and Middle River corridor, is strongly influenced by project operations. Of the three stations, the Old River location is closest to Golden Gate and is therefore most susceptible to seawater intrusion. The other stations are outside of the Old and Middle River corridor and are thus more strongly influenced by Vernalis water quality and local drainage conditions. Also, these locations are further from Golden Gate and therefore less susceptible to seawater intrusion.

Table VI.2 provides a broad qualitative interpretation of salinity differences between the current condition and without project scenarios for each location under wet and dry hydrologic conditions. Appendix B compares the two scenarios by location and month through frequency distribution charts. Table VI.2 denotes current conditions being more saline and less saline than the without project scenario by an "up" arrow (↑) and "down" arrow (↓), respectively. Similarity between the two scenarios is depicted by a dash (---). Non-irrigation season months are grayed out in the table. A rigorous numerical criterion was not followed to fill in the table; rather the comparison was accomplished through a visual inspection and should be interpreted in broad terms only. The frequency distribution charts in Appendix B provide a more precise quantitative comparison of the scenarios.

Old River @ Bacon Island shows a strong positive influence of the projects on water quality under most conditions. The projects, by maintaining higher Delta outflow, protect this station from severe seawater intrusion throughout the late spring thru fall under drier hydrologic conditions. Project operations result in minor salinity degradation during the winter (December-January) of drier years and the spring (April-May) of wetter years. However, this degradation is minor and does not impair beneficial uses of the water.

San Joaquin River @ Stockton shows a much weaker influence of the projects on water quality. Given this station's further distance from Golden Gate, the projects' maintenance of higher outflow has less influence on its water quality. However, benefits are observed in the summer (June-August) of drier years. This station typically shows salinity degradation under current

conditions, relative to the without project scenario, during the non-irrigation season and in the early spring. As the Stockton station is highly sensitive to conditions in the San Joaquin River entering the Delta, most of this degradation is associated with higher Vernalis salinity. Vernalis salinity under current conditions is regulated to protect agricultural beneficial uses; therefore, degradation at this station does not result in beneficial use impairment.

Month	Old River @ Bacon Island		San Joaquin River @ Stockton		Grant Line Canal @ Tracy Rd. Bridge	
	Wet	Dry	Wet	Dry	Wet	Dry
January	---	↑	↑	↑	↑	↑
February	---	---	↑	↑	↑	↑
March	---	---	↑	↑	↑	↑
April	↑	---	↑	↑	↑	↑
May	↑	↓	↑	---	---	---
June	---	↓	---	↓	---	---
July	---	↓	---	↓	↓	---
August	---	↓	---	↓	↓	---
September	---	↓	---	---	---	---
October	---	↓	↑	↑	↑	↑
November	---	---	↑	↑	↑	↑
December	---	↑	↑	↑	↑	↑

Table VI.2. Change in Study Area Salinity under Current Conditions Relative to Without Project Scenario: Three Locations for Wet and Dry Hydrologic Conditions. The table denotes current conditions being more saline and less saline than the without projects scenario by an "up" arrow (↑) and "down" arrow (↓), respectively. Similarity between the two scenarios is depicted by a dash (---).

In broad terms, Grant Line Canal @ Tracy Road Bridge exhibits a similar water quality response as seen at Stockton. This station is also strongly influenced by water quality conditions at Vernalis. Given this station's distance from Golden Gate, seawater intrusion would rarely be experienced and therefore, project operations during dry years do not provide a noticeable water quality benefit at this station.

B.   Observed Water Quality Analysis

The DSM2 hydrodynamic and water quality modeling analysis discussed in the previous section shows periods of dramatic salinity intrusion into the central and southern Delta. Such conditions

have not been observed in recent history due to the operation of the SWP-CVP upstream reservoirs and Delta facilities. Although the modeled conditions were hypothetical in that the specific without project hydrology did not occur historically, periods of dramatic salinity intrusion into the central and southern Delta are not without precedent. This section summarizes work that was conducted to evaluate salinity data that were collected in the study area in the 1920s through 1940s prior to the construction of Shasta Dam and other upstream project reservoirs (Tetra Tech Inc. 2015b). These data show that the study area was subject to severe seawater intrusion, even during this early period before agriculture in the Sacramento River basin was fully developed.

1. Methods

This analysis of historical interior Delta salinity builds on an analysis of salinity trends in the western Delta (Hutton et al. 2015, Tetra Tech Inc. 2014). The western Delta salinity trend analysis was based on all available data from water years 1922-2012, collected by various state and federal entities. As part of this earlier effort, salinity data in scanned paper reports from DWR and its predecessor entity, Department of Public Works were digitized and integrated with modern data from the California Data Exchange Center (CDEC) into a single database. Because the focus of this earlier effort was on the western Delta, CDEC data were compiled only from relevant stations. However, all salinity data (both western Delta and interior Delta stations) were scanned and digitized as part of the effort.

Similar to the earlier western Delta effort, appropriate data cleaning methodologies were applied to the historical interior Delta data to develop a monthly data set to evaluate salinity changes over the past nine decades. Maps were developed for specific hydrologic conditions and time periods, by developing averages and other statistical metrics of the available data, and by interpolating across the Delta channels. Statistical analyses of trends at key locations were performed to support interpretation of the maps.

Data are presented as maps over different time intervals (1922-1944; 1945-1967; and 1968-2012), given similar ranges in the position of the X2 isohaline and San Joaquin River flows. Maps are presented for salinity aggregated as the mean, 25th percentile, median (50th percentile), and the 75th percentile. In general the maps show the intrusion of salinity into the central and southern Delta when X2 values are high and especially when San Joaquin River flows are low. For the cases where salinity intrusion occurs, and given similar hydrology, the 1922-1944 salinities are often different from 1945-1967 and 1968-2012 periods.

Box plots were used to summarize the data shown in maps. As expected, summer specific conductance values are higher than spring values, although the magnitude of the difference varies by region. There are also differences of specific conductance over the time intervals considered: areas typically in the western portion of the study domain show decreases over the period, and in the south, show small increases.

Observed salinity data were averaged in preparation for presentation on maps and were classified into different groups that were characteristic of the season and hydrology. A monthly average specific conductance was calculated for each station and month. For the grab sample-based data, this was simply the average of all the observations in a given month. For the continuous CDEC data, hourly and 15-minute data were averaged to the daily level. In this averaging process, if at least 50% of the possible values in a day (12 observations for hourly data or 48 observations for 15-minute data) were missing, the daily average was also identified as missing. On each date the non-missing value with the largest original time resolution (daily > hourly > 15 minute) is kept for monthly averaging. The monthly average is also undefined if more than 50% of the days in the month are missing. Once the monthly averages were calculated, they were split into subsets based on four categories:

- Monthly San Joaquin River X2 position. Three San Joaquin River X2 categories were defined: (1) < 54 km, (2) 54-82 km, and (3) > 82 km. Gaps in the time series, as calculated in the 2014 report, were generally filled through linear interpolation.
- Season. Two seasonal categories were defined: (1) Spring (April-June) and Summer (July-September).
- Vernalis flow. Two Vernalis flow categories were defined: (1) above or (2) below the median flow (to the nearest 1,000 cfs) within each season.
- Time period. Three time periods were defined: (1) WYs 1922-1944, (2) WYs 1945-1967, and (3) WYs 1968-2012. The mean as well as the 25th, 50th, and 75th percentiles of the monthly averages were evaluated for each subset.

2.   Results

Maps were compiled in Tetra Tech Inc. (2015b) by method of data aggregation (mean, 25th percentile, 50th percentile, and 75th percentile). In general the maps show intrusion of salinity into the central and southern Delta when X2 values are high and especially when San Joaquin River flows are low. The analysis clearly shows how the distribution of interior Delta salinity in the summer months has changed following the construction and operation of Shasta Dam.

Three maps (Figures VI.1 thru VI.3) are illustrative of the suite of maps provided in the 2015 report. The maps clearly show that salinity intrusion into the study area was severe prior to the operation of upstream project reservoirs and resulted in conditions that were unfavorable to agricultural beneficial uses. While not an exact match, the salinity distribution resembles that provided in the without project DSM2 simulation.

Box and whisker plots (Figures VI.4 and VI.5) illustrate additional analyses provided in the 2015 report. These sample figures demonstrate that, although the without project conditions were characterized by more severe seawater intrusion events, the seawater intrusion was not universal throughout the entire study area. In particular, locations that were strongly influenced by conditions along the San Joaquin River at Vernalis were typically less salty under without project

conditions than under current conditions. As noted previously in this document, under similar hydrologic conditions, Vernalis salinity was lower prior to development of CVP projects upstream of Vernalis. Again, while not an exact match, these findings are in line with those provided in the without project DSM2 simulation.

C.   Water Availability Analysis Using the Salinity Criterion

Section V evaluated the availability of surface water for agricultural use in the study area utilizing the inflow criterion. The approach effectively used Delta inflow as a "trigger" for imposing curtailments by assuming that water was available for diversion in the study area only when Delta inflows was positive. As noted previously, the inflow criterion does not account for circumstances when seawater intrusion is sufficiently severe to impair beneficial use of available water. The purpose of this section is to evaluate the availability of surface water in the study area under without project conditions that is of adequate quality to meet agricultural beneficial uses. This salinity criterion provides an approach to trigger water use curtailments as a function of hydrologic conditions. It is envisioned that the following methodology will be refined to develop a real time approach for informing decisions on water use curtailment in the study area. Methods and results based on the proposed methodology are provided below.

1.   Methods

The proposed salinity criterion methodology is summarized below in four steps. The methodology requires the specification of a salinity "trigger"; this trigger is a salinity value that is defined as the maximum salinity that can be put to beneficial use. Given the study area's assumed response to seawater intrusion, the methodology identifies irrigated lands that are subject to salinity impairment for a given hydrologic condition.

The methodology was applied using two separate approaches. One approach (Approach 1) assumes that water quality simulation results are available from DSM2 or another water quality model. The second approach (Approach 2) assumes that water quality simulation results are not available and utilizes flow-salinity relationships to estimate the extent of salinity intrusion in the study area. Both approaches are discussed below.

a)   Antecedent Outflow

Seawater intrusion is influenced by hydrologic conditions in general and the time history of Delta outflow in particular. This time history was mathematically defined by Denton (1993) and termed antecedent outflow. Antecedent outflow, G, is defined by the following routing function similar to a relationship used by Harder (1977):

$$\frac{\partial G}{\partial t} = \frac{(Q - G) * G}{\beta} \quad ....(VI.1)$$

where Q is Delta outflow and β is an empirically determined constant. As Denton (1993) points out, the term β/G governs the rate at which G approaches steady state.

Approach 1 utilizes salinity estimates produced by DSM2 simulations and therefore does not rely on antecedent outflow estimates. Approach 2, on the other hand, requires antecedent outflow estimates. This analysis calculated an end-of-month (rather than average month) antecedent outflow assuming monthly average outflow from the DSM2 without project scenario and a nominal β value of 5710 cfs-months. Possible analysis refinements include (1) calibrating the β constant to provide a better fit to DSM2 salinity data in the study area and (2) conducting the analysis on a daily time step.

b) *Delta Salinity Gradient*

Approach 1 utilized DSM2 salinity data to directly characterize the salinity gradient in the study area. Approach 2 adopted the Delta Salinity Gradient (DSG) modeling approach (Hutton et al. 2015, Hutton 2014) to mathematically describe how far upstream a salinity isohaline travels into the study area as a function of antecedent outflow. DSG model equations (Equations VI.2 and VI.3) were calibrated with DSM2 data from the without project scenario for three river reaches in the study area. The calibration assumed an index salinity distance (X2) defined by a 2.0 mS/cm surface isohaline[2] (Tetra Tech 2015a). The three river reaches – Old, Middle and San Joaquin – are shown in Figure VI.6. Calibrated model constants are provided for each river reach in Table VI.3.

$$X = X2 * \left[\frac{\ln\left(\frac{S - S_b}{S_o - S_b}\right)}{\tau} \right]^{-\Phi_2} \qquad \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots (VI.2)$$

$$X2 = \Phi_1 * G^{\Phi_2} \quad \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots (VI.3)$$

where:

X = distance of salinity isohaline (S) from Golden Gate in km

X2 = distance of index salinity isohaline (2.0 mS/cm surface) from Golden Gate in km; this definition differs from the conventional definition of X2

S = salinity isohaline in mS/cm, defined as the salinity "trigger" or the maximum salinity that can be put to beneficial use

G = antecedent outflow in cfs

S_o, S_b, Φ_1 and Φ_2 = calibrated model constants

---

[2] The assumed 2.0 mS/cm index differs from the conventional 2.64 mS/cm surface isohaline associated with a 2 ppt bottom salinity.

$$\tau = \ln\left[\frac{2.0 - S_b}{S_o - S_b}\right]$$

River Reach	Φ_1	Φ_2	S_o (mS/cm)	S_b (mS/cm)
Old River	696	-0.234	24.7	0.38
Middle River	624	-0.221	24.6	0.44
San Joaquin River	465	-0.187	24.7	0.34

Table VI.3. DSG Model Constants for Study Area River Reaches

c) *Curtailment Area & Volume*

Relationships between channel distance and cumulative downstream area were developed for the three river reaches – Old, Middle and San Joaquin – within the study area (Tetra Tech 2015a); the same relationships were employed by Approaches 1 and 2. These relationships allow for the estimation of isohaline location and total area downstream of a prescribed salinity trigger, i.e. the curtailment area. These relationships are provided as a map in Figure VI.7 and as lookup tables in Appendix C. Thus, by defining a salinity trigger, the curtailment area can be calculated for any hydrologic condition.

Once the curtailment area is estimated, the curtailment volume can be estimated over a given time interval:

$$Curtailment\ Volume = \frac{A_{curtail} * Q_{ncd}}{A_{delta}} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (VI.4)$$

where $A_{curtail}$ is the curtailment area in acres, Q_{ncd} was previously defined as Delta net channel depletions in acre-feet, and A_{delta} was previously defined as the total irrigated area of the Delta = 393,400 acres. This calculation step is only defined when $Q_{ncd} > 0$. This estimate could be refined through modeling analysis using the Delta Island Consumptive Use (DICU) model.

2. Results

Following the methodology outlined above and assuming a salinity trigger of 2.0 mS/cm, curtailment area and volume were calculated for every month over the period October 1921 through September 2012 utilizing the hydrology developed in Section V.

The curtailment volume was calculated on a monthly basis and averaged by month and 40-30-30 water year type. Results are provided for Approach 1 (DSM2 estimates) in Table VI.4 and for Approach 2 (DSG estimates) in Table VI.5. These values, reported as a volume in thousand acre-ft per year, represent water use that occurred when salinity exceeded the assumed salinity trigger. The full period of record does not reflect the extent of potential curtailment, given that the early period of record is characterized by lower upstream water use and higher without project antecedent outflow. Therefore, results are also provided in Table VI.6 and Figure VI.8

(Approach 1) and Table VI.7 and Figure VI.9 (Approach 2) for a more recent period following October 1967.

WY Type	June	July	August	September	October	November	Total
Wet	0	0	0	0	0	0	1
Above Normal	0	2	5	2	0	0	9
Below Normal	0	4	17	6	1	0	28
Dry	1	15	37	16	5	0	74
Critical	9	41	50	25	13	2	141

Table VI.4 Study Area Excess Use Using 2.0 mS/cm Salinity Criterion (Approach 1): Water Years 1922-2002 Averages by Month and 40-30:30 Water Year Type (TAF)

WY Type	June	July	August	September	October	November	Total
Wet	0	0	0	0	0	0	1
Above Normal	0	1	3	0	0	0	5
Below Normal	1	7	17	3	0	0	28
Dry	1	18	36	8	1	0	64
Critical	5	34	53	22	7	0	122

Table VI.5 Study Area Excess Use Using 2.0 mS/cm Salinity Criterion (Approach 2): Water Years 1922-2012 Averages by Month and 40-30:30 Water Year Type (TAF)

WY Type	June	July	August	September	October	November	Total
Wet	0	0	0	0	0	0	1
Above Normal	0	1	2	0	0	0	3
Below Normal	0	8	31	12	0	0	51
Dry	3	25	54	20	3	0	104
Critical	9	43	58	30	16	3	160

Table VI.6 Study Area Excess Use Using 2.0 mS/cm Salinity Criterion (Approach 1): Water Years 1968-2002 Averages by Month and 40-30:30 Water Year Type (TAF)

WY Type	June	July	August	September	October	November	Total
Wet	0	1	0	0	0	0	1
Above Normal	0	1	1	0	0	0	2
Below Normal	1	14	25	5	0	0	45
Dry	3	41	64	13	1	0	122
Critical	8	52	78	32	10	0	179

Table VI.7 Study Area Excess Use Using 2.0 mS/cm Salinity Criterion (Approach 2): Water Years 1968-2012 Averages by Month and 40-30:30 Water Year Type (TAF)

The curtailment volume estimates differ from those provided in Section V because these estimates are based on a salinity trigger, whereas the previous estimates are based on a Delta inflow trigger. It is worthwhile to note the seasonal lag associated with the curtailment volumes estimated from the salinity criterion. Curtailments based on the inflow criterion are limited to the spring and summer months (April – August) whereas curtailments based on the salinity criterion are limited to the summer and fall months (typically June – November). This difference is reasonable given that salinity intrusion is affected by the time history of Delta outflow.

D.   Quasi-Validation of Water Quality Modeling

It is recognized that the extremely low Delta outflow conditions associated with the without project scenario are outside the calibration range of the DSM2 model. To assess model validity under these conditions, the historical salinity data were compared with simulation results. This comparison is not purported to be a true model validation, as no attempt was made to model the actual hydrologic, hydrodynamic, topographic and bathymetric conditions that existed during the period when data were collected. A true model validation is complicated by the spatial and temporal sparseness of historical observations in the study area.

Figure VI.10 provides graphical comparisons of salinity observations and model predictions at two locations in the study area. The first three graphs (a)-(c) show results along Middle River at or near a location currently identified by the RKI RMID015. The final graph (d) shows results along Old River at or near a location currently identified by the RKI ROLD024. All graphs compare observed data (black squares) with the DSM2 without project simulation results described previously (blue line), the applicable DSM2-calibrated DSG model predictions (red line) utilizing historical (DAYFLOW) hydrology, and a DSM2 simulation utilizing historical hydrology (black line). These comparisons suggest that although the DSM2 historical simulation does not demonstrate a consistent prediction bias, the DSM2-calibrated DSG model is likely under-representing seawater intrusion into the study area under extremely low outflow conditions. Furthermore, these comparisons demonstrate that the without project hydrology results in much greater seawater intrusion than experienced in the 1920s and 1930s due to greater water use upstream of the Delta.

Figure VI.10 (a) compares observed and modeled salinity during the summer and fall of 1924, one of the driest periods on record for the Central Valley. If a "perfect" DSM2 simulation was produced and a "perfect" DSG fit to the simulation results were performed, we would expect the red line to match the time trajectory of the observed data. The DSG model clearly under-estimates salinity intrusion into Middle River during this period. Furthermore, the observed data suggests that the peak salinity occurs in October rather than in September, as suggested by the DSG predictions and the DSM2 without project simulation. Similar observations are made at the Middle River location during the summer and fall of 1931and 1934 (graphs (b) and (c)) as well as the Old River location during the summer and fall of 1931 (graph (d)).

Figure VI.11 compares observed and modeled salinity gradients in the study area under a range of low antecedent outflow conditions. The figure shows the salinity gradient relative to distance from Golden Gate in units of kilometers. The top left chart shows the salinity gradients for an outflow range of 500-1000 cfs; the bottom right chart shows the salinity gradients for an outflow range of 4000-4500 cfs. Observed data span water years 1922-44 and are shown as box and whisker plots. Modeled data are represented by the DSM2-calibrated DSG models for the San Joaquin, Old and Middle River reaches in the study area. The figure demonstrates that the model captures the approximate shape of the observed salinity gradient and is consistent with the observations associated with Figure VI.10, i.e. the DSG models appear to under-estimates

salinity intrusion into the study area. Based on these consistent observations, this analysis concludes that the use of DSM2 and the DSM2-calibrated DSG models as part of the proposed salinity criterion methodology allows for a reasonable and conservative method of evaluating water supply availability in the study area.
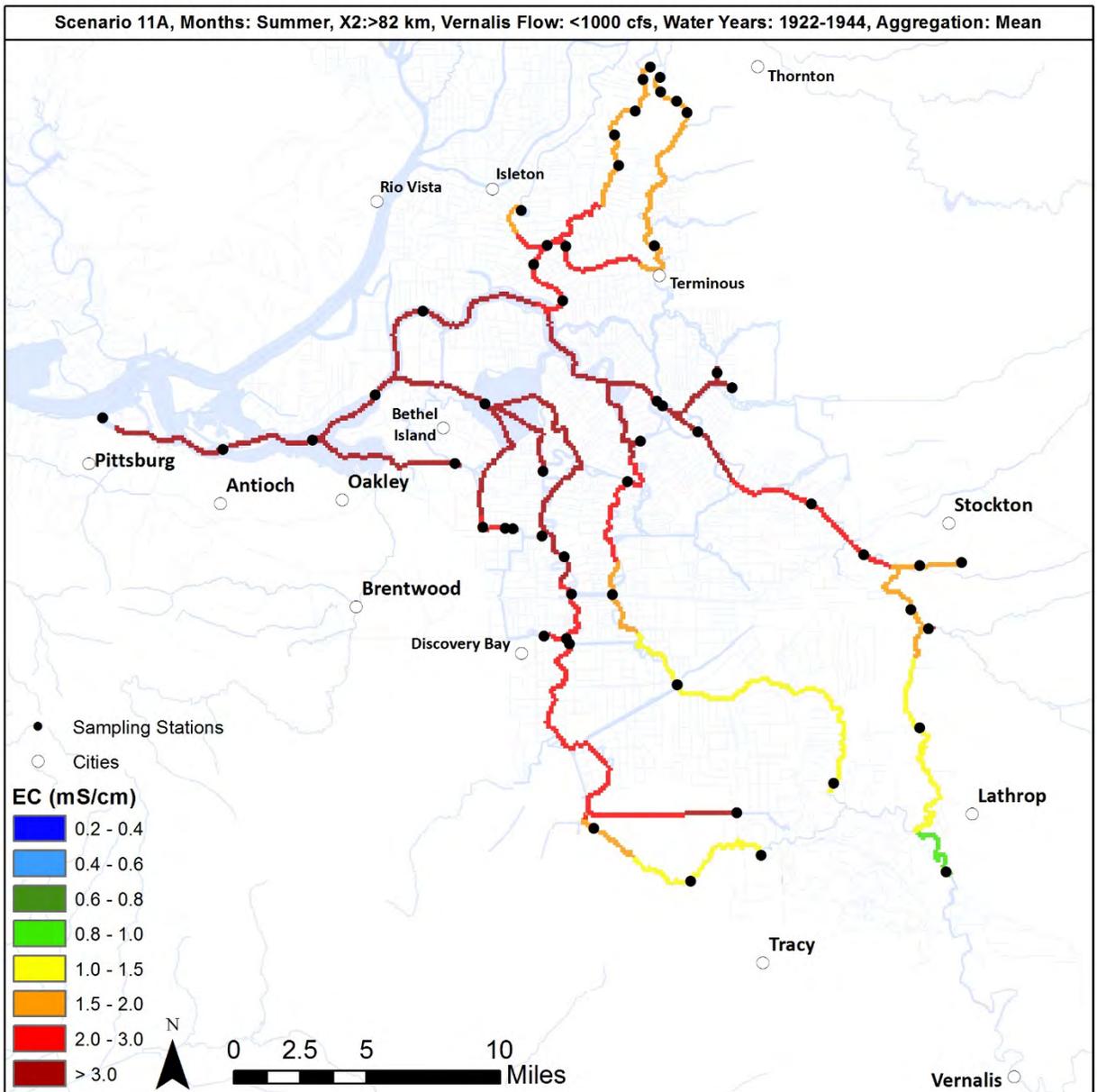
Figure VI.1 Mean Salinity Distribution in the Study Area for Water Years 1922-44: X2 > 82 km; Summer Season; Vernalis Flow < 1000 cfs (from Tetra Tech Inc. 2015b)
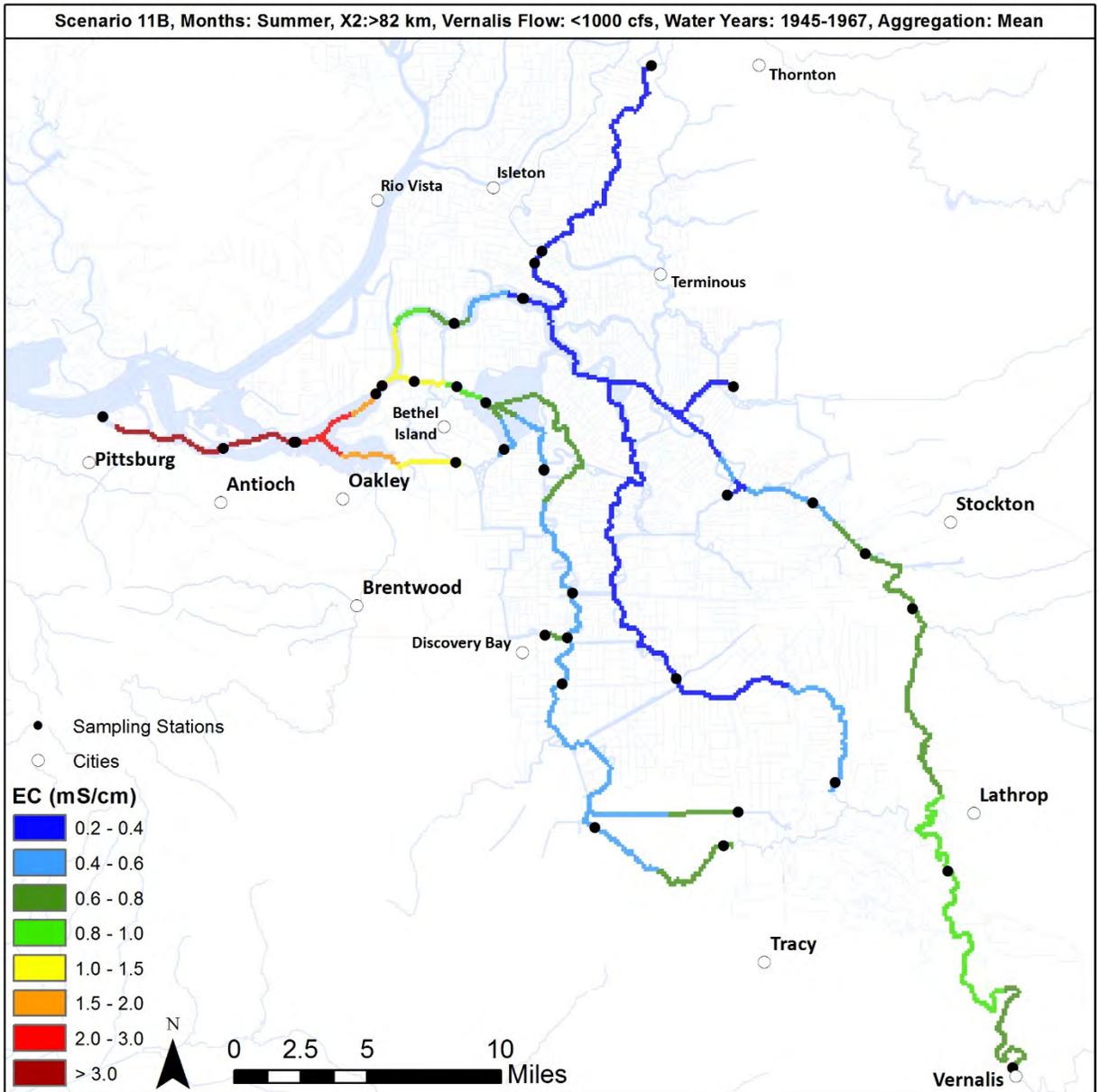
Figure VI.2 Mean Salinity Distribution in the Study Area for Water Years 1945-67: X2 > 82 km; Summer Season; Vernalis Flow < 1000 cfs (from Tetra Tech Inc. 2015b)
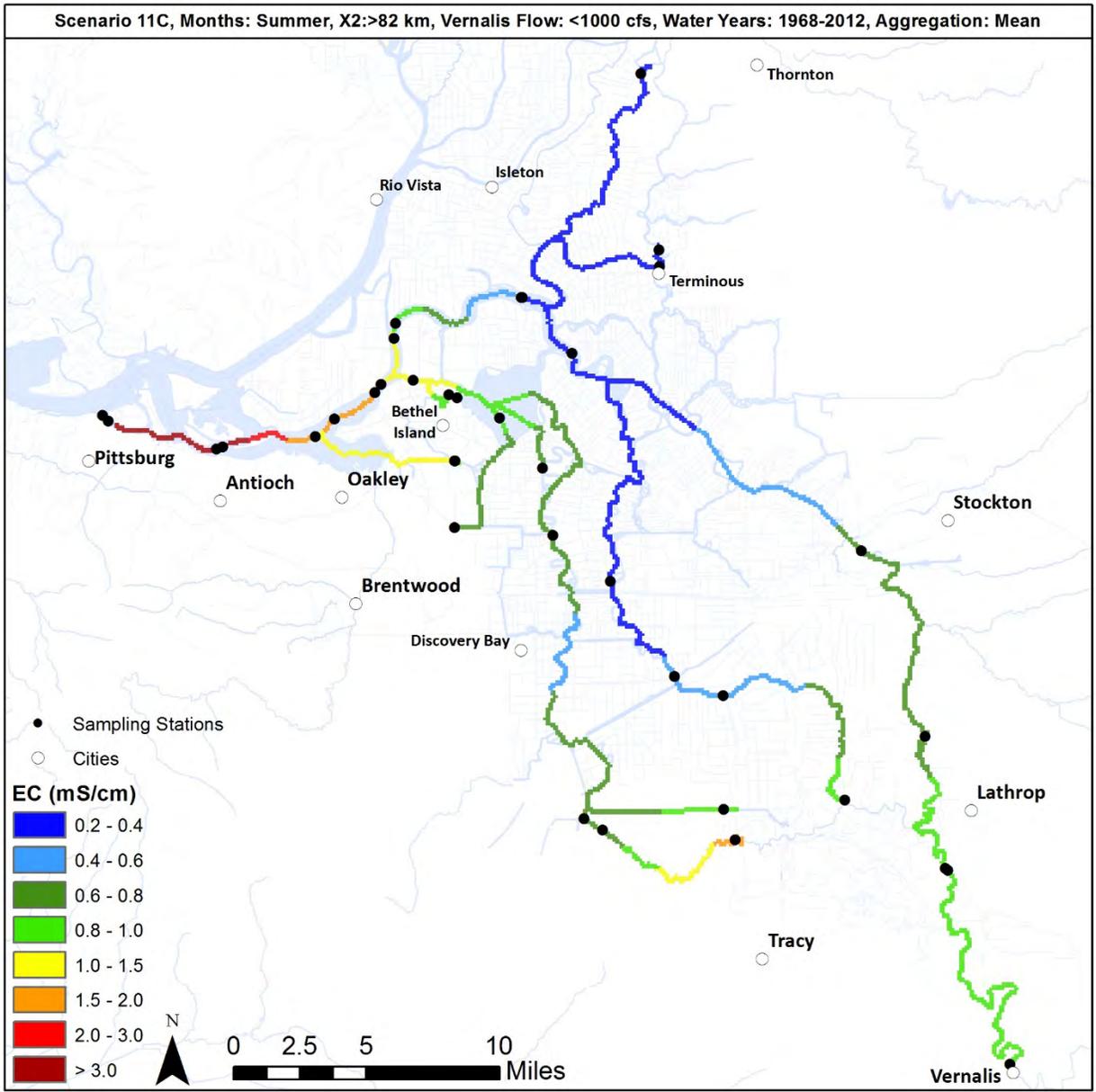
Figure VI.3 Mean Salinity Distribution in the Study Area for Water Years 1968-2012: X2 > 82 km; Summer Season; Vernalis Flow < 1000 cfs (from Tetra Tech Inc. 2015b)
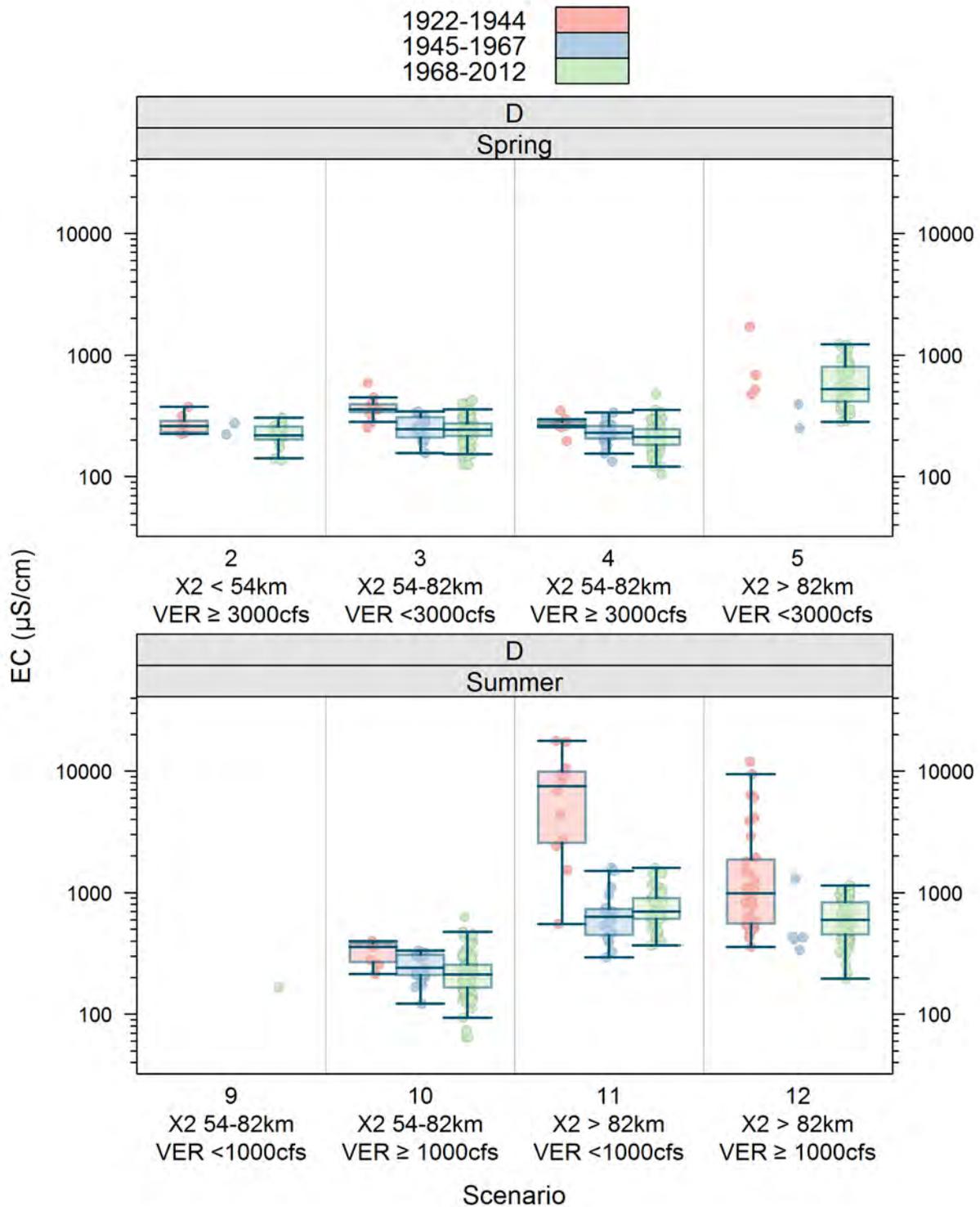
Figure VI.4. Box and Whisker Plots Comparing Monthly Average Salinity in the Vicinity of Franks Tract and Old River Downstream of Bacon Island for Three Time Periods (from Tetra Tech Inc. 2015b)
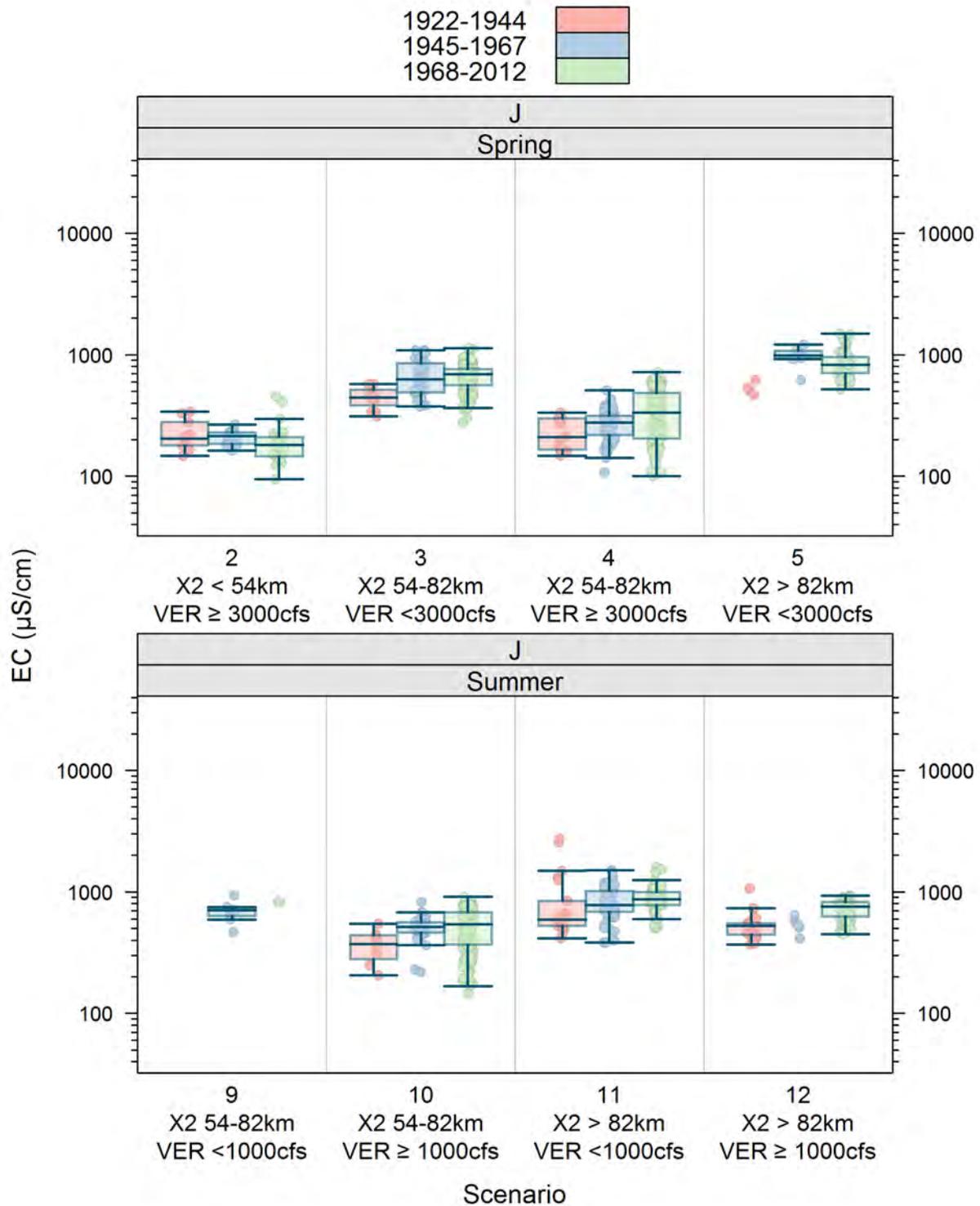
Figure VI.5. Box and Whisker Plots Comparing Monthly Average Salinity along the San Joaquin River between Vernalis and Stockton for Three Time Periods (from Tetra Tech Inc. 2015b)
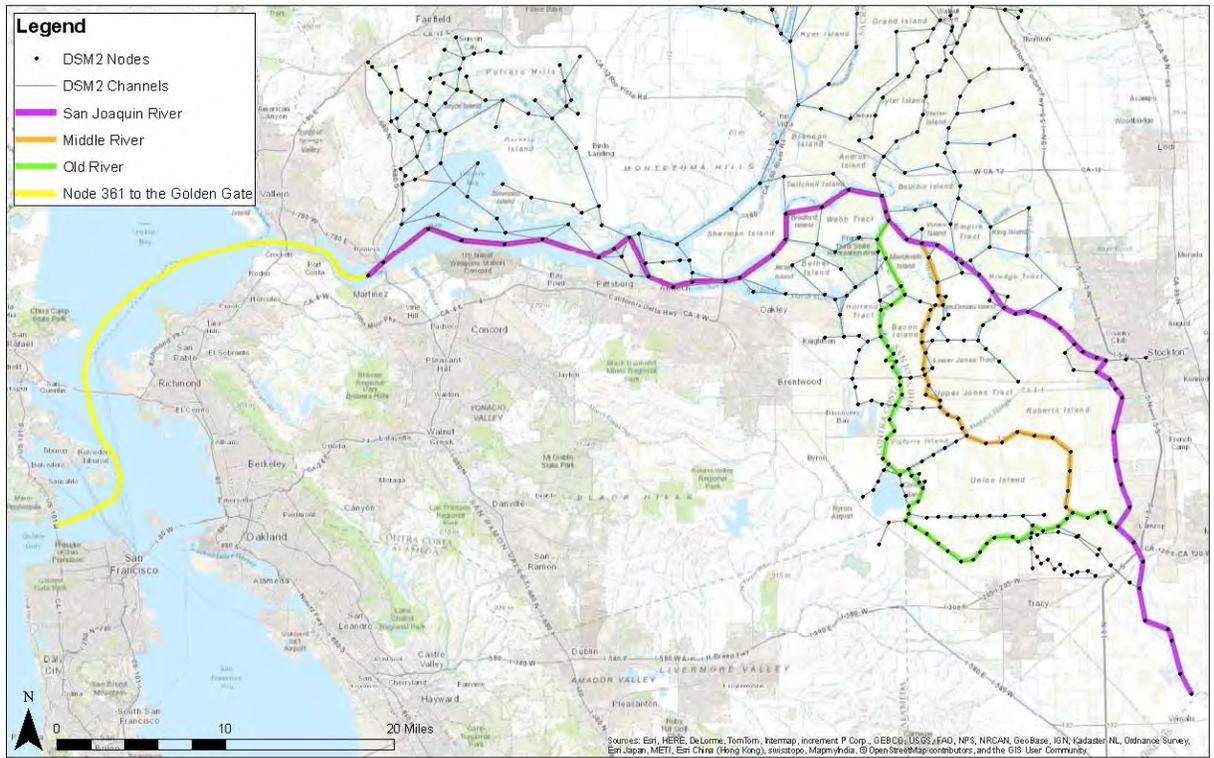
Figure VI.6 Study Area River Channels Utilized in Salinity Criterion Analysis
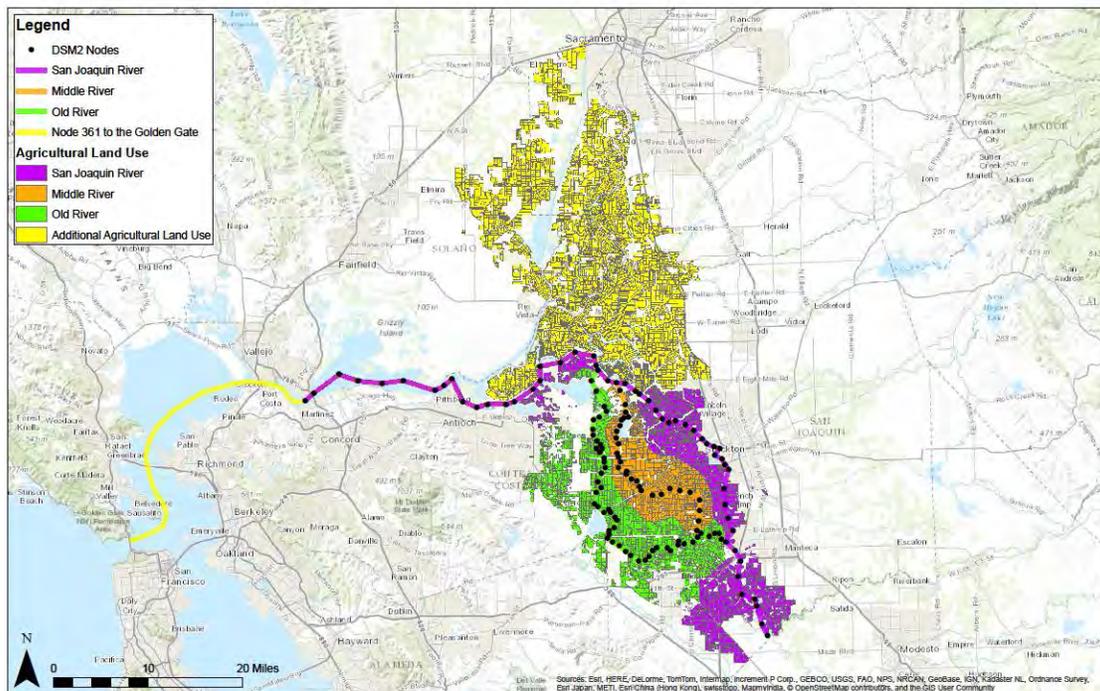
Figure VI.7 Assumed Relationship Between Study Area Diversions and River Reach
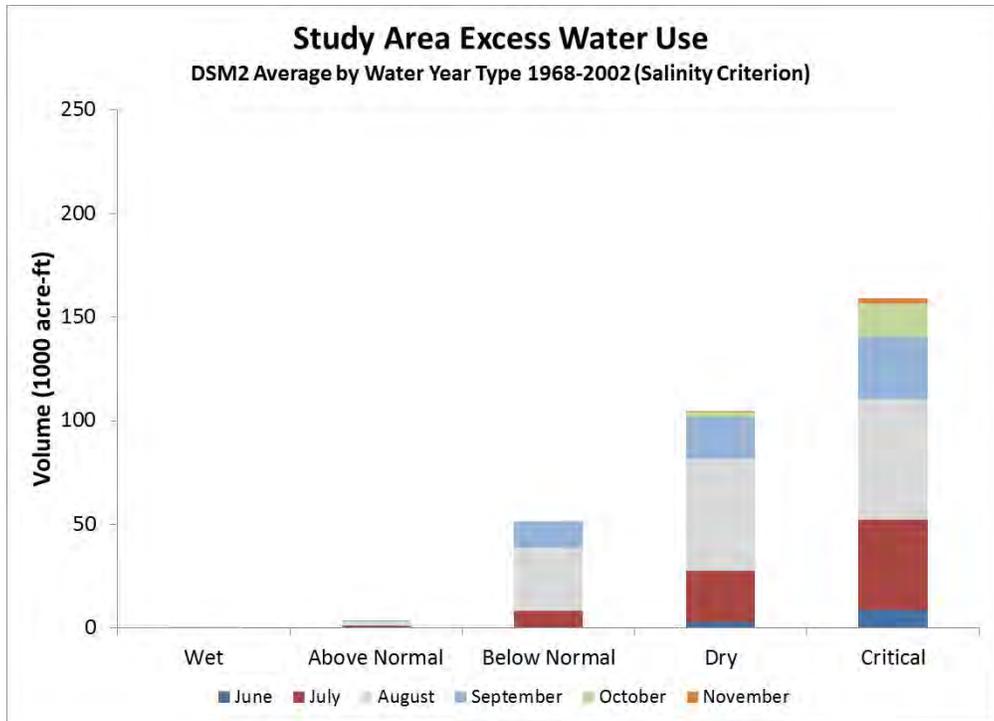
Figure VI.8 Study Area Excess Diversion Using 2.0 mS/cm Salinity Criterion (Approach 1): Water Years 1968-2003 Averages by Month and 40-30-30 Water Year Type (TAF)
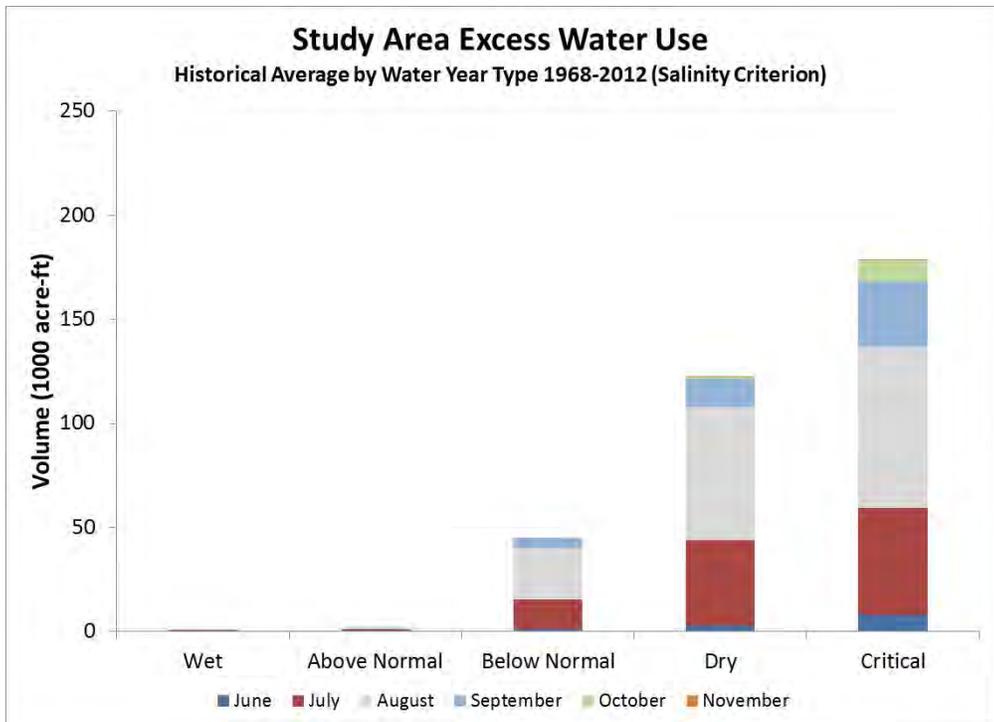
Figure VI.9 Study Area Excess Diversion Using 2.0 mS/cm Salinity Criterion (Approach 2): Water Years 1968-2012 Averages by Month and 40-30-30 Water Year Type (TAF)

Figure VI.10 Comparison of Salinity Observations & Predictions

(a)

(b)

(c)

Comparison of Salinity Observations & Predictions
June-December 1934 Middle River P.O. (RMID015)

(d)

Comparison of Salinity Observations & Predictions
June-December 1931 Holland Dam (ROLD024)
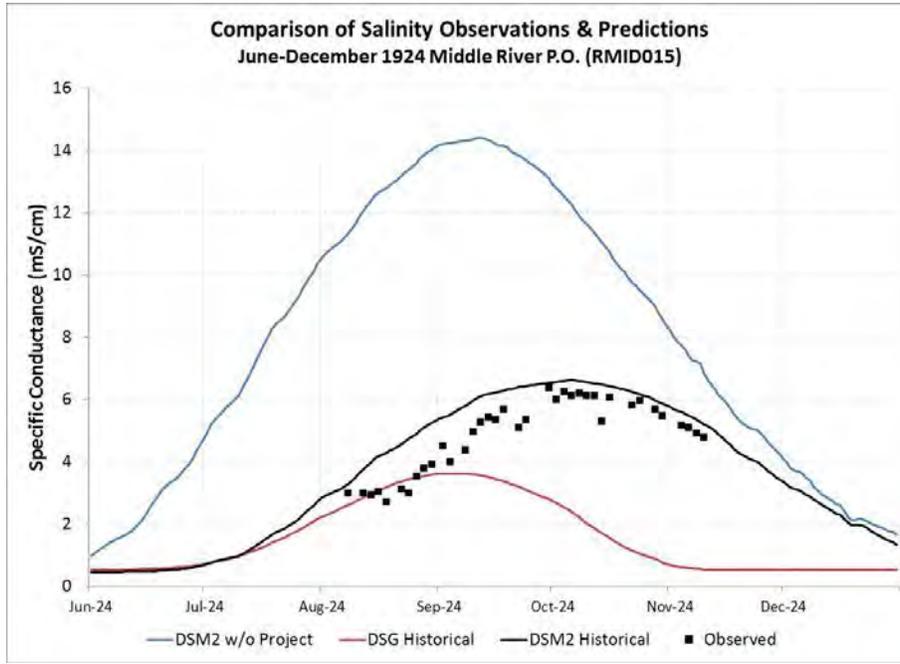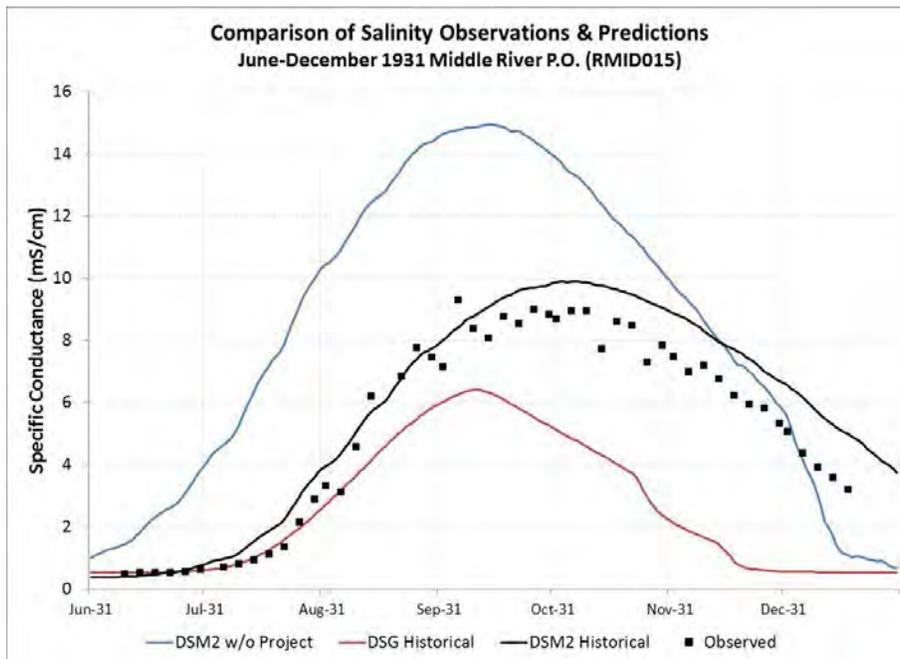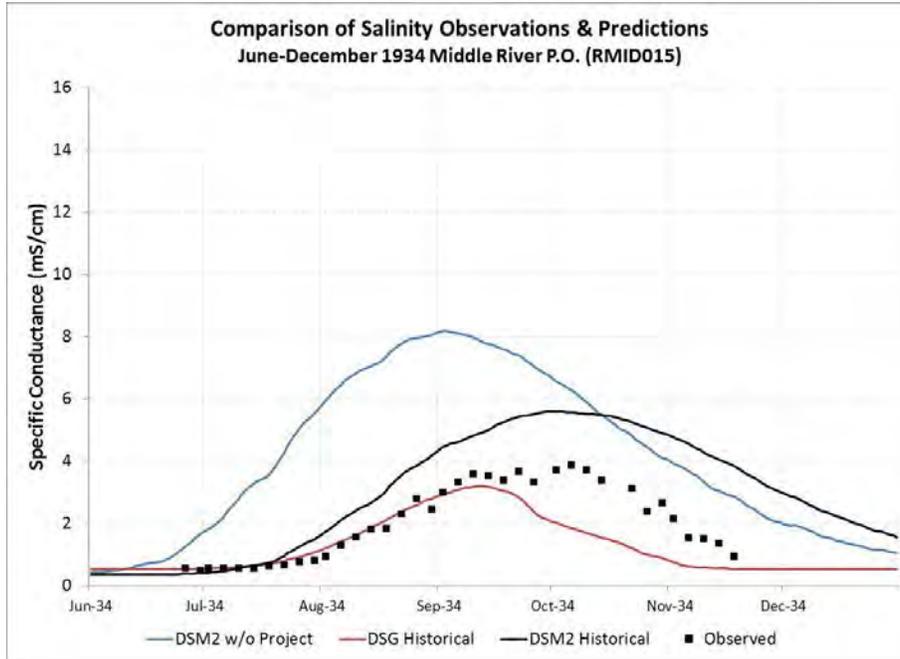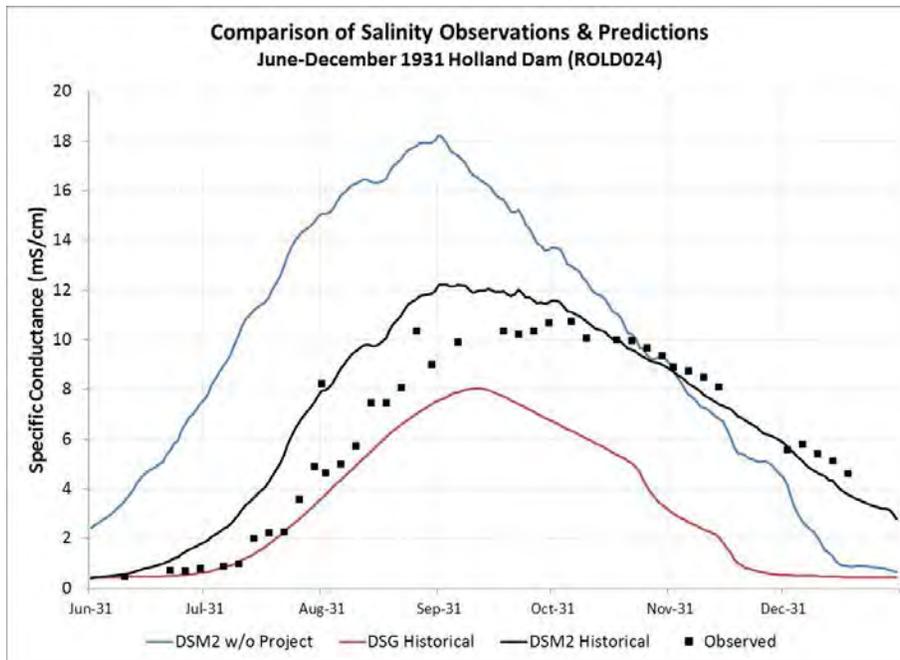
Figure VI.11

Study Area Salinity Gradient Under Various Antecedent Outflow Regimes: Comparison of DSM2 and Observed Salinity Data Water Years 1922-44
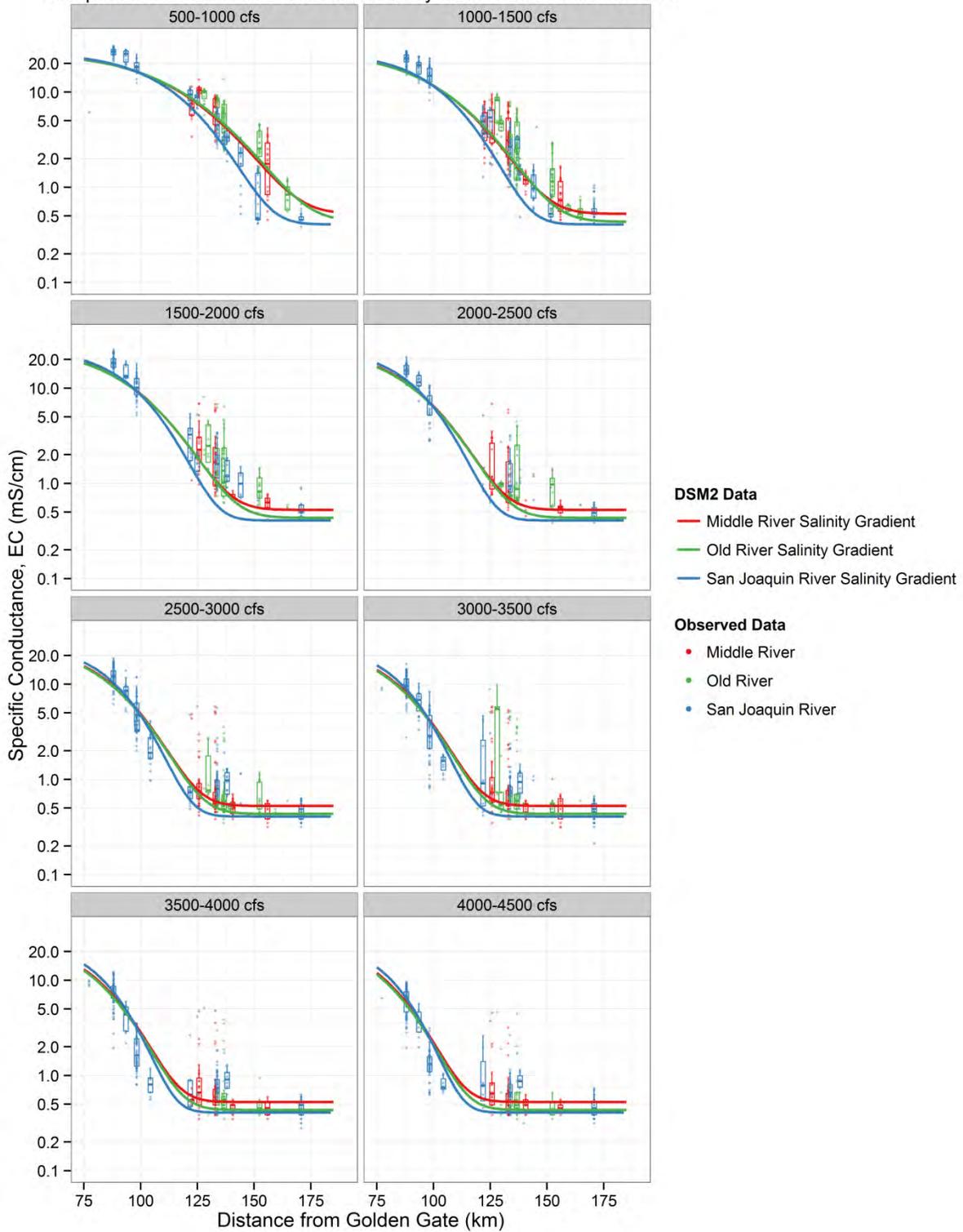
VII. Summary & Conclusions

This report presents two approaches for estimating the availability of water for in-Delta agricultural users south of the San Joaquin River. Both approaches assume that a "without project" hydrology is the appropriate baseline for measuring water availability for in-Delta water users located in the study area. This "without project" hydrology is a hypothetical hydrology that removes SWP-CVP upstream storage and in-Delta facility operations from the hydrologic record. As this hydrologic condition (and its associated water quality) cannot be measured in the field, both approaches rely on modeling frameworks as described in this report.

The first approach, an inflow criterion, assumes that when monthly Delta inflow approaches zero, no water is available for in-Delta agricultural use and curtailment of all water use in the study area is warranted. Furthermore, the criterion assumes that if monthly Delta outflow is positive, i.e. Delta inflow exceeds full in-Delta water use, water is available for all in-Delta use and no curtailment is warranted. This latter assumption ignores circumstances when Delta outflow is positive but sufficiently small such that seawater intrusion impairs the beneficial use of water in the study area, thereby limiting water availability for diversion.

The second approach, a salinity criterion, assumes that water is available for in-Delta agricultural use within the study area provided that water is of adequate quality to be put to beneficial use. As described in the report, the salinity criterion requires the use of hydrodynamic model simulations or mathematical representations of in-Delta flow-salinity relationships and specification of a salinity "trigger" to estimate water availability in the study area. Given that the low outflow conditions characteristic of the without project hydrology are outside the calibration range of the DSM2 model (which was used in the salinity criterion analysis), Delta salinity data collected in the 1920s and 1930s before construction of Shasta Dam were examined in detail. Two key conclusions were drawn from this data examination: (1) the study area was subject to severe seawater intrusion before construction and operation of the SWP-CVP and (2) the use of DSM2 and the DSM2-calibrated flow-salinity models allow for a reasonable and conservative method of evaluating water supply availability in the study area as part of the salinity criterion.

The inflow criterion analysis suggests that excess diversions are taking place in the study area, these diversions are centered in the April through August period, and the excess diversions are in the range of 300,000 acre-feet in dry and critical water years. The inflow criterion suggests that excess diversions take place in most years, but in smaller volumes under wetter hydrologic conditions.

The salinity criterion analysis also suggests that excess diversions are taking place in the study area. However, this analysis shows the diversions later in the season (typically June through November) with volumes in the range of 100,000 to 200,000 acre-feet in dry and critical water years. The salinity criterion suggests that excess diversions are of little consequence under wetter hydrologic conditions.

VIII. References

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IX.   Appendix A: Methodology to Estimate Vernalis Salinity Under Without Project Conditions (from USBR & SDWA 1980)

This appendix presents a methodology to estimate salinity at the San Joaquin River at Vernalis in units of specific conductance (mS/cm). The methodology was developed in the report "Effects of the CVP upon the Southern Delta Water Supply: Sacramento – San Joaquin Delta, California" (USBR & SDWA 1980).

A.   Calculate Salt Load Based on Flow (Table VI-7, page 89)

TABLE VI - 7
CHLORIDE LOAD VS. FLOW COEFFICIENTS AT VERNALIS

1930 - 1950

MONTH	C1	C2	# OF PAIRS*	R
OCTOBER	.3416451758E+03	.7238303788	7	.993
NOVEMBER	.3393044927E+03	.6880766404	6	.987
DECEMBER	.3639052910E+03	.6787756342	7	.972
JANUARY	.3928349175E+03	.6231583178	10	.965
FEBRUARY	.5368474514E+03	.5675747831	9	.914
MARCH	.4968879101E+03	.6035477710	10	.951
APRIL	.3866605718E+03	.5624873484	9	.942
MAY	.3805863844E+03	.5399998219	9	.920
JUNE	.6355065225E+03	.5175446121	9	.849
JULY	.6038658134E+03	.6219848451	8	.900
AUGUST	.3874538954E+03	.7410226741	8	.991
SEPTEMBER	.3500905302E+03	.7524035817	8	.989

* # OF PAIRS DOES NOT INCLUDE RESTRICTION POINT (.5,200)

$y = C1*(x)^{C2}$

B. Convert Salt Load to Chloride Concentration (page 110)

$$p/m = \frac{Load}{Flow \times 1.36}$$

where,

p/m = parts per million Cl^-
$Load$ = chloride load in tons
$Flow$ = 1,000's of acre-feet

C. Calculate Specific Conductance EC from Chloride Concentration (page 86)

$$Cl^- = 0.15 \ EC - 5.0 \qquad\qquad (2a)$$
$$0 < EC < 500$$

$$Cl^- = 0.202 \ EC - 31.0 \qquad\qquad (2b)$$
$$500 < EC < 2000$$

Rearranging the equations to solve for EC yields:

$EC = (Cl- + 5.0) / 0.15$ $\qquad$ $0 < EC < 500$

$EC = (Cl- + 31.0) / 0.202$ $\qquad$ $500 < EC < 2000$

X.   Appendix B: DSM2 Salinity Frequency Charts

The charts provided in this appendix compare salinity exceedance probabilities associated with two DSM2 scenarios: an existing conditions scenario (blue line) and a without project conditions scenario (red line). Charts are provided for every month at three locations in the study area: Old River at Bacon Island (ROLD024), San Joaquin River at Stockton (RSAN063), and Grant Line Canal at Tracy Road Bridge. Salinity data are in units of uS/cm (mS/cm x 1000) and are monthly averaged and shown on a log scale in the charts. A simple interpretation of the charts is as follows: (1) a 0.2 exceedance probability means that the salinity is higher than that value 20% of the time and lower than that value 80% of the time, (b) periods when the red line is above the blue line are indicative of periods when SWP-CVP operations improve water quality conditions, and (c) periods when the blue line is above the red line are indicative of periods when SWP-CVP operations degrade water quality conditions.
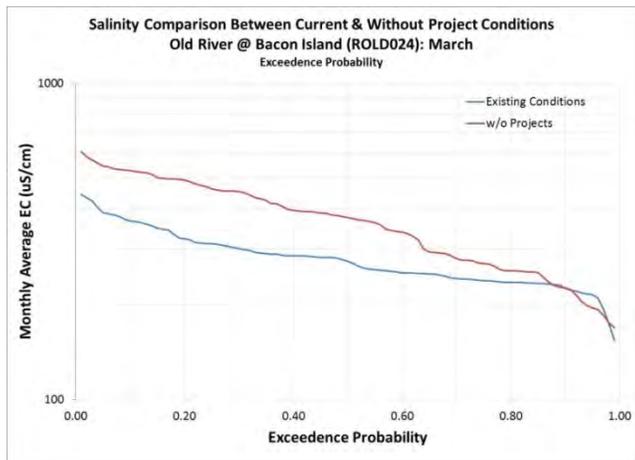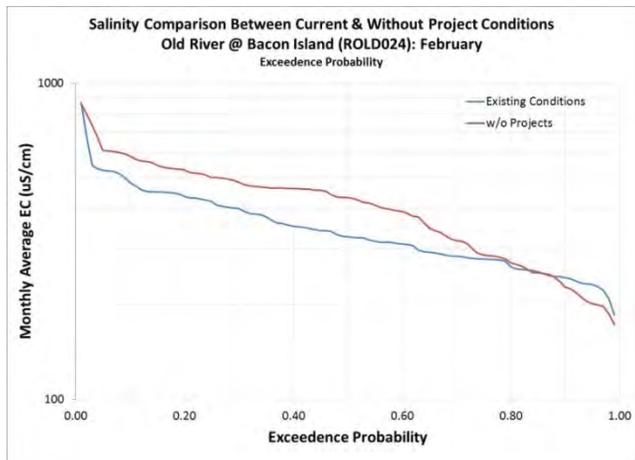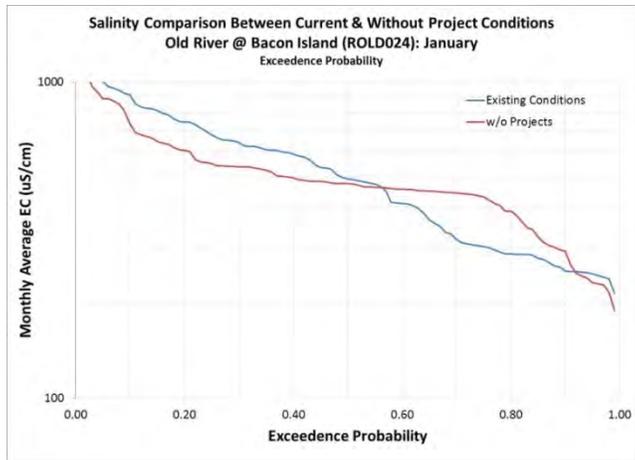
Figure B.1 Salinity Comparison between Current & Without Projects Scenarios: Old River @ Bacon Island (ROLD024); January, February & March
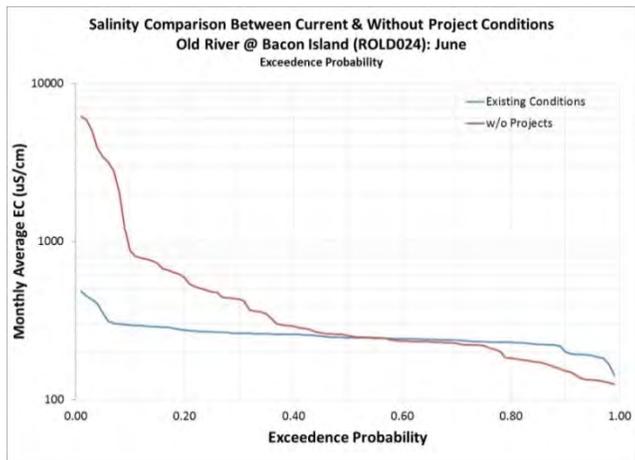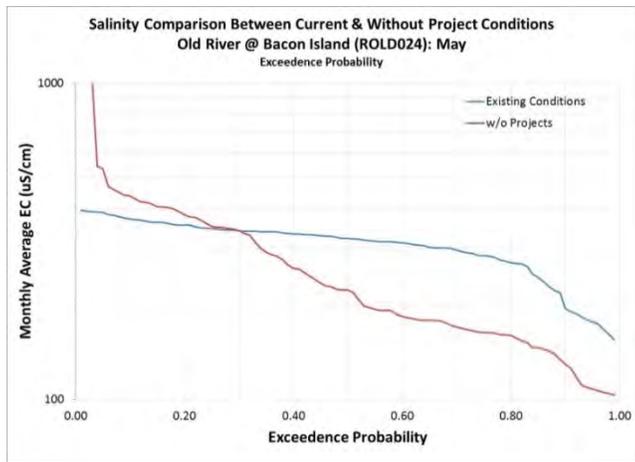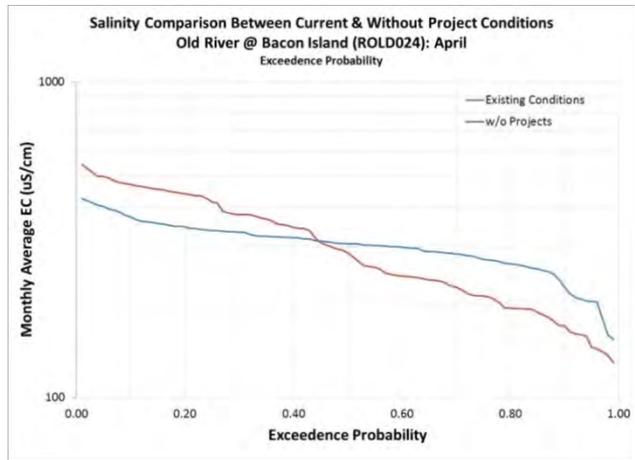
Figure B.2 Salinity Comparison between Current & Without Projects Scenarios: Old River @ Bacon Island (ROLD024); April, May & June
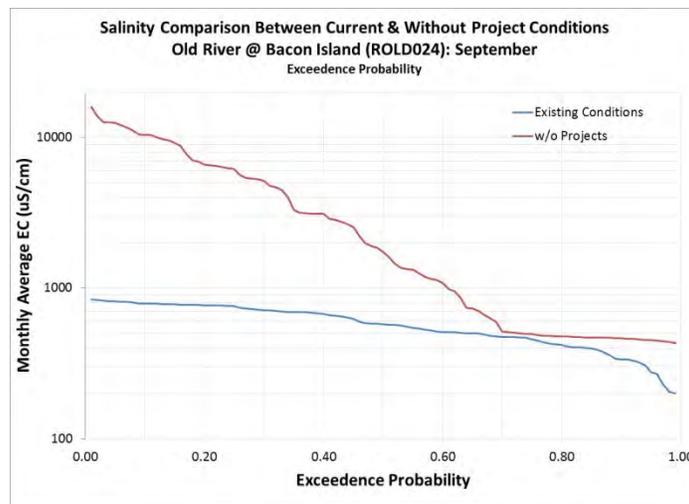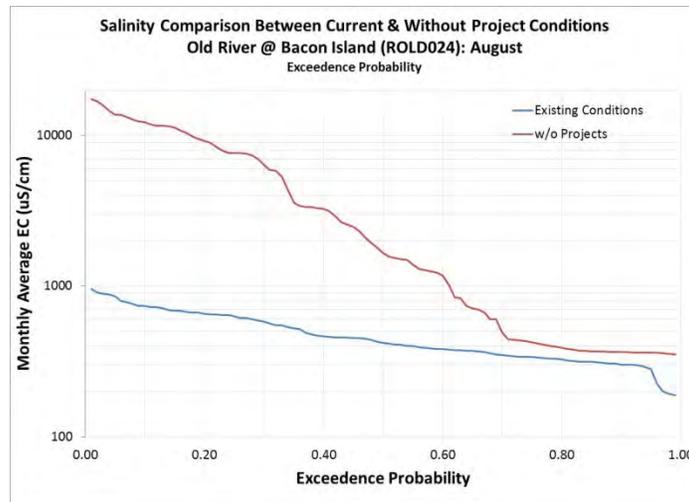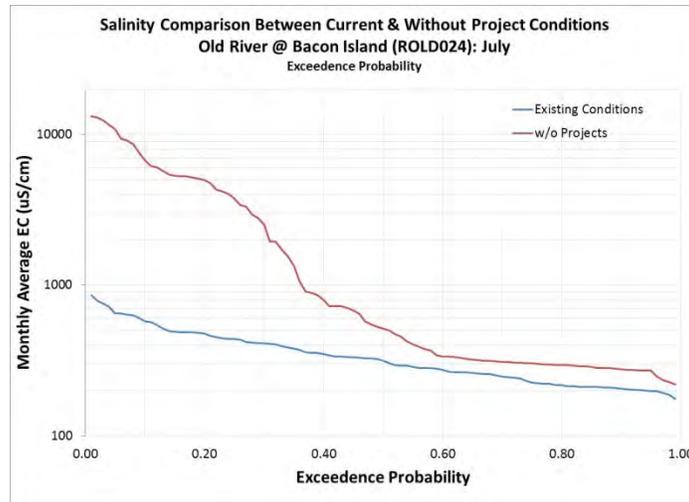
Figure B.3 Salinity Comparison Between Current & Without Projects Scenarios: Old River @ Bacon Island (ROLD024); July, August & September
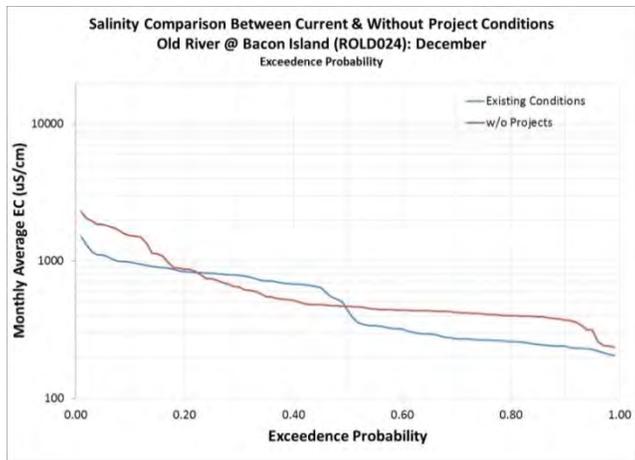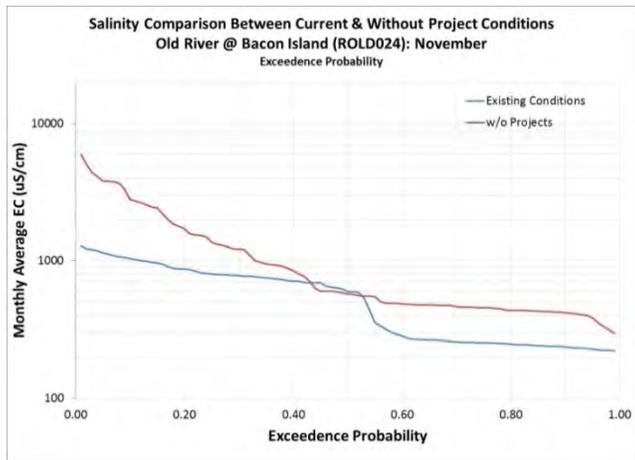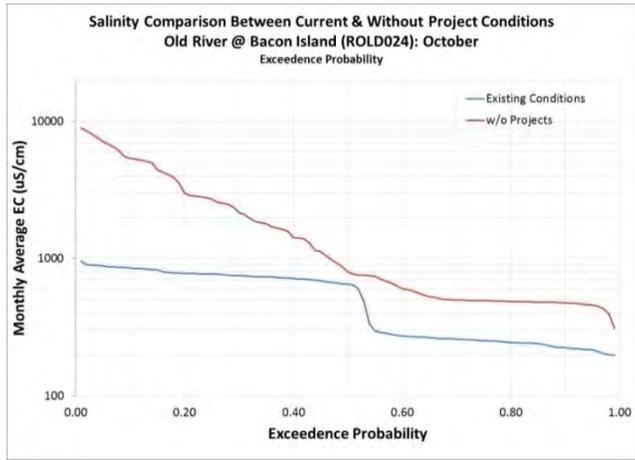
Figure B.4 Salinity Comparison Between Current & Without Projects Scenarios: Old River @ Bacon Island (ROLD024); October, November & December
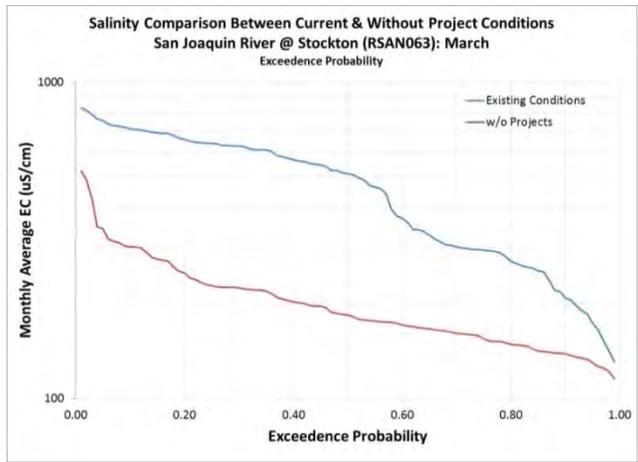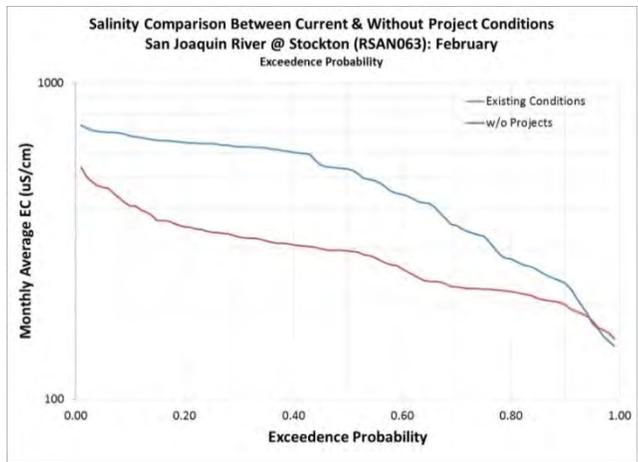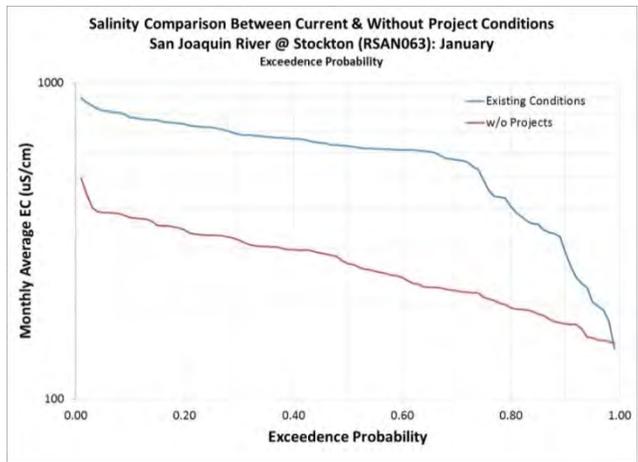
Figure B.5 Salinity Comparison Between Current & Without Projects Scenarios: San Joaquin River @ Stockton (RSAN063); January, February & March
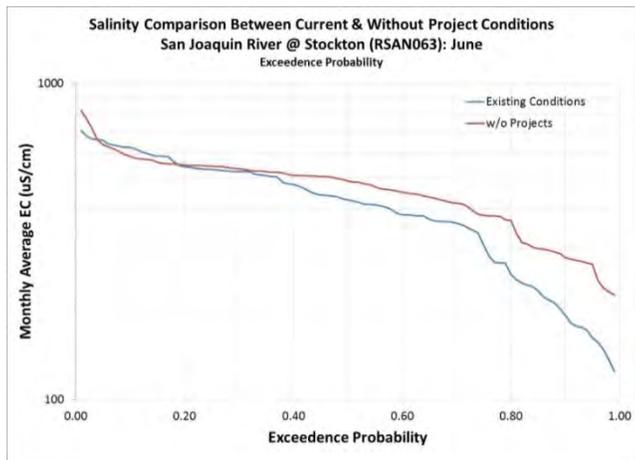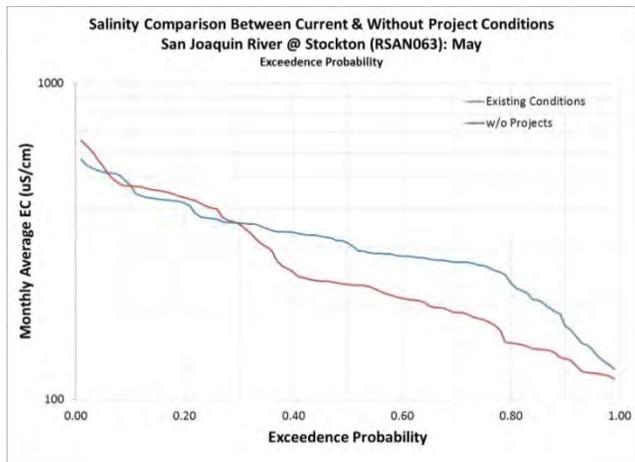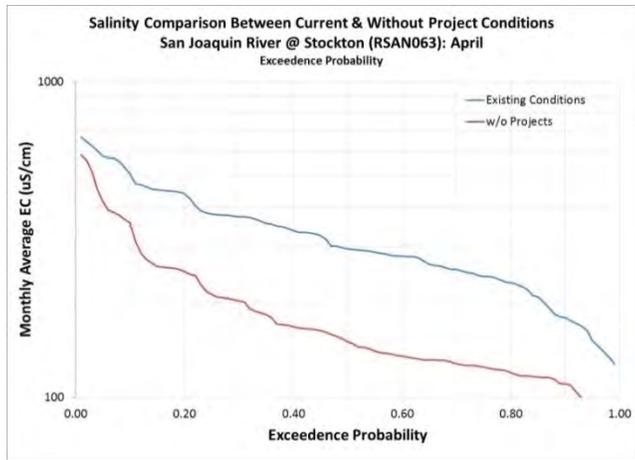
Figure B.6 Salinity Comparison Between Current & Without Projects Scenarios: San Joaquin River @ Stockton (RSAN063); April, May & June
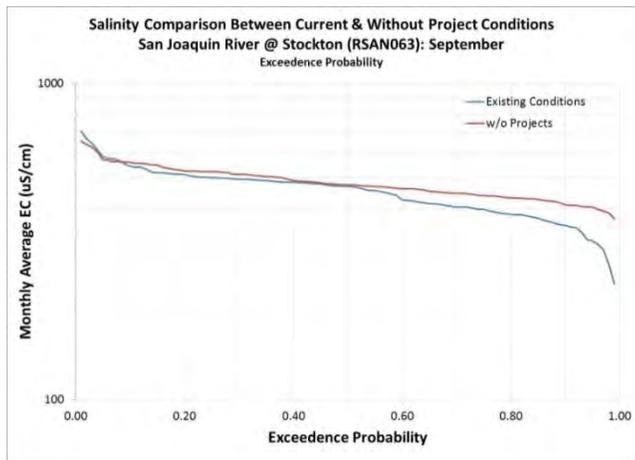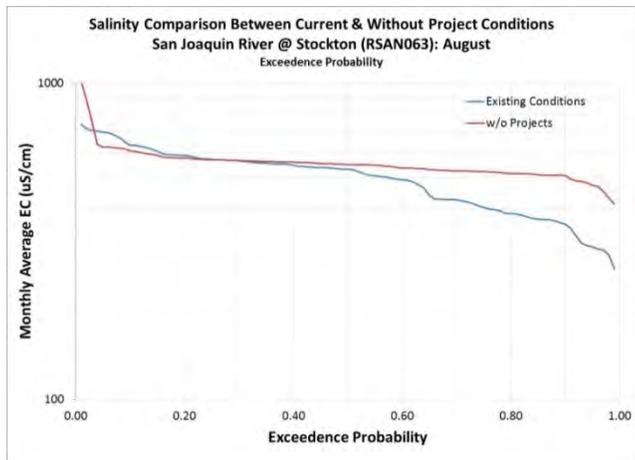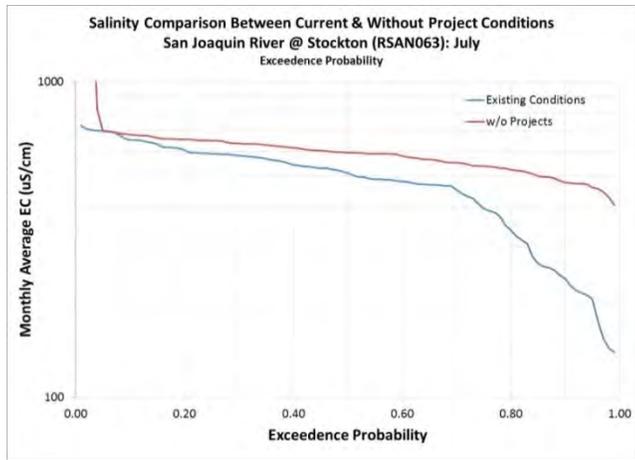
Figure B.7 Salinity Comparison Between Current & Without Projects Scenarios: San Joaquin River @ Stockton (RSAN063); July, August & September
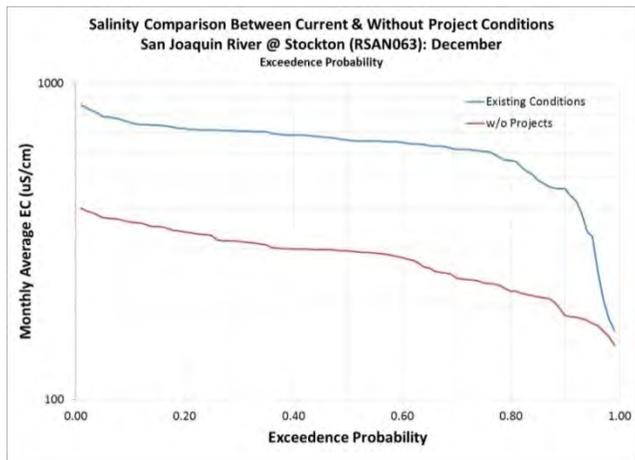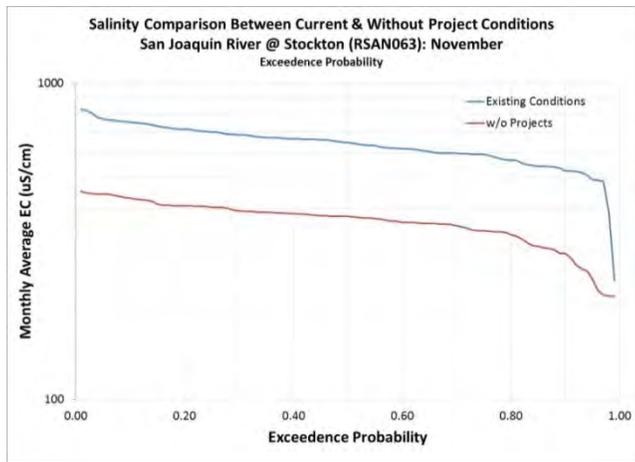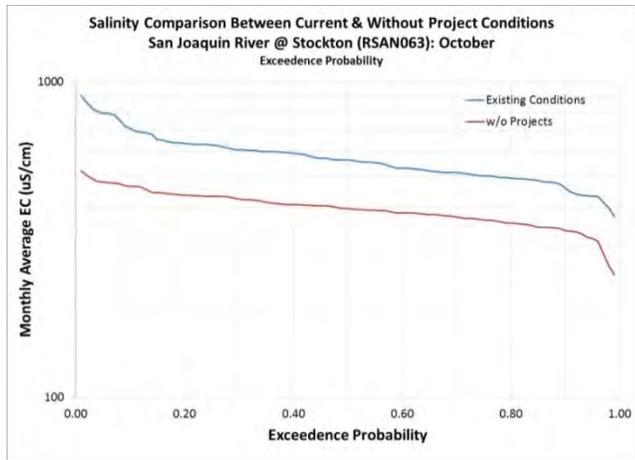
Figure B.8 Salinity Comparison Between Current & Without Projects Scenarios: San Joaquin River @ Stockton (RSAN063); October, November & December
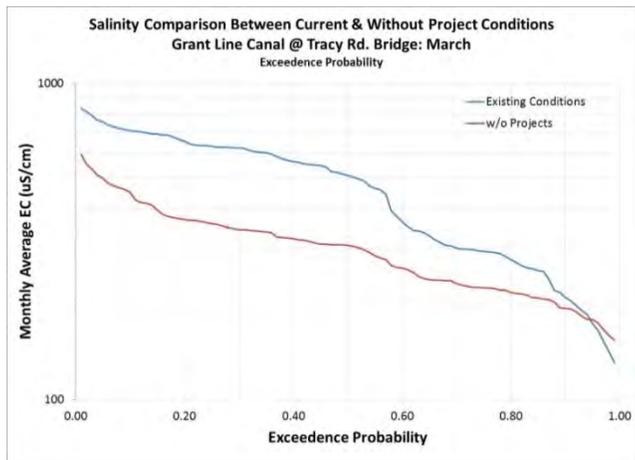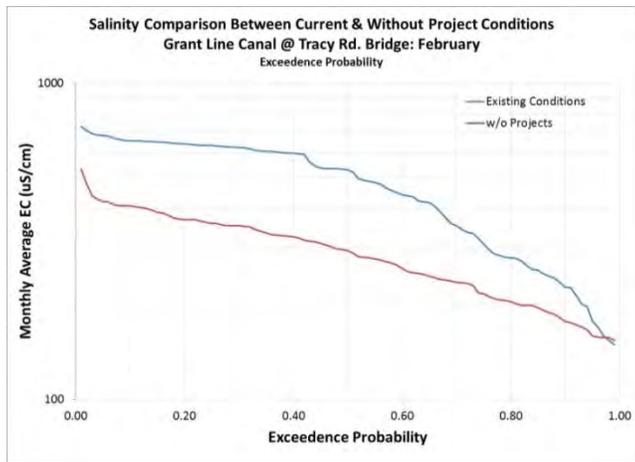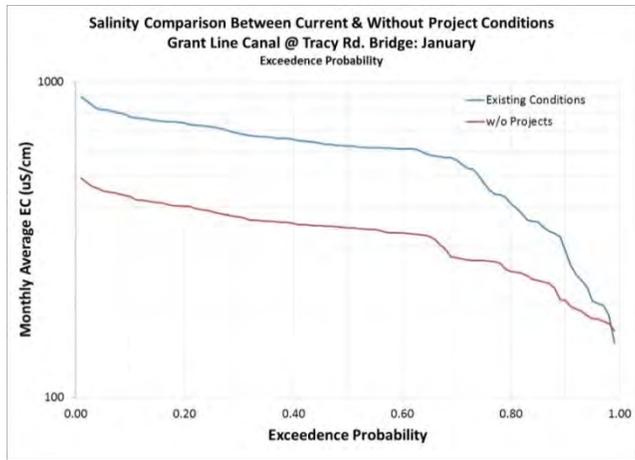
Figure B.9 Salinity Comparison Between Current & Without Projects Scenarios: Grant Line Canal at Tracy Road Bridge; January, February & March
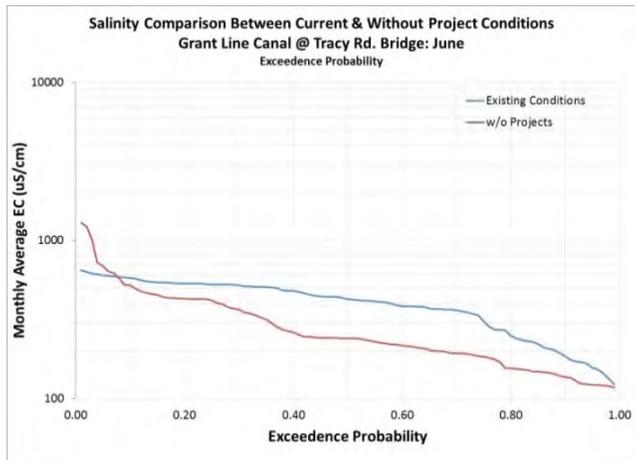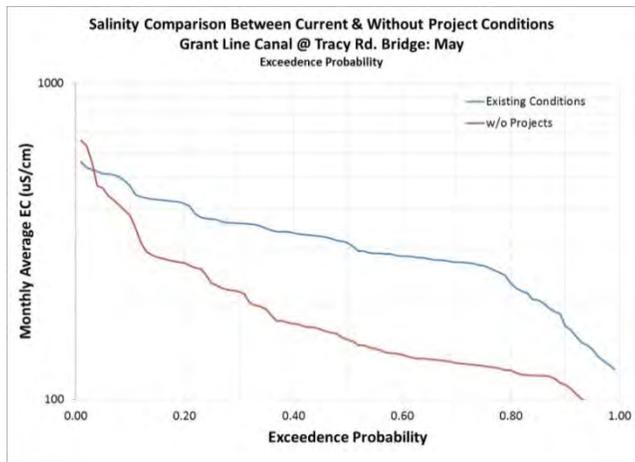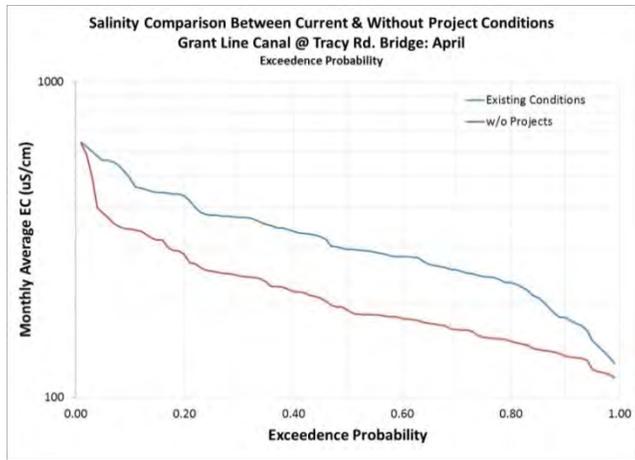
Figure B.10 Salinity Comparison Between Current & Without Projects Scenarios: Grant Line Canal at Tracy Road Bridge; April, May & June
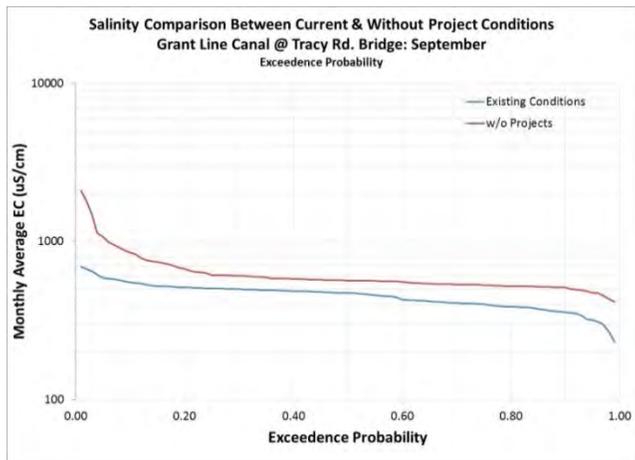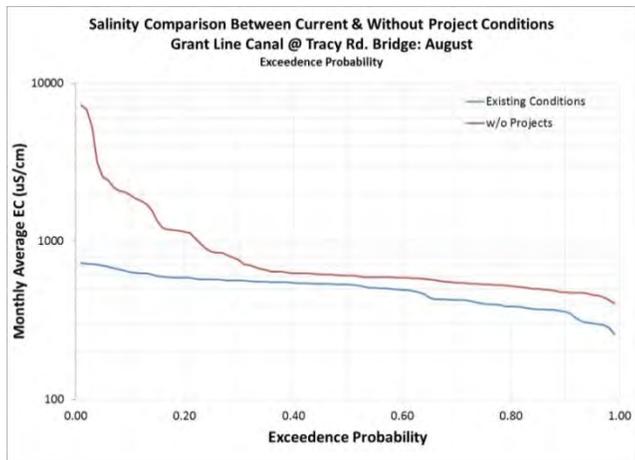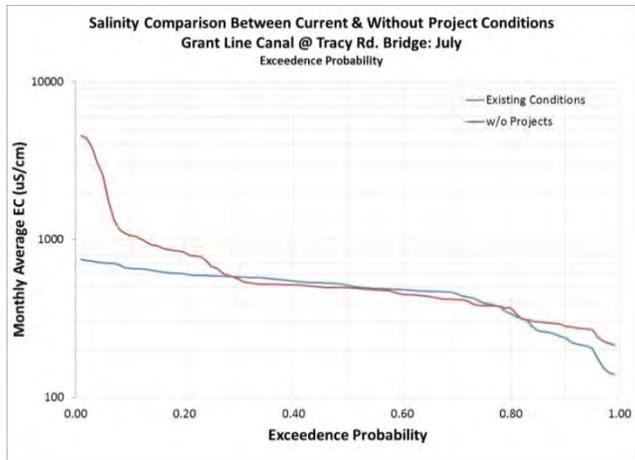
Figure B.11 Salinity Comparison Between Current & Without Projects Scenarios: Grant Line Canal at Tracy Road Bridge; July, August & September
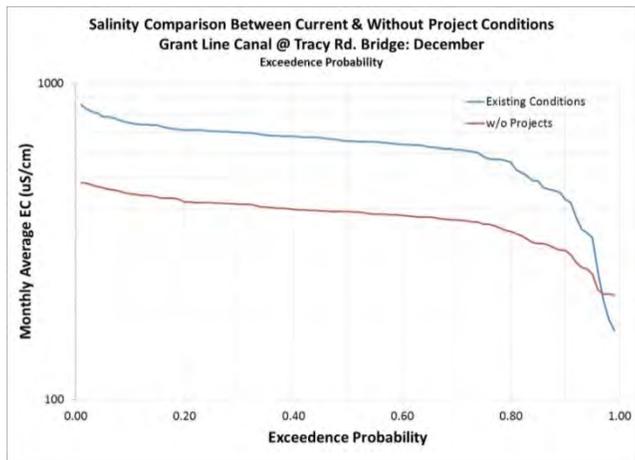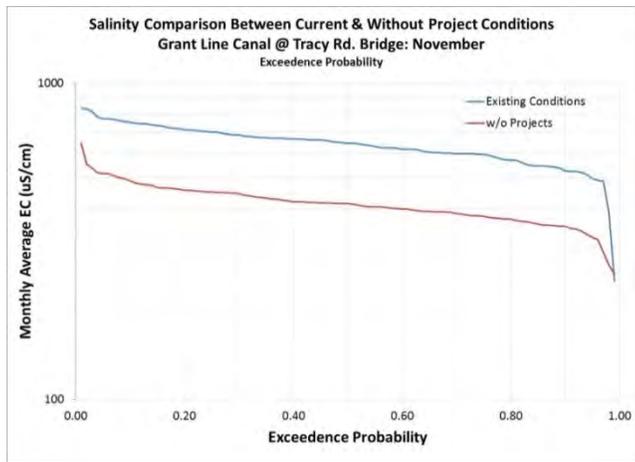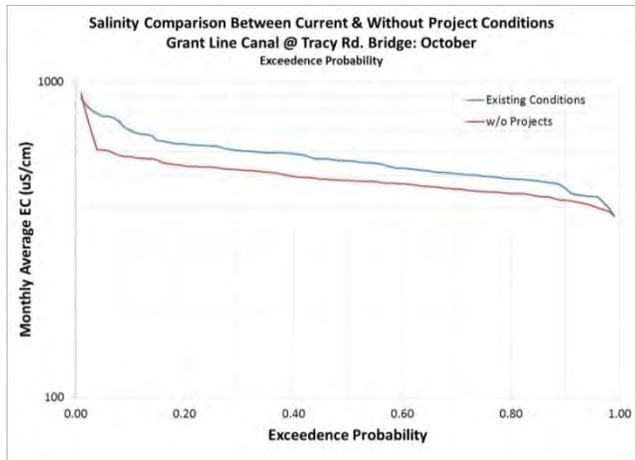
Figure B.12 Salinity Comparison Between Current & Without Projects Scenarios: Grant Line Canal at Tracy Road Bridge; October, November & December

Appendix C: Study Area Channel Distance – Area Lookup Tables

Relationships between channel distance and cumulative downstream area were developed for the three river reaches – Old, Middle and San Joaquin – within the study area (Tetra Tech 2015a). Such relationships provide a method to estimate the location and total area downstream of a prescribed salinity trigger, i.e. the curtailment area. These relationships are provided as lookup tables (Tables C.1, C.2 and C.3) in this appendix. Thus, by defining a salinity trigger, the downstream curtailment area can be calculated for any hydrologic condition defined by the antecedent outflow G.

DSM2 Node No.	Distance from Golden Gate (km)	Cumulative Area (acres)	DSM2 Node No.	Distance from Golden Gate (km)	Cumulative Area (acres)
45	94.0	0	21	136.9	27460
469	97.9	2166	20	138.0	28153
44	99.8	3066	19	139.3	28153
43	102.3	3140	18	140.4	28157
42	105.8	4758	16	141.8	29896
41	108.8	5683	15	143.2	30018
40	112.0	5802	14	144.3	30736
39	113.6	6257	13	145.3	31170
38	114.5	6400	12	148.7	34307
37	117.0	6400	11	151.5	36573
35	118.5	6411	10	153.7	38453
34	120.0	6411	9	156.1	39316
33	122.2	6534	8	158.4	39664
32	122.9	6713	7	160.5	39947
30	124.9	8542	6	162.6	41542
29	127.0	11212	5	165.2	46789
26	128.9	13437	4	168.4	58958
25	130.1	17114	3	170.7	62019
24	131.3	19868	2	171.9	65712
23	133.0	23503	1	175.1	70536
22	134.8	25924	17	177.3	72761

Table C.1 San Joaquin River Distance-Area Lookup Table

DSM2 Node No.	Distance from Golden Gate (km)	Cumulative Area (acres)	DSM2 Node No.	Distance from Golden Gate (km)	Cumulative Area (acres)
38	114.5	0	183	147.7	35143
103	116.6	927	182	149.0	36257
101	118.6	1649	72	150.1	36452
100	121.6	2423	71	150.8	36685
98	122.5	3002	70	151.5	38696
97	124.1	3308	69	152.6	39885
97	125.2	3614	68	153.9	40856
94	126.8	4586	67	155.3	41819
93	127.7	6642	66	156.5	43448
92	128.9	7124	65	158.1	46482
91	129.8	7455	64	159.2	48720
90	130.7	11535	63	160.2	49684
89	131.8	11901	62	161.3	50676
88	132.5	12509	61	162.2	53684
86	133.7	12699	60	163.9	54455
85	134.4	13312	59	164.7	58363
84	135.4	13960	57	166.3	58747
82	136.5	15130	56	167.0	61133
81	138.0	18269	55	168.1	63407
80	139.2	19749	54	169.7	66222
79	140.3	23254	53	170.7	66681
78	142.2	28466	52	171.6	66934
77	143.0	29462	51	173.1	68215
75	144.4	29632	50	174.1	68898
192	145.4	31079	49	174.8	69471
187	146.0	31432	48	175.9	71657
185	147.1	32264	8	176.8	72005

Table C.2 Old River Distance-Area Lookup Table

DSM2 Node No.	Distance from Golden Gate (km)	Cumulative Area (acres)	DSM2 Node No.	Distance from Golden Gate (km)	Cumulative Area (acres)
35	118.5	0	117	136.7	12226
134	119.9	425	116	137.9	13501
133	122.5	849	115	138.9	16208
132	123.7	1083	114	139.9	17192
130	124.8	2527	113	140.7	18943
129	125.6	2656	112	142.7	22210
128	126.2	2905	111	144.2	24891
127	127.1	3433	110	146.0	29094
126	128.3	4212	108	147.7	32089
125	129.5	4558	109	149.8	34926
124	130.5	6920	107	151.6	36954
122	132.1	7326	106	153.3	38884
121	132.7	7997	105	155.2	40701
120	133.7	9000	104	156.8	41634
119	134.7	9483	52	157.7	41887
118	136.1	11505			

Table C.3 Middle River Distance-Area Lookup Table

Technical Analysis in Support of South Delta Diversion Curtailment in Dry Years
Final Report

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June 3, 2015

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1. INTRODUCTION

The Sacramento – San Joaquin Delta is a source of water supply for water users located in the Delta and for the users south-of-Delta. The Delta receives flow primarily from the Sacramento and San Joaquin Rivers, as well as from other smaller rivers such as the Mokelumne, Cosumnes and Calaveras on the eastside of the Delta (Eastside Streams), as well as tidal flow from San Francisco Bay. Delta inflow from the Sacramento and San Joaquin Rivers are partially a result of the stored water releases from the upstream reservoirs operated by the Central Valley Project (CVP) and State Water Project (SWP). The water released from these reservoirs is diverted from the Delta for the water supply needs of the south-of-Delta CVP and SWP contractors, in addition to meeting the existing regulatory requirements. This study examined the contribution of Sacramento and San Joaquin River flows to water users in the Delta under current conditions, as well as conditions that were simulated to represent freshwater inflows that would occur in the absence of the projects.

The primary tool used for this work was the California Department of Water Resources' DSM2 model. The model was run for different inflow scenarios and the resulting simulation of volumetric contributions of flow and salinity were used to describe behavior under project and without project conditions. The following inflow scenarios were used to simulate 82-year (water years 1922-2003) Delta hydrodynamics, electrical conductivity (EC) and volumetric fingerprinting using DSM2 for the following four scenarios:

Scenario A: Current conditions with hydrology based on the DWR's 2013 Delivery Reliability Report (DRR)

Scenario B: Scenario A without in-Delta agricultural diversions

Scenario C2[1]: "Without Project" conditions. This hydrology development removed the impairment caused by the upstream CVP and SWP reservoirs on the Sacramento

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[1] This was originally referred to as Scenario C, but was relabeled to C2 after a different EC boundary condition was utilized, as described in the following chapter.

and San Joaquin Rivers, and the CVP and SWP diversions in the Delta. Using impaired and unimpaired flow time series information downstream of the following SWP/CVP reservoirs, we estimate changes to flow volumes from the following reservoirs: Oroville, Friant (Millerton), New Melones, Shasta (and Trinity River inflows), and Folsom. The changes to flows downstream of the reservoir locations (increase or decrease, depending on month and year) were represented as changes to stream flows at the following locations: Sacramento River at Freeport, Yolo Bypass, and San Joaquin River at Vernalis. The Without Project hydrology was estimated on a monthly basis. The Without Project scenario excludes south Delta CVP-SWP export facilities, the Delta Cross Channel (DCC), south Delta temporary barriers and Montezuma Salinity Control Gate. It includes Contra Costa Water District (CCWD) and North Bay Aqueduct (NBA) diversions, and the BBID diversion was moved to the Old River.

Scenario D: Scenario C2 without in-Delta agricultural diversions. This scenario also excludes NBA and CCWD diversions.

Scenario E: Flows assuming actual (DAYFLOW) hydrology from water year 1922-1944.

The following chapters describe the DSM2 runs utilized, the development of a simplified modeling framework using DSM2 output, i.e., a Delta Salinity Gradient model applied to channels in the South Delta, the validation of the DSM2 output data using South Delta observed salinity from the pre-Project period, and the development of a relationship between irrigated area and distance from Golden Gate Bridge along the major river channels in the South Delta. Because the DSM2 results are voluminous, this memorandum is accompanied by electronic results for flow, EC, and volumetric fingerprint values, and only a few key aspects of the output are highlighted in the document and appendices.

2. DSM2 ANALYSIS

The DSM2 analysis used input files developed by DWR to represent current conditions (i.e., the existence of projects, reservoir operations, and exports from the Delta) driven by an 82-year hydrology representing WY 1922-2003. Thus, Scenario A, as defined in Chapter 1 was based on DWR inputs, and these inputs were modified to represent other scenarios. The most important changes related to the development of the without project hydrology boundary and the without project EC boundary condition at Vernalis on the San Joaquin River that are described below.

2.1 WITHOUT PROJECT HYDROLOGY BOUNDARY

The "Without Project" Delta hydrology boundary conditions were used to represent the conditions without the CVP and the SWP project. The Without Project hydrology removed the impairment caused by upstream CVP and SWP reservoirs and CVP and SWP diversions in the Delta but maintained impairments caused by upstream agricultural and municipal project diversions.

The Without Project boundary was developed by modifying the Delta inflow using the difference between inflow and releases for the upstream reservoirs operated by CVP and SWP simulated by CALSIM II.[2] The inflow to the Delta from Sacramento River and Yolo Bypass was modified by the difference between inflow and releases to the Oroville, Shasta and Folsom reservoirs. For the Without Project scenario, the inflow from Trinity River was also subtracted. The total of Sacramento River and Yolo Bypass flow from CALSIM II current conditions represents the original flow from the Sacramento Valley to the Delta. It was then modified by the difference between the release and inflow to the three reservoirs, and minus inflow from the Trinity River to obtain the Without project flow, as follows:

$$SAC\_mod = C169 + C157 + (I4 + I6 + I300) - (C4 + C6 + C8) - I1 \qquad (1)$$

Each component as defined in CALSIM II for the current conditions is:
C169: Sacramento River flow

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[2] This information was obtained from previous DWR work.

C157: Yolo Bypass flow
I4: Sacramento River Inflow to Shasta Lake
I6: Feather River Inflow to Lake Oroville
I300: American River upstream Inflow to Folsom
C4: Release from Shasta Lake
C6: Feather River downstream of Oroville
C8: American River below Folsom Dam
I1: Trinity River Inflow

The calculated modified inflow from the Sacramento Valley was then split into Sacramento River flow and Yolo Bypass flow based on the operation rules from CALSIM II. The gate from Sacramento River to Yolo is assumed to open at a flow of 21,000 cfs. The maximum flow in the Sacramento River is assumed to be 62,000 cfs. Flows above 62,000 cfs are assumed to spill into Yolo Bypass. This is based on existing CALSIM operating rules for the bypass. The estimated Without Project flow at Sacramento River and Yolo Bypass, compared to current conditions from CALSIM II is shown in Figure 1 and Figure 2. Inflows at Freeport were set to zero when the calculated inflows resulted in negative values.

The San Joaquin River inflow for the Without Project boundary was developed by modifying the inflow from Vernalis and the difference between releases and inflow to the New Melones and Millerton (Friant) Reservoirs. For the Without Project boundary (for the C2 scenario), both the New Melones and Millerton Reservoirs were unimpaired. The return flow from the Exchange Contractor flows into San Joaquin River at Salt Slough and Merced.

The equation used to calculate modified inflow from the San Joaquin River for the C2 scenario (SJR_modc2) is:

$$SJR\_modc2 = C639 + (I10\text{-}C10) + (I18\text{-}C18) + R614J + R619H - D607B\_Mod - 400 \text{ cfs} \tag{2}$$

Where,
C639: San Joaquin River below Vernalis
I10: Inflow to New Melones
I18: inflow to Millerton
C10: Release from New Melones
C18: Release from Millerton
D607B: Mendota pool/Exchange DIV
D607B_mod: Mendota pool/Exchange DIV capped using SJR flow below
Mendota Pool (C607) C607: SJR below Mendota Pool
R614j: pool exchange contractors return flows to SJR at Salt Slough
R619h: pool exchange contractors return flows to SJR at Merced

The assumed 400 cfs term is groundwater loss from the San Joaquin River channel. When the above equation resulted in negative flows, a minimum flow of 150 cfs was used. When using the minimum flow of 150 cfs, DSM2 occasionally resulted in dry channels. When this occurred, a higher flow of 300 cfs was used. The estimated Without Project flow at San Joaquin River at Vernalis, compared to current conditions from CALSIM II is shown in Figure 3.

2.2   EC at San Joaquin River

For the EC boundary conditions at Vernalis, the equations documented in a previous analysis by the Water and Power Resources Service and the South Delta Water Agency were used.[3] The approach first calculated salt load based on the San Joaquin River flow (Figure 4). The estimated salt load was then converted to concentrations of chloride (Cl). The salt load was converted to concentrations based on equations on page 110 in the Water and Power Resources Service and the South Delta Water Agency (1980) report:

$$p/m = Load / (flow \times 1.36) \tag{3}$$
where,
p/m = parts per million Cl^-
load = chloride load in tons
flow = 1000's of acre-feet

The calculated Cl- concentrations were then converted to EC using the following equations (page 86 in 1980 report):

$$Cl^- = 0.15EC - 5.0 \qquad\qquad 0 < EC < 500 \tag{4}$$
$$Cl^- = 0.202EC - 31.0 \qquad 500 < EC < 2000 \tag{5}$$
Then:
$$EC = (Cl^- + 5.0) / 0.15 \qquad 0 < EC < 500 \tag{6}$$
$$EC = (Cl^- + 31.0) / 0.202 \qquad 500 < EC < 2000 \tag{7}$$

Estimated EC at the Vernalis boundary is shown in Figure 5.

2.3   DSM2 runs for scenarios A, C2, D, and E

The DSM2 model, version 8.0.6, was run for the 82-year hydrology using the planning mode. The tide file used is the 82-year planning tide records at Martinez (planning-2-SL). The gate file used is the 82-year planning gate at Clifton Court. The operation rules used

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[3] Effects of the CVP upon the Southern Delta Water Supply, Sacramento-San Joaquin River Delta, California, prepared jointly by the Water and Power Resources Service and the South Delta Water Agency, June 1980; Scanned copy available online at:
http://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/docs/cmnt081712/cwin/cwinappendix_f.pdf

for Montezuma Slough and South Delta temporary barriers are the planning rules for these locations.

Scenario E is run using DAYFLOW records as the hydrological boundary, including the Sacramento River at Freeport, San Joaquin River near Vernalis, Yolo Bypass, Mokelumne, Calaveras, and Cosumnes River for the time period of 1922-1944. For Scenario E, the tide at Martinez was developed by subtracting 0.55 ft from the current 82-year planning tide, based on the difference between the baseline and 1920's sea level at Golden Gate, in order to represent tide levels in the 1920s.

The model simulated EC concentrations for the A and C2 scenarios are shown for illustration at two locations in Figure 6 and Figure 7. Model results for all scenarios are provided electronically.

2.4 COMPARISON OF VOLUMETRIC FINGERPRINTS ACROSS SELECTED STATIONS IN THE SOUTH DELTA FOR SCENARIOS C2 AND D

In this section, we compare model simulated percent volumetric contribution from source waters from two scenarios: scenario C2 and D, at 14 locations listed in Table 1. Simulated volumetric contributions from four major source waters were compared: Ag (agricultural /DICU flow), East (eastside streams), Sac (Sacramento River at Freeport), and SJR (San Joaquin River flow at Vernalis). The comparisons were made for each month from January to December. For each station, a total of 12 plots (representing January to December) were created (Appendix A).

The comparison of Scenarios C2 and D showed the effects of DICU flow on simulated volumetric contributions on monthly basis. The results suggest that without DICU flow, SJR contribution is 100% at many locations. With the contribution from DICU flow (Scenario C2), SJR flow contribution is lower. The contribution of DICU flow at some Delta locations appears to be significant.

The relationship between the San Joaquin River flow and the percent volumetric contribution from the Sacramento River was also evaluated for the 14 stations (individual plots not shown). The results generally suggested a negative relationship between volumetric contribution from the Sacramento River and San Joaquin River flow. The contribution from the Sacramento River decreased exponentially with San Joaquin River flow and is only evident at very low San Joaquin River flow. For locations proximal to the head of the rivers (e.g., Old River) the contribution from the Sacramento River is minimal.

Table 1
Selected output locations in the south Delta

Station	Name
Old River @ Holland	Rold014
Old River @ Bacon Island	Rold024
Old River @ Hwy 4	Rold034
Just outside of CCF intake	chswp003
Old River @ Tracy Rd Bridge	Rold059
Old River @ Union Island (Old R @ Middle R)	oldr_midr
Old River @ Head	Rold074
Grant Line Canal @ Tracy Rd Bridge	CHGRL009
Middle River @ Holt	Rmid005
Middle River @ Bacon Island	Rmid015
Middle River @ Victoria Canal	Rmid027
SJR @ Turner Cut	RSAN046
SJR @ Stockton	RSAN063
SJR @ Brandt Bridge	RSAN072
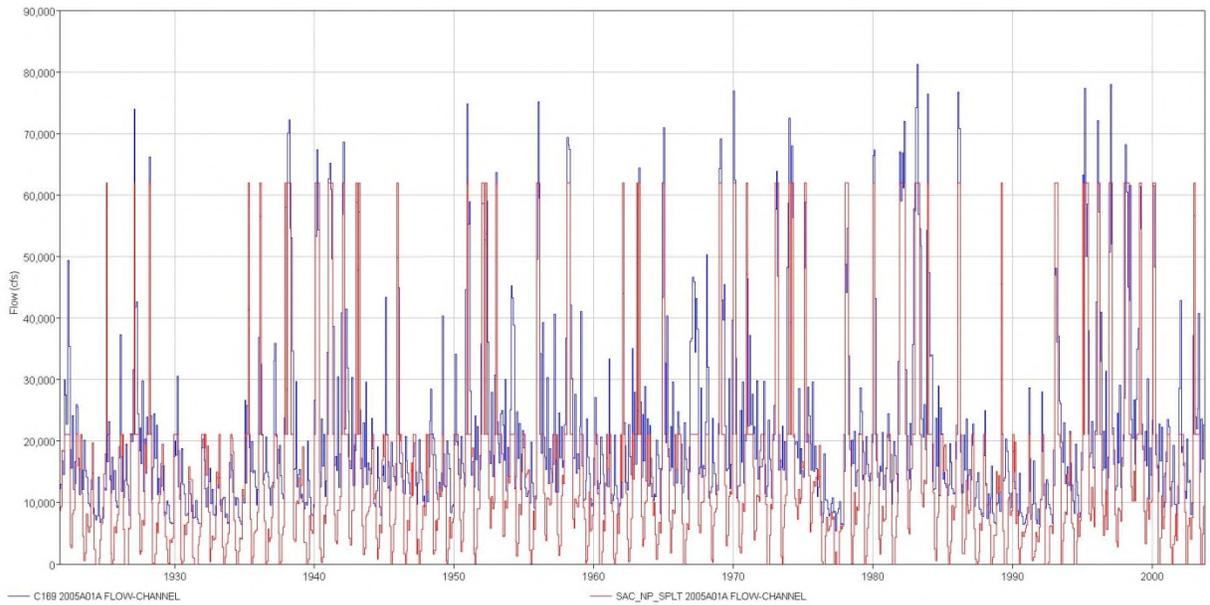
Figure 1   Comparison of Sacramento River inflow to the Delta for the current conditions (blue) and the Without Project C2 scenario (red)
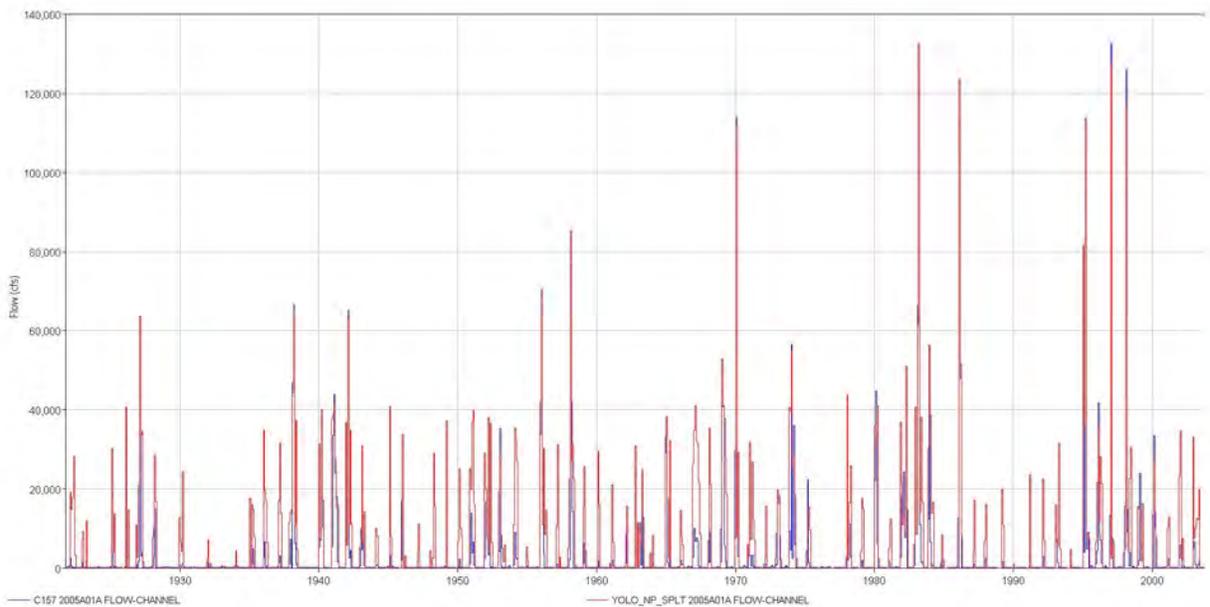
Figure 2   Comparison of Yolo Bypass inflow to the Delta for the current conditions (blue) and the Without Project C2 scenario (red)
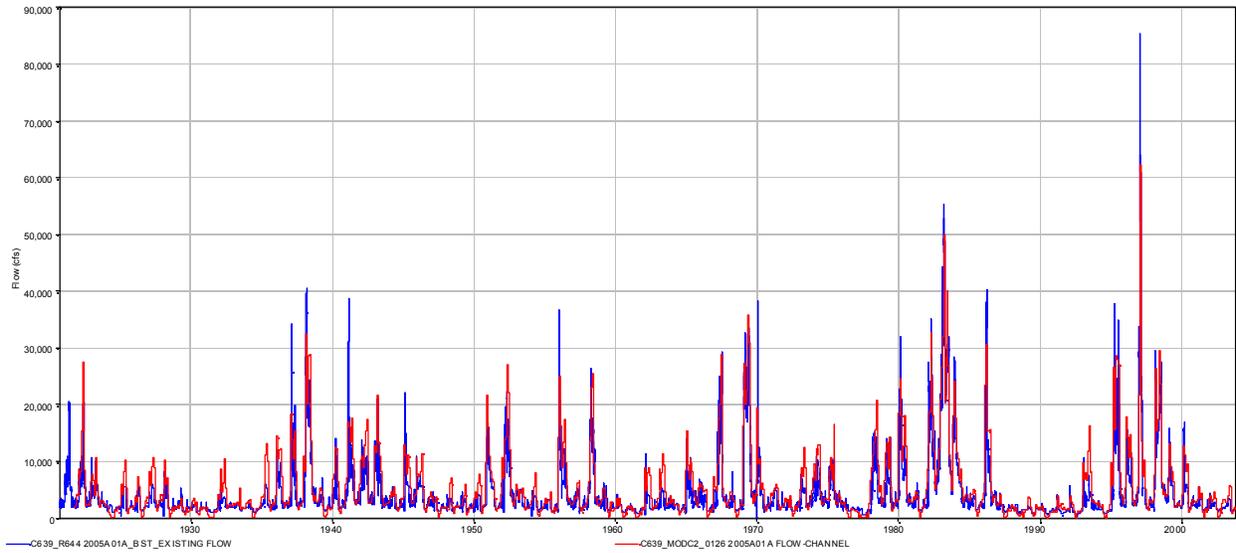
Figure 3 *Comparison of San Joaquin River inflow to the Delta for current conditions (Scenario A, blue) and the Without project C2 scenario (red)*

TABLE VI - 7
CHLORIDE LOAD VS. FLOW COEFFICIENTS AT VERNALIS

1930 - 1950

MONTH	C1	C2	# OF PAIRS*	R
OCTOBER	.3416451758E+03	.7238303788	7	.993
NOVEMBER	.3393044927E+03	.6880766404	6	.987
DECEMBER	.3639052910E+03	.6787756342	7	.972
JANUARY	.3928349175E+03	.6231583178	10	.965
FEBRUARY	.5368474514E+03	.5675747831	9	.914
MARCH	.4968879101E+03	.6035477710	10	.951
APRIL	.3866605718E+03	.5624873484	9	.942
MAY	.3805863844E+03	.5399998219	9	.920
JUNE	.6355065225E+03	.5175446121	9	.849
JULY	.6038658134E+03	.6219848451	8	.900
AUGUST	.3874538954E+03	.7410226741	8	.991
SEPTEMBER	.3500905302E+03	.7524035817	8	.989

* # OF PAIRS DOES NOT INCLUDE RESTRICTION POINT (.5,200)

$y = C1*(x)^{C2}$

Figure 4   *Coefficients relating salt load and flow, estimated for each month. Source: Effects of the CVP upon the Southern Delta Water Supply, Sacramento-San Joaquin River Delta, California, prepared jointly by the Water and Power Resources Service and the South Delta Water Agency, June 1980.*
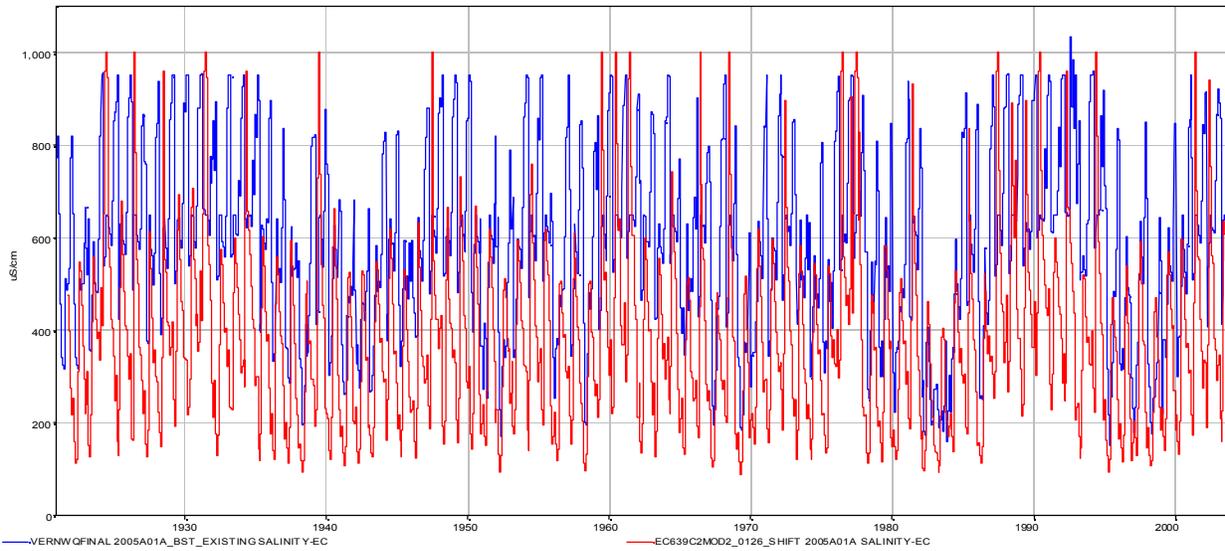
Figure 5.   *Estimated EC at Vernalis current conditions (Scenario A, blue) and without Project (Scenario C2, red).*
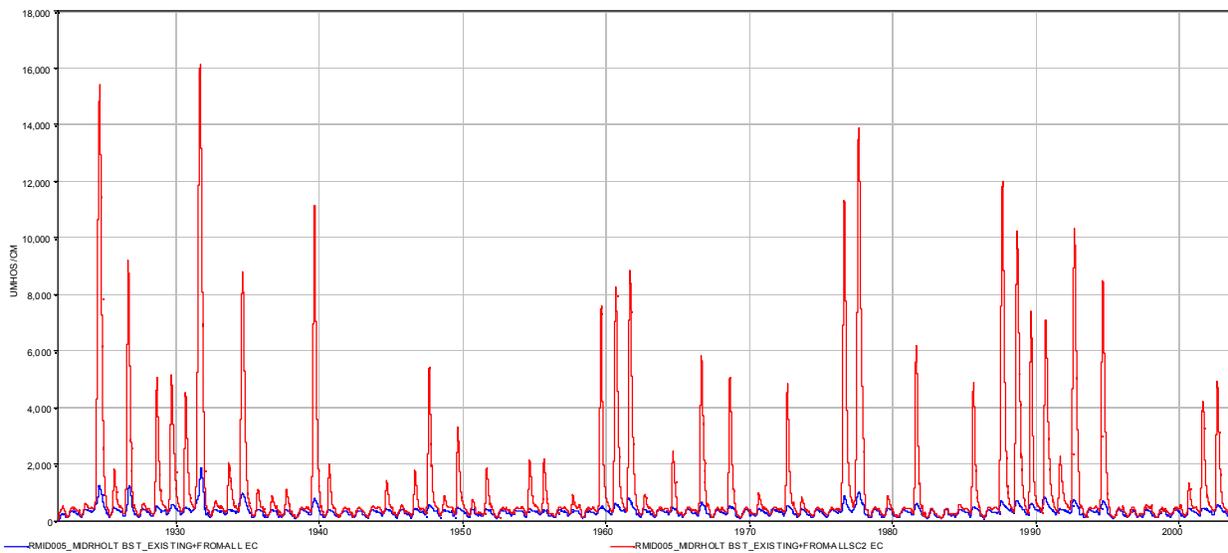
Figure 6   *DSM2 simulated EC at Middle River @ Holt (Rmid005) under the C2 scenario (red), and comparison to Scenario A (blue).*
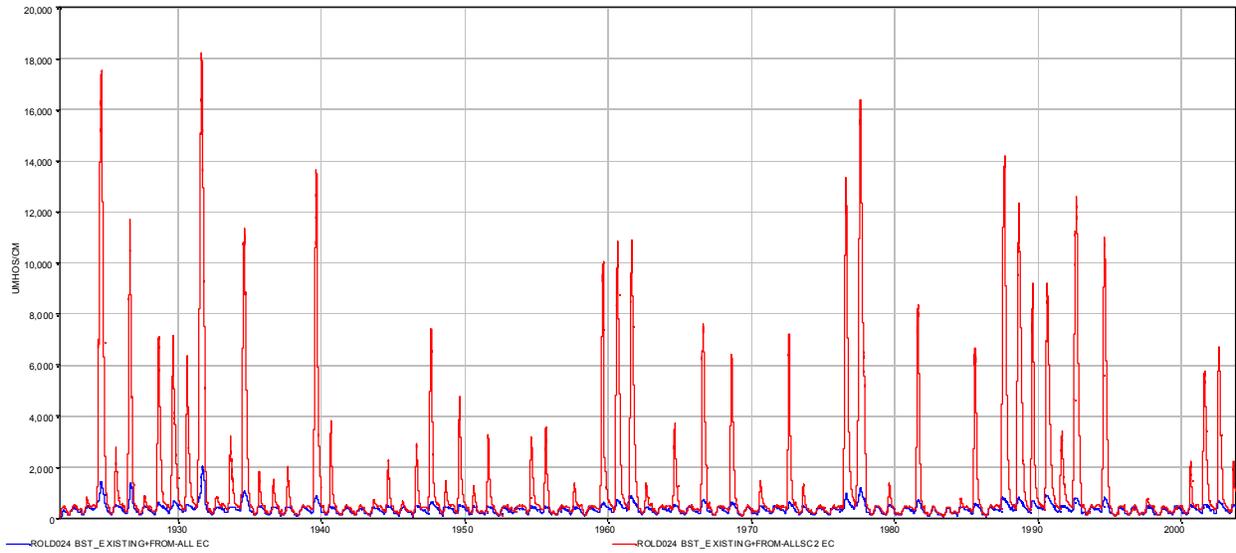
Figure 7   DSM2 simulated EC at Old River at Bacon Island (Rold024) under the C2 scenario (red), and comparison to Scenario A (blue).

3. USING THE DELTA SALINITY GRADIENT (DSG) MODEL TO FIT DSM2 DATA IN THE SOUTH DELTA

The Delta Salinity Gradient (DSG) model has been developed to represent salinity in the Western Delta as a function of the time history of freshwater inflow.[4] The DSG model, however, has not been focused on salinity in the southern Delta. In the present analysis, DSM2 output in the South Delta was used to calibrate DSG models for Scenario C2, as described in Chapters 1 and 2. A DSG model for Scenario A was performed in a similar manner; those results are presented in Appendix B.

Starting with the daily electrical conductivity outputs from DSM2, we made several refinements to narrow the scope of the dataset such that it is primarily relevant to (1) the Southern Delta alone, and (2) to the intrusion of seawater rather than other sources of salinity, e.g., agricultural runoff from the San Joaquin valley. Based on coordinates of the DSM2 nodes, distances from Golden Gate were computed along the river channels (Figure 8). DSM2 nodes along the San Joaquin (SJ), Middle (MID), and Old (OLD) rivers further than 85km inland were retained for analysis with the DSG model. The DSG model was fitted separately for the three river channels, and all data were considered from 85 km inland to the defined end of the corresponding channel (for the San Joaquin River 184.4 km; for the Old River 176.8 km; and for the Middle River 157.7 km). As shown in Figure 8, a portion of the distance for the Old and Middle River channels overlaps with the San Joaquin river channel. Thus, data from 85 km to 118.5 km on San Joaquin River channel were included in the fitting process for the Middle River DSG model. Similarly, data from 85 km to 114.5 km on the San Joaquin River channel were used in the fitting for the Old River DSG model.

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[4] Hutton, P.H., J. S. Rath, L. Chen, M. J. Ungs, and S. B. Roy (in review) Nine Decades of Salinity Observations in the San Francisco Bay and Delta: Modeling and Trend Evaluation. ASCE Journal of Water Resources Planning and Management.

The input flows (actual flow and antecedent G-flow) for the C2 Scenario are shown in time series form in Figure 9, and as a distribution in Figure 10.

The DSM2 output often displayed a non-monotonic salinity gradient, with salinity decreasing from the western model boundary through portions of the Delta and then increasing again further inland. This is hypothesized to be due to elevated salinity in San Joaquin inflows. To mitigate this phenomenon's effects on estimation of DSG model parameters, we only trained the DSG model using data from nodes west of the node with the minimum salinity on a given day, reach, and scenario. It is acknowledged that this rather simple filter is imperfect and perhaps merits further refinement, in light of the extreme hydrology associated with scenario C2, but appears to give reasonably good results.

The DSG model was fitted using the actual flows at Martinez based on <u>daily DSM2 output</u>, which display a tidal influence rather than the monthly NDOI values computed from DSM2 <u>input</u>. The monthly NDOI values were found to be insufficient to explain the daily EC values.

An antecedent flow, G, dataset was calculated using the each scenario's flow (Q) time series, in this case the flow at Martinez. The β parameter related to this calculation is the same as for the current calibration of the DSG model to EC data in the western Delta. As the primary flow regime of interest for this analysis is lower flows with higher salt intrusion, we are not using the variable ocean boundary salinity that was introduced to the DSG model to deal with suppression of near-ocean ECs under high outflows. In other words, the parameter γ is left fixed at positive infinity. Also, recognizing that the region of interest has generally lower salinities than the western Delta, we centered the representation of the gradient in the model around the isohaline X_C corresponding to the adjustable EC value S_C. Currently, this parameter is not statistically estimated but instead left at an illustrative value of 2 mS/cm.

The first attempt at fitting tried to only estimate the parameters ϕ_1 and ϕ_2, leaving the boundary salinities at the values in the current calibration of the DSG model for the western Delta—$S_b = 0.2$ mS/cm and $\hat{S} = 53$ mS/cm, but this resulted in unsatisfactory fits. Allowing them to be estimated freely resulted in less biased fits, although the theoretical appeal of a prescribed, a priori boundary value is lost. Two different estimation procedures were tried: numerical non-linear least squares (nls) and maximum a posteriori (map) fit of a Bayesian student's t model. The fitting procedures give slightly different results (Table 2). A fully Bayesian estimate of $\hat{S}$ for the San Joaquin C2 model (only performed for one scenario due to computational intensity) allows for comparison with the estimated "boundary salinity" with the range of DSM2 values. Figure 11 confirms the estimate is near the maximum EC; the rare cases where the training data are above the $\hat{S}$ estimate seem okay in the context of the Bayesian model being an estimate of the *center* of EC distribution conditional on a given antecedent flow.

Figure 12 shows the calculated values of salinity from the fitted DSG models for the Old, Middle, and San Joaquin River for an illustrative range of G-glows. Figure 13 through Figure 16 illustrate the spatial and flow variability of the fitted model in various ways and compare it to DSM2 data used in training. Figure 17 is a direct comparison of model predictions with training data.

Table 2
Diagnostics of DSG predictions of DSM2-simulated EC for Scenario C2 in terms of a linear model $EC_{DSM} = a + b \cdot EC_{DSG}$ and best fit DSG parameters for two different estimation procedures: non-linear least squares (nls) and maximum a posteriori (map) fit of a Bayesian student's t model. Columns in gray are not estimated in model training.

Scenario	Reach	Fit	Model Diagnostics				DSG Parameters (EC units: mS/cm, flow units: cfs)							
			r^2	Std. Error	a	b	ϕ_1	ϕ_2	S_b	$\widehat{S}$	S_C	γ	δ	$\beta \times 10^{-10}$
C2	MID	map	0.91	1.25	0.20	0.98	679	-0.230	0.377	25.9	2.00	∞	1.00	1.5
C2	MID	nls	0.91	1.24	0.00	1.00	691	-0.230	0.527	25.0	2.00	∞	1.00	1.5
C2	OLD	map	0.93	1.08	0.12	0.99	766	-0.244	0.351	26.0	2.00	∞	1.00	1.5
C2	OLD	nls	0.94	1.08	0.00	1.00	734	-0.238	0.435	25.3	2.00	∞	1.00	1.5
C2	SJ	map	0.93	1.10	0.12	0.98	537	-0.203	0.325	26.2	2.00	∞	1.00	1.5
C2	SJ	nls	0.93	1.10	0.00	1.00	511	-0.195	0.408	25.1	2.00	∞	1.00	1.5
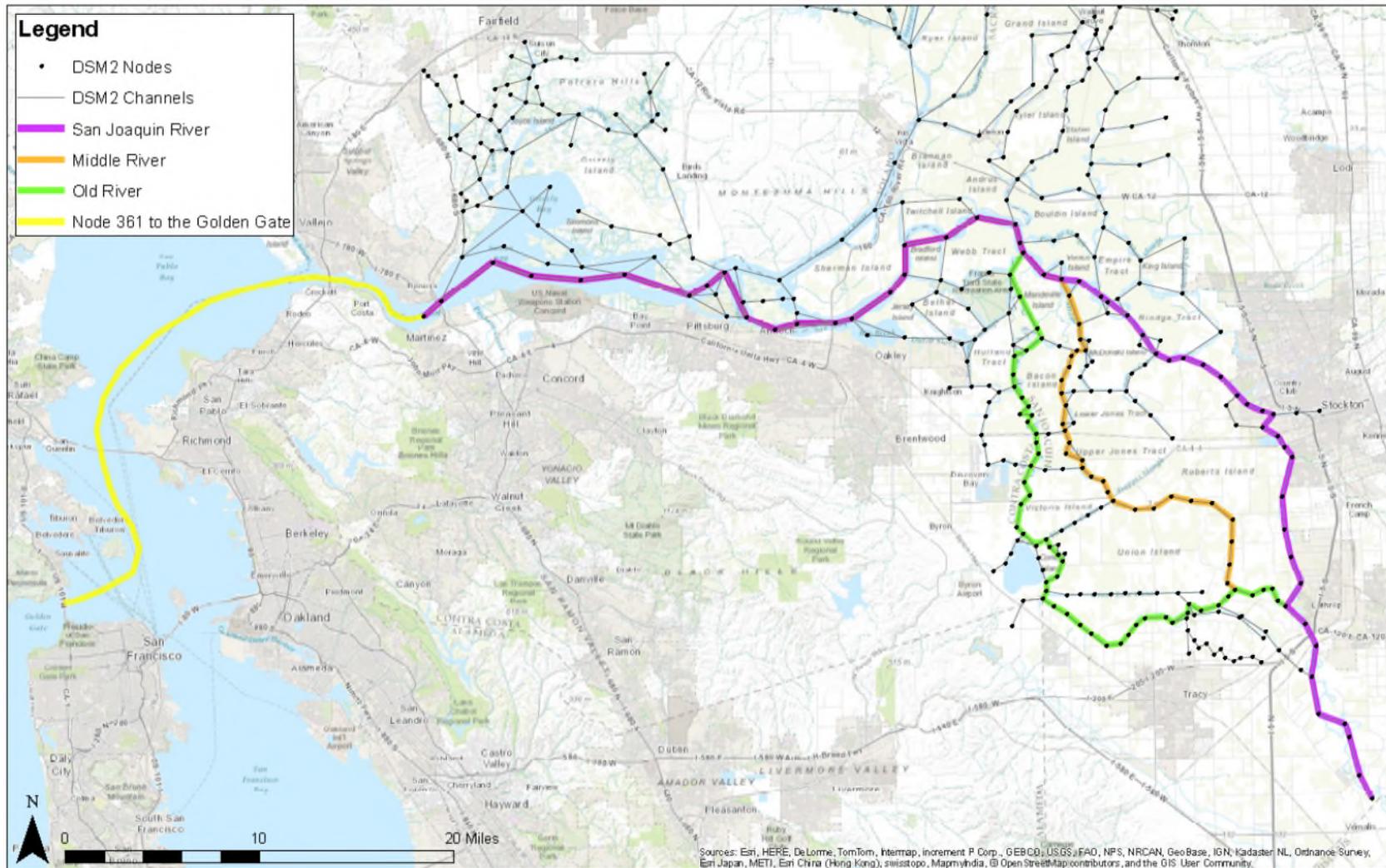
Figure 8   *Distances for DSM2 nodes from Golden Gate Bridge for the Old, Middle and San Joaquin Rivers, estimated along the channels used in DSM2.*
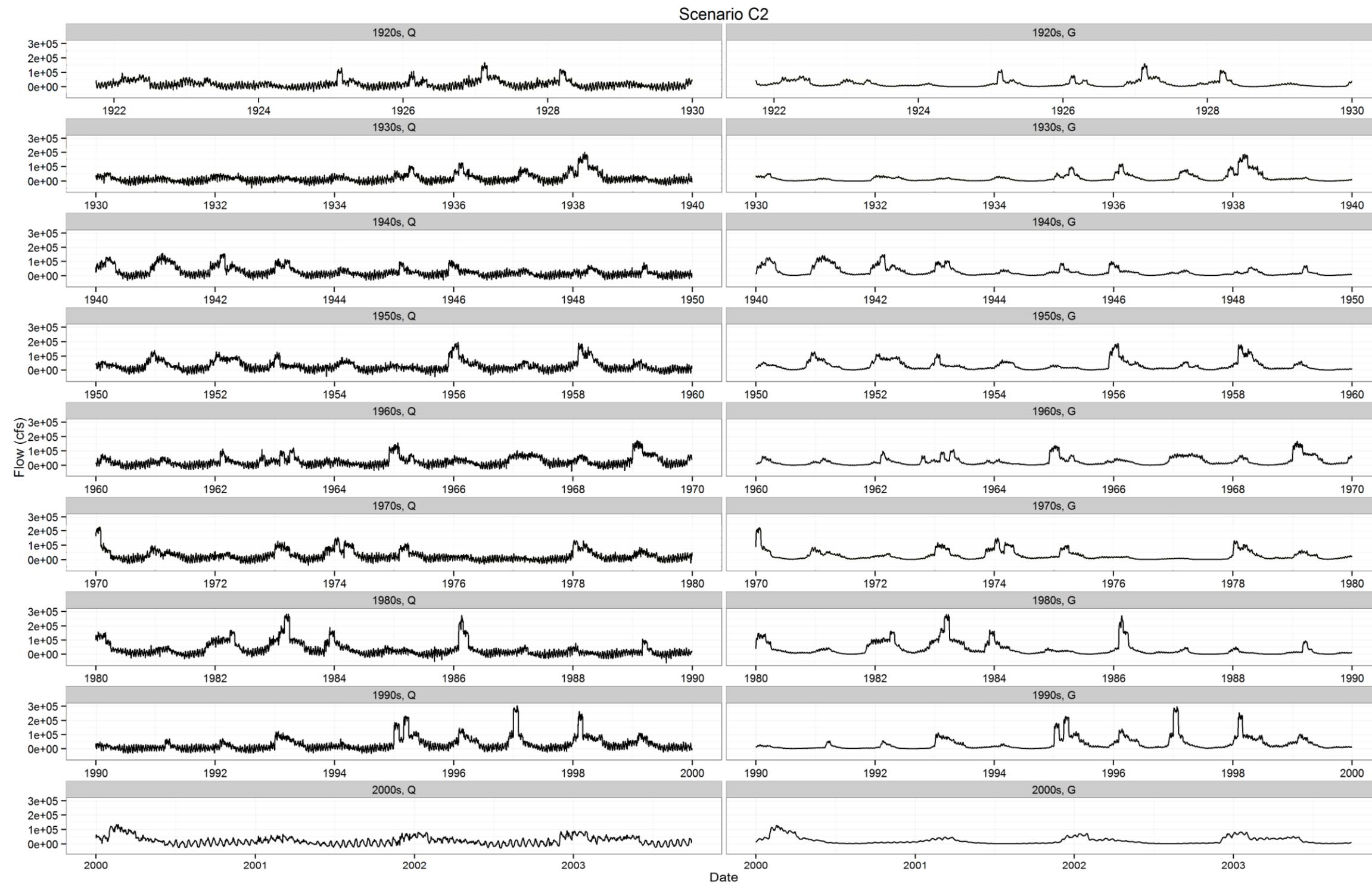
Figure 9   *Time series plots of net Delta outflow, Q, approximated as modeled flow past Martinez, and corresponding antecedent flows, G, for Scenario C2.*

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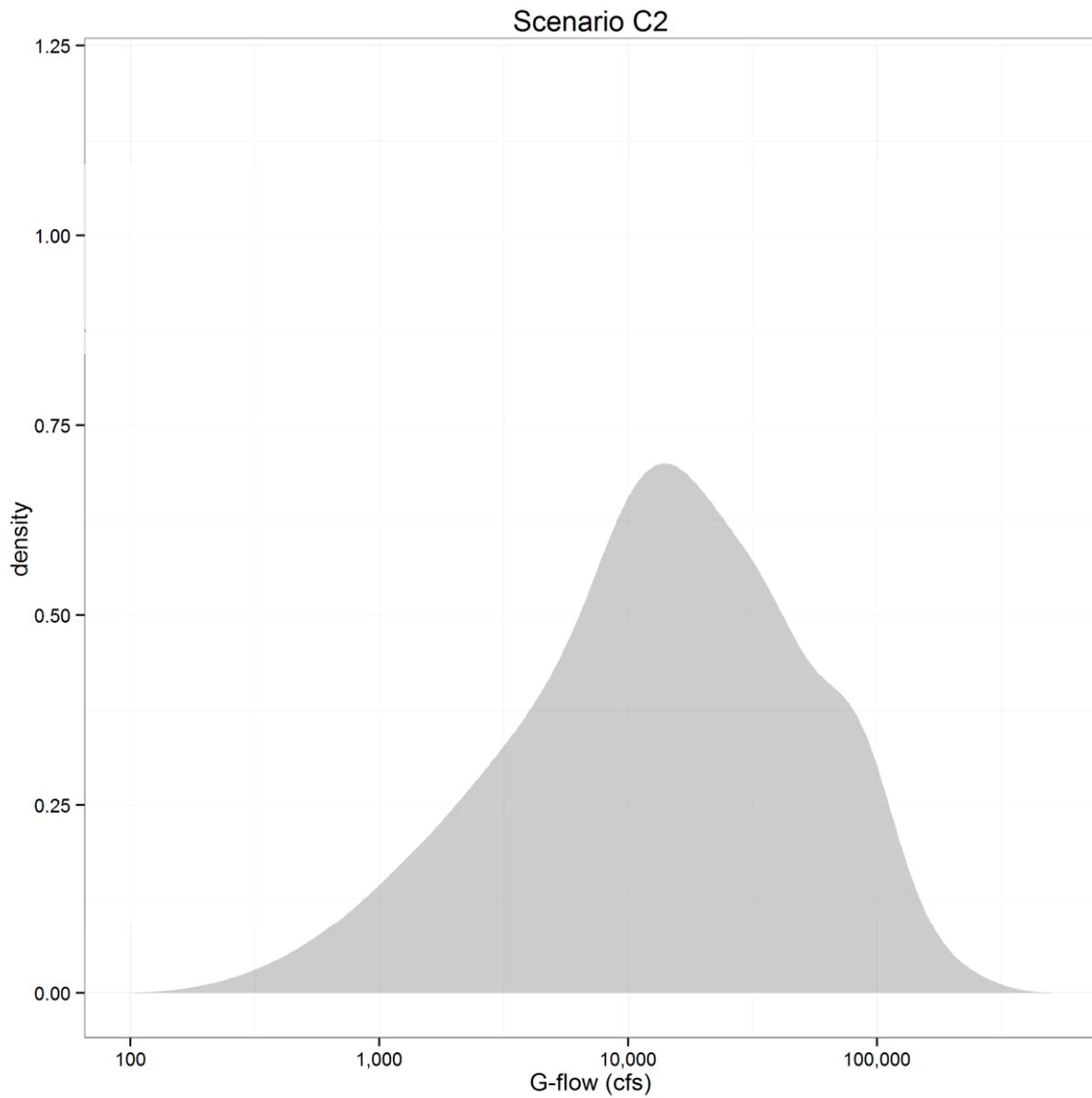
Figure 10   Scenario C2 smoothed frequency distribution of G-flow.

Statistically estimated Ŝ (red) vs. EC density estimate
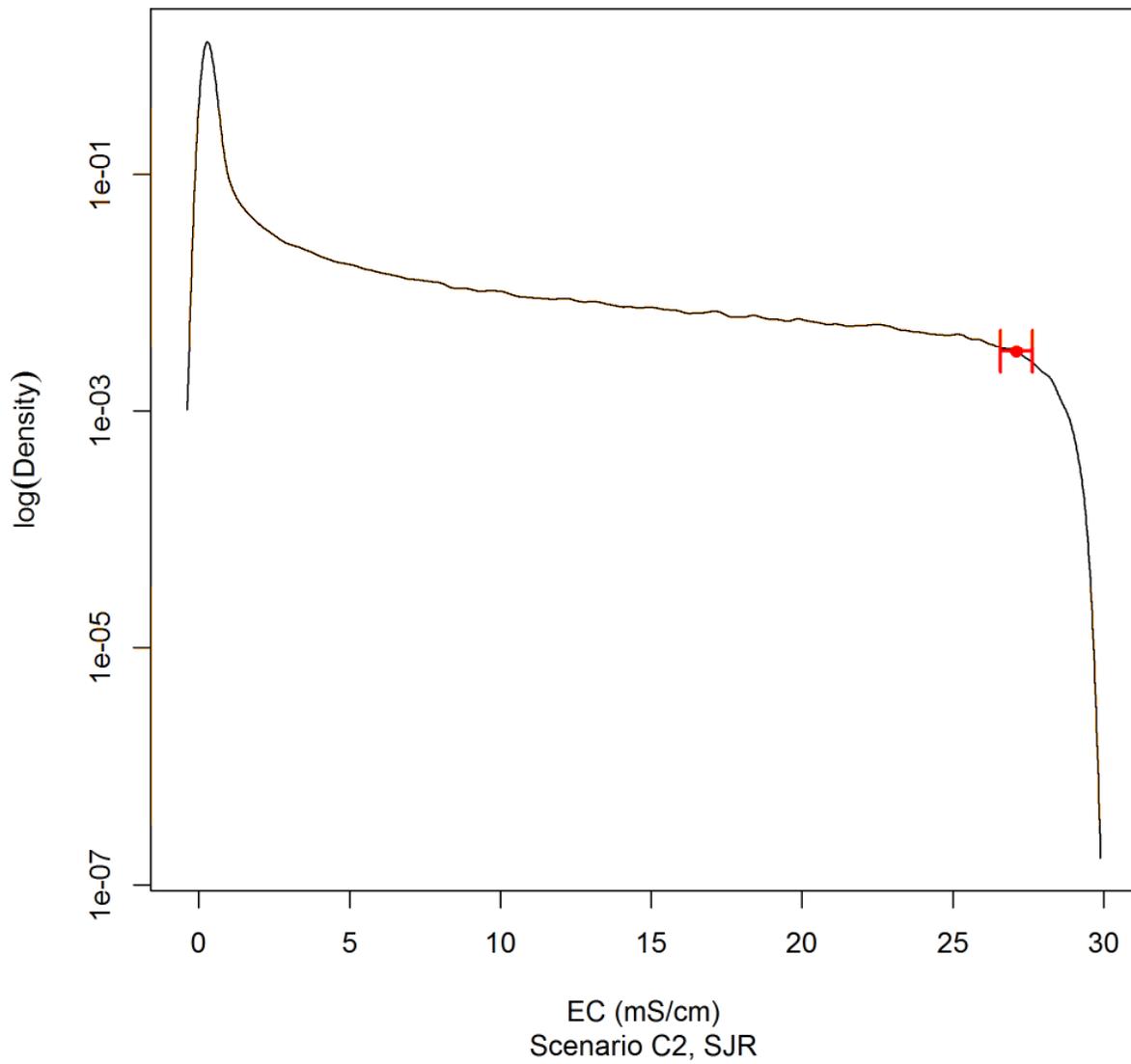
Figure 11   *Illustrating the estimation of $\widehat{S}$ as a free parameter—the posterior mean with a 95% interval (shown in red) is close to the maximum DSM2 simulated EC.*
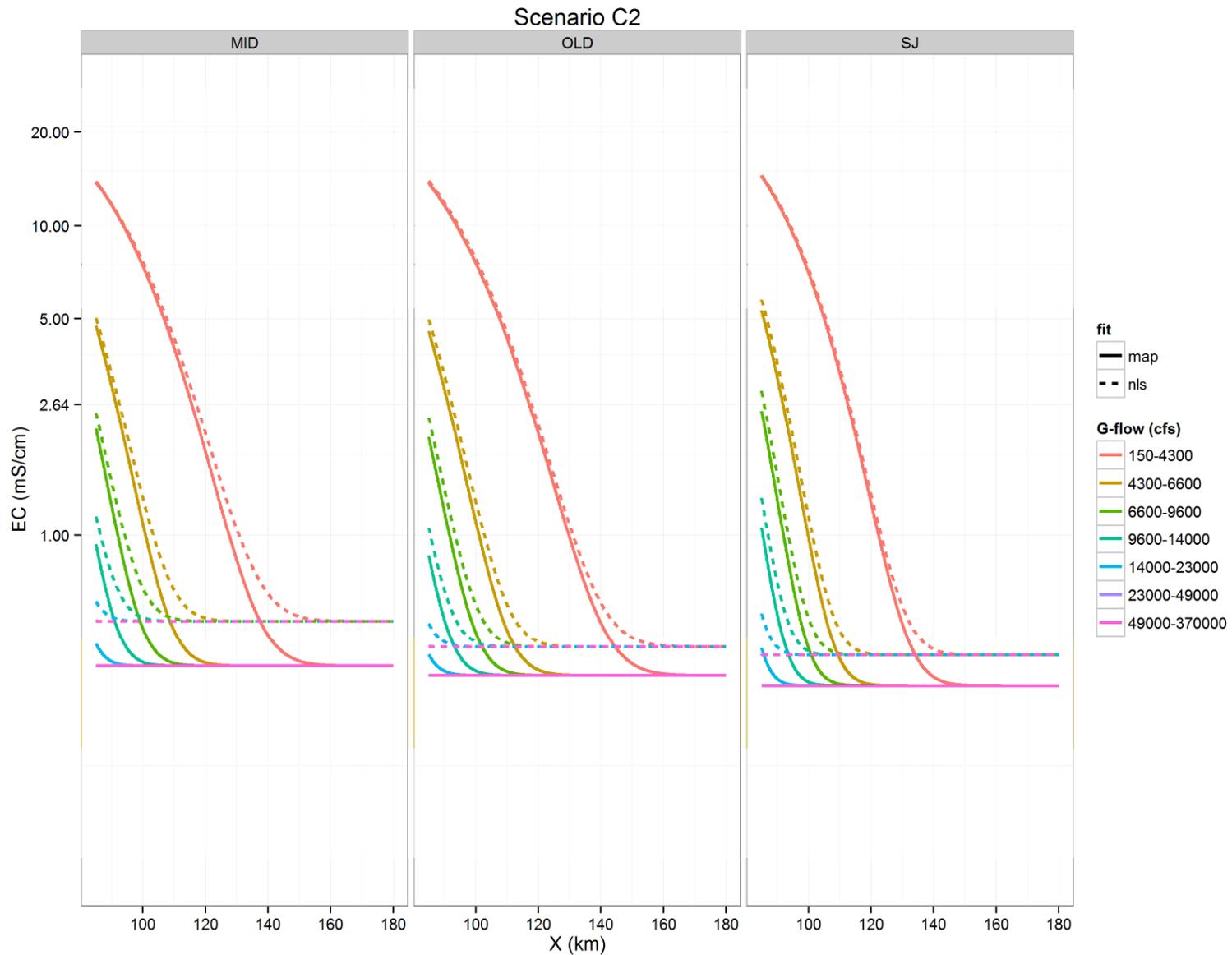
Figure 12   *Illustration of spatial variation in DSG predictions using the median G-flow in seven evenly spaced (in terms of G-flow percentiles) flow bins.*
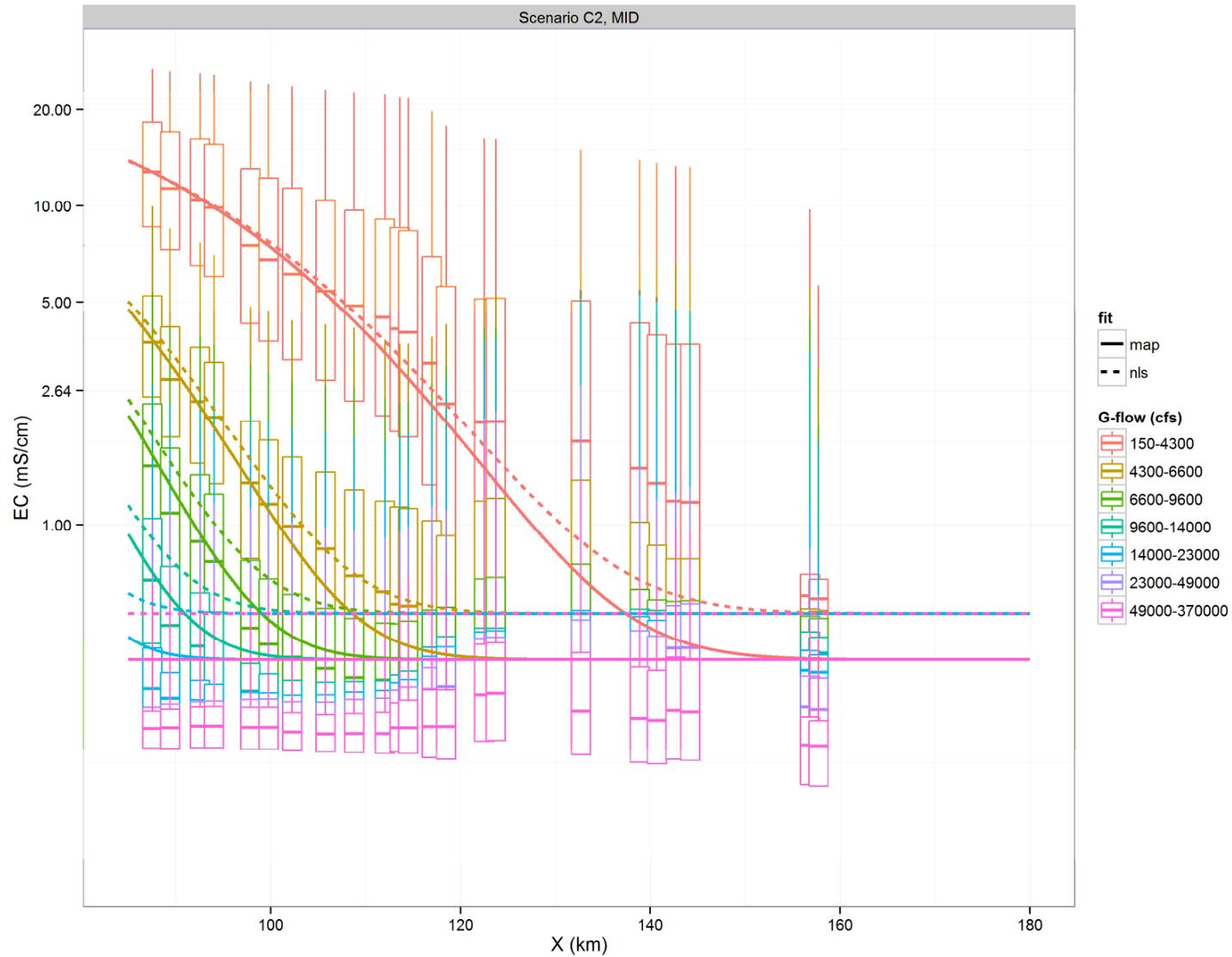
Figure 13   *As in Figure 12, except with box plots showing the distribution of DSM2 data at each distance. Scenario C2, Middle River.*

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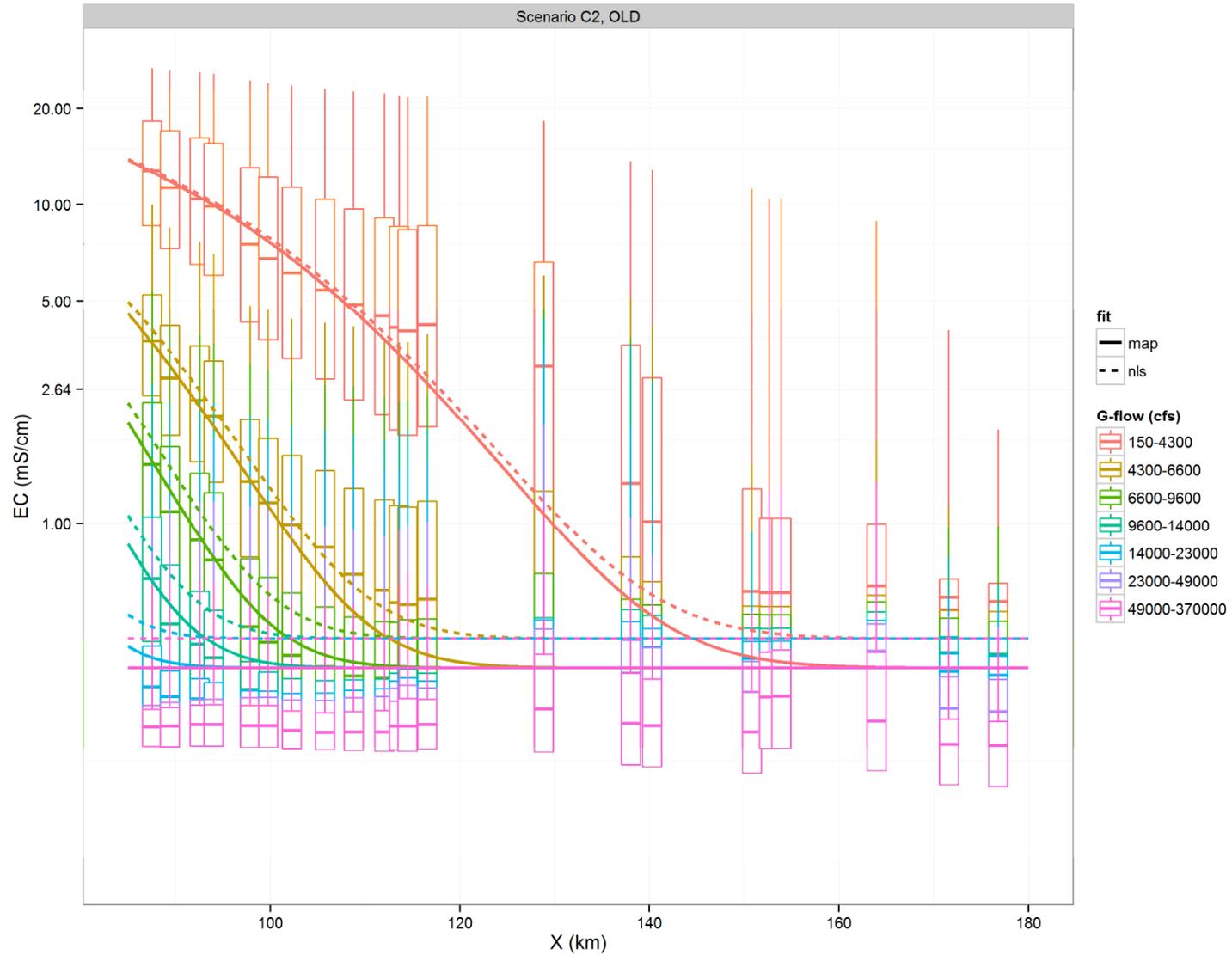
Figure 14   As in Figure 12, except with box plots showing the distribution of DSM2 data at each distance. Scenario C2, Old River.
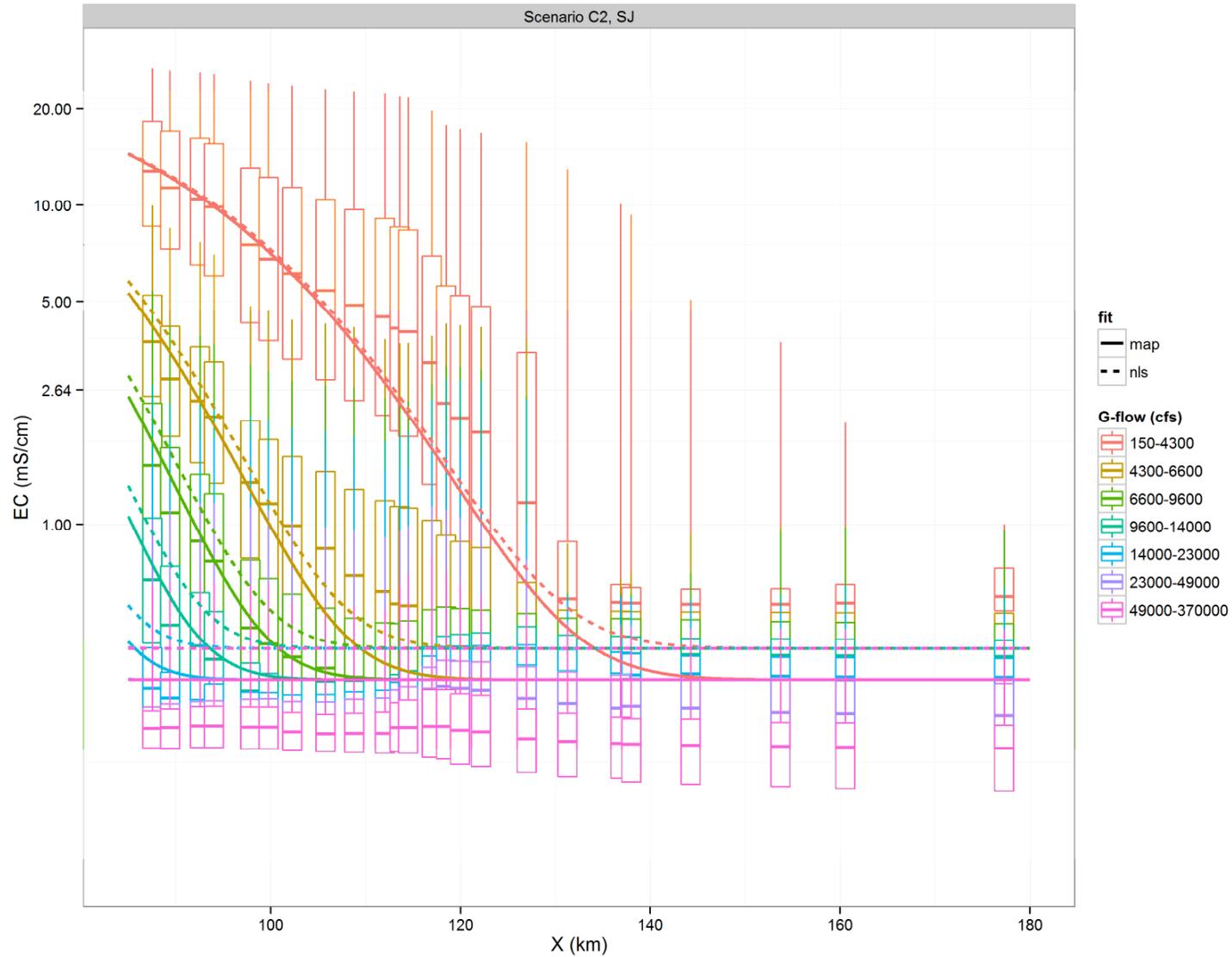
Figure 15   As in Figure 12, except with box plots showing the distribution of DSM2 data at each distance. Scenario C2, San Joaquin River

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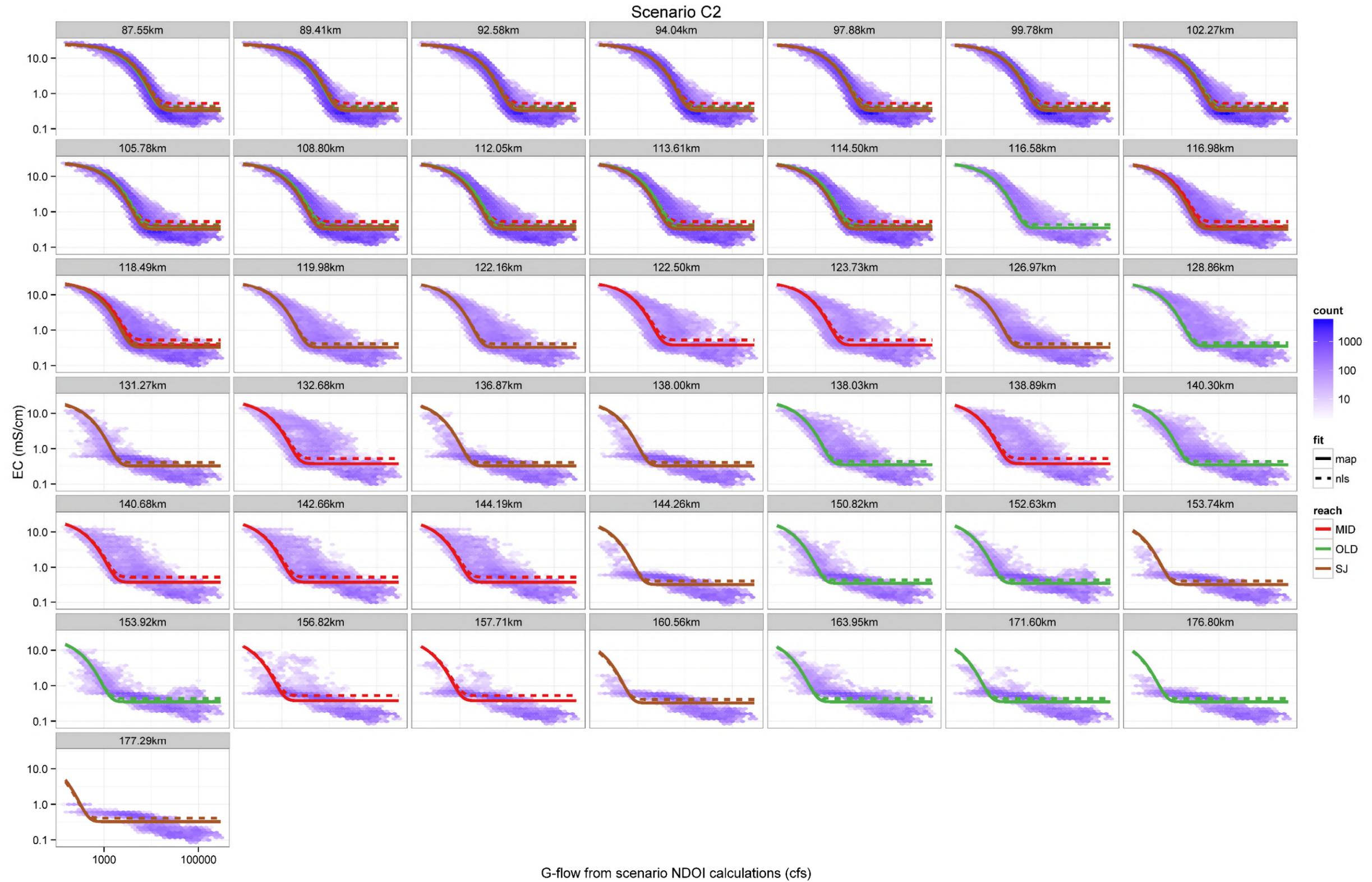
Figure 16   Flow response of DSM2 simulations and DSG predictions of EC at each DSM 2 location, Scenario C2. Log scale on both axes.
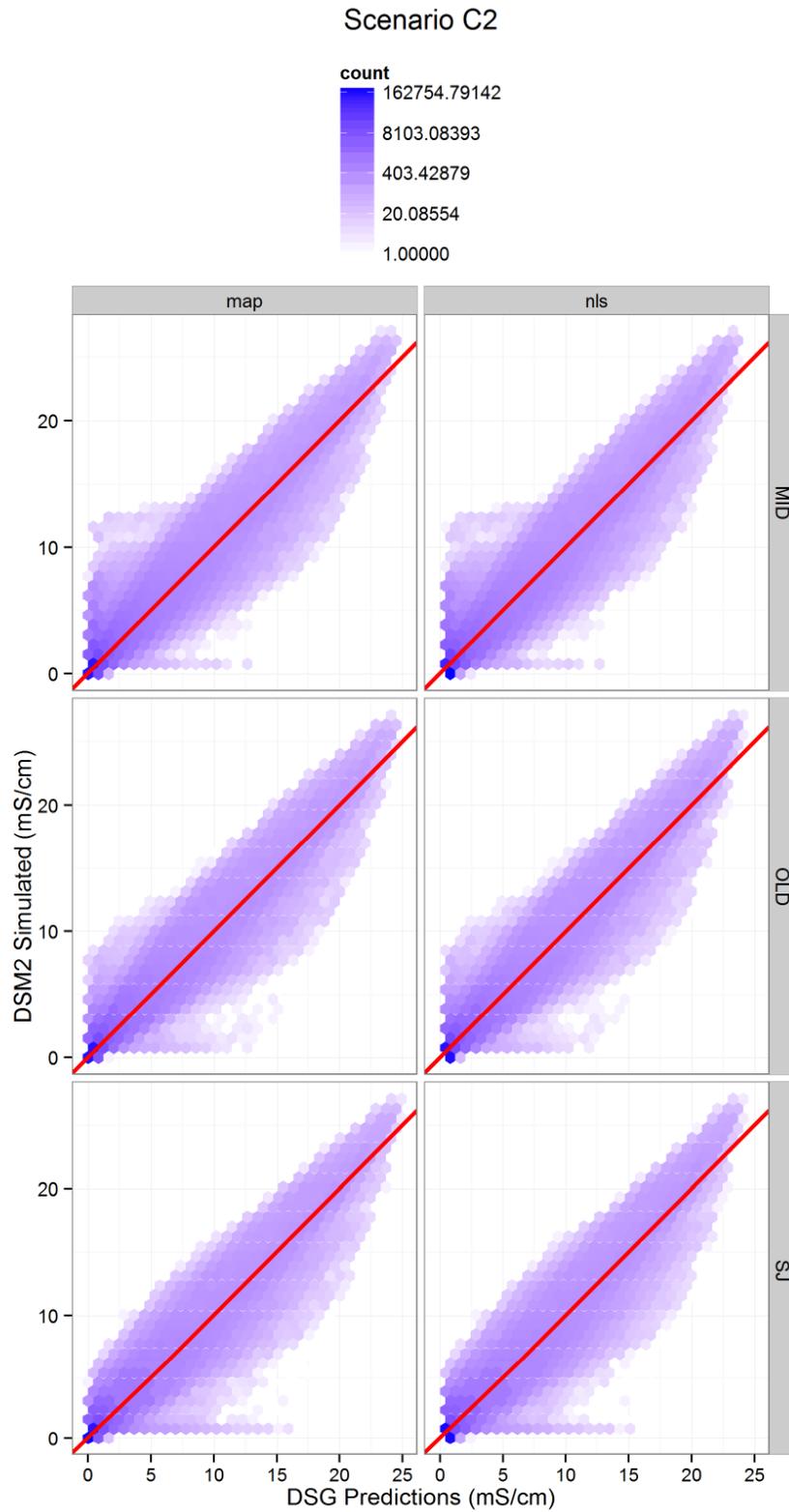
Figure 17   DSG predictions vs training data and 1:1 line (red).

4. VALIDATION OF DSM2 AND DSG MODEL RESULTS

The DSM2 model has not been calibrated for flow and salinity conditions that occurred in the early decades of the 20th century, which include some extremely dry conditions in the 1920s and early 1930s. To build confidence in the application of DSM2 to low flow conditions observed in the without Project scenario, we performed a limited validation using observed salinity data from the South Delta,[5] and using the DSG model that was calibrated to the Without project C2 Scenario.

To compare the model and data, we related EC and distance, where individual plots were developed for a range of G-flow values from 500 to 4,500 cfs in increments of 500 cfs. Each plot contained observed data points from either WY1922-1944 or WY1922-1968, as long as the observed data fell in the identified G-flow range. Each plot shows the DSG model line for the three river channels, calculated using the mid-point G-flow value. Thus, the plot for 500-1,000 cfs shows DSG plots for 750 cfs. Overall, this exercise shows that the DSG model is a reasonable representation of the data, even at some of the most extreme low flow conditions observed in the 20th century. This provides support for the use of the re-calibrated DSG model and the DSM2 model in applications where Delta water quality behavior is to be modeled under conditions of very low flows.

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[5] Tetra Tech (2015) Mapping and Trend Evaluation of Interior Delta Salinity, Final report prepared for the Metropolitan Water District of Southern California.
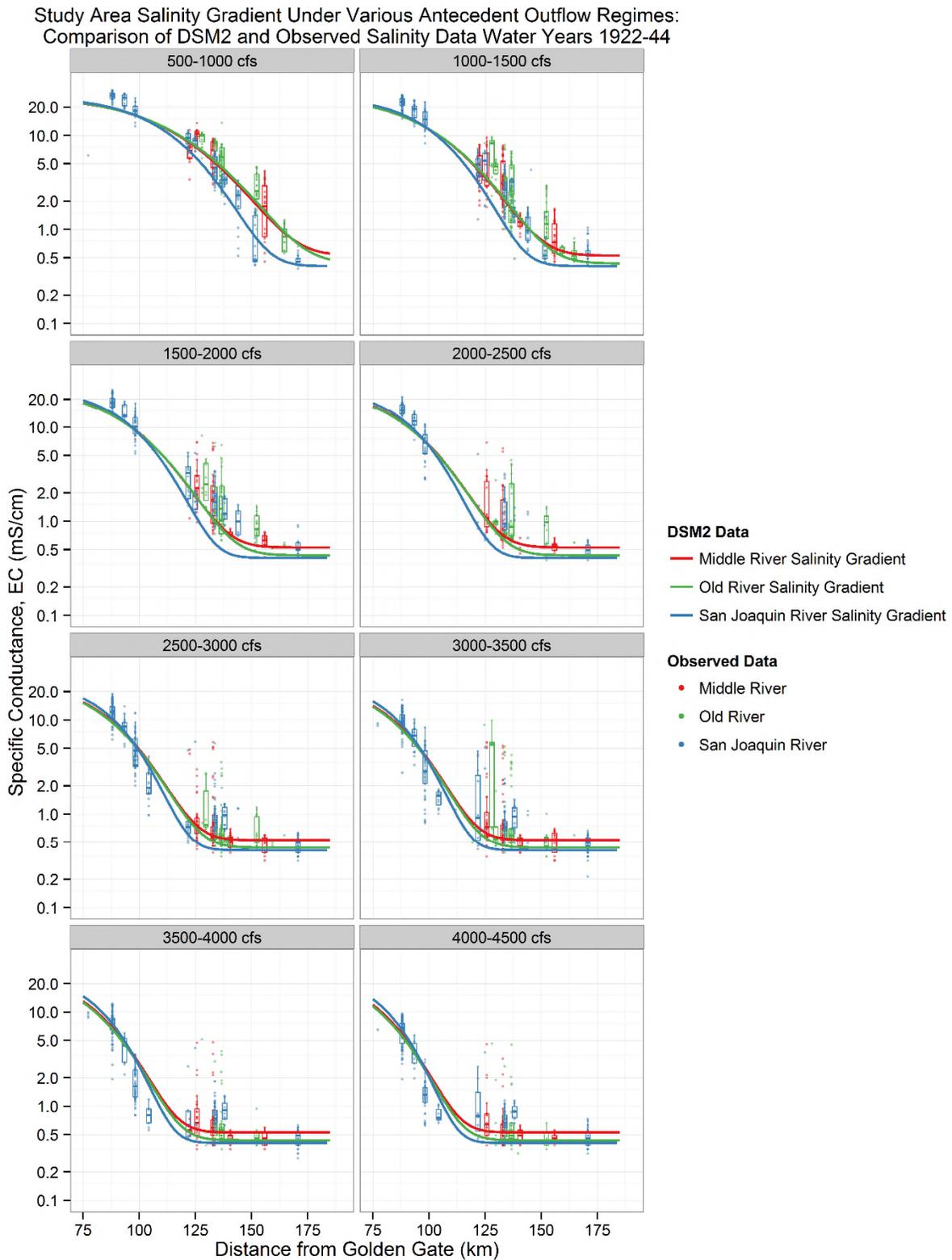
Figure 18   *Comparion of observed salinity data (1922-1944) and DSG model salinity for specified G-flow ranges.*
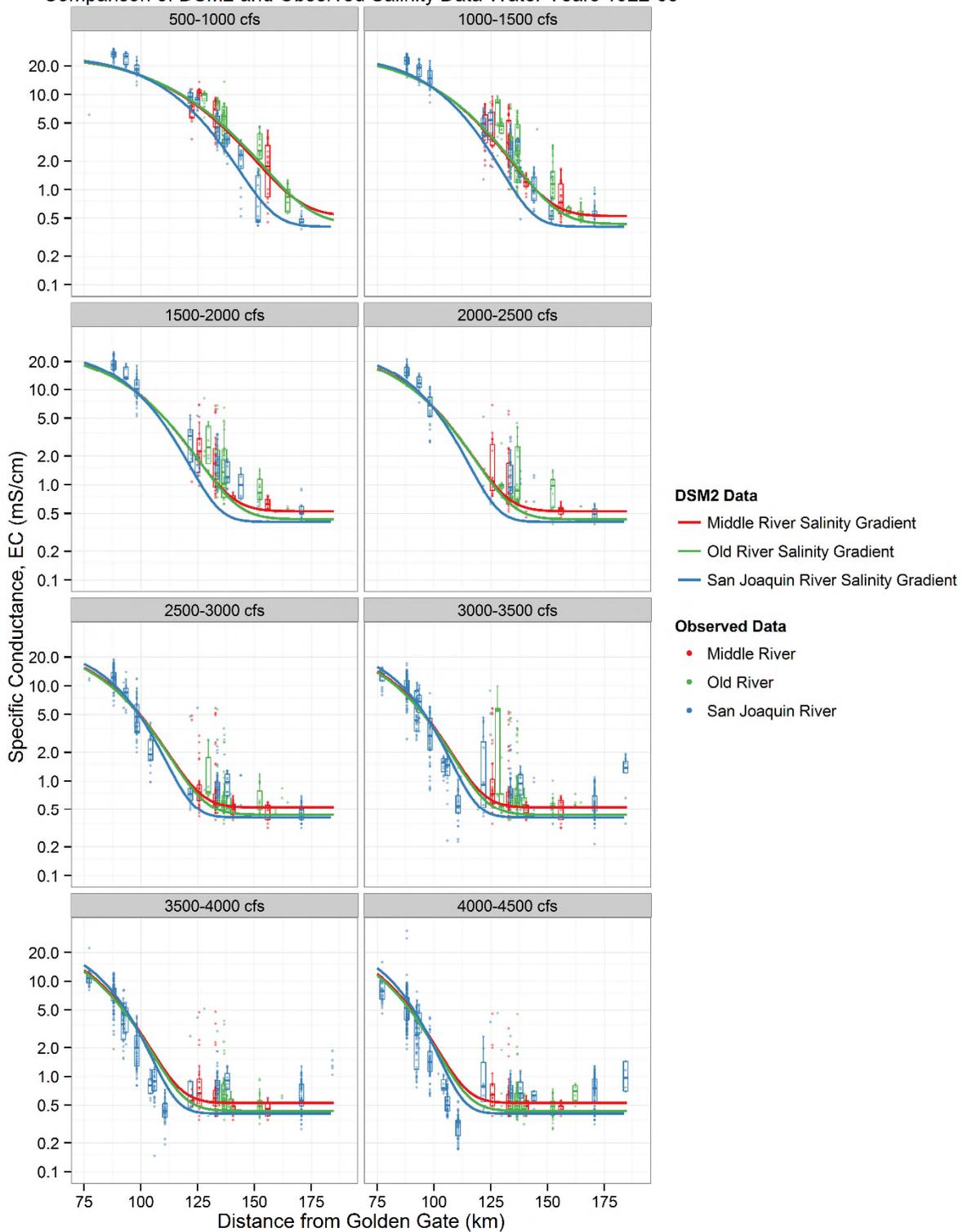
Figure 19   *Comparion of observed salinity data (1922-1968) and DSG model salinity for specified G-flow ranges.*

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5. ESTIMATION OF AGRICULTURAL AREA BY DISTANCE FROM GOLDEN GATE

As part of this task, we computed the irrigated agricultural area by distance along the Old, Middle, and San Joaquin River channels south of the San Joaquin River. Data on agricultural land use in the Delta region was obtained from DWR.[6] The data consisted of discrete polygons or parcels of land across the entire Delta.

The agricultural land use parcels were divided up as follows. First, a buffer around each of the three rivers of interest was created. The buffer extended out 5 miles, except where there is less than 10 mile distance between neighboring rivers (including the Sacramento River, which was taken into consideration when assigning the land use, but not included in the analysis itself). Only areas south of the San Joaquin River were considered in this analysis, and some small, isolated pockets of land distant from the river channel were excluded. Where the Old, Middle, and San Joaquin Rivers are close together, the land was divided up approximately so that the land use polygons are assigned to the nearer river. The nearest DSM2 node was calculated for each land use polygon within each river stretch, and then assigned to it. This was accomplished using the simple nearest distance from polygon edge to node point. The acreage of agricultural land use was summed for each node, and accumulated as one moves upstream. This method is approximate where the rivers come together (some polygons assigned to one node might be better attributed to a different one on a different river), but everywhere else this approach works well at assigning polygons to the correct node.

A map showing the channels and the agricultural areas is presented in Figure 20. The total agricultural area in the Delta is 393,400 acres, of which 73,500 acres was associated with

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[6] Jane Schafer-Kramer (2015) Personal Communication, April 3.

the San Joaquin River, 42,000 acres was associated with the Middle River, and 72,000 acres was associated with the Old River.
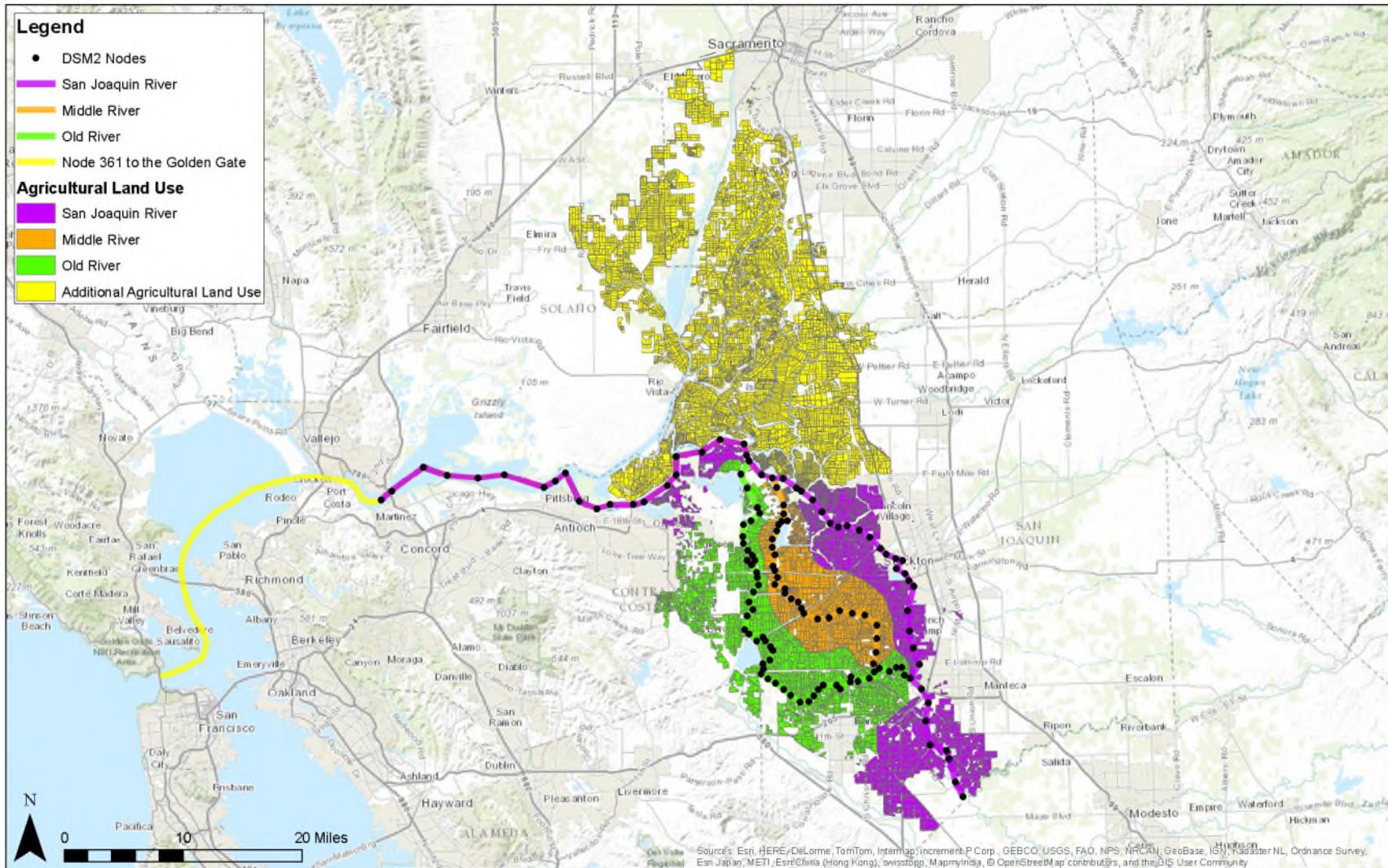
Figure 20   Agricultural area by river river channel.

APPENDIX A VOLUMETRIC FINGERPRINTS FOR WITHOUT PROJECT SCENARIOS WITH AND WITHOUT DELTA ISLAND CONSUMPTIVE USE

Station

1 Old River @ Holland (ROLD14)
2 Old River @ Bacon Island (ROLD24)
3 Old River @ Hwy 4 (ROLD34)
4 Just outside of CCF intake (CHSWP003)
5 Old River @ Tracy Rd Bridge (ROLD059)
6 Old River @ Middle River (OLDR_MIDR)
7 Old River @ Head (ROLD074)
8 Grant Line Canal @ Tracy Rd Bridge (CHGRL009)
9 Middle River @ Holt (RMID005)
10 Middle River @ Bacon Island (RMID015)
11 Middle River @ Victoria Canal (RMID027)
12 San Joaquin River @ Turner Cut (RSAN046)
13 San Joaquin River @ Stockton (RSAN063)
14 San Joaquin River @ Brandt Bridge (RSAN072)

Figure 21   Map showing 14 stations used for plotting volumetric fingerprints in the following pages

Figure 22   CHGRL009: Grant Line Canal @ Tracy Rd Bridge
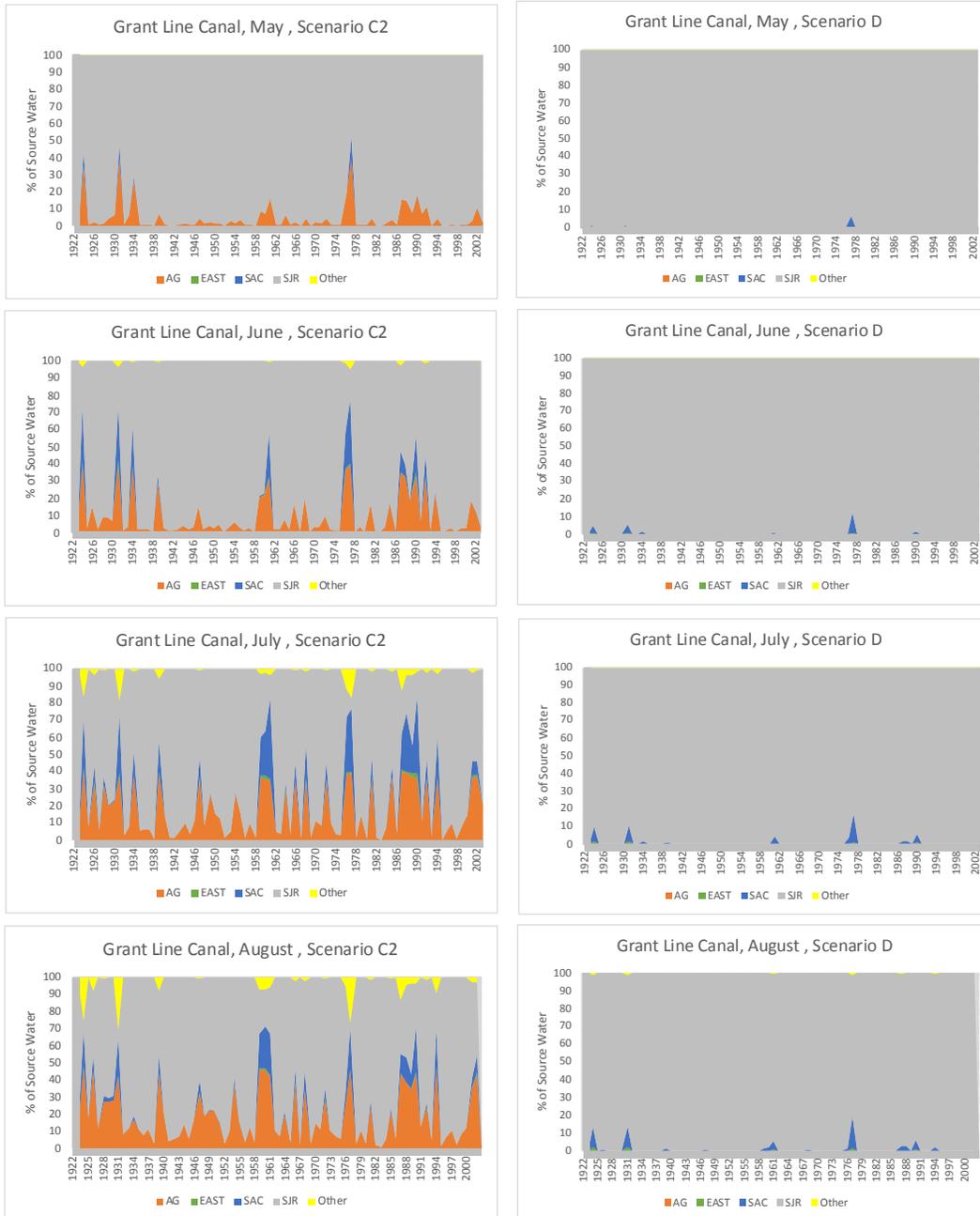
Figure 23   CHGRL009: Grant Line Canal @ Tracy Rd Bridge
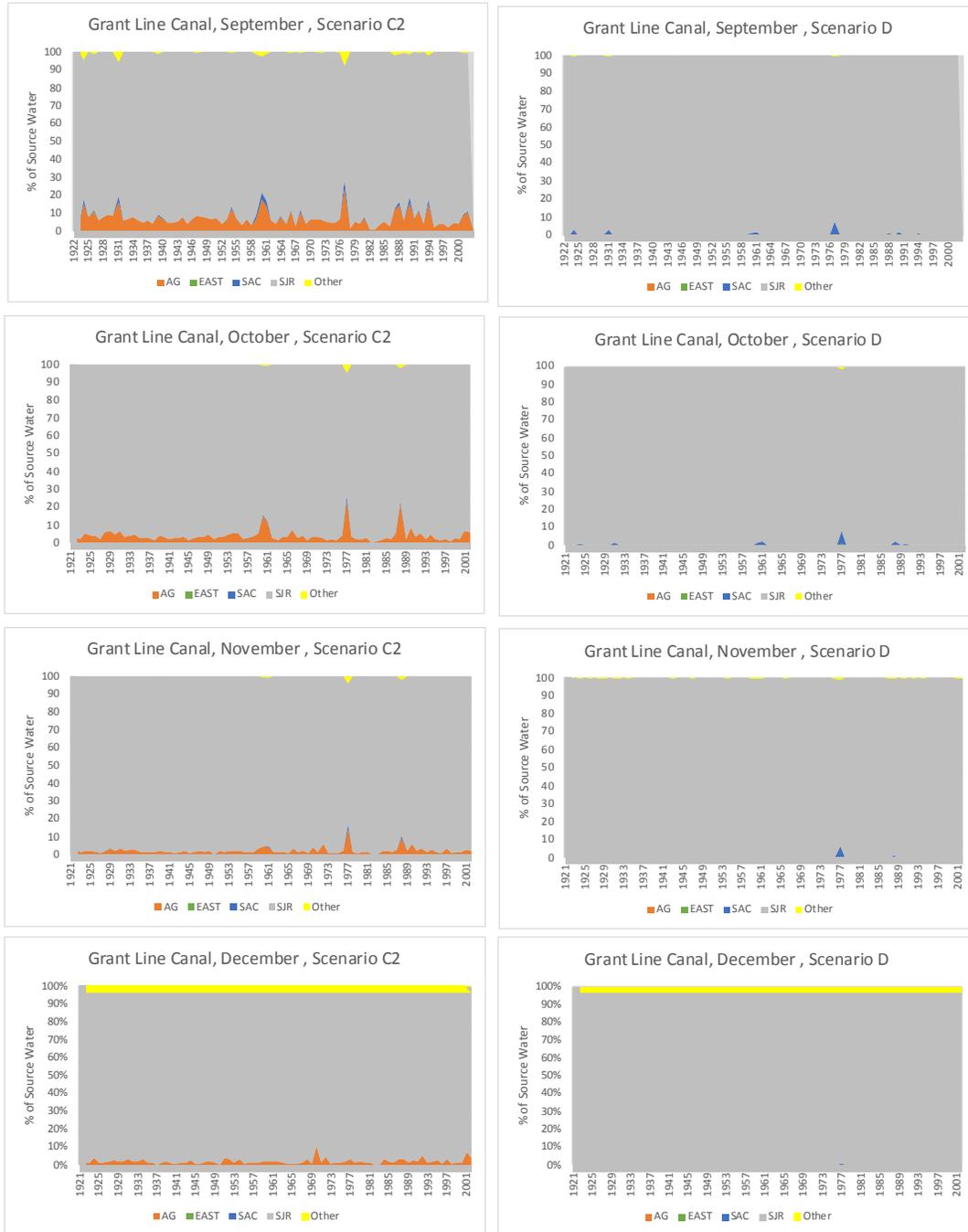
Figure 24   CHGRL009: Grant Line Canal @ Tracy Rd Bridge
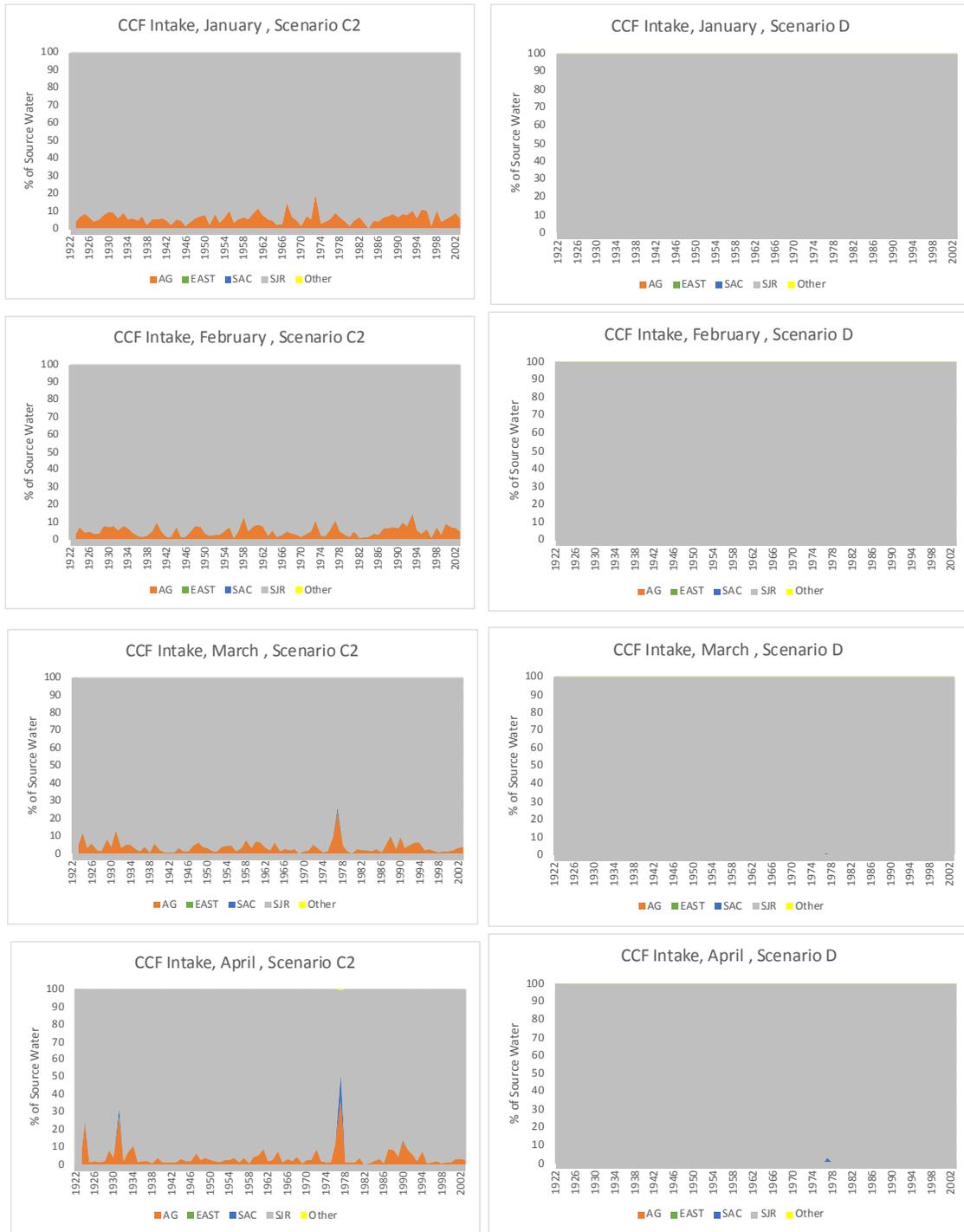
Figure 25   CHSWP003: CCF Intake
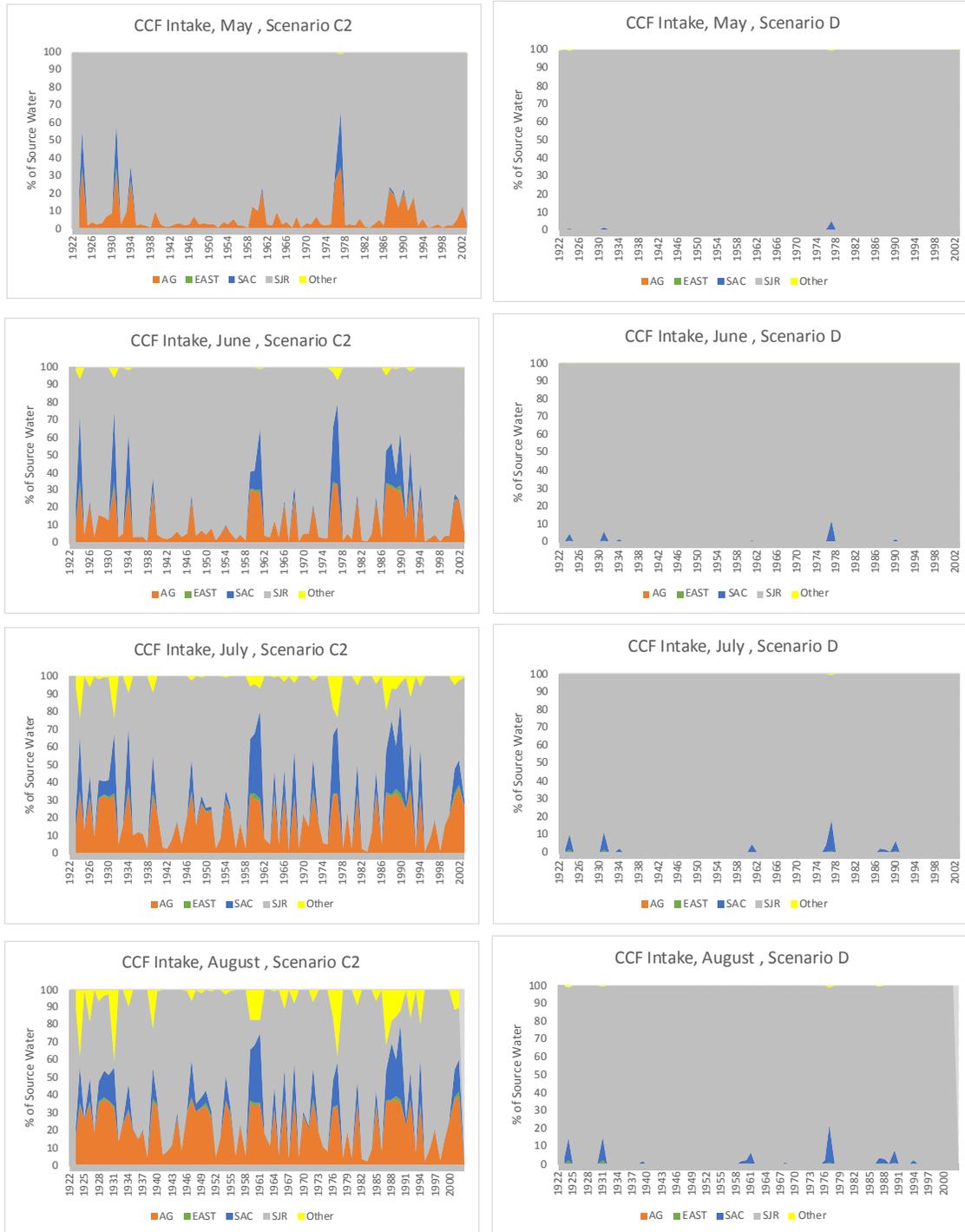
Figure 26   CHSWP003: CCF Intake
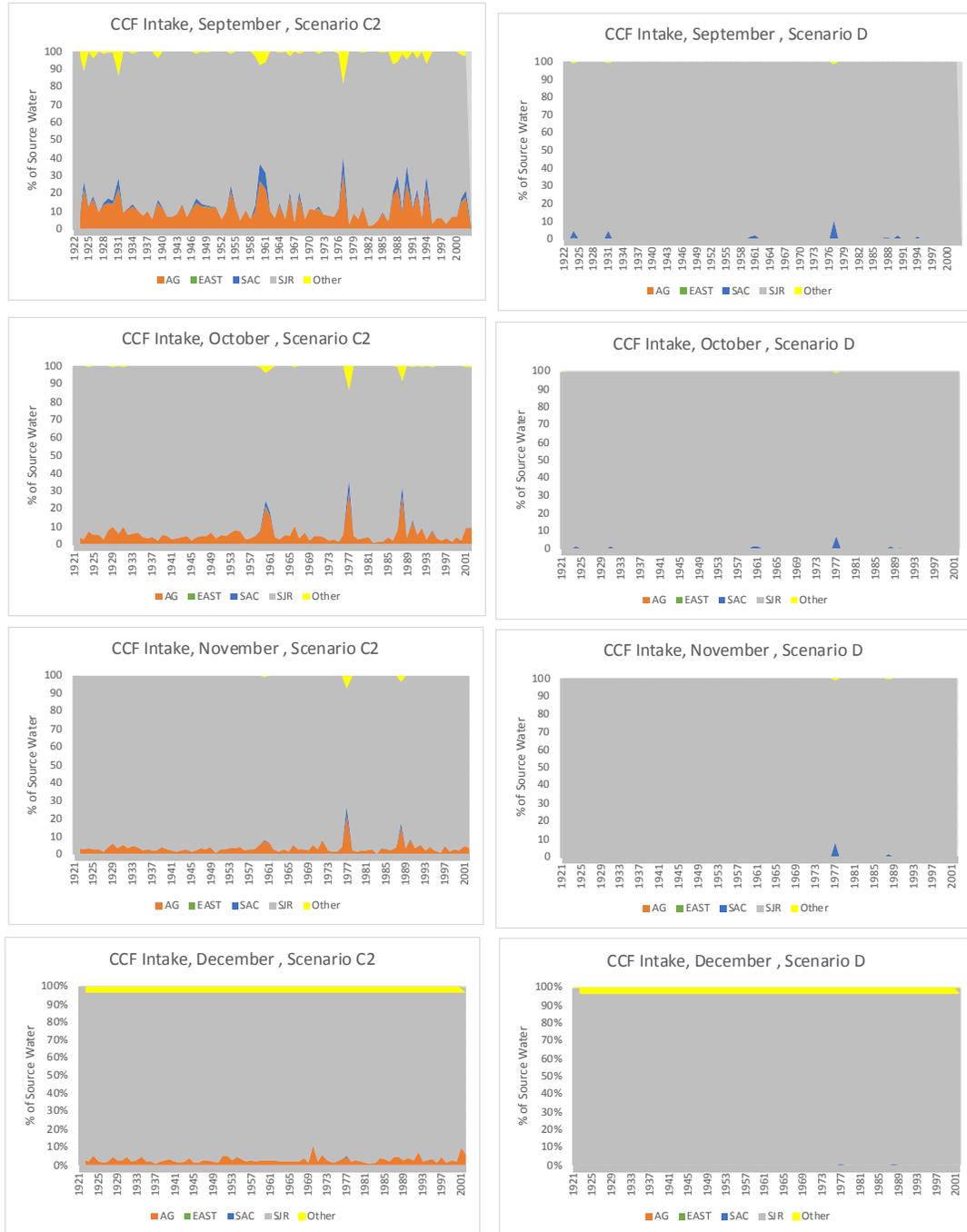
Figure 27   CHSWP003: CCF Intake
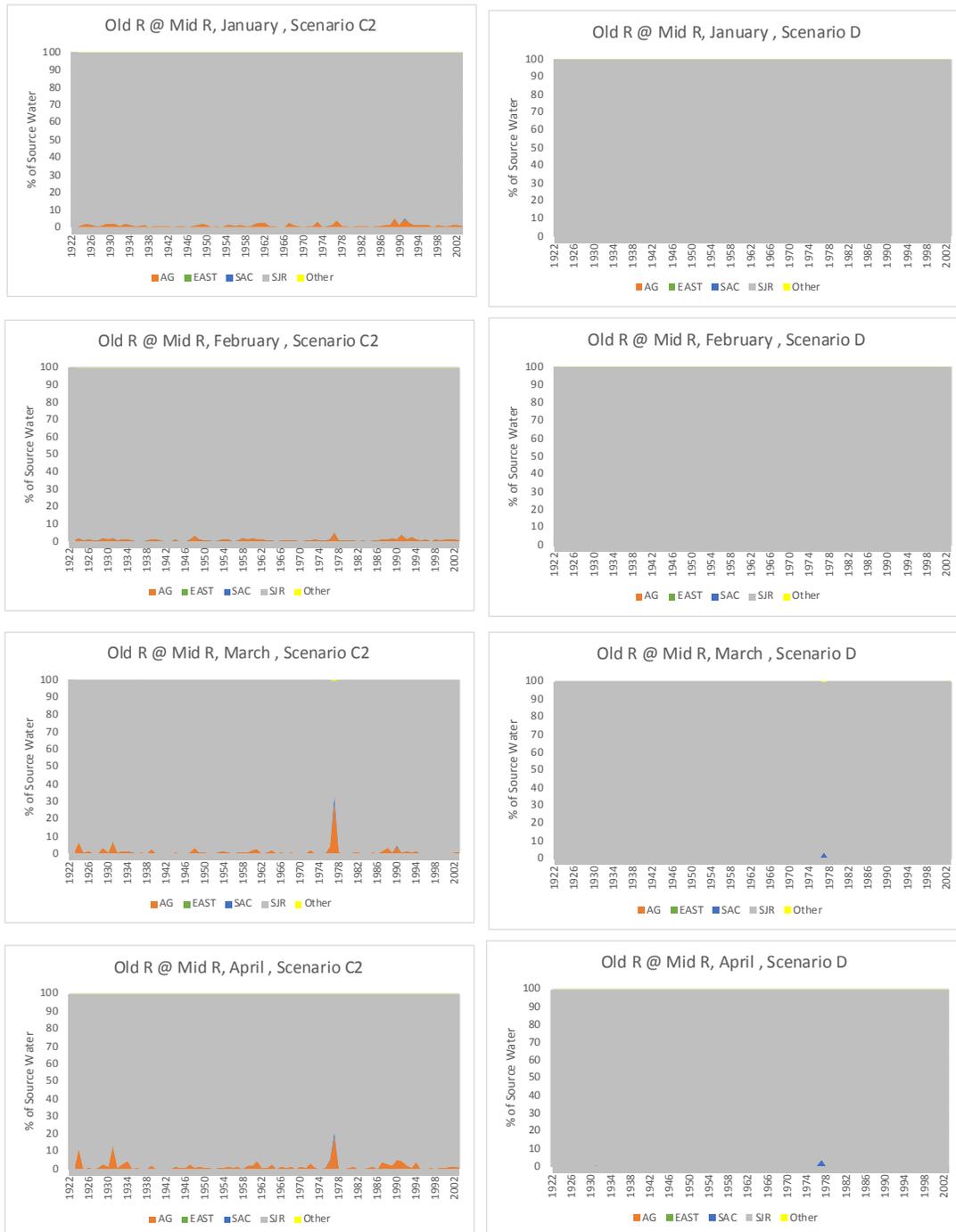
Figure 28   Oldr midr: Old River at Middle River
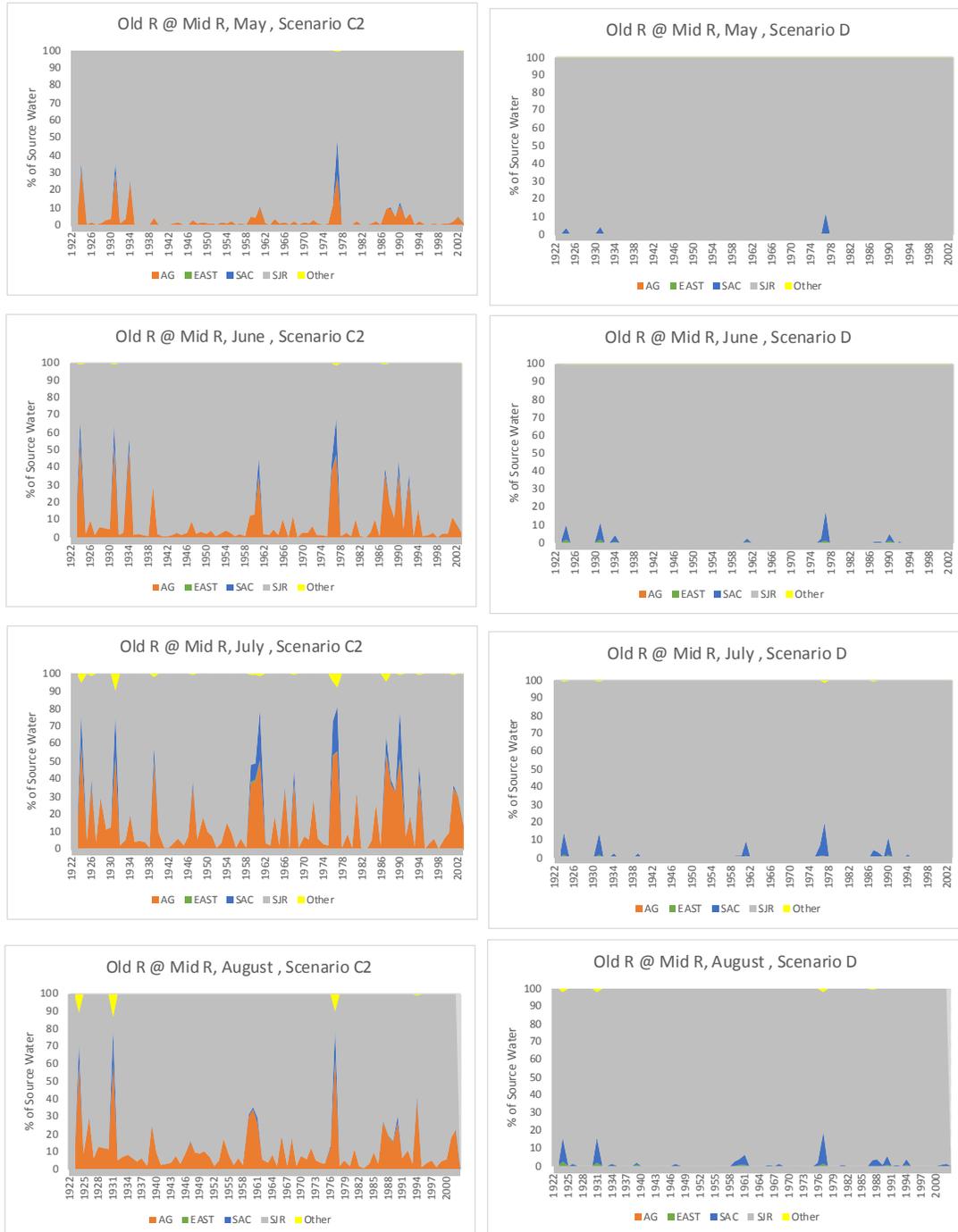
Figure 29   Oldr midr: Old River at Middle River

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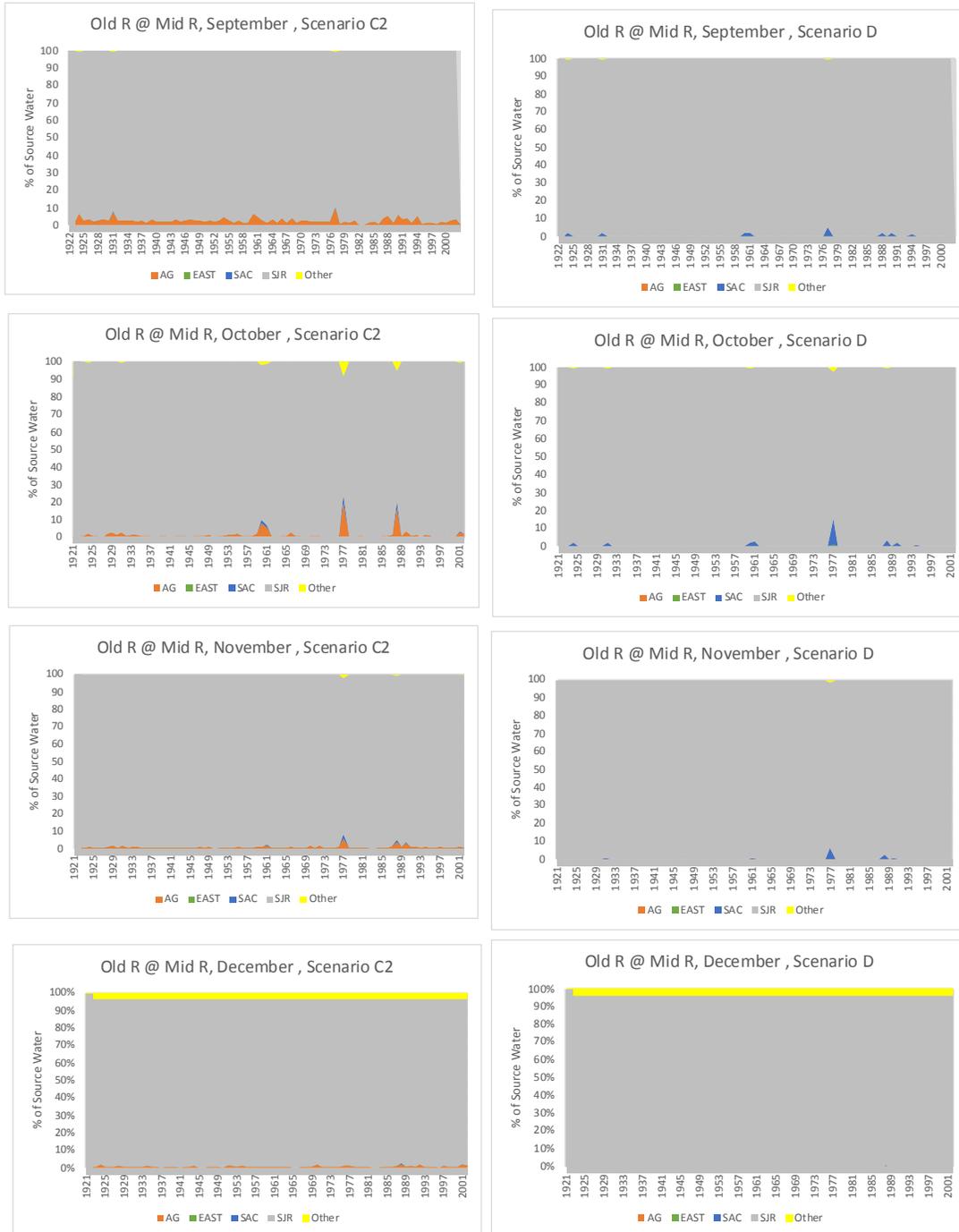
Figure 30   *Oldr midr: Old River at Middle River*

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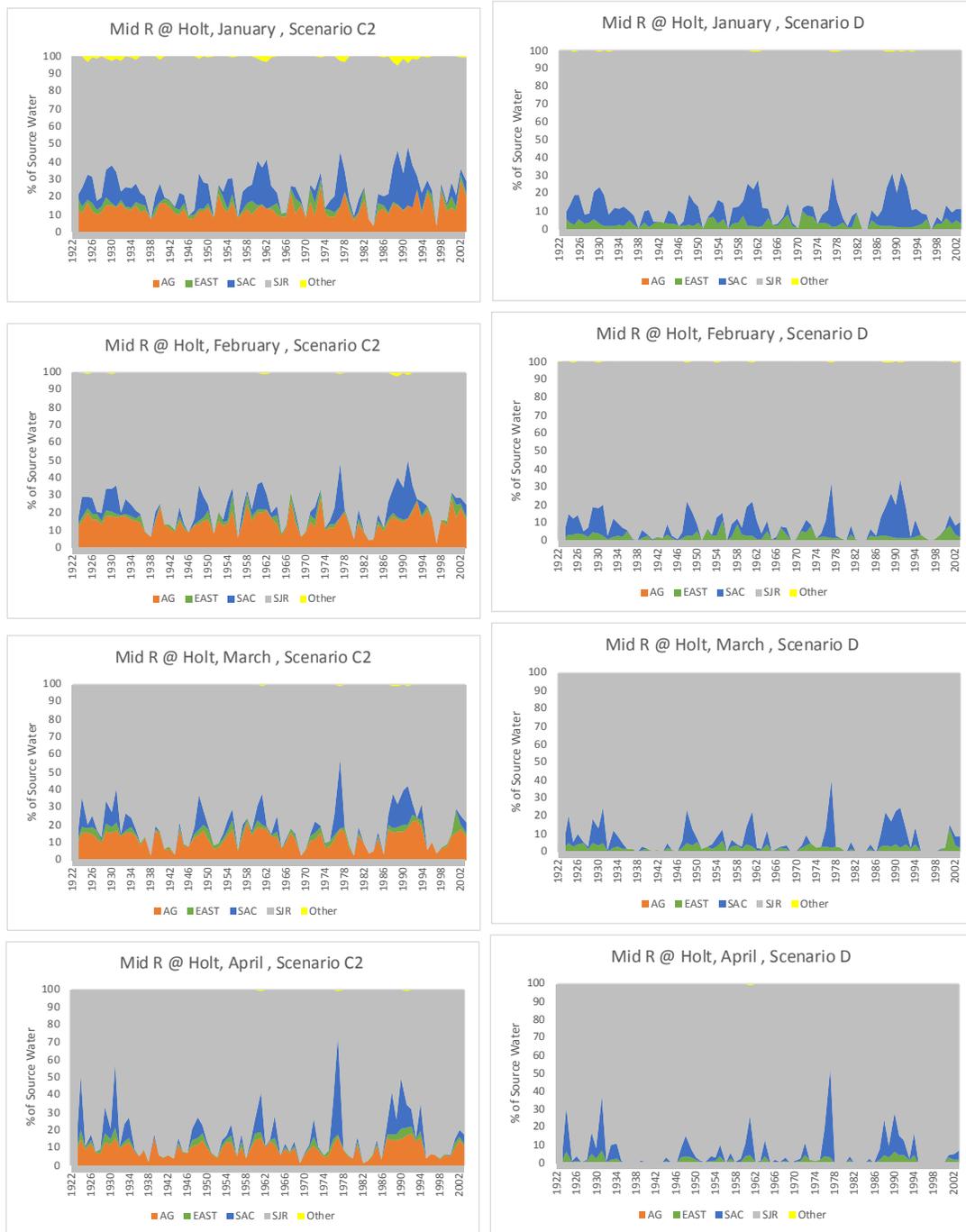
Figure 31   Rmid005: Middle River @ Holt
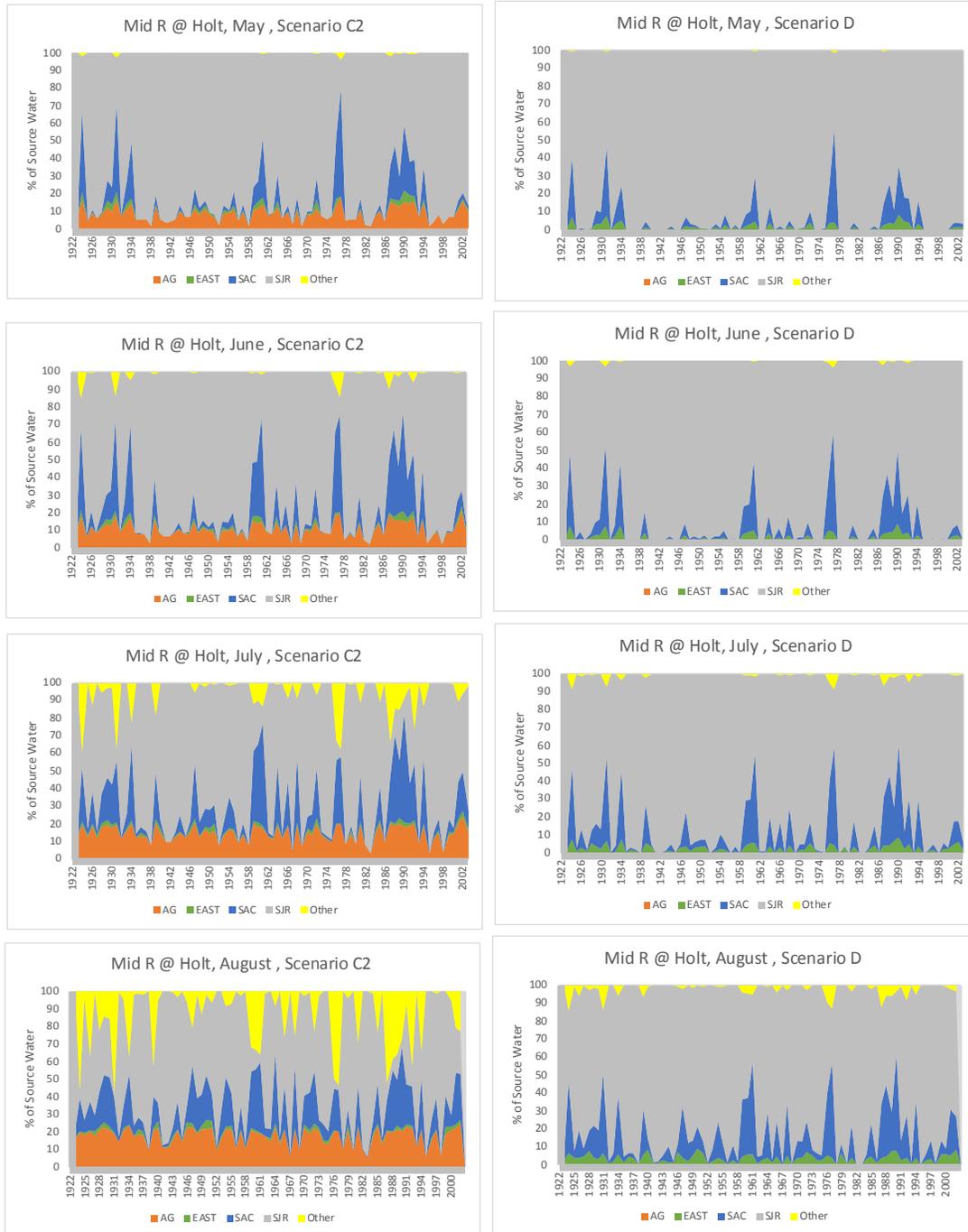
Figure 32   Rmid005: Middle River @ Holt
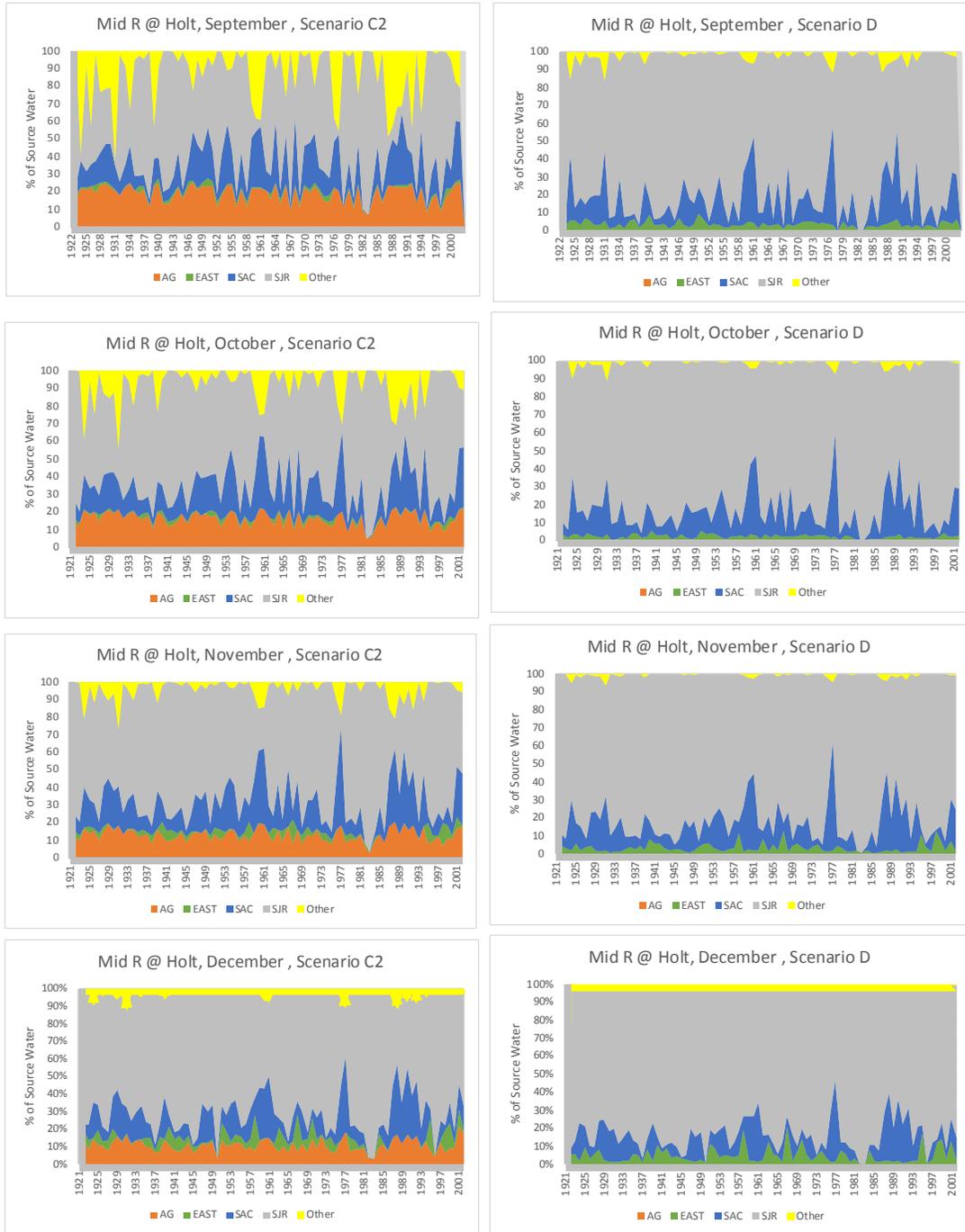
Figure 33   Rmid005: Middle River @ Holt

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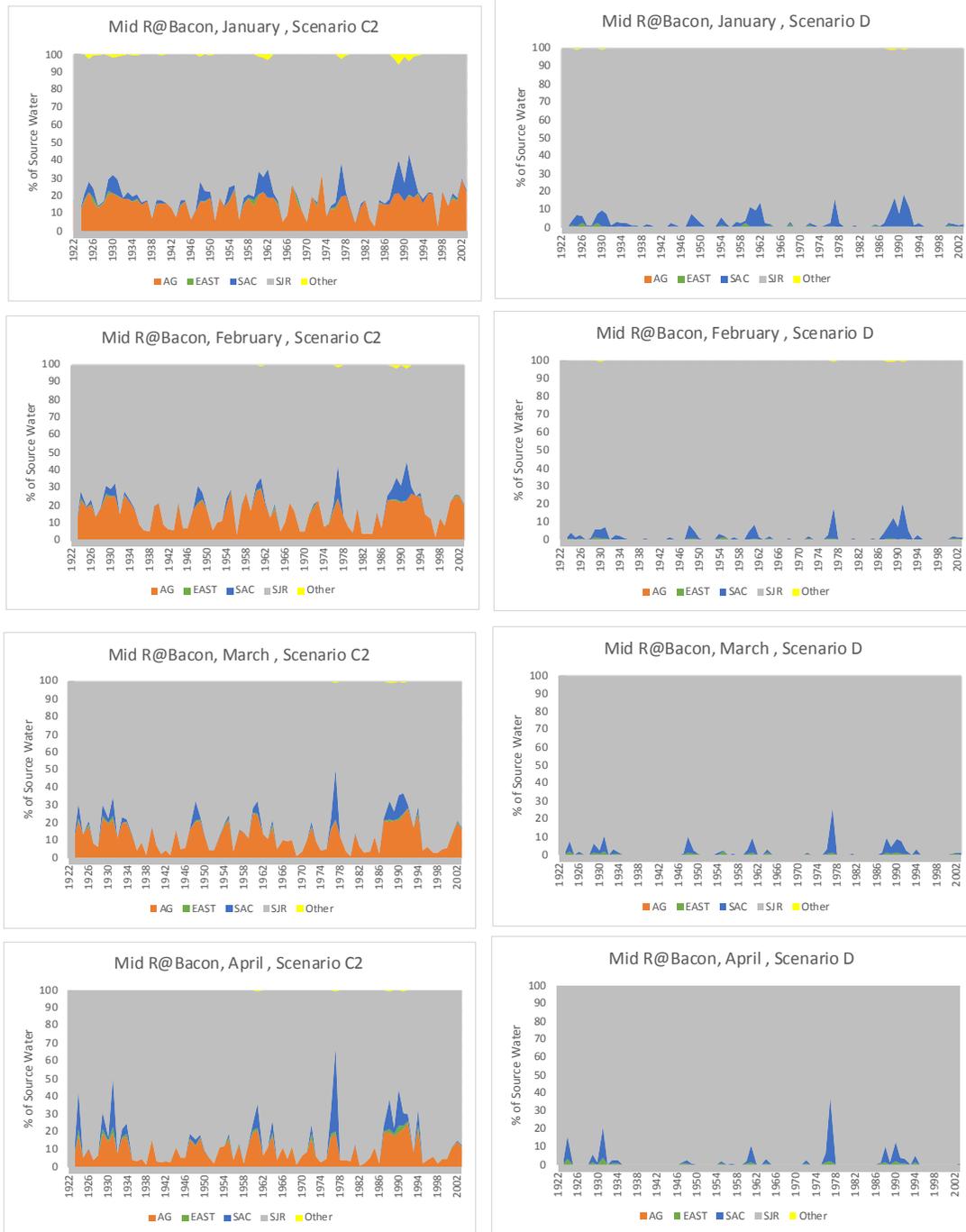
Figure 34   Rmid015: Middle River @ Bacon Island

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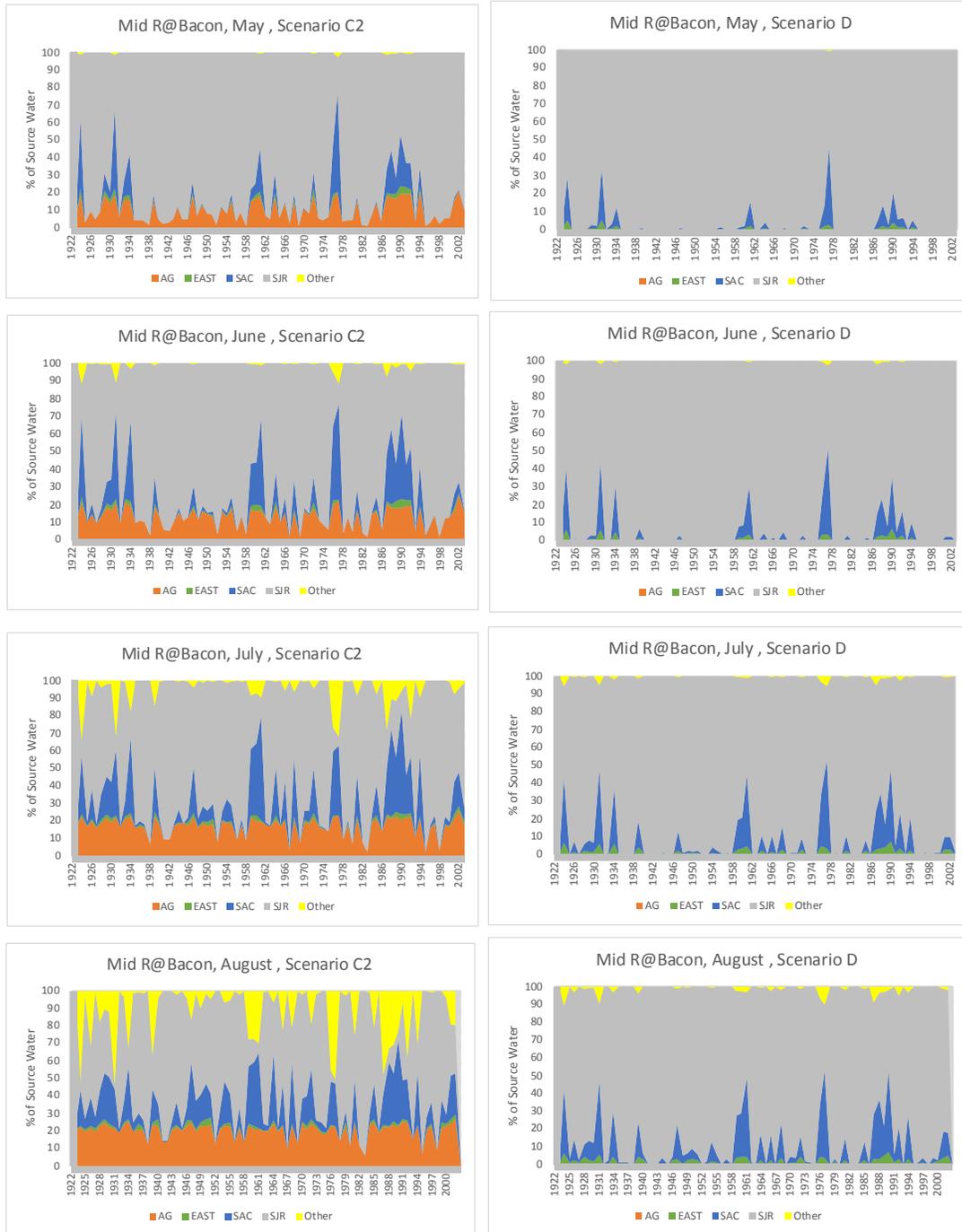
Figure 35   Rmid015: Middle River @ Bacon Island

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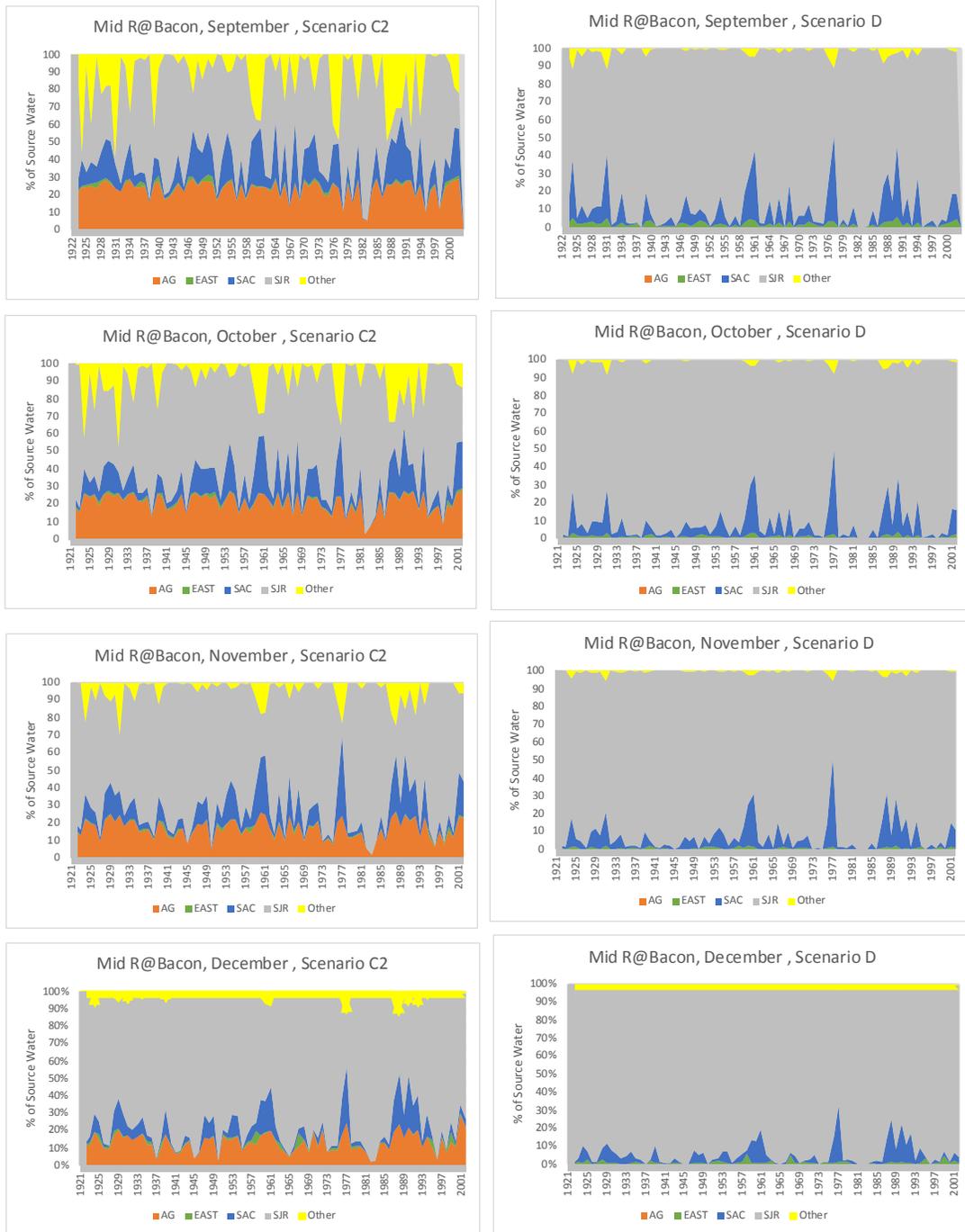
Figure 36   *Rmid015: Middle River @ Bacon Island*

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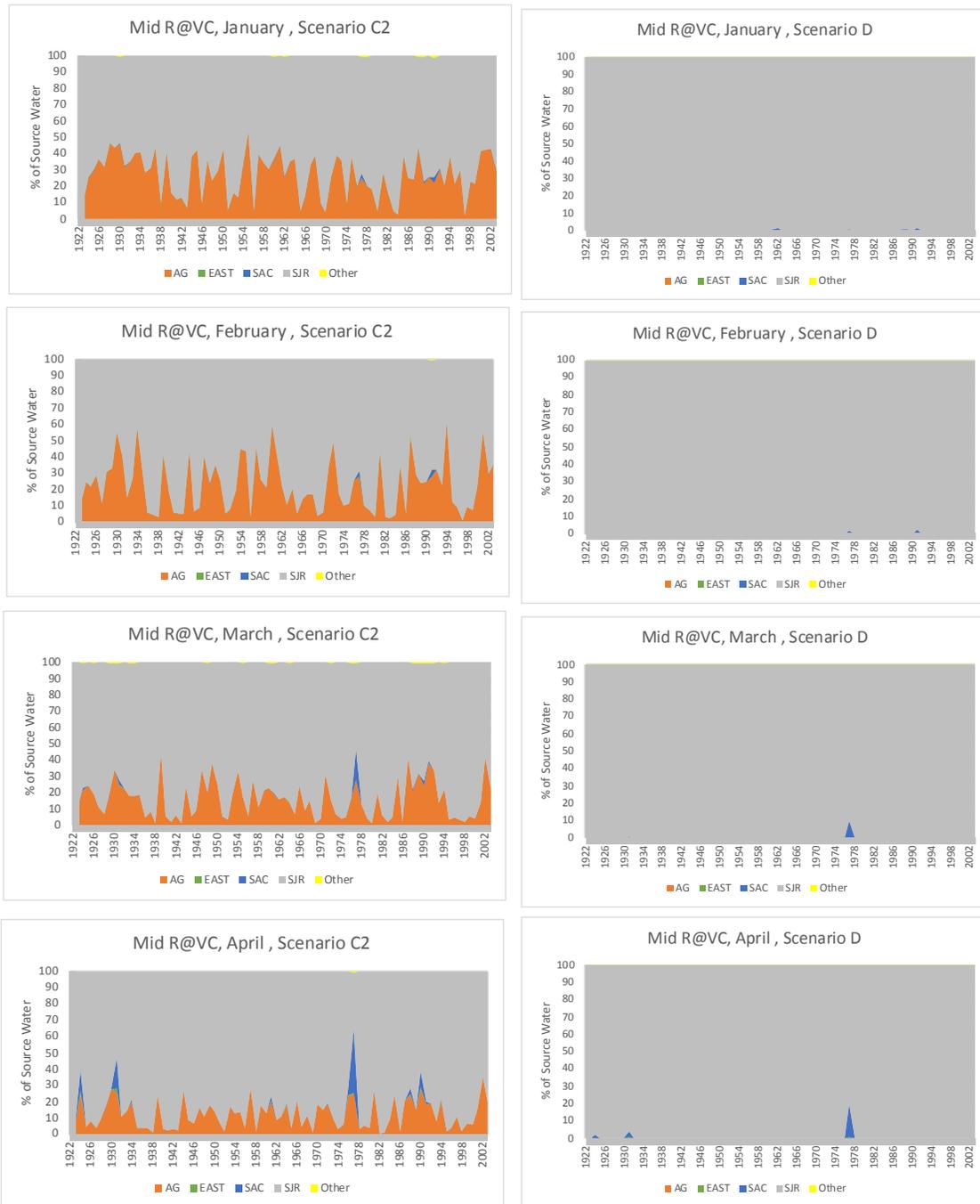
Figure 37   Rmid027: Middle River @ Victoria Canal
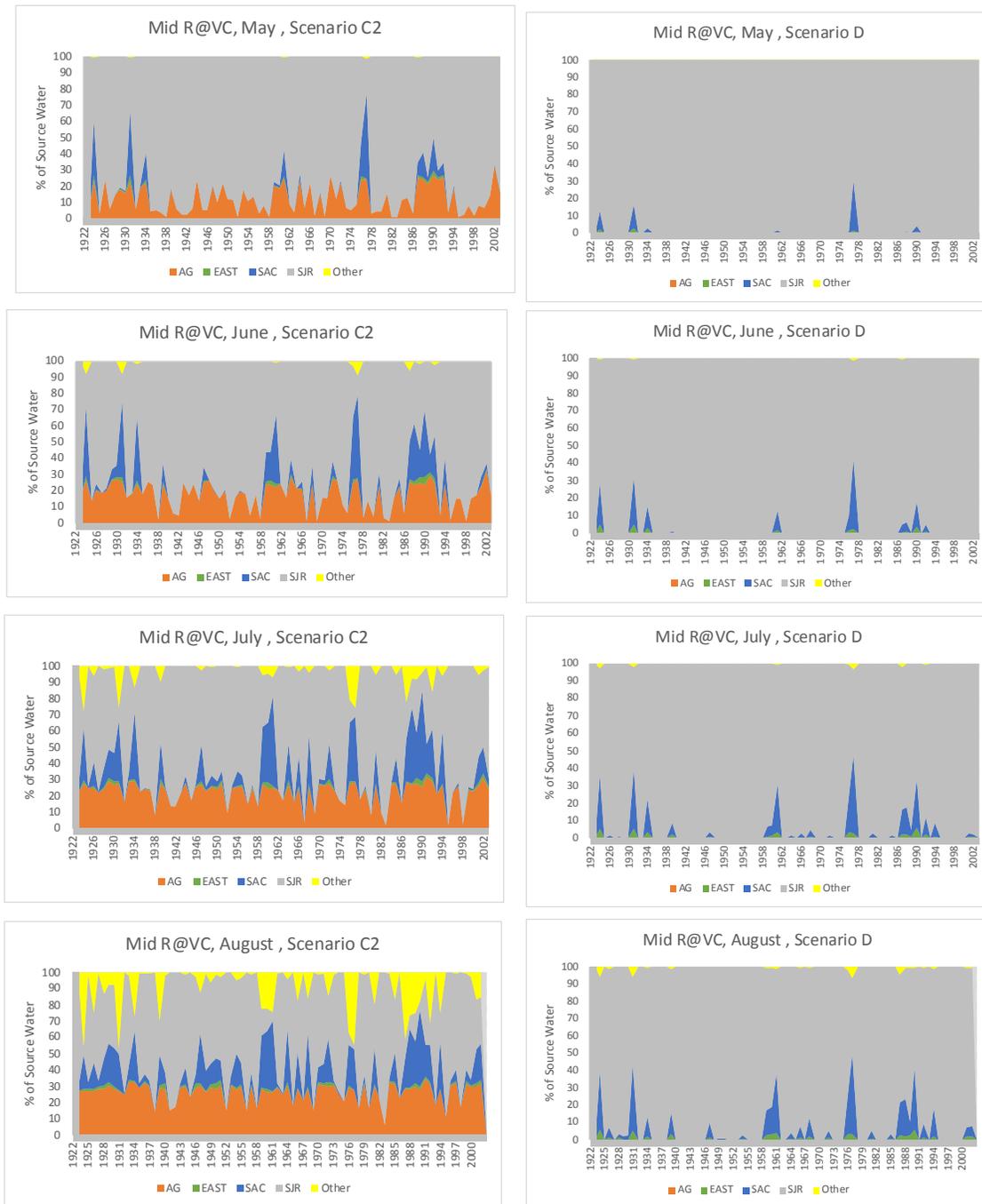
Figure 38   Rmid027: Middle River @ Victoria Canal
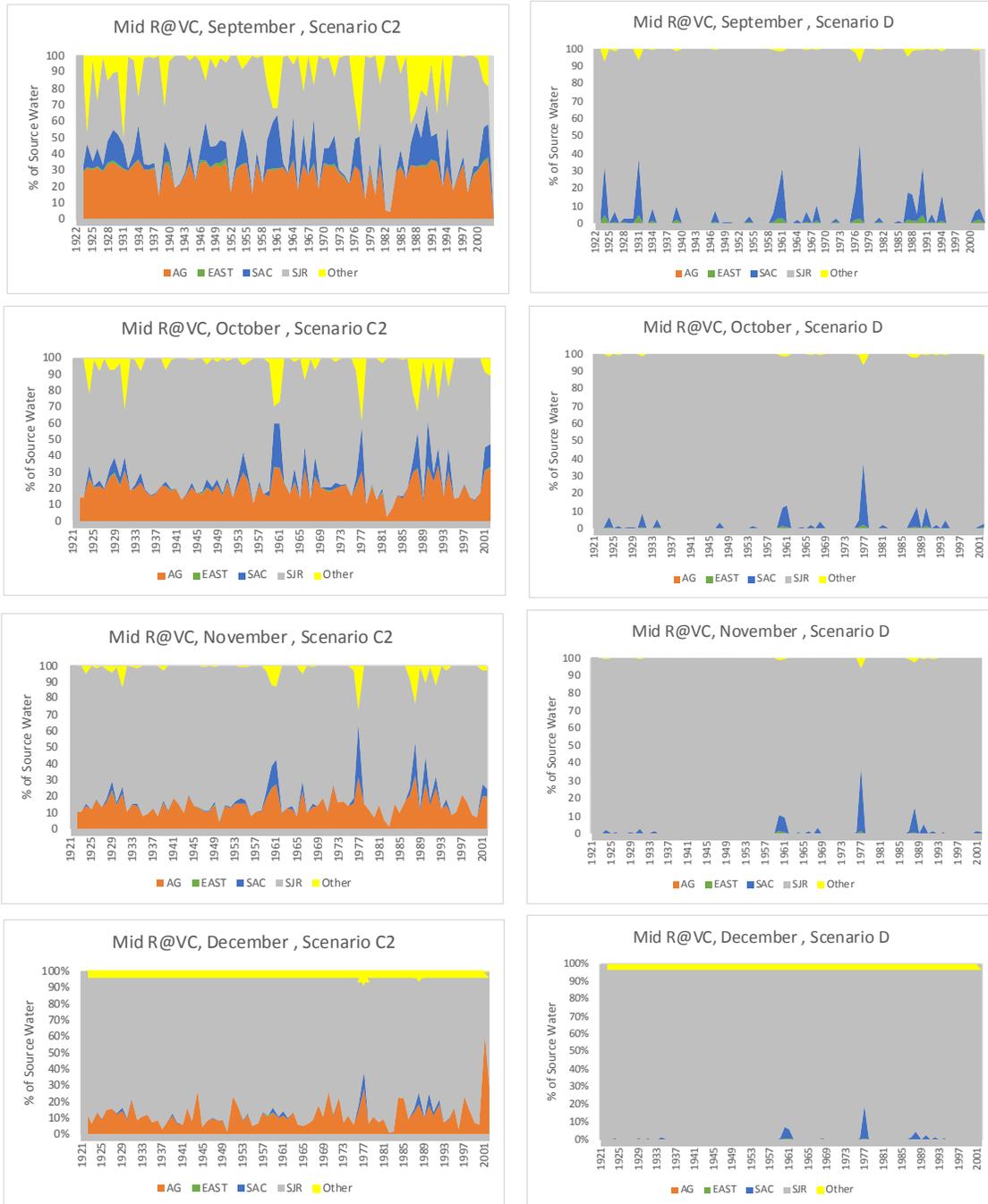
Figure 39   Rmid027: Middle River @ Victoria Canal
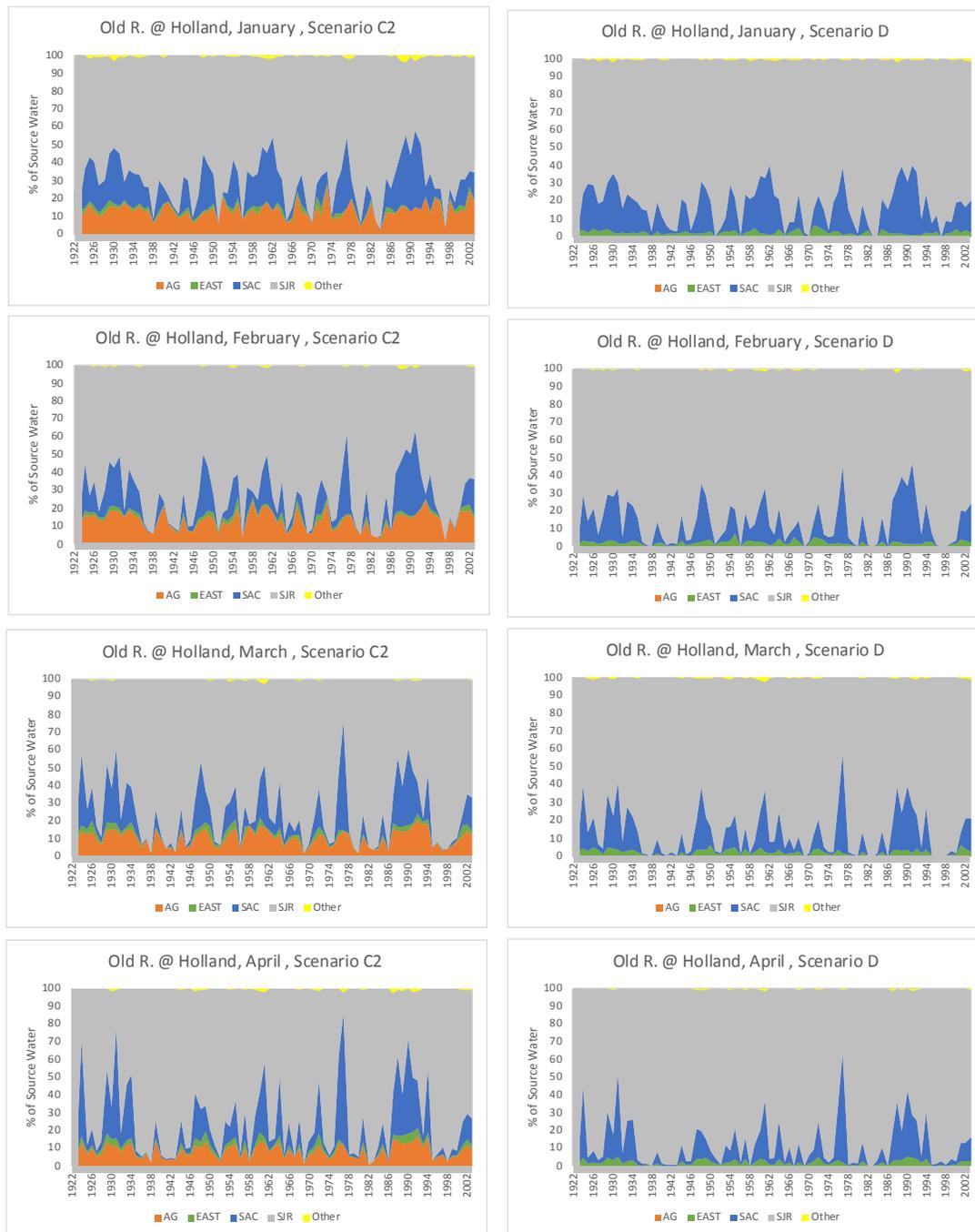
Figure 40   Rold014: Old River @ Holland
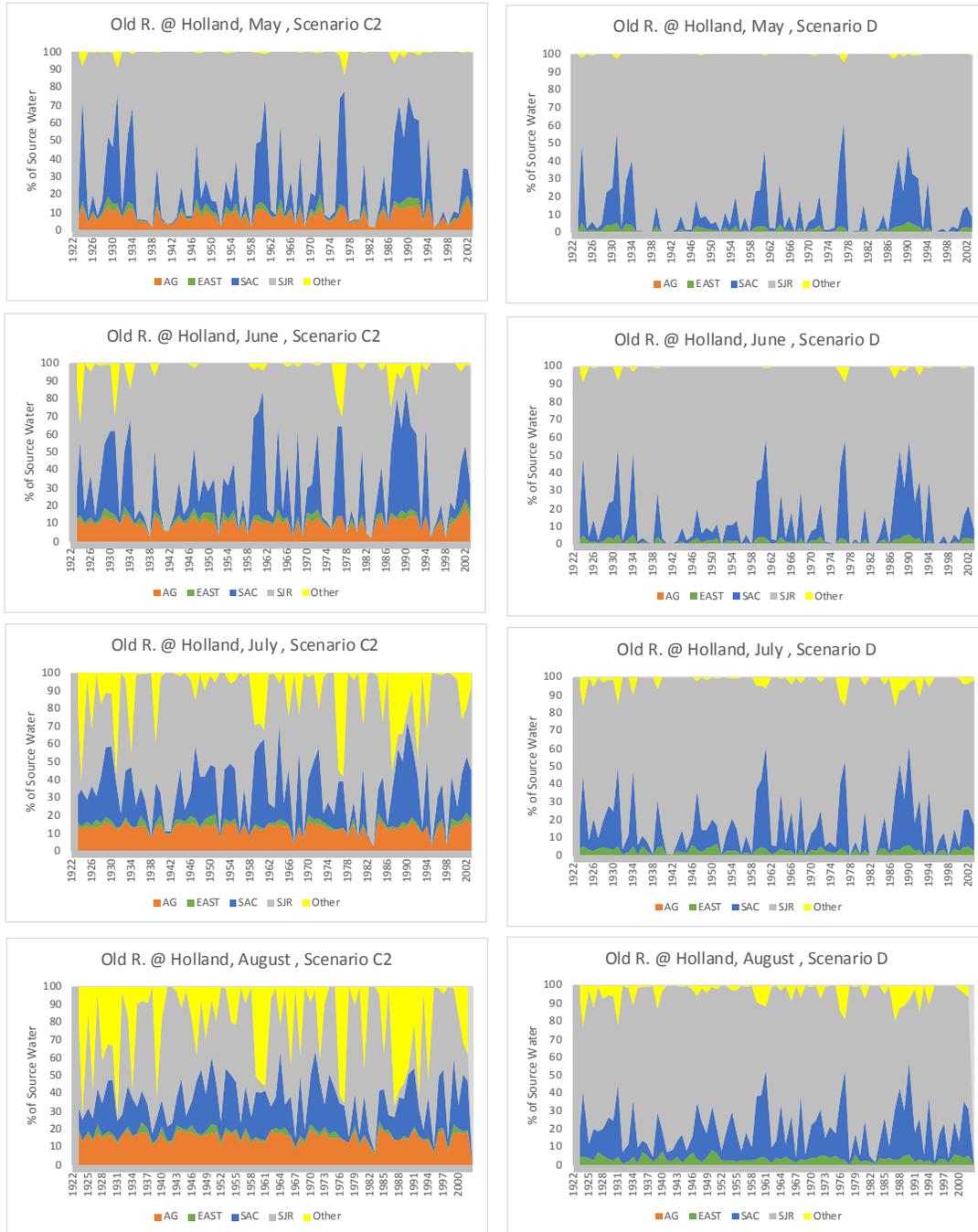
Figure 41   Rold014: Old River @ Holland
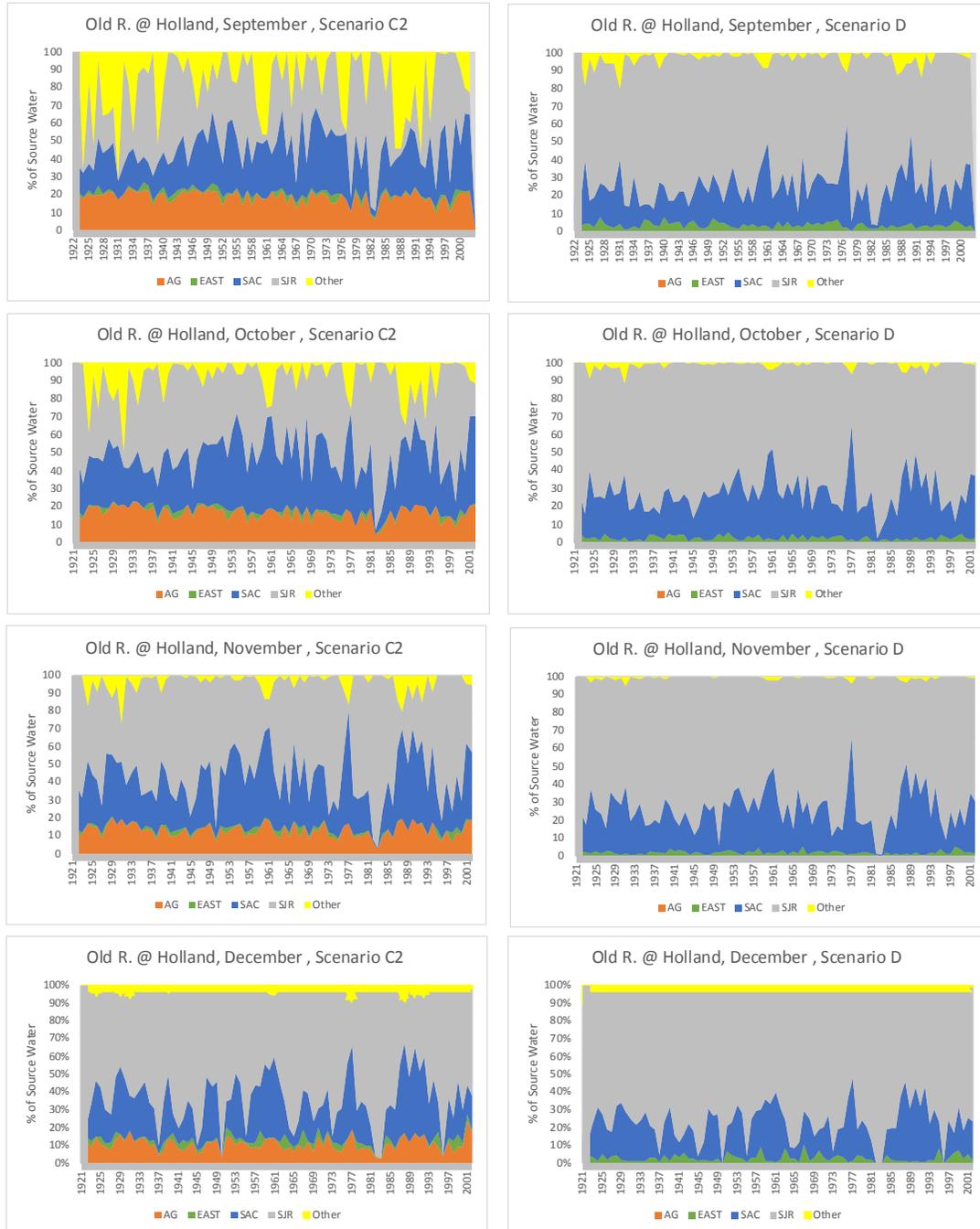
Figure 42   Rold014: Old River @ Holland
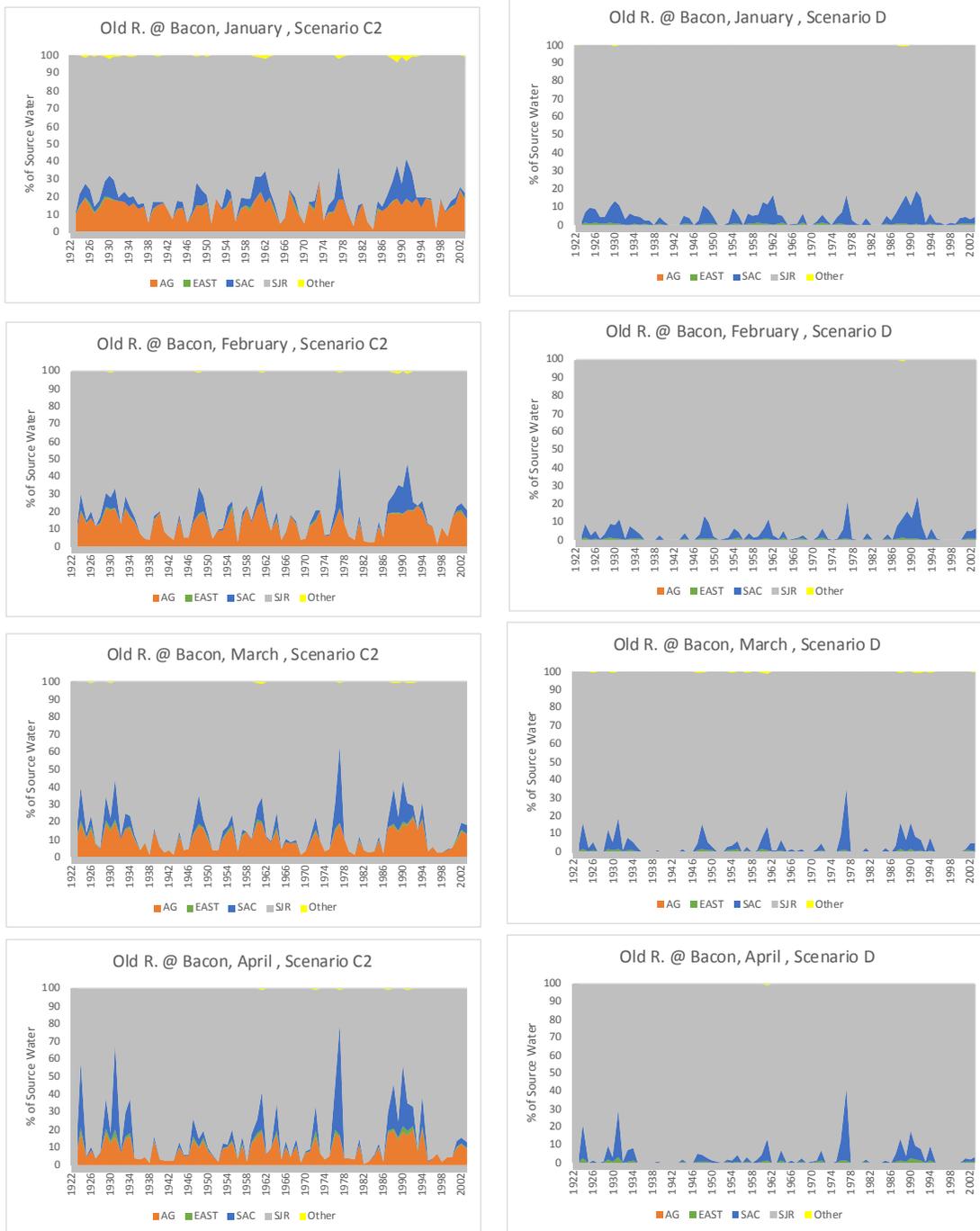
Figure 43   Rold024: Old River @ Bacon Island
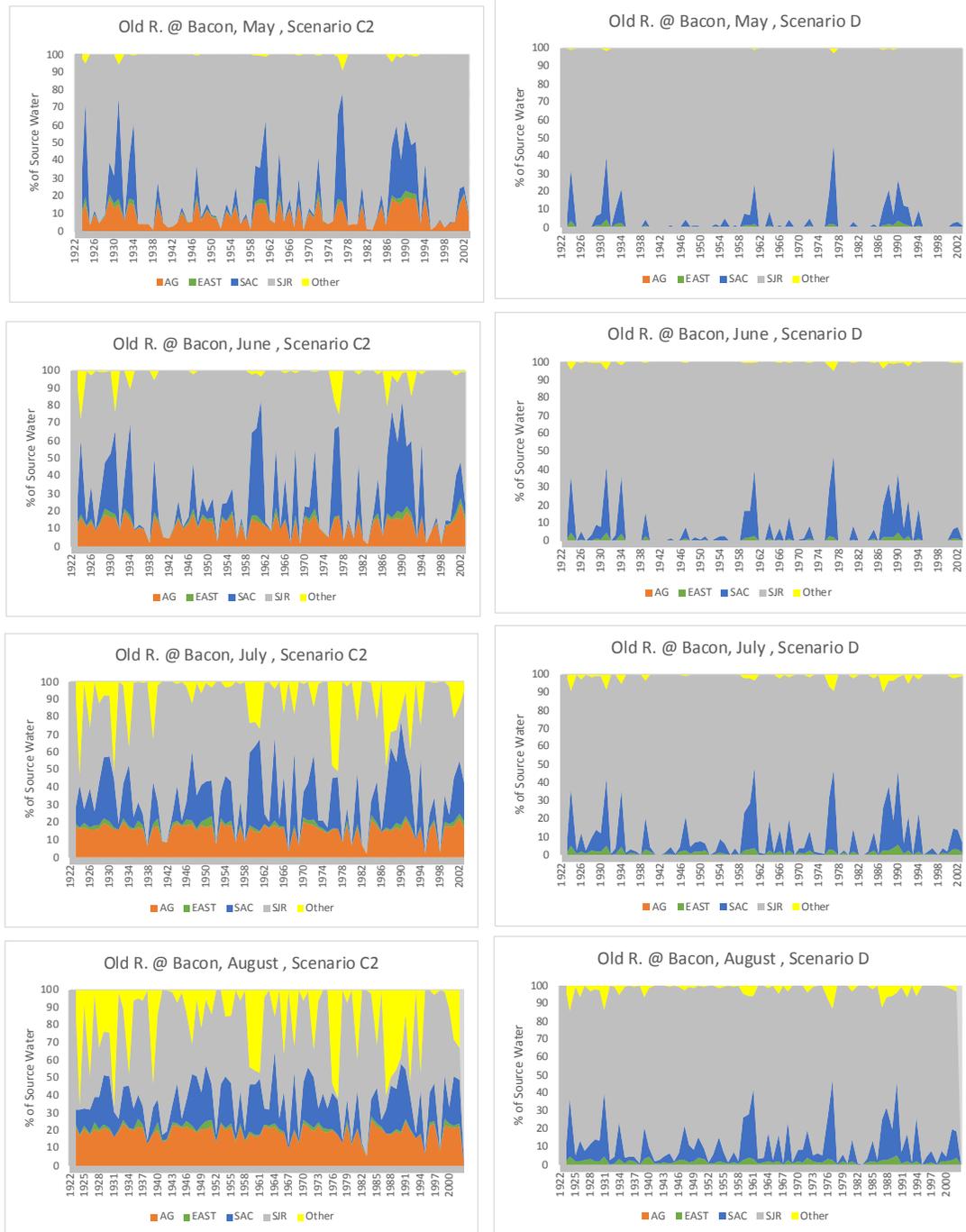
Figure 44   Rold024: Old River @ Bacon Island
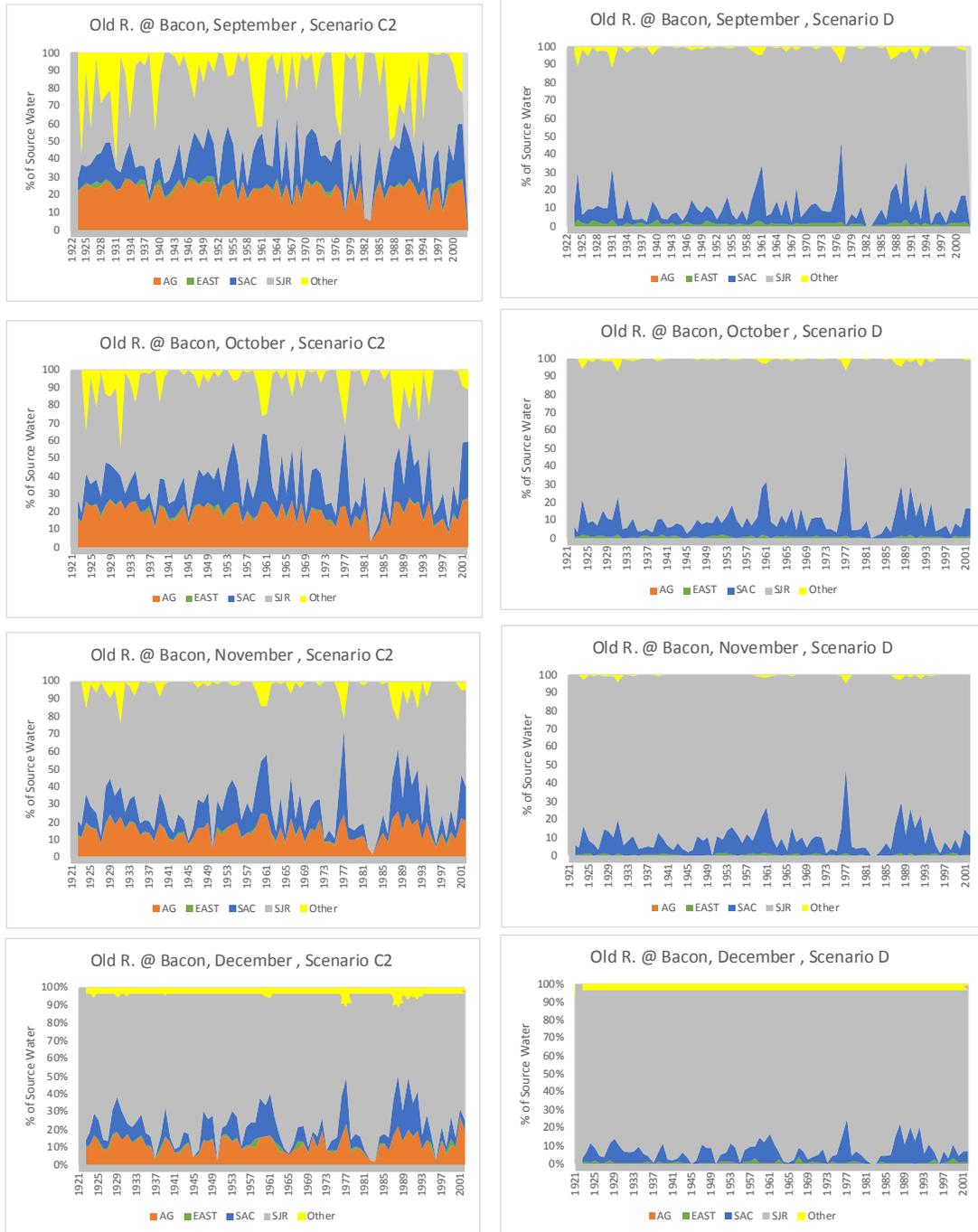
Figure 45   Rold024: Old River @ Bacon Island

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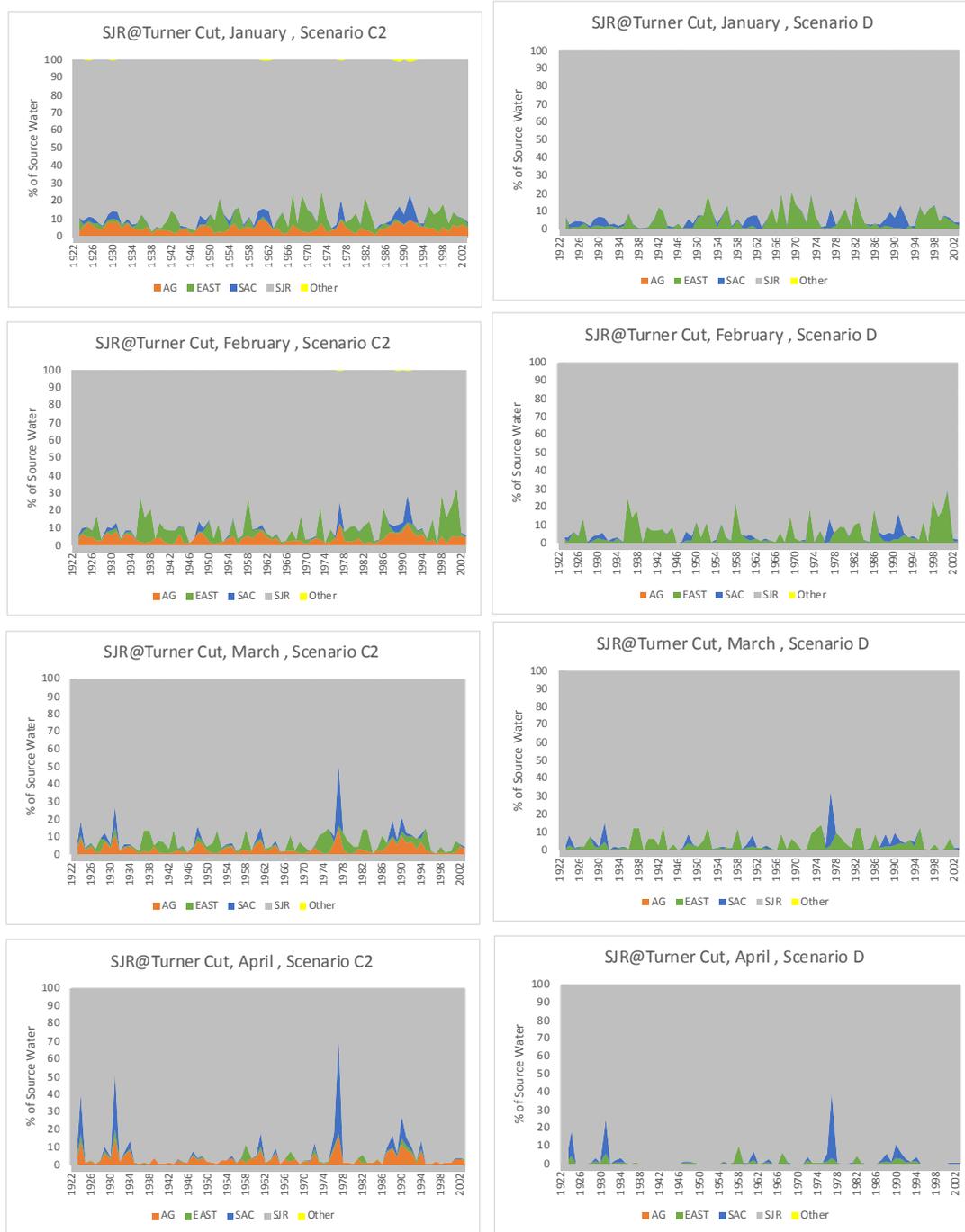
Figure 46   RSAN046: SJR @ Turner Cut
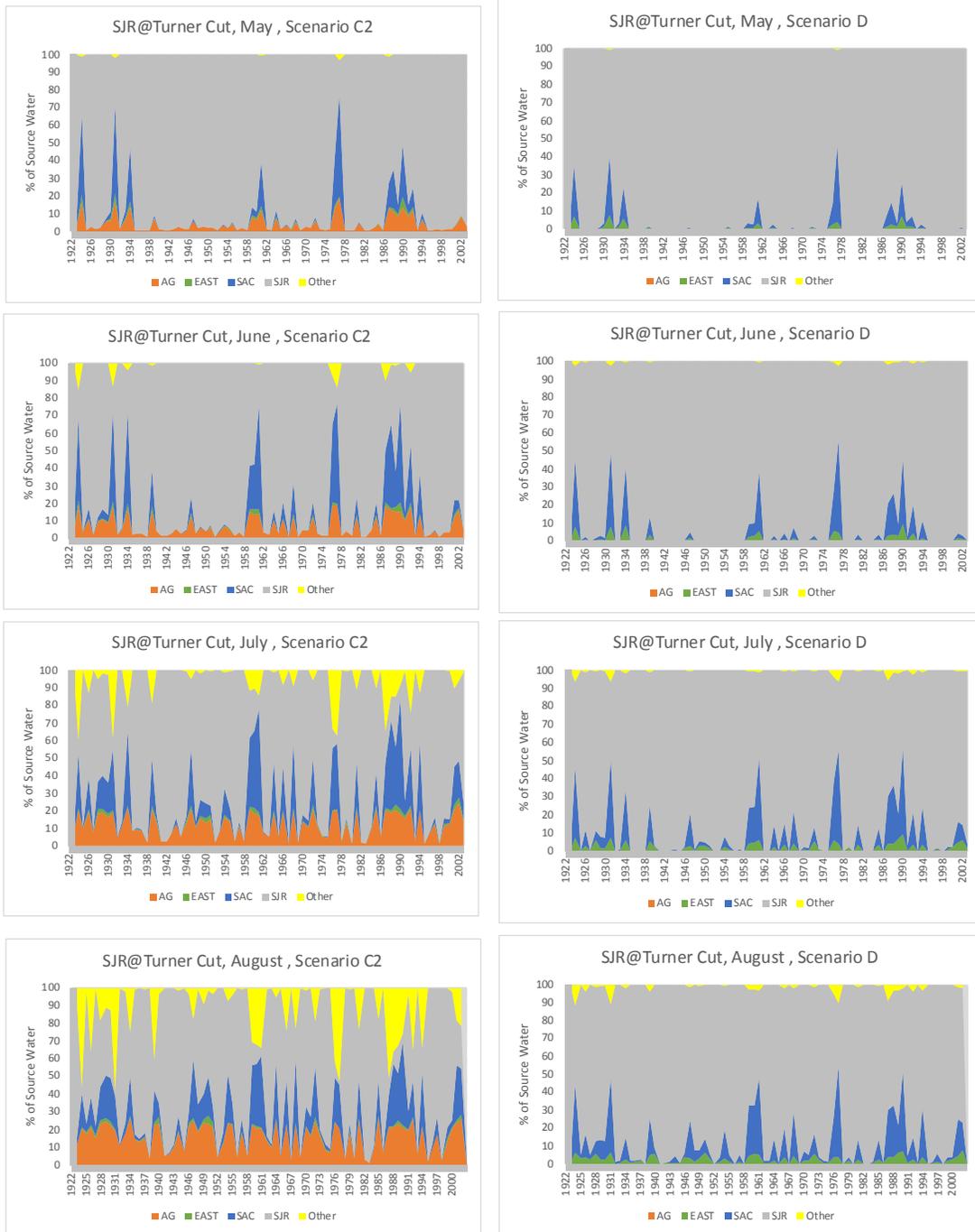
Figure 47   RSAN046: SJR @ Turner Cut
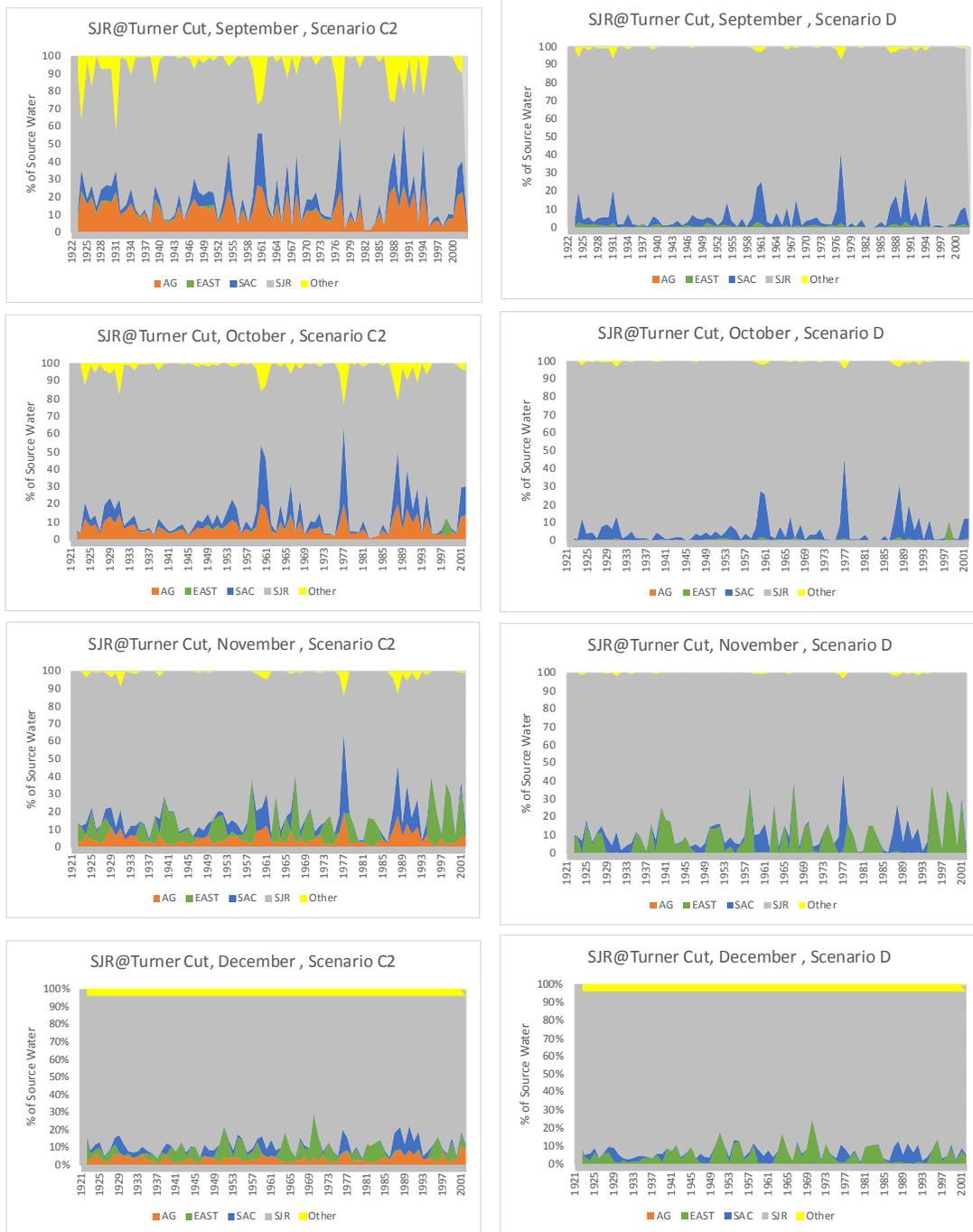
Figure 48 **RSAN046: SJR @ Turner Cut**

Figure 49   RSAN063: SJR @ Stockton

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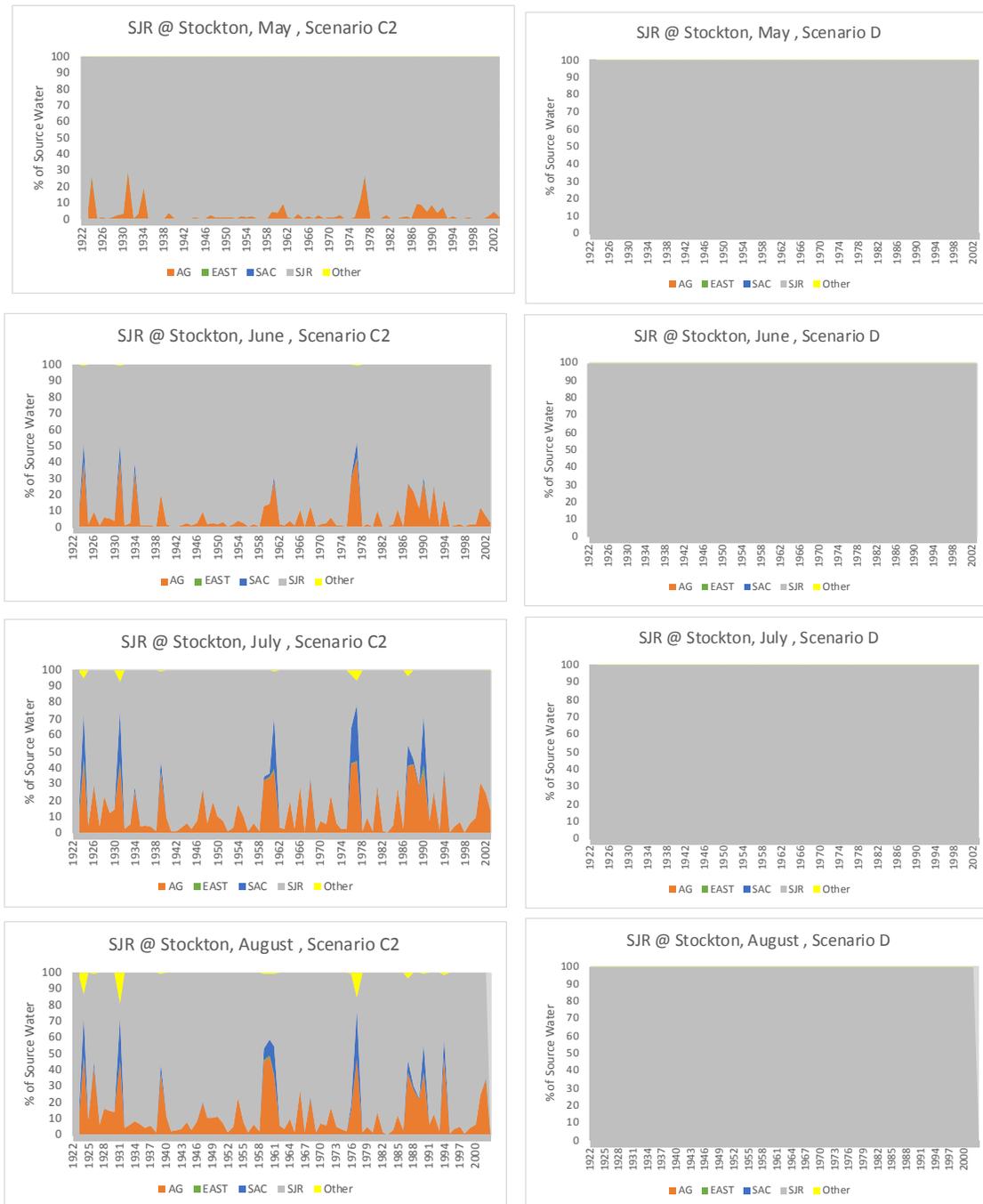
Figure 50   RSAN063: SJR @ Stockton

Figure 51   RSAN063: SJR @ Stockton

Figure 52   RSAN072: SJR @ Brandt Bridge

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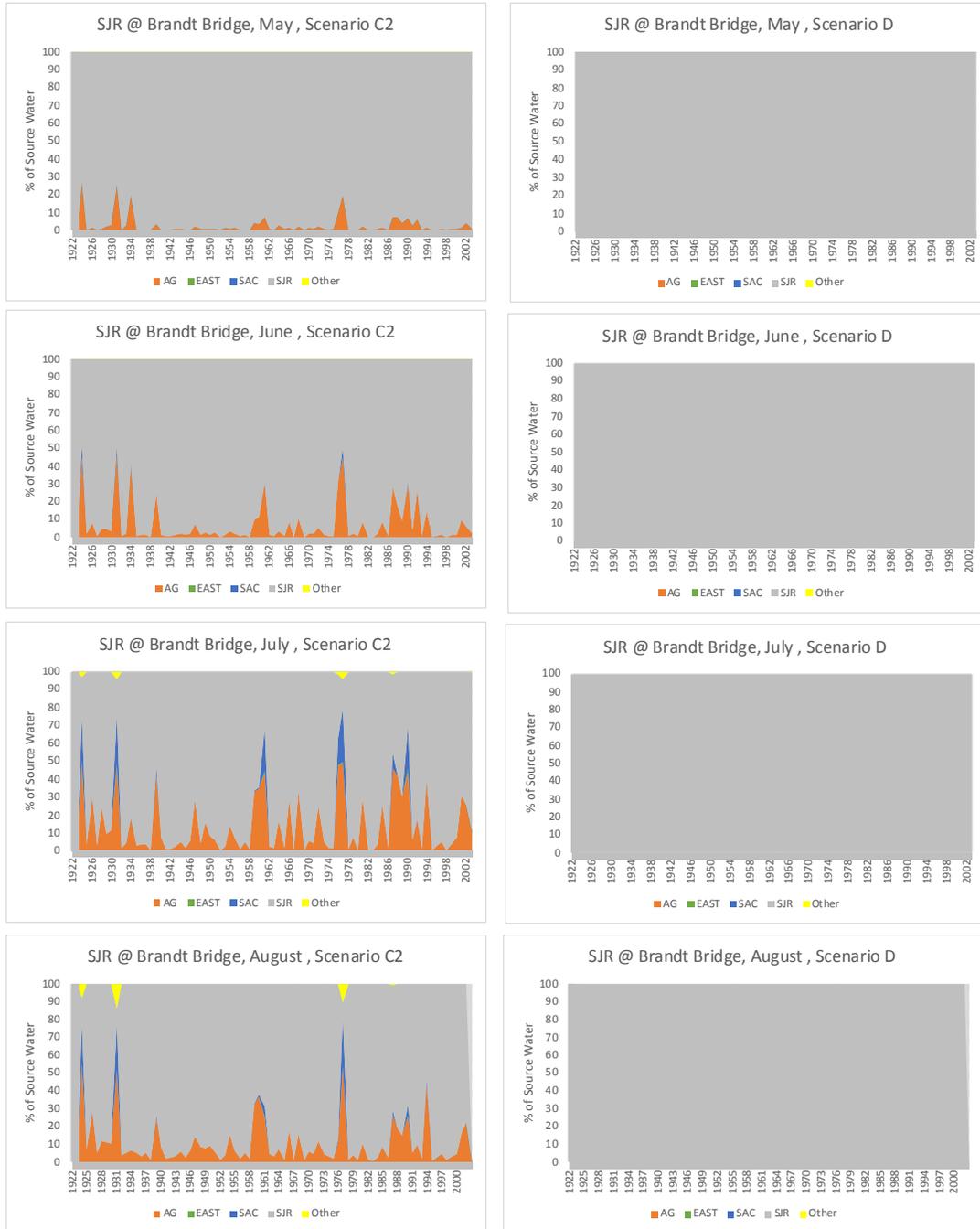
Figure 53   RSAN072: SJR @ Brandt Bridge

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Figure 54   RSAN072: SJR @ Brandt Bridge
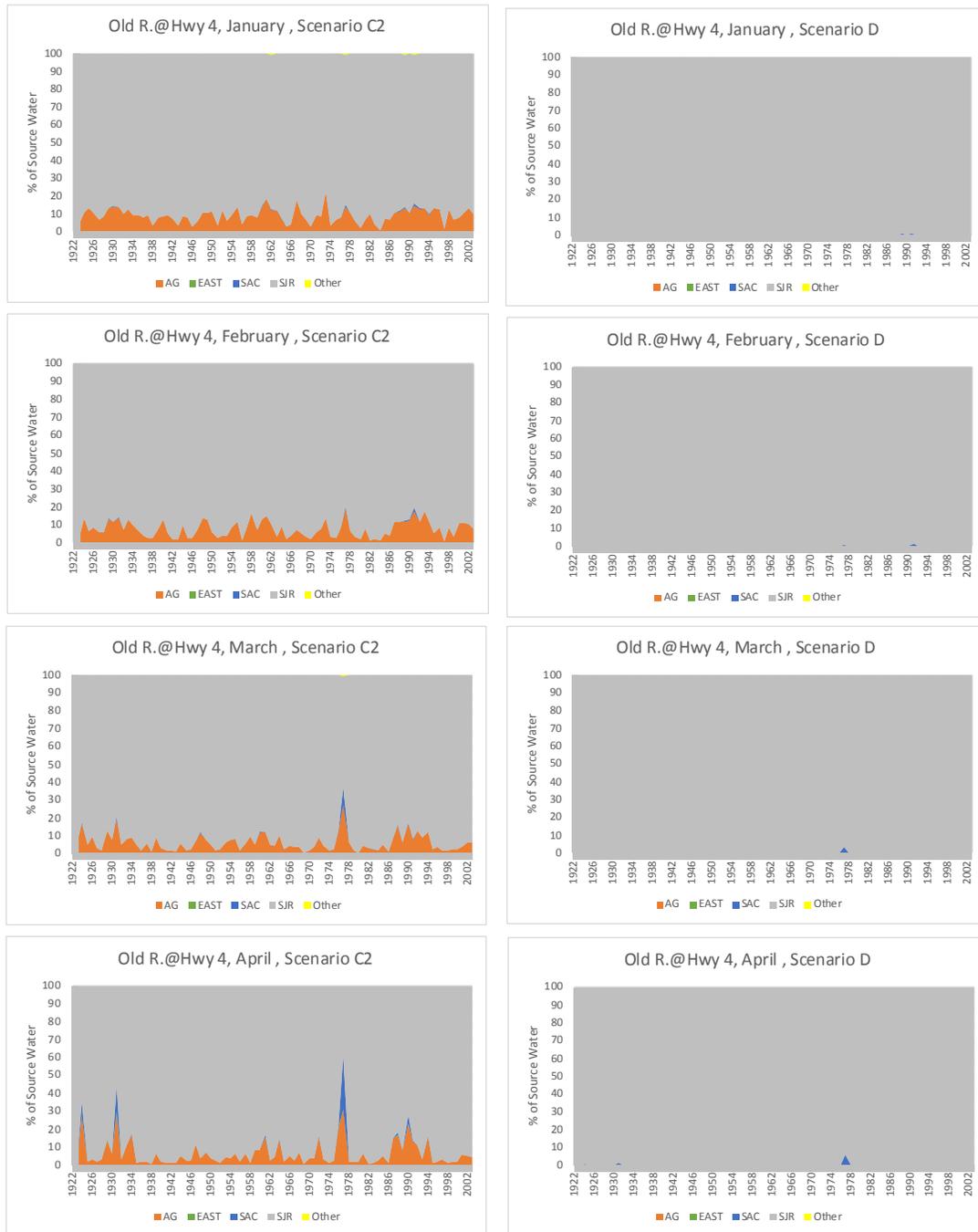
Figure 55   RoId034: Old River @ Hwy 4

Figure 56   RoId034: Old River @ Hwy 4

Figure 57   Rold034: Old River @ Hwy 4

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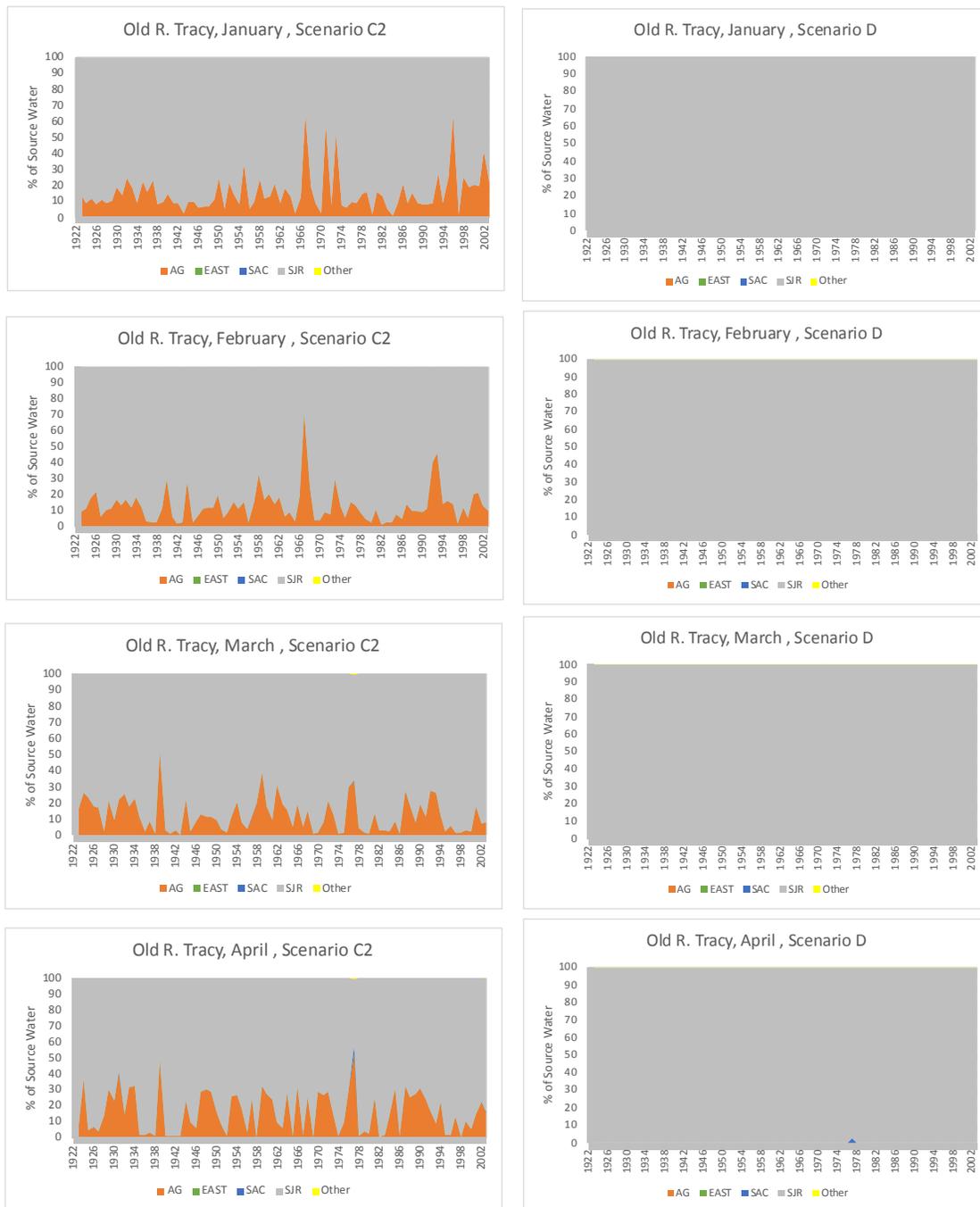
Figure 58   *Rold059: Old River @ Tracy*
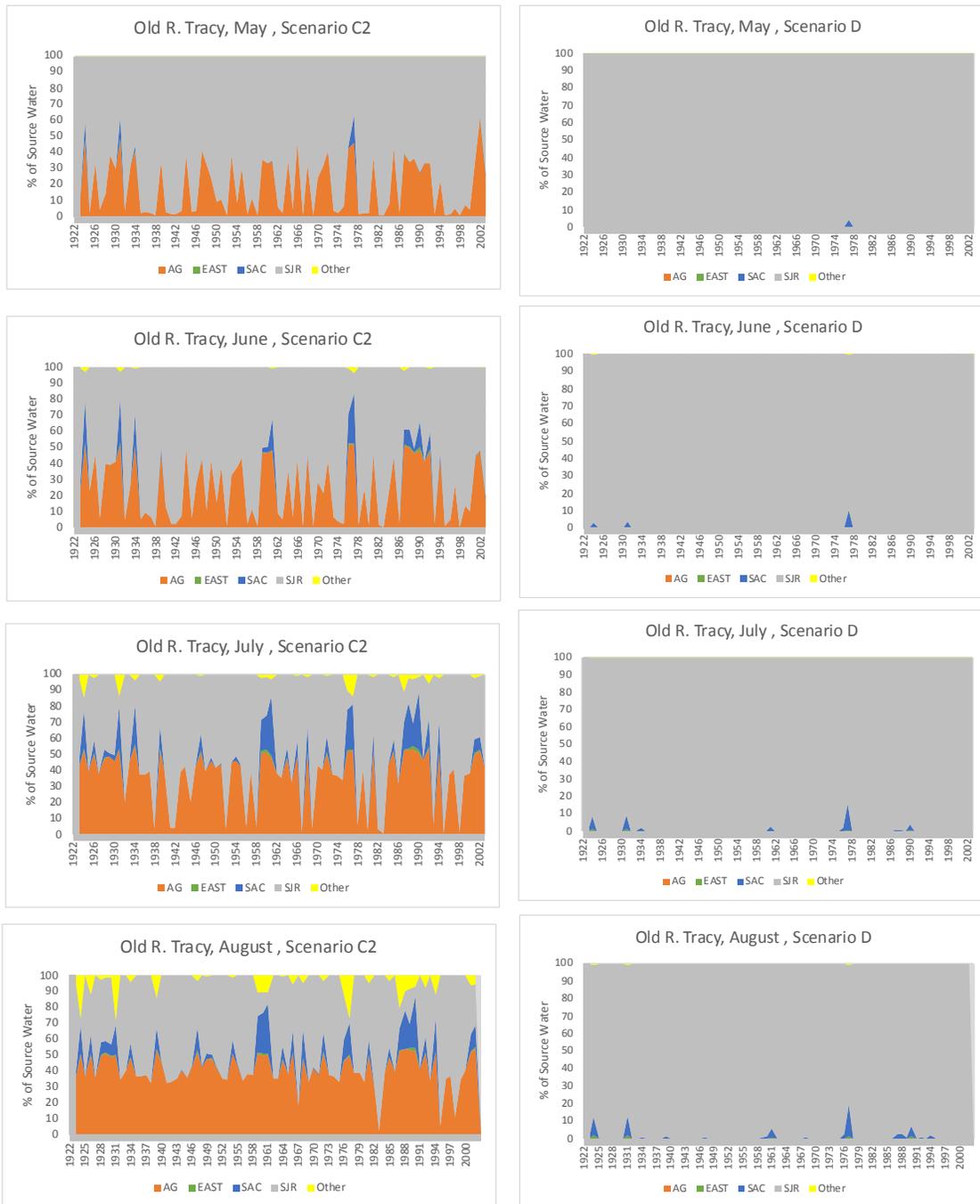
Figure 59   Rold059: Old River @ Tracy
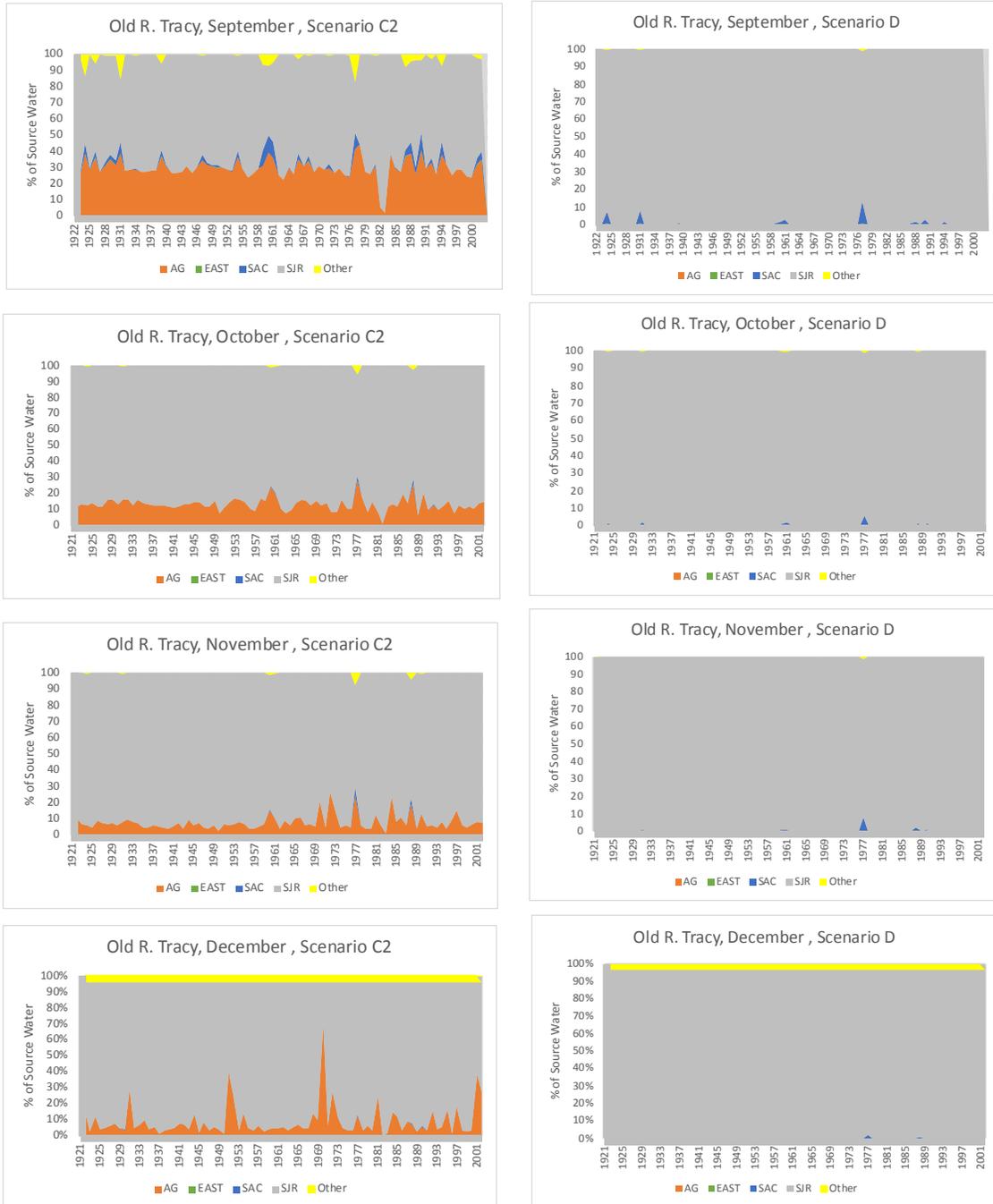
Figure 60   *Rold059: Old River @ Tracy*

Figure 61   Rold074: Old River @ Head

Figure 62   RoId074: Old River @ Head

Figure 63   Rold074: Old River @ Head

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APPENDIX B SCENARIO A DSG FITTING RESULTS

This appendix contains the parameter estimates and diagnostic plots from fitting the DSG model to DSM2 simulations of South Delta electrical conductivity data for Scenario A. See the results for Scenario C2 presented in Section 3 of the South Delta Diversion Curtailment Analysis document for more details.

Note that although the flows displayed in Figure 64 and Figure 65 are based on the DSM2 flow output at Martinez (MTZ), the DSG estimates are estimated using a G flow derived from the Net Delta Outflow Index, NDOI.

Table 3
Diagnostics of DSG predictions of DSM2-simulated EC for Scenario A in terms of a linear model $EC_{DSM} = a + b \cdot EC_{DSG}$ and best fit DSG parameters for two different estimation procedures: non-linear least squares (nls) and maximum a posteriori (map) fit of a Bayesian student's t model. Columns in gray are not estimated in model training.

Scenario	Reach	Fit	Model Diagnostics				DSG Parameters (EC units: mS/cm, flow units: cfs)							
			r^2	Std. Error	a	b	ϕ_1	ϕ_2	S_b	$\hat{S}$	S_c	γ	δ	$\beta \times 10^{-10}$
A	MID	map	0.91	0.39	0.02	1.03	758	-0.241	0.274	22.1	2.00	∞	1.00	1.5
A	MID	nls	0.91	0.39	0.00	1.00	693	-0.230	0.312	22.2	2.00	∞	1.00	1.5
A	OLD	map	0.90	0.40	0.03	1.02	749	-0.239	0.323	23.2	2.00	∞	1.00	1.5
A	OLD	nls	0.90	0.40	0.00	1.00	692	-0.230	0.365	23.1	2.00	∞	1.00	1.5
A	SJ	map	0.91	0.38	0.02	1.03	764	-0.242	0.267	21.9	2.00	∞	1.00	1.5
A	SJ	nls	0.91	0.38	0.00	1.00	695	-0.230	0.304	22.1	2.00	∞	1.00	1.5
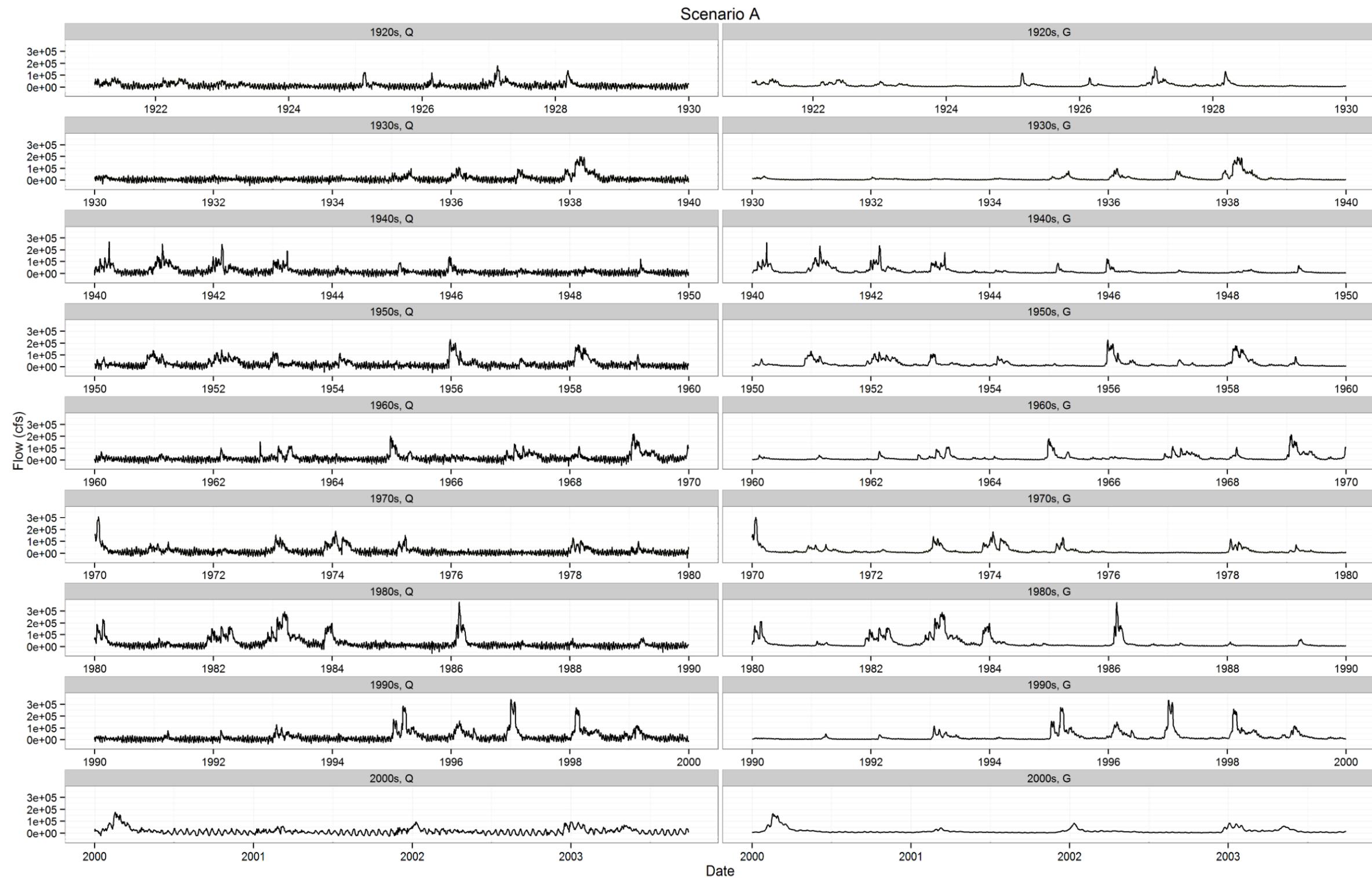
Figure 64   Time series plots of net Delta outflow, Q, approximated as modeled flow past Martinez, and corresponding antecedent flows, G, for Scenario A.
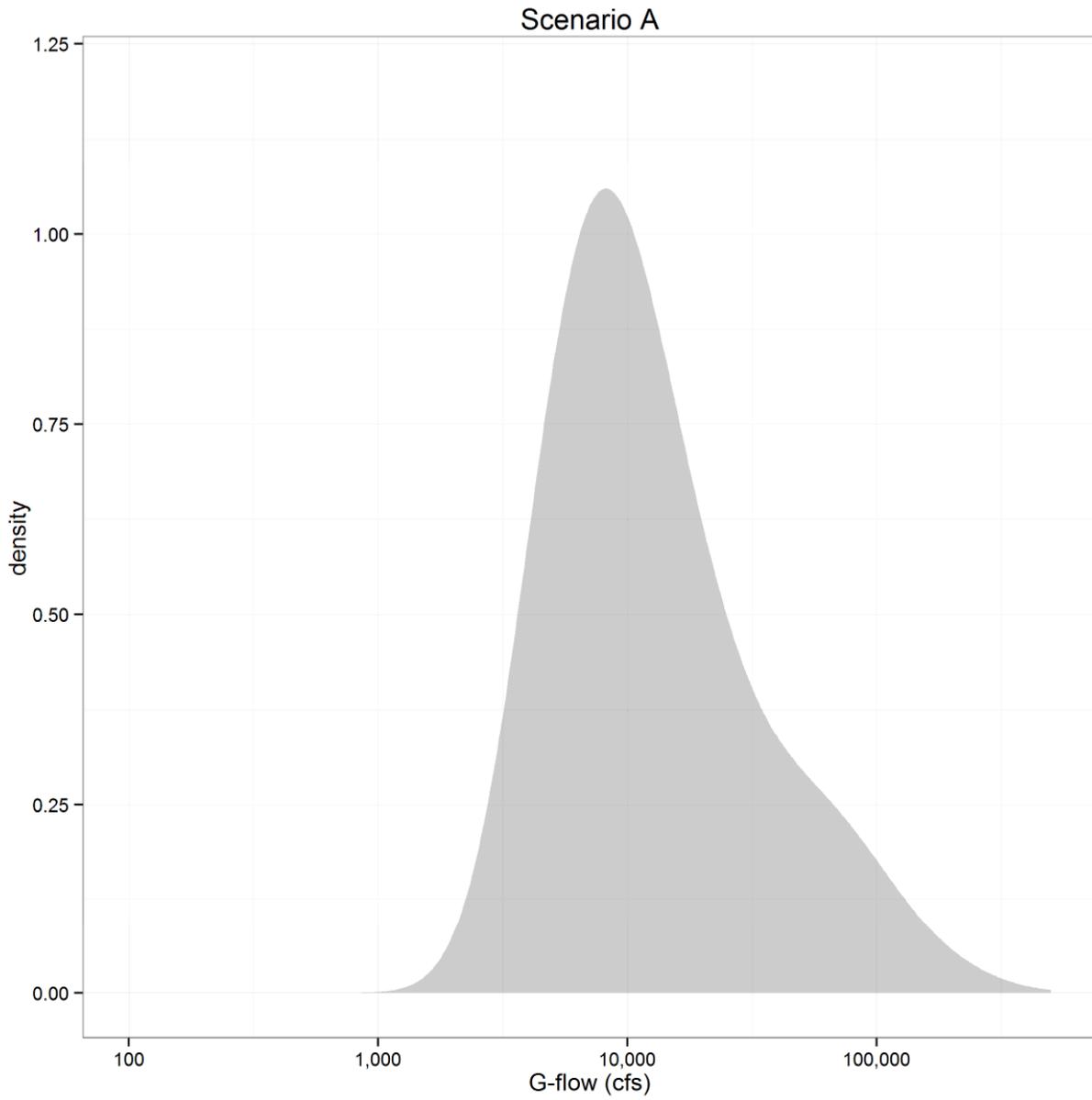
Figure 65   *Scenario A smoothed frequency distribution of G-flow.*
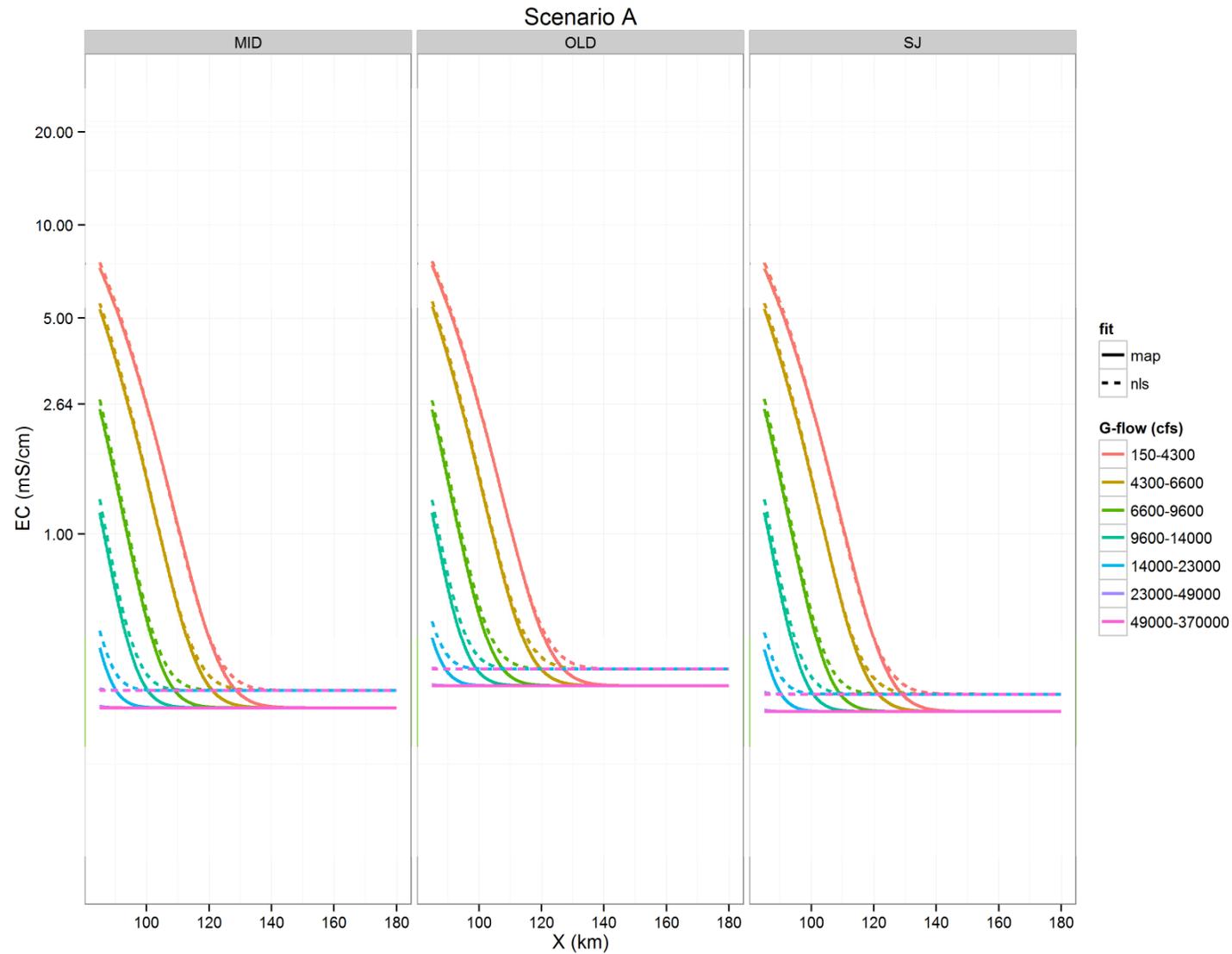
Figure 66   *Illustration of spatial variation in DSG predictions using the median G-flow in seven evenly spaced (in terms of G-flow percentiles) flow bins.*
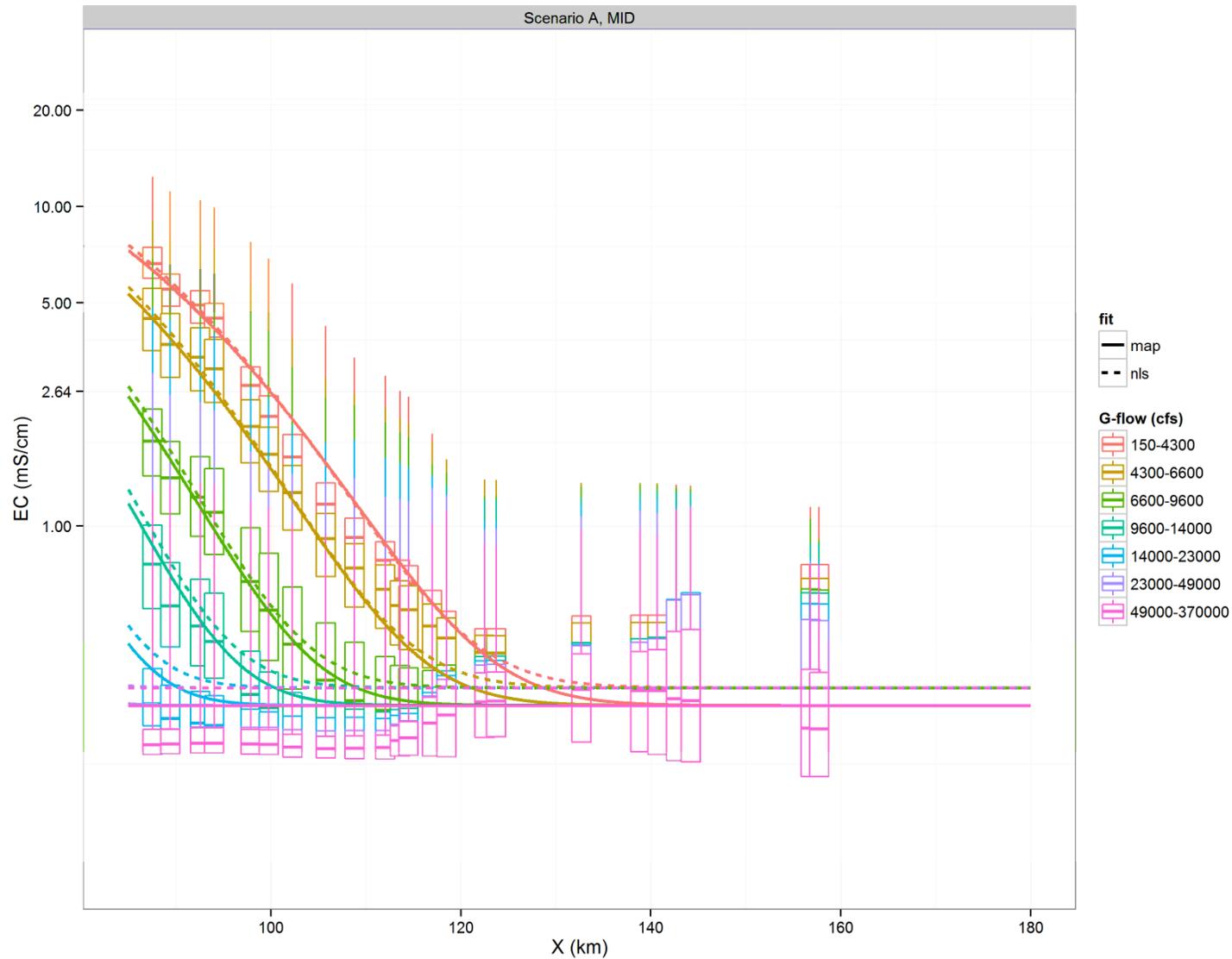
Figure 67   *As in Figure 66, except with box plots showing the distribution of DSM2 data at each distance. Scenario A, Middle River.*

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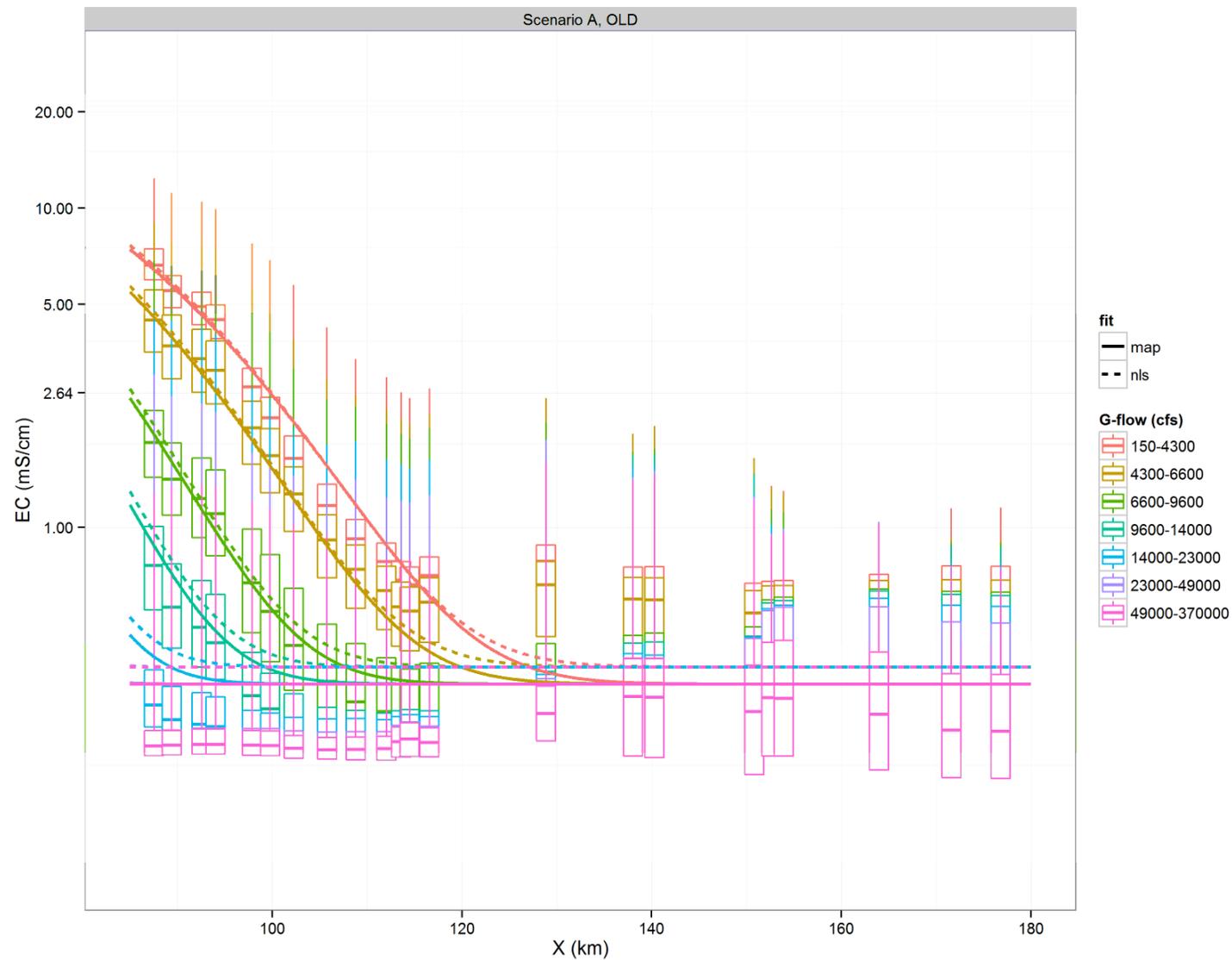
Figure 68   As in Figure 66, except with box plots showing the distribution of DSM2 data at each distance. Scenario A, Old River.

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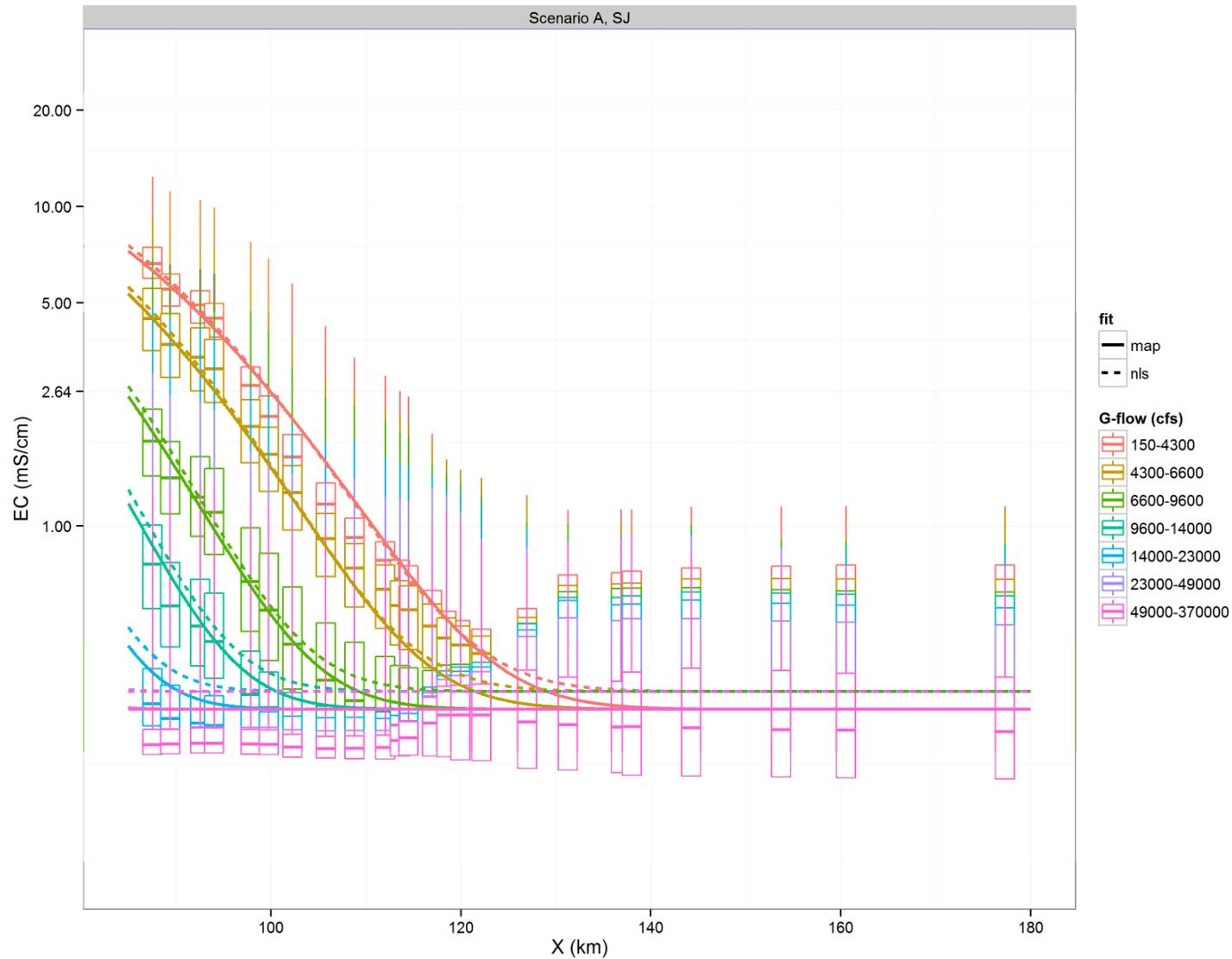
Figure 69   *As in Figure 66, except with box plots showing the distribution of DSM2 data at each distance. Scenario A, San Joaquin River.*

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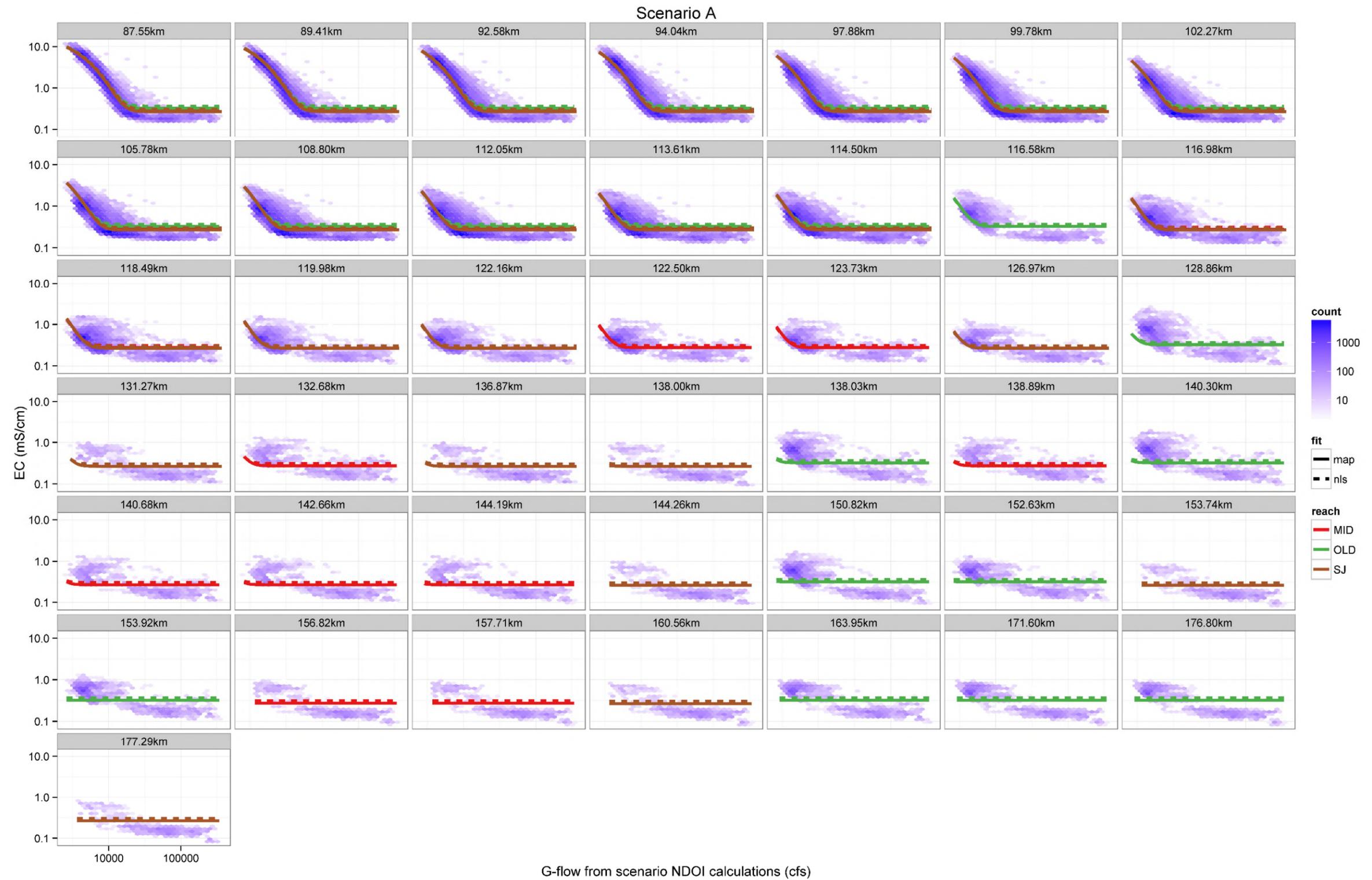
Figure 70   *Flow response of DSM2 simulations and DSG predictions of EC at each DSM 2 location, Scenario A. Log scale on both axes.*
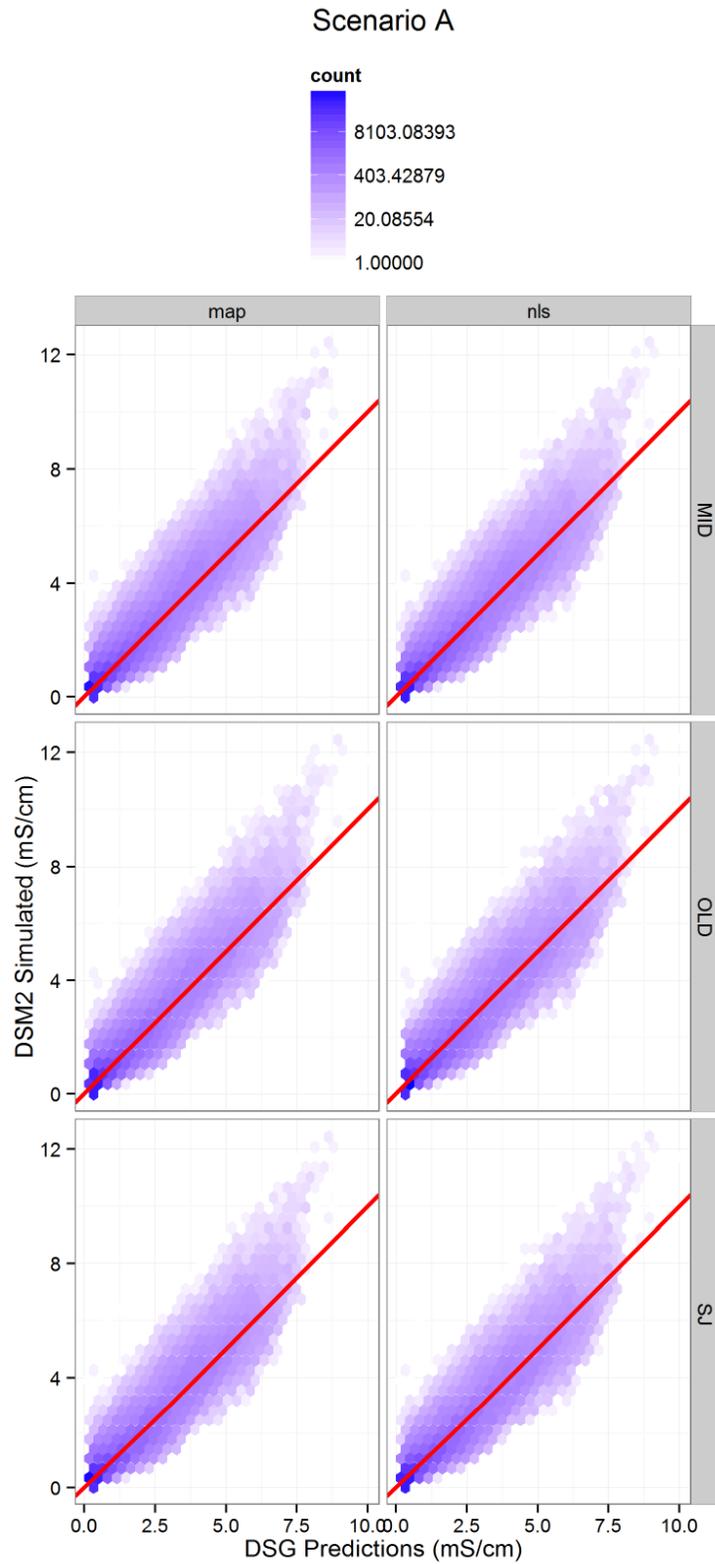
Figure 71   DSG predictions vs training data and 1:1 line (red).

DRAFT TECHNICAL MEMORANDUM

2012 – 2015 Delta Salinity Conditions under a Without Project Scenario

PREPARED FOR:	Terry Erlewine/SWC
PREPARED BY:	Tyler Hatch/CH2M HILL
	Chandra Chilmakuri/CH2M HILL
DATE:	June 5, 2015

Study Objective

The purpose of this study is to analyze salinity conditions in the south Delta channels under a Without Project scenario using the January 1, 2012 to August 31, 2015 Central Valley rim inflows. 2012 - 2015 historic and projected Sacramento River and San Joaquin River inflows to the Delta were modified to remove the impairments related to the upstream CVP – SWP reservoirs under the Without Project Scenario in addition to zeroing out the Delta exports at the Banks and Jones Pumping Plants and closing the Delta Cross Channel. The 2012 – 2015 study is an extension of a previous study of Without Project conditions for the year 2014. The multi-year timeframe allows understanding Delta salinity conditions under a sequence of differing hydrologic conditions.

Approach

A DSM2 model capable of simulating 2012-2015 historical Delta hydrodynamics and salinity conditions obtained from the DWR was used for representing the With Project scenario in this task. DWR used 2012 – 2015 Delta inflows, exports and salinity as the boundary conditions for the DSM2 model.

For the 2012-2015 Without Project DSM2 model, adjusted daily Delta inflow data at Vernalis and Freeport provided by the SWC were used as boundary conditions. As shown in Figures 1 and 2, Sacramento and San Joaquin Without Project inflows to the Delta are significantly lower (in some cases negative) in the summer and fall months compared to the historical conditions primarily due to the lack of contributions from project reservoir storage. The Without Project Scenario also assumed zero Delta exports from Banks and Jones Pumping Plants. The Without Project DSM2 model also uses historical electrical conductivity estimates for salinity boundary conditions at Freeport consistent with the historical DSM2 model. However, for the San Joaquin River at Vernalis modified electrical conductivity estimates were used to account for the unimpaired conditions under the Without Project scenario. The modified Vernalis EC estimates for the Without Project scenario were computed based on a methodology provided by the SWC, which is outlined in the Appendix A of this memo. For the Without Project conditions, the Delta Cross Channel gates were assumed to be closed for the entire length of the simulation.

Clifton Court Forebay (CCF) gate operations under the historical and Without Project DSM2 simulations were modified to represent Priority 3 gate operations. Under the Without Project simulation, instead of relocating BBID's existing DICU diversion from inside the CCF and closing the CCF gates, the With Project CCF gate operations were assumed to allow for the BBID diversion to continue. Even though the CCF gates are operational under the Without Project scenario, resulting Clifton Court inflow (Figure 3) confirms that inflow to CCF occurs only during the months with BBID diversion.

Sacramento River at Freeport timeseries input into the Without Project DSM2 model used only the positive flows provided. All negative flows were set to zero. Figure 1 below shows a comparison of the historical record, the Without Project timeseries with negative values from SWC, and the timeseries input into DSM2. In the summer months, the demands upstream of the Delta exceed the supply when there is no storage available to supplement the river flows into the Delta.

For the San Joaquin River at Vernalis, the Without Project DSM2 simulation used a 20 cfs base flow, when the Without Project flows from SWC are negative in order to achieve model stability in the channels near the San Joaquin River boundary in the DSM2 model. This base flow was used to keep water in the few channels downstream of Vernalis and was diverted upstream of the Old River (model node 4). Figure 2 shows a comparison between the historical Vernalis flows, the Without Project flows from SWC, and the Without Project flows used in the DSM2 simulation. In addition, the

diversion component of the Delta Island Consumptive Use (DICU) in the channels near the San Joaquin River boundary (at node 1 and 3) were set to zero when the base flow was the only flow assumed in the model at Vernalis. Without curtailing the DICU diversions at model nodes 1 and 3, the base flow would have to be large enough to meet the DICU demand and keep water in the channel.

Based on the modified electrical conductivity at Vernalis under the Without Project conditions, zero or negative flows have zero electrical conductivity. This assumption of zero EC was continued even though 20 cfs base flow was assumed under the Without Project scenario. However, the artificial base flow of 20 cfs with zero EC could therefore dilute salinity in the San Joaquin River near the Vernalis boundary that would otherwise exist in higher concentrations. A sensitivity analysis using the same model and assuming 2014 historical salinity for the 20 cfs base flows shows that the resulting salinity in the San Joaquin River near the Vernalis boundary is somewhat sensitive, but the differences are minimal beyond model node 4. In addition, while the DICU diversion values are set to zero at nodes 1 and 3, the DICU drain flow is continued in the model, which continues to add salt to the Delta channels.

For conditions projected from May 2, 2015 to August 31, 2015, stage and electrical conductivity at the downstream boundary was assumed at 2014 values for both the With Project and Without Project scenarios. For the With Project conditions, 2014 conditions were assumed for May 2, 2015 to August 31, 2015 for all inflows and outflows with the exception of inflows at Freeport and Vernalis and outflows for SWP and DMC. Projected 2015 with project flows at Vernalis were calculated as the sum of New Melones monthly outflows and San Joaquin River above the Stanislaus River flows after removing any contractor deliveries from the forecasted operations provided by the U.S. Bureau of Reclamation to the SWRCB in support of the 2015 TUC petition (http://www.waterboards.ca.gov/waterrights/water_issues/programs/drought/docs/tucp/2015/inputsheet_april90_upstream_ops.pdf). Projected 2015 With Project flows at Freeport were estimated as the balance of Delta monthly inflows and outflows, and assuming SWP and CVP Delta exports to be zero for May through August 2015. The Without Project simulation used the same boundary inflows and diversions as the With Project simulation for May 2, 2015 to August 31, 2015 period with the exception of Sacramento River at Freeport and San Joaquin River at Vernalis inflows, which were assumed to be zero. Figures 1 and 2 show the assumed inflow boundary conditions for 2015 projected conditions.

Results

Due to a lack of inflow at both Freeport and Vernalis during the summer and fall months under the Without Project scenario, salinity is much higher in the Delta compared to the historical conditions. During these months there is no fresh water to dilute the higher salinity intrusion, and as a result, the tide brings saltier water further into the Delta. In figures 5 to 52, the saltwater-freshwater interface has moved much further inland by the end of June in the Without Project Scenario than the With Project conditions. The Sacramento River inflows tend to be much higher than the San Joaquin River inflows and cause the salt to be in higher concentrations in the south Delta. However, low flows in the Sacramento River allow the salt concentrations to be relatively high in the north Delta as well. By September the flows in the Sacramento River are high enough to push the saltwater interface further to the south. The area around Frank Tract tends to hold higher salinity water late into the year even after the Sacramento and San Joaquin Delta inflows have flushed much of the saltwater back out of the Delta. The contribution of New Melones Reservoir to flows at Vernalis appears to be a major component of the historical flows during the summer and fall months. Contour plots of weekly EC conditions for 2012 - 2015 are provided as electronic attachments to this memorandum.

Martinez EC Sensitivity Simulations

To consider the potential effect of modified NDOI on the Martinez EC boundary condition, a sensitivity analysis was performed of the modeled salinity under the With Project and Without Project cases by using the Martinez salinity boundary condition estimated using the DWR's G-Model, instead of the historical Martinez EC values. Figure 4 compares the daily-average Martinez EC values for the historical conditions, G-model estimates using With Project NDOI, and G-model estimates using Without Project NDOI. The G-Model salinity values are higher on average than the historical salinity used. DSM2 model for both With Project and Without Project cases were simulated with G-model based EC values specified at Martinez. DSM2 results showed that the higher salinity conditions extended further into the Delta under both the With Project and Without Project cases. Since the Martinez tide and the hydrology used remained unchanged under the sensitivity runs, the resulting

hydrodynamics remained consistent with the original simulations. Therefore, using the G-model based EC values resulted in similar durations of salinity as compared to the simulations using historical Martinez EC.

Summary

The results in this memorandum show that without the CVP-SWP project reservoir storage, salinity would be much higher in the Delta during dry years than under the historical (With Project) conditions. There appears to be some pockets of higher salinity that persist late into the fall months in the central/south Delta channels over the multiple dry years simulated. However, due to the higher storm flows into the delta in the Without Project scenario, the driest years still have most of the salinity flushed east of Antioch in the spring months. The high salinity in the summer and fall months would further limit the beneficial use of water from the Delta during years like 2012 through 2015 under the Without Project scenario.

Limitations

Simulation of Delta salinity under With Project conditions and Without Project conditions using DSM2 are subject to limitations of the model and the approach used. DSM2 limitations and uncertainties are well documented in the DWR Annual Reports (http://baydeltaoffice.water.ca.gov/modeling/deltamodeling/annualreports.cfm).

Salinity in San Joaquin River upstream of Head of Old River is likely not accurate due to artificial base flows assumed for model stability, and curtailing of the DICU diversions upstream of Head of Old River (at model nodes 1 and 3), under the Without Project scenario. Projections of Delta inflows and exports for May – Aug 2015 are also subject to change.

The salinity contour plots presented in this memorandum were created from point data in the model using kriging. As a result, the zones where the contours are calculated may be influenced by a neighboring channel without direct access to comingled salinity. An example of this is the Sacramento Deep Water Ship Channel and the Sacramento River on September 6, 2014.

Sacramento River Inflow

FIGURE 2: SAN JOAQUIN RIVER AT VERNALIS DSM2 MODEL INFLOW FOR 2012 TO 2015
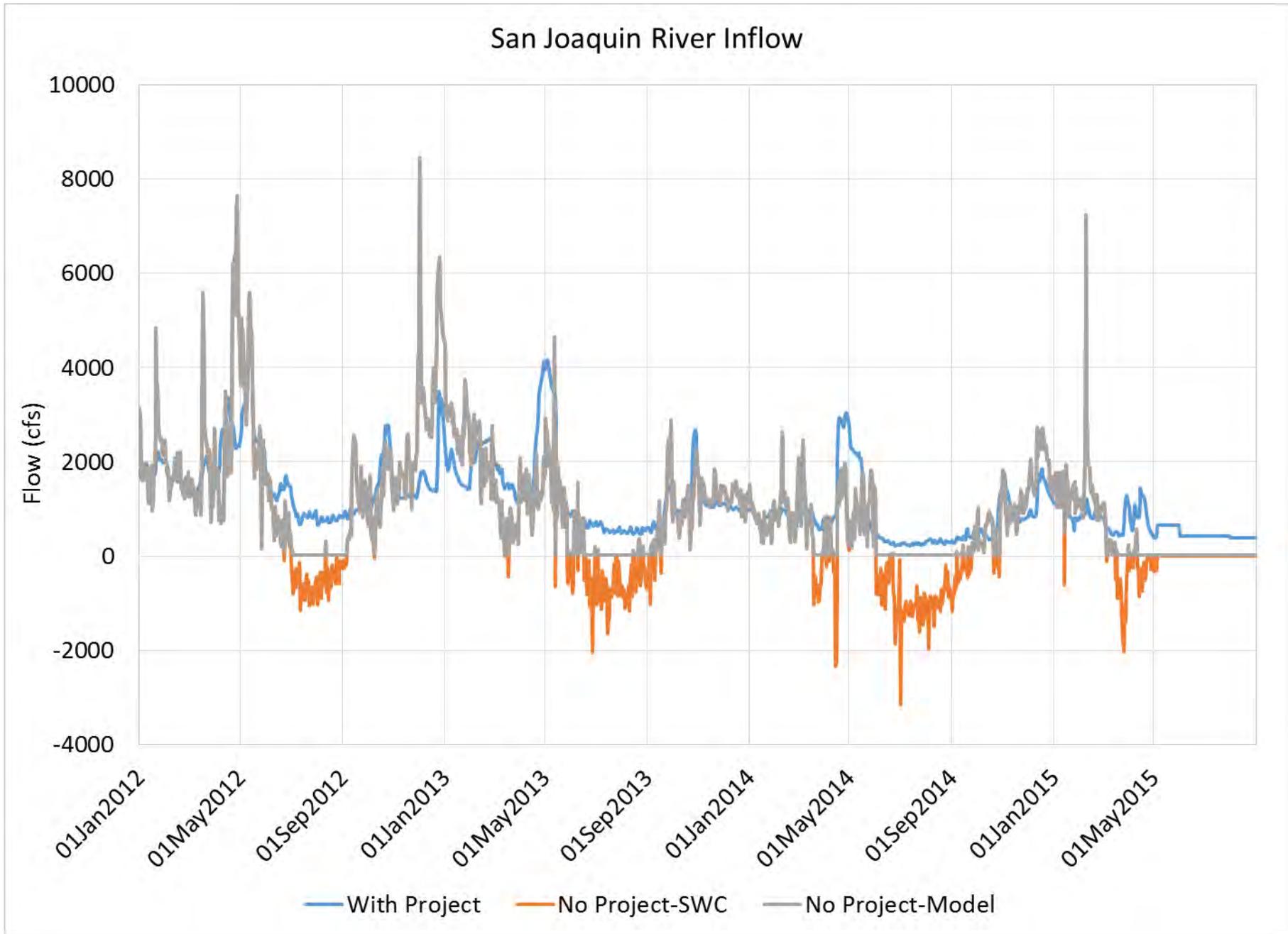
FIGURE 3: ASSUMED BBID DICU DIVERSION, AND DSM2 RESULT OF CLIFTON COURT FOREBAY INFLOW
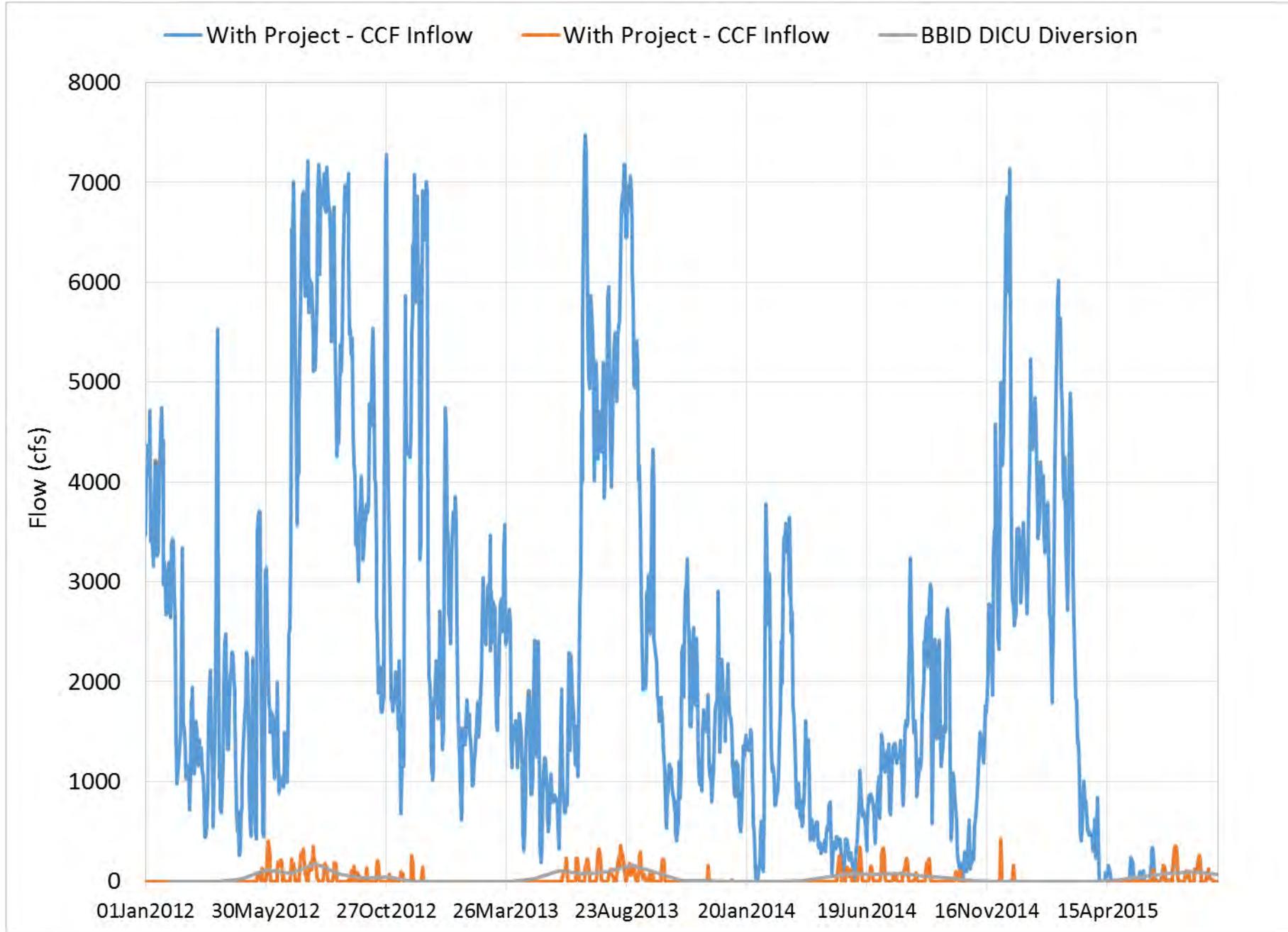
FIGURE 4: DAILY AVERAGED EC AT MARTINEZ FOR 2012 TO 2015
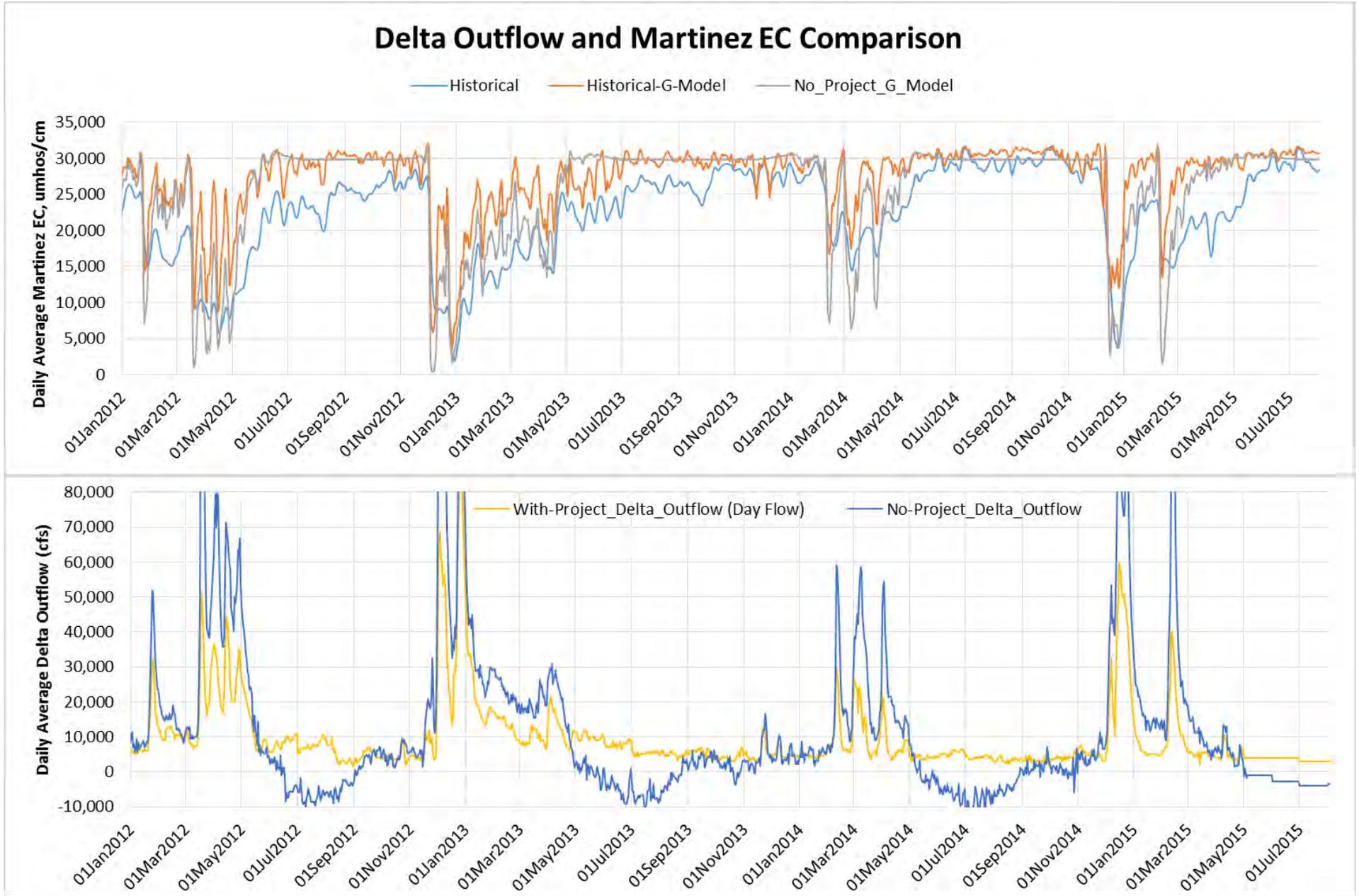
FIGURES 5 TO 52

Contour plots of DSM2 electrical conductivity in the Delta on a 4 week timestep for 2011-2015 for With Project conditions (left) and Without Project conditions (right)

Time: 08/11/2012 — With Project

Time: 08/11/2012 — Without Project

Avg Concentration

- Less than 500
- 500 to 1,000
- 1,000 to 2,000
- 2,000 to 3,000
- 3,000 to 4,000
- 4,000 to 5,000
- 5,000 to 7,500
- 7,500 to 10,000
- 10,000 to 20,000
- 20,000 to 30,000

Avg Concentration

Less than 500	4,000 to 5,000
500 to 1,000	5,000 to 7,500
1,000 to 2,000	7,500 to 10,000
2,000 to 3,000	10,000 to 20,000
3,000 to 4,000	20,000 to 30,000

Time: 11/30/2013

With Project

Time: 11/30/2013

Without Project

Avg Concentration

Less than 500	4,000 to 5,000
500 to 1,000	5,000 to 7,500
1,000 to 2,000	7,500 to 10,000
2,000 to 3,000	10,000 to 20,000
3,000 to 4,000	20,000 to 30,000

Time: 01/24/2015 — With Project

Time: 01/24/2015 — Without Project

Avg Concentration

- Less than 500
- 500 to 1,000
- 1,000 to 2,000
- 2,000 to 3,000
- 3,000 to 4,000
- 4,000 to 5,000
- 5,000 to 7,500
- 7,500 to 10,000
- 10,000 to 20,000
- 20,000 to 30,000

Appendix A: Methodology to Estimate Vernalis Salinity Under Without Project Conditions (from USBR & SDWA 1980) – provided by SWC

Calculate Salt Load Based on Flow (Table VI-7, page 89)

TABLE VI - 7
CHLORIDE LOAD VS. FLOW COEFFICIENTS AT VERNALIS

1930 - 1950

MONTH	C1	C2	# OF PAIRS*	R
OCTOBER	.3416451758E+03	.7238303788	7	.993
NOVEMBER	.3393044927E+03	.6880766404	6	.987
DECEMBER	.3639052910E+03	.6787756342	7	.972
JANUARY	.3928349175E+03	.6231583178	10	.965
FEBRUARY	.5368474514E+03	.5675747831	9	.914
MARCH	.4968879101E+03	.6035477710	10	.951
APRIL	.3866605718E+03	.5624873484	9	.942
MAY	.3805863844E+03	.5399998219	9	.920
JUNE	.6355065225E+03	.5175446121	9	.849
JULY	.6038658134E+03	.6219848451	8	.900
AUGUST	.3874538954E+03	.7410226741	8	.991
SEPTEMBER	.3500905302E+03	.7524035817	8	.989

* # OF PAIRS DOES NOT INCLUDE RESTRICTION POINT (.5,200)

$$y = C1*(x)^{C2}$$

Convert Salt Load to Chloride Concentration (page 110)

$$p/m = \frac{Load}{Flow \times 1.36}$$

where,

p/m = parts per million Cl⁻
Load = chloride load in tons
Flow = 1,000's of acre-feet

Calculate Specific Conductance EC from Chloride Concentration (page 86)

$$Cl^- = 0.15 \ EC - 5.0 \tag{2a}$$
$$0 < EC < 500$$

$$Cl^- = 0.202 \ EC - 31.0 \tag{2b}$$
$$500 < EC < 2000$$

Rearranging the equations to solve for EC yields:

EC = (Cl- + 5.0) / 0.15   0 < EC < 500

EC = (Cl- + 31.0) / 0.202 500 < EC < 2000

ATTACHMENT 3

State Water Resources Control Board

To: Michael Patrick George, Delta Watermaster

From: Micah Green, Water Rights Analyst

Re: Issues Related to Overlap between Pre-1914 and Riparian Water Right Claims in the Delta

Date: December 15, 2017

Pursuant to your request, I have researched an issue raised in the course of my review of responses to the Division of Water Rights' 2015 Information Order submitted by water right claimants within the Legal Delta.

I. Question Presented

Under California water law and within the Legal Delta, are there any circumstances under which riparian and appropriative rights can "overlap" becoming indistinguishable or inseparable such that either or both may be lawfully exercised at the election of the holder?

II. Short Answer

It is possible to perfect both riparian and appropriative water rights for beneficial use on the same parcel. However, riparian and appropriative rights are distinct property interests that must be separately established. There is no California precedent recognizing "overlapping" or "intertwined" water rights, and water laws against hoarding and non-use operate to preclude the duplicative exercise of water rights.

III. Factual and Legal Background

On February 4, 2015, the State Water Resources Control Board (the "Board"), Division of Water Rights issued an Order for Additional Information ("Information Order") to 445 different parties claiming riparian and pre-1914 appropriative rights in the Delta and the Sacramento and San Joaquin River watersheds.[1] The claimants subject to the Information Order represent 90 percent, by volume, of

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[1] State Water Resources Control Board Order WR 2015-0002-DWR at p. 1, available at: http://www.waterboards.ca.gov/waterrights/water_issues/programs/drought/docs/2015sacsjinfoorder.pdf (hereinafter "Information Order").

reported water use by water right claimants in the Delta, and 90 percent, by volume, of the remaining reported diversions from the Sacramento and San Joaquin River watersheds.[2]

The Information Order, issued pursuant to drought emergency authority, called for these claimants to submit "all documentation" supporting the basis for their claimed rights, and requested a "separate" accounting of water diverted under each claimed right.[3] To support riparian claims, the Information Order sought "the property patent date and patent map."[4] For pre-1914 appropriative claims, the Information Order sought "a copy of notice filed with the county, copy of property deed, and all other information…pertaining to initial diversion and continued beneficial use of water."[5] The deadline for submitting this information was March 6, 2015.[6]

In the Delta, a unique history of land acquisition and use dating back to California's statehood serves as the backdrop for many claimed water rights. Most of the lands in the Delta were passed from federal ownership to the State of California by the Swamp and Overflowed Lands Act of 1850.[7] In turn, California offered land patents to individuals and associations willing to develop these inundated areas into cultivatable farmland.[8] Upon payment, purchasers were issued a receipt known as a Certificate of Purchase, which counted as "*prima facie* evidence of legal title."[9] With a Certificate of Purchase in hand, individuals and associations formed for the purpose of reclamation could legally occupy and cultivate the lands described in their Certificates of Purchase. However, until the State of California issued a patent signed by the Governor, purchasers did not hold actual legal title to such lands. Prior to acquiring title via patent, many of these early purchasers diverted water from the streams and rivers running through or adjacent to the subject lands for agricultural and domestic use. Rights to this water were based on the "possessory rights" acquired by settlers as "occupants on the public lands."[10] Upon the issuance of a patent, these settlers acquired fully vested riparian rights with priority dates that were

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[2] *Ibid.*

[3] *Id.* at p. 2; see also Cal. Code Regs., tit. 23, § 879, subd. (c).

[4] *Ibid.*

[5] *Ibid.*

[6] *Ibid.*

[7] 43 U.S.C. § 982.

[8] See generally Cal. Statutes, Ch. 151 (1855); Cal. Statutes, Ch. 235 (1858); Cal. Statutes, Ch. 314 (1859); Cal. Statutes, Ch. 352 (1861); Cal. Statutes, Ch. 356 (1861); Cal. Statutes, Ch. 397 (1863); Cal. Statutes, Ch. 415 (1868); Cal. Statutes, Ch. 573 (1870); Cal. Statutes, Ch. 425 (1872); Cal. Statutes, Ch. 157 (1891); Cal. Statutes, Ch. 444 (1909).

[9] Cal. Statutes, Ch. 397, § 17 (1863).

[10] *Lux v. Haggin* (1886) 69 Cal. 255, 376-379; see also *Crandall v. Woods* (1857) 8 Cal. 136, 143 (under the law of riparian rights, one without title who "locates upon and appropriates public lands belonging to the United States" has a right to irrigate the lands through which the water naturally flows).

deemed to "relate back" to the date of settlement, under either a Certificate of Purchase[11] or an equitable claim of title based on settlement.[12]

In light of this factual and legal history, many of the materials submitted in response to the Information Order are accompanied by the assertion that certain riparian and pre-1914 appropriative rights in the Delta are "overlapping" and in some cases cannot be legally separated absent adjudication.[13] In turn, many in-Delta water users subject to the Information Order claim both riparian and pre-1914 rights, but maintain that it is impossible to determine the amount of water diverted under each individual claimed right. Moreover, when certain pre-1914 appropriative rights were threatened with curtailment during the drought in 2015, some Delta diverters claiming dual rights asserted that they would continue to divert at the same rate under their riparian rights if their appropriative rights were curtailed.[14]

IV. Discussion

A. Riparian and appropriative rights are separate and distinct property interests. California courts have established fact-specific requirements that must be met in order to separately perfect each type of right.

Water diversion and use in California is governed by a "dual system" of property interests, which recognizes both riparian and appropriative water rights.[15]

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[11] *Haight v. Costanich* (1920) 184 Cal. 426, 430.

[12] *Pabst v. Finmand* (1922) 190 Cal. 124, 130-131 (the "date of first lawful entry" controls. There are at least two types of "lawful entry:" entry under a Certificate of Purchase, and entry under an equitable claim of title. If a land acquirer received a Certificate of Purchase from the U.S. Land Office, the date of entry relates back to at least the date of entry under the Certificate (see *Haight v. Costanich* (1920) 184 Cal. 426, 430). If land had been settled before filing for a Certificate of Purchase, the settlers would have an equitable claim of title against all parties other than the United States, and the date of entry under the equitable claim controls (see *Pabst v. Finmand*, (1922) 184 Cal. 426, 430; see also *Crandall v. Woods* (1857) 8 Cal. 136, 143).

[13] See, e.g., Dante Nomellini Jr., *Explanatory Attachment* at p. 2, available at:
http://waterboards.ca.gov/water_issues/programs/delta_watermaster/docs/reports/attach_b.pdf;
John Herrick, *Explanatory Attachment* at p. 2, available at:
http://waterboards.ca.gov/water_issues/programs/delta_watermaster/docs/reports/attach_c.pdf;
Central Delta Water Agency, *Public Comment Letter Re: February 17, 2015, Informational Item 4*, available at:
http://www.waterboards.ca.gov/waterrights/water_issues/programs/drought/docs/infomational_order/cdwafeb2015.pdf;
Jennifer Spaletta, *Response to 2015 Drought Information Order Re Pre-1914 Rights* at p. 1-2, available at:
http://waterboards.ca.gov/water_issues/programs/delta_watermaster/docs/reports/attach_e.pdf.

[14] See Testimony of Brian Coats, Byron-Bethany Irrigation District Administrative Civil Liability Hearing/West Side Irrigation District Cease and Desist Order Hearing at p. 16, available at:
http://www.waterboards.ca.gov/waterrights/water_issues/programs/hearings/byron_bethany/docs/exhibits/pt/wr9.pdf.

[15] *El Dorado Irrigation District v. State Water Resources Control Board* (2006) 142 Cal.App.4th 937, 961 (hereinafter "*El Dorado*").

Riparian Rights

Riparian rights support the diversion of water flowing in a natural watercourse for beneficial use on contiguous lands.[16] The foundational principle of the riparian doctrine is that water rights may be obtained and exercised as an incident of property ownership.[17] If water naturally flows past or through a parcel of privately owned land, such a parcel is known as "riparian" or "contiguous" land.[18] The amount of water available under a riparian right is non-quantifiable, because riparian landowners may divert and reasonably use as much of the natural flow in the adjacent watercourse as necessary to meet the beneficial uses of the riparian parcel.[19] Riparian rights are correlative with the rights of other riparians on the watercourse,[20] but the limit of the right is the amount of water that can be put to reasonable and beneficial use on the riparian parcel.[21] Moreover, only the smallest parcel maintaining contiguity to a natural watercourse retains riparian diversion and use rights.[22] This rule eliminates riparian rights from formerly riparian parcels when riparian land is subdivided and sold as smaller parcels, unless there is sufficient evidence of the contemporaneous intent to preserve riparian rights for use on any newly non-contiguous lands.[23] If evidence of such intent is not sufficient, riparian rights to divert and use water on all non-contiguous parcels terminate by operation of law.[24]

Based on these principles, a riparian water right contains at least the following two elements: (1) ownership of land; and (2) a riparian connection between the subject land and a natural watercourse, either physically or through preservation. Moreover, lawful exercise of a riparian right is subject to five general limitations. First, water diverted under a riparian right must be put to reasonable and beneficial use.[25] Second, riparian rights generally attach to natural watercourses and the waters flowing naturally therein, with some limited exceptions.[26] Third, the place of use for a riparian right is limited to the

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[16] *People v. Shirokow* (1980) 26 Cal.3d 301, 307 (hereinafter "*Shirokow*").
[17] *United States v. State Water Resources Control Board* (1986) 182 Cal.App.3d 82, 101.
[18] *Ibid*.
[19] *Pabst v. Finmand* (1922) 190 Cal. 124, 129.
[20] *Southern California Inv. Co. v. Wilshire* (1904) 144 Cal. 68, 70.
[21] *Prather v. Hoberg* (1944) 24 Cal.2d 549, 560; see also *Pabst v. Finmand* (1922) 190 Cal. 124, 129.
[22] *Rancho Santa Margarita v. Vail* (1938) 11 Cal.2d 501, 529.
[23] *Hudson v. Dailey* (1909) 156 Cal. 617, 624-625.
[24] *Ibid.*
[25] Cal. Const. Art. X, § 2.
[26] *Chowchilla Farms Inc. v. Martin* (1933) 219 Cal. 1, 19-26 (note that a channel not created by natural forces can be deemed legally "natural" and give rise to riparian rights if the circumstances indicate that the channel has effectively become part of the natural watershed over time. Factors that point toward a natural channel include the length of time that the channel has been in use and the degree to which the flow in the channel is controlled by natural or artificial forces).

riparian parcel, unless the right was preserved for use on non-riparian land when it was severed from the residual riparian parcel.[27] Even if the right has been preserved for use on a non-riparian parcel, water diverted under a riparian right cannot be used on a parcel outside of the watershed from which it was originally diverted.[28] Fourth, water diverted under a riparian right cannot be transferred (sold or otherwise conveyed to a third party) separately from the riparian property.[29] Fifth, water diverted under a riparian right cannot be held in storage for use at a later time.[30]

Appropriative Rights

Unlike riparian rights, appropriative rights are not established by the settlement or ownership of riparian real property.[31] Instead, appropriative rights arise from and are limited to the actual diversion of a quantifiable amount of water for a beneficial use at a designated location.[32] As a general principle, "[t]he appropriation doctrine…applies to 'any taking of water for other than riparian or overlying uses.'"[33]

In 1855, the California Supreme Court recognized that the right to divert water could be acquired based on actual diversion and use; in so doing, the Court adopted a legal framework prioritizing appropriative rights based on the sequence in which they were acquired.[34] Based on that 1855 recognition of the prior appropriation doctrine in California, diverters could acquire rights to water by actually diverting water and putting such water to beneficial use.[35] Until 1872, there was no statutory or administrative process for providing notice of such a claim to other parties; however, posting a notice at the point of diversion was a commonly accepted method for doing so.[36]

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[27] *Pleasant Valley Canal Co. v. Borror* (1998) 61 Cal.App.4th 742, 753, 772 (hereinafter *Pleasant Valley*, citing *Holmes v. Nay* (1921) 186 Cal. 231, 235 and stating that "a riparian right may be exercised only on the owner's riparian land," then applying the rule that contemporaneous evidence of intent is required to preserve riparian rights for non-contiguous land).

[28] *Rancho Santa Margarita v. Vail* (1938) 11 Cal.2d 501, 528-529.

[29] *Spring Valley Water Co. v. County of Alameda* (1927) 88 Cal.App. 157, 168.

[30] *Shirokow, supra,* 26 Cal.3d 301, 307.

[31] *Pleasant Valley, supra,* 61 Cal.App.4th 742, 753.

[32] *Arizona v. California* (1931) 283 U.S. 423, 459; *Crane v. Stevinson* (1936) 5 Cal.2d 387, 398 (hereinafter "*Crane*"); *El Dorado, supra,* 142 Cal.App.4th 937, 961.

[33] *Shirokow, supra,* 26 Cal.3d 301, 307 (quoting *City of Pasadena v. City of Alhambra* (1949) 33 Cal.2d 908, 925; see also Cal. Water Code, § 1201 (codifying this principle).

[34] *Irwin v. Phillips* (1855) 5 Cal. 140, 147.

[35] *Ibid.*

[36] Wells A. Hutchins, *Water Rights Laws in the Nineteen Western States* at p. 293-294.

In 1872, the California legislature enacted standard procedures for making and recording appropriative claims.[37] Under the 1872 statutory scheme, an appropriative claim could be asserted by posting a notice at the point of intended diversion stating the amount of water to be diverted and listing the intended purpose and place of use.[38] Claimants taking advantage of the new scheme were required to record this notice with the Recorder's Office for the county in which the point of diversion was located.[39] Because participation in the 1872 framework was voluntary, registration with the county is not an essential element to establish an appropriative right. However, compliance with the registration protocol is a persuasive piece of evidence of the underlying water right; compliance also offered claimants a date of priority relating back to the first steps taken toward initial diversion of water.[40]

The legislature enacted the Water Commission Act of 1913, which became effective, following referendum validation, on December 19, 1914.[41] This act created the Water Commission, the predecessor to the Board, and established that the exclusive procedure for acquiring appropriative water rights in California would thenceforth be through an administrative process before the Water Commission.[42] To appropriate water that is surplus to the water required to serve the beneficial uses of riparians and earlier appropriators, prospective diverters apply for a permit from the Water Commission (or its successor, the Board).[43] Application for such a permit requires (1) notice of intent to divert water (providing an opportunity for protest) and (2) a timetable for development of the physical facilities necessary to divert, convey, and apply the subject water to a beneficial use.[44] After the Water Commission (now the Board) determines that granting the permit would not injure another legal user of water and the permittee has put the water to beneficial use, the Water Commission issues a license confirming the water right.[45]

The relevant statutes and case law identify five elements that must be met in order to perfect a pre-1914 appropriative water right. First, an appropriation must be properly noticed.[46] Notice may be

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[37] Civil Code of 1872, §§ 1410-1422, available at:
http://digitalcommons.csumb.edu/cgi/viewcontent.cgi?article=1000&context=hornbeck_usa_3_h.

[38] Civil Code of 1872, § 1415.

[39] *Ibid.*

[40] Civil Code of 1872, § 1418.

[41] Stats. 2013, ch 586.

[42] Cal. Water Code, § 1225.

[43] Cal. Water Code, §§ 1250 et seq.

[44] Cal. Water Code, §§ 1250 et seq.; Cal. Water Code §§ 1375 et seq.

[45] Cal. Water Code, §§ 1600 et seq.

[46] *Haight v. Costanich* (1920) 184 Cal. 426, 431-433.

formal, such as a notice recorded with the county or posted at the point of diversion,[47] or informal, through an outward manifestation of intent to divert water by constructing a channel or diversion structure at the point of diversion.[48] Second, the claim must be based on an actual diversion, as opposed to a prospective or purely speculative one.[49] Third, the claimant must have actually diverted and used water prior to 1914, because appropriations beginning after 1914 must be approved by the Water Commission (or its successor, the Board).[50] Fourth, the water diverted must be applied to a beneficial purpose.[51] Fifth, the claimant must establish a specific amount of water actually diverted.[52] Supported by sufficient evidence, these five elements establish a *prima facie* pre-1914 appropriative water right.

B. Riparian and appropriative rights may be perfected for use on the same parcel of land. However, appropriative rights may only be perfected by demonstrating the essential elements of appropriation.

It is possible to perfect both riparian and appropriative water rights to support beneficial use on the same parcel.[53] However, a claimant must establish the essential elements of each type of right in order to independently support each claim. And, for each type of water right, the claimant must observe the specific limitations on the right claimed. For instance, as noted above, a riparian water right will not support storage or transfer of water to a non-riparian parcel, because water diverted pursuant to a riparian right is limited to direct application to beneficial use on the riparian land.[54] Similarly, a riparian right is limited to diversion and use of the natural flow of water in the watercourse, while an

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[47] *Millview County Water District v. State Water Resources Control Board* (2014) 229 Cal.App.4th 879, 905 (hereinafter "*Millview*") (citing Civil Code of 1872, § 1415).

[48] *Nevada County and Sacramento Canal Co. v. Kidd* (1869) 37 Cal. 282, 311-312; *Haight v. Costanich* (1920) 184 Cal. 426, 431-433.

[49] *McDonald v. Bear River and Auburn Water and Mining Co.* (1859) 13 Cal. 220, 232-233; *Haight v. Costanich* (1920) 184 Cal. 426, 431-433; *Turlock Irrigation District v. Zanker* (2006) 140 Cal.App.4th 1047, 1054.

[50] *Fall River Valley Irrigation District v. Mt. Shasta Power Corp.* (1927) 202 Cal. 56, 66 (citing the statutory provision that became Cal. Water Code, § 1225); *Temescal Water Company v. Department of Public Works* (1955) 44 Cal.2d 90, 95-97.

[51] *McDonald v. Bear River and Auburn Water and Mining Co.* (1859) 13 Cal. 220, 232-233; *Nevada County and Sacramento Canal Co. v. Kidd* (1869) 37 Cal. 282, 311-312; *Crane, supra,* 5 Cal.2d 387, 398; *Haight v. Costanich* (1920) 184 Cal. 426, 431-433; *Arizona v. California* (1931) 283 U.S. 423, 459; *El Dorado, supra,* 142 Cal.App.4th 937, 961; *Millview, supra,* 229 Cal.App.4th 879, 905.

[52] See, e.g., *Crane, supra,* 5 Cal.2d 387, 398; *Arizona v. California* (1931) 283 U.S. 423, 459; *Millview, supra,* 229 Cal.App.4th 879, 905 (this element alone precludes an assertion of "overlapping" and collectively "unquantifiable" water rights, because claimants must independently establish the amount diverted under the appropriative claim in order to affirmatively establish the priority of the appropriative right).

[53] *Rindge v. Crags Land Co.* (1922) 56 Cal.App. 247, 252 (hereinafter "*Rindge*").

[54] *City of Lodi v. East Bay Municipal Utilities District* (1937) 7 Cal.2d 316; *Moore v. California Oregon Power Co.* (1943) 22 Cal.2d 725, 731; *City of Pasadena v. City of Alhambra* (1949) 33 Cal.2d 908, 925-926; but see Cal. Water Code, § 1707 (allowing dedication of water arising under riparian rights for instream beneficial uses).

appropriator is entitled to divert non-natural flows that have been abandoned.[55] Appropriative rights can also be perfected through applying water to riparian land if the water was diverted from a non-contiguous source and conveyed through a controlled system to the riparian parcel.[56] In summary, each claim must be supported by the essential elements of the right claimed, and must also observe the limitations attributable to the right claimed.

The decisions of the Board apply this principle to conclude that the exercise of each right remains distinguishable from the other, based on both the elements and the limitations that apply differently to each right. In 2011, the Board faced a claim of indistinguishable overlapping riparian and pre-1914 water rights *In the Matter of Draft Cease and Desist Order Against Unauthorized Diversions by Woods Irrigation Company*.[57] In that proceeding, the Board's Division of Water Rights issued a draft Cease and Desist Order ("CDO") that aimed to limit the amount of water that Woods could divert and distribute in its Delta water service area.[58] In response, Woods asserted "overlapping" pre-1914 and riparian rights that entitled it to divert more water than indicated in its service agreements.[59] In its Order adopting the CDO, the Board rejected the theory of overlapping rights, because to accept the theory "would mean assuming that water was diverted under an appropriative right on riparian lands, and that the riparian owners can then switch to diverting under riparian rights, and 'double-count' the water."[60] After reviewing the authorities cited by Woods in support of its overlapping rights theory,[61] the Board concluded that "none of these authorities hold [sic] that a riparian right holder may use the available natural supply of water on riparian land for a riparian purpose, and then claim that the use was under an

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[55] *Bloss v. Rahilly* (1940) 16 Cal.2d 70, 76 (as opposed to "natural flow," "foreign water" is water that did not originate in the watershed from which the claimant diverts water ("foreign in origin") or which has been diverted to storage from and later released to the watershed ("foreign in time"). (See *E. Clemens Horst Co. v. New Blue Point Mining Co.* (1918) 177 Cal. 631, 637-640.) "Abandoned" water is that which has been lawfully diverted and released by a diverter who intends to relinquish dominion and control over such water. (See *Utt v. Frey* (1895) 106 Cal. 392, 396-397.) Water that is appropriated or used and subsequently flows back into a stream is subject to appropriation. (Cal. Water Code, §§ 1201-1202.) The right to divert abandoned water only applies to water that has already been abandoned; it does not include a right to compel the continued abandonment of water in the future. (See *Lindblom v. Round Valley Water Co*. (1918) 178 Cal. 450, 454; *Stevens v. Oakdale Irr. Dist*. (1939) 13 Cal.2d 343, 348.).

[56] See, e.g., *Pleasant Valley, supra,* 61 Cal.App.4th 742.

[57] State Water Resources Control Board Order WR-2011-005; State Water Resources Control Board Order WR-2012-0012.

[58] State Water Resources Control Board Order WR-2011-005 at 5-6.

[59] *Id.* at p. 34-35.

[60] *Id.* at p. 35.

[61] See *Rindge, supra,* 56 Cal.App 247; *Porters Bar Dredging Co. v. Beaudry* (1911) 15 Cal.App. 751; *Pleasant Valley, supra,* 61 Cal.App.4th 742; State Water Resources Control Board Board Decision D-1282 (1967).

appropriative right which developed while its riparian rights lay dormant."[62] The Board recognized the possibility that appropriative rights may "wrap around" riparian rights, but also noted that the appropriative right is distinct in operation and "is not in addition to available riparian rights, such that the right holder can divert two times as much, or transfer the appropriative right while continuing to divert under the riparian one."[63]

After the Woods CDO was adopted, the parties reached a settlement that was subsequently approved by the Board.[64] The Order adopting the CDO, although superseded by the approved settlement of the case, nonetheless illustrates the Board's position that riparian and appropriative rights are not intertwined so as to be indistinguishable under California water law. This position is consistent with the long-standing differentiation among the elements of and limitations on appropriative as compared to riparian water rights.[65]

Also in 2011, the Millview County Water District asserted "overlap" of a riparian and a pre-1914 appropriative right to divert water from the same source for use on riparian land. In addressing this claimed "overlap," the Board noted that the appropriative right might not have been perfected, because there was no evidence that water had been put to a "wrap around" use, within the meaning of that term as used in the *Woods* Order.[66] On review of the Superior Court's grant of a writ of mandate, the Court of Appeal recognized that "a [Board] finding to this effect would have precluded any appropriation," and agreed with the Board's conclusion that the Water District "could not perfect the…claim as an appropriative water right without actually using the diverted water on non-contiguous land."[67]

Regardless of whether the place of use is a riparian parcel, an appropriative claimant must meet the essential elements for perfection of an appropriative right discussed above (in Section IV.A) to obtain a valid appropriative water right. To perfect a pre-1914 appropriative right, claimants must meet the

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[62] State Water Resources Control Board Order WR-2011-005 at p. 37.

[63] *Id.* at p. 35.

[64] See State Water Resources Control Board Order WR-2016-0006-Exec.

[65] *City of Lodi v. East Bay Municipal Utility District* (1937) 7 Cal.2d 316, 335; *Shirokow, supra,* 26 Cal.3d 301, 307; *El Dorado, supra,* 142 Cal.App.4th 937, 961; *Millview, supra,* 229 Cal.App.4th 879, 887.

[66] State Water Resources Control Board Order WR-2011-0016 at p. 24.

[67] *Millview, supra,* 229 Cal.App.4th 879 at 887, 905 (some might be tempted to describe the Court of Appeal's finding as mere *dicta*, because the Court did not expressly rely on the lack of evidence of a "wrap around" use to decide the merits of the case. However, in making this finding, the Court was providing guidance for the proceeding on remand. Therefore, the Court of Appeal's determination on this point has binding effect. (See *Garfield Medical Center v. Belshe* (1998) 68 Cal.App.4th 798, 806.).

elements of (1) notice, (2) actual diversion, (3) evidence of actual diversion and use of water prior to 1914, (4) beneficial use, and (5) a specific amount of water.[68]

C. The constitution, statutes, court decisions, regulations, and policies of the State of California require beneficial use and preclude the duplicative exercise of water rights. There is no California authority supporting the concept of "overlapping" or "indistinguishable" riparian and appropriative water rights.

The assertion of "overlapping" water rights contained in many of the Information Order responses appears to be based on the premise that pre-patent water use on riparian land is appropriative in nature.[69] Assuming that appropriative rights were perfected through diversion and use on riparian land prior to the date of patent, these responses assert that "overlapping" riparian rights vested on top of pre-patent appropriative rights when title was transferred from public to private ownership.[70]

The cases cited in support of this argument do not reference "overlapping" water rights. Both *Pleasant Valley Canal Co. v. Borror* and *Rindge v. Crags Land Co.* recognize that riparian and appropriative water rights could be perfected through water use that began prior to acquisition of a patent and continued after the patent date.[71] However, neither case holds that a pre-patent diversion of water for use on adjacent public land constitutes an appropriation. Instead, the court in *Pleasant Valley* held that the claimant's acquisition of a riparian right did not deprive him of his pre-existing rights to appropriate water via a shared ditch from upriver land.[72] Similarly, *Rindge* recognized that the right to appropriate water to physically separate riparian property would survive the acquisition of title and riparian rights in the downstream riparian property.[73] However, neither case holds that pre-patent water use was

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[68] See *supra,* Part IV.A (many Information Order responses support pre-1914 appropriative claims by relying solely on the patent(s) and Certificate(s) of Purchase tied to a riparian parcel. (See*,* e.g., Response of Bettencourt Farming LLC supporting S016492, available at:
http://waterboards.ca.gov/water_issues/programs/delta_watermaster/docs/reports/attach_i.pdf;
Response of Kurt and Sandra Kautz Family Trust supporting S016909, available at:
http://waterboards.ca.gov/water_issues/programs/delta_watermaster/docs/reports/attach_k.pdf.) Such evidence, standing alone, falls short of meeting the essential elements of an appropriative right.).

[69] See, e.g., Jennifer Spaletta, *Response to 2015 Drought Information Order Re Pre-1914 Rights* at p. 1-2, available at: http://waterboards.ca.gov/water_issues/programs/delta_watermaster/docs/reports/attach_e.pdf.

[70] *Ibid.* (citing *Rindge, supra,* 56 Cal.App. 247, 252; *Pleasant Valley, supra,* 61 Cal.App.4th 742, 774).

[71] *Rindge, supra,* 56 Cal.App. 247, 252; *Pleasant Valley, supra,* 61 Cal.App.4th 742, 774.

[72] *Pleasant Valley*, *supra*, 61 Cal.App.4th 742, 774.

[73] *Rindge, supra,* 56 Cal.App. 247, 252.

necessarily appropriative in nature, nor that "overlapping" rights were created upon the issuance of a patent.[74]

Rather than creating an "overlapping" right, the vesting of a riparian right upon acquisition of title operates to change a conditional riparian right, based on land occupation, into an unconditional riparian right, based on land ownership.[75] As discussed above (in Section IV.B), appropriative rights can be acquired separately from riparian rights and applied to the same parcel.[76] However, there is no support in the law for a riparian right "overlapping" with a previously perfected appropriative right upon the issuance of a patent.

Water diverted in California must be "put to beneficial use to the fullest extent" possible.[77] This principle operates to prohibit diversion of more water than is reasonably necessary to meet the purposes for which water was diverted.[78] In *Senior v. Anderson*, the California Supreme Court applied the beneficial use limitation specifically to the exercise of appropriative rights on riparian land.[79] There, the claimant had appropriated water for use on riparian land prior to the acquisition of a patent; the quantity of the claimed appropriation exceeded the amount that could be put to beneficial use on the riparian parcel.[80] The Court held that, upon acquiring a patent, the claimant did not obtain a right to any additional quantity of water by virtue of the newly vested riparian right.[81] This holding illustrates that the exercise of appropriative and riparian rights is limited to the amount needed for beneficial use on the land, even when both rights are asserted for use on the same parcel.

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[74] Even assuming *arguendo* that pre-patent water use on a riparian parcel gave rise to an appropriative right, such rights may be subject to forfeiture for non-use. In a forfeiture action before the Board, diversions are attributed to the highest priority right held by the claimant. (See State Water Resources Control Board Order WR 2016-0001.) In the context of a claim of "overlapping" rights, the higher priority right is likely the riparian right, so long as natural flow is available, because the priority date of the riparian right relates back to the first possessory steps taken by the claimant's predecessor. (See *Haight v. Costanich* (1920) 184 Cal. 426, 430; *Pabst v. Finmand* (1922) 190 Cal. 124, 130-131.) If all diversions to a riparian parcel are attributed to the riparian right, and there is no further evidence of appropriation, the appropriative right will have been un-exercised for a long period of time. In a forfeiture action, the party asserting forfeiture has the burden of identifying (1) five consecutive years of non-use and (2) the presence of a contemporaneous and conflicting claim to the un-used water. (Cal. Water Code, § 1241; *Millview, supra,* 229 Cal.App.4th 879, 891-905.)

[75] *Lux v. Haggin* (1886) 69 Cal. 255, 350-387.

[76] *Rindge, supra,* 56 Cal.App. 247, 252.

[77] Cal. Const. Art. X, § 2.

[78] *California Pastoral and Agricultural Co. v. Madera Canal and Irrigation Co.* (1914) 167 Cal. 78 (although this case predates by 14 years the adoption of Article X, section 2, the doctrine of reasonable and beneficial use is a common law principle that pre-dates the constitutional provision).

[79] *Senior v. Anderson* (1900) 130 Cal. 290.

[80] *Id.* at p. 296.

[81] *Ibid.*

The limitation that beneficial use imposes on water rights is well-settled pursuant to Article X, section 2 of the California Constitution. As the Supreme Court explained in *California Pastoral and Agricultural Co. v. Madera Canal and Irrigation Co.*, "[t]he state has limited the right to appropriate waters of a stream to such waters as are reasonably necessary for the purpose for which the water is in fact appropriated."[82] Because of this principle, a diversion that exceeds the reasonably necessary amount "is contrary to the policy of our law and unauthorized…[such diversions] confer no right, no matter for how long continued."[83]

D. A riparian right for use of water on a parcel that does not maintain contiguity with a natural watercourse must be supported by evidence of intent to preserve the riparian right at the time of subdivision. As illustrated by recent cases in the Delta, severance without contemporaneous evidence of intent to preserve a riparian right precludes retention and exercise of the vestigial riparian claim.

Upon completion of the patent process, large swaths of riparian land in the Delta were subdivided and sold as individual parcels.[84] Many of these parcels did not maintain contiguity with a natural watercourse after subdivision and conveyance. Many Delta responses to the Information Order claim riparian rights but reference points of diversion and/or places of use on property that does not appear to be contiguous to a natural watercourse.[85]

Of course, where riparian rights are terminated due to severance, owners of severed land could thereupon perfect an appropriative right to divert and use water on formerly riparian lands.[86] Such a right would need to be supported by evidence of appropriation in accordance with the law at the time of the appropriation. If such evidence indicates that the lawful appropriation occurred after severance

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[82] *California Pastoral and Agricultural Co. v. Madera Canal and Irrigation Co.* (1914) 167 Cal. 78, 85.

[83] *Ibid.;* see also *Mt. Shasta Power Corp. v. McArthur* (1930) 109 Cal.App. 171, 191 ("An appropriator obtains title to the extent only of his use of the water for beneficial purposes.").

[84] See, e.g., John Thompson, *Early Reclamation and Abandonment of the Central Sacramento-San Joaquin Delta* (2006) at p. 49-58, available at: http://ccrm.berkeley.edu/resin/pdfs_and_other_docs/background-lit/EarlyReclamationandAbandomentofDelta.pdf (discussing large-scale reclamation and subdivision projects on Sherman and Twitchell Islands.).

[85] See, e.g., Response of Joy and Robert Augusto Trust supporting S016918, available at: http://waterboards.ca.gov/water_issues/programs/delta_watermaster/docs/reports/attach_f.pdf; Response of Everett Luiz and Sons Dairy supporting S016530 and S016937, available at: http://waterboards.ca.gov/water_issues/programs/delta_watermaster/docs/reports/attach_g.pdf; Response of Honker Lake Ranch supporting S016906, available at: http://waterboards.ca.gov/water_issues/programs/delta_watermaster/docs/reports/attach_h.pdf.

[86] See Cal. Water Code, § 1201 (allowing for appropriative use of water on non-riparian lands.).

but prior to 1914, the appropriative right would not be subject to the Board's permitting authority.[87] Even if severance took place after 1914, a formerly riparian owner would still have the opportunity to petition for an appropriative right through the permit and licensing process administered by the Board and its predecessors dating back to the Water Commission Act of 1913.[88]

In *Phelps v. State Water Resources Control Board*, the Court of Appeal recognized the evidentiary standard applicable to Delta claimants asserting dual rights.[89] There, the claimants conceded that their properties were non-contiguous to any natural watercourse, and the Court noted that "there was no language in the deeds to show they retained riparian rights in parcels that no longer abut natural watercourses."[90] However, in support of their riparian claims, the claimants argued that surface waters and groundwater were sufficiently connected to establish a riparian connection, and that their predecessors in interest intended to retain riparian rights when acquiring the non-contiguous parcels.[91] The Court of Appeal affirmed the trial court's rejection of these arguments, concluding that the record supported invalidation of the riparian claims.[92] Turning to the claimants' pre-1914 appropriative claims, the Court also affirmed the trial court's finding that the claimants "failed to establish actual appropriation of water for irrigation before 1914," in light of conflicting evidence about the extent of general irrigation practices in the area surrounding their properties.[93] In so holding, the Court essentially demonstrated that water right claims may be rejected where: (1) a claimant's parcel is not contiguous to any natural watercourse, (2) there is no evidence to support a finding of contemporaneous intent to preserve riparian rights for the severed parcel, and (3) there is no evidence to support a finding of actual appropriative use prior to 1914.[94]

In *Modesto Irrigation District v. Tanaka*, the Sacramento Superior Court issued a decision that further illustrates the evidentiary challenges facing Delta claimants.[95] Tanaka, a landowner in the Delta, claimed

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[87] *Temescal Water Company v. Department of Public Works* (1955) 44 Cal.2d 90, 95-97.
[88] *Ibid.*
[89] *Phelps v. State Water Resources Control Board* (2007) 157 Cal.App.4th 89 (hereinafter "*Phelps*").
[90] *Id.* at p. 116-117.
[91] *Ibid.*
[92] *Id.* at p. 117-118.
[93] *Id.* at p. 118-119.
[94] *Id.* at p. 116-119.
[95] *Modesto Irrigation District v. Tanaka* (May 26, 2016) Sacramento Sup. Ct., Case No. 34-2011-00112886, available at:
http://www.waterboards.ca.gov/water_issues/programs/delta_watermaster/docs/midv_tanaka_final160526.pdf (hereinafter "*Tanaka*").

both riparian and pre-1914 rights to divert water for irrigation.[96] Because Tanaka's property was not contiguous to a natural watercourse, the Court considered proffered evidence of contemporaneous intent to preserve a riparian right when the subject parcel was severed from the larger riparian parcel.[97] The claimant submitted evidence of language in the deed transferring interest in the property along with all "tenements, hereditaments and appurtenances thereunto belonging."[98] Finding this language to be "patently silent" as to riparian rights under existing case law,[99] the Superior Court held that the general language in the transfer documents was not sufficient evidence of intent to preserve riparian rights for Tanaka's non-contiguous parcel.[100] Next, in evaluating the alternative pre-1914 claim, the Court looked for evidence of actual appropriative use since prior to 1914.[101] Because the claimant relied on general irrigation practices by her predecessors in interest, and because the evidence indicated that the diversion facilities serving the property had been constructed without a permit after 1914, the Court found no evidence to support either a pre-1914 water right or a permitted or licensed appropriation.[102] It is important to note that the *Tanaka* decision is currently under appeal,[103] and the legal conclusions of the Superior Court are not precedential unless and until affirmed on appeal in a published opinion. However, *Tanaka* is illustrative of the burdens Delta claimants encounter in developing and presenting evidence in support of water right claims on non-contiguous parcels.

Many of the responses to the Information Order by in-Delta water users claiming dual rights appear to mirror the basis of dual claims that was asserted and rejected in *Woods, Phelps,* and *Tanaka*.[104] Because

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[96] *Ibid.*

[97] *Id.* at p. 4-8.

[98] *Id.* at p. 6.

[99] See *Tanaka, supra,* at p. 7 (quoting *Murphy Slough Association v. Avila* (1972) 27 Cal.App.3d 649, 655). Note that, while *Murphy Slough* finds that general "tenements, hereditaments and appurtenances" deed language is "patently silent" as to riparian rights, it acknowledges that the circumstances surrounding a conveyance may demonstrate an intent to preserve riparian rights, even when the transfer documents are silent. The Court in *Tanaka* did not address this basis for proving intent, apparently because no such circumstances were persuasively advanced by the claimant.

[100] *Tanaka, supra,* at p. 8.

[101] *Id.* at p. 14-15.

[102] *Ibid.*

[103] See California Courts, Third Appellate District, Docket for Case No. C083430, available at: http://appellatecases.courtinfo.ca.gov/search/case/dockets.cfm?dist=3&doc_id=2169957&doc_no=C083430 (stating notice of appeal lodged 11/15/2016.).

[104] See, e.g., Response of Joy and Robert Augusto Trust supporting S016918, available at: http://waterboards.ca.gov/water_issues/programs/delta_watermaster/docs/reports/attach_f.pdf; Response of Everett Luiz and Sons Dairy supporting S016530 and S016937, available at: http://waterboards.ca.gov/water_issues/programs/delta_watermaster/docs/reports/attach_g.pdf;

these responses were required to be submitted under relatively short time constraints, many of the responses explicitly reserve the right to provide additional evidence to support their water right claims if their claims are legally challenged. Nonetheless, several of the responses relate to properties that appear to be non-contiguous to natural watercourses assert riparian claims, but submit no evidence demonstrating a contemporaneous intent to preserve riparian rights for non-contiguous parcels.[105] Moreover, like the claimants in *Phelps* and *Tanaka*, many responses rely on long-standing general irrigation practices to support pre-1914 claims instead of documenting specific appropriative use.[106]

E. In times of severe drought, diversions under riparian rights in the Delta could be limited by the availability of natural flow in the Delta channels.

Riparian rights only authorize diversions of "natural flow."[107] However, application of the "natural flow" rule is complicated by the unique physical circumstances in the Delta. First, the Delta is hydrologically connected to the salty water of San Francisco Bay, and beyond that, the Pacific Ocean. In addition, the State Water Project and the Central Valley Project (the "Projects") store and release water that intermingles with water from other sources in natural watercourses throughout the Delta. Therefore, as you and I have observed in the course of recent investigations in the Delta, it is difficult for individual diverters to determine whether the water flowing past their properties is "natural flow" or previously stored water released by the Projects to serve a defined purpose.

(footnote continued from previous page)
Response of Honker Lake Ranch supporting S016906, available at:
http://waterboards.ca.gov/water_issues/programs/delta_watermaster/docs/reports/attach_h.pdf; Response of Bettencourt Farming LLC supporting S016492, available at:
http://waterboards.ca.gov/water_issues/programs/delta_watermaster/docs/reports/attach_i.pdf;
Response of Kurt and Sandra Kautz Family Trust supporting S016909, available at:
http://waterboards.ca.gov/water_issues/programs/delta_watermaster/docs/reports/attach_k.pdf.
[105] See, e.g., Response of Joy and Robert Augusto Trust supporting S016918, available at:
http://waterboards.ca.gov/water_issues/programs/delta_watermaster/docs/reports/attach_f.pdf;
Response of Everett Luiz and Sons Dairy supporting S016530 and S016937, available at:
http://waterboards.ca.gov/water_issues/programs/delta_watermaster/docs/reports/attach_g.pdf;
Response of Honker Lake Ranch supporting S016906, available at:
http://waterboards.ca.gov/water_issues/programs/delta_watermaster/docs/reports/attach_h.pdf.
[106] See, e.g., Response of Bettencourt Farming LLC supporting S016492, available at:
http://waterboards.ca.gov/water_issues/programs/delta_watermaster/docs/reports/attach_i.pdf;
Response of Kurt and Sandra Kautz Family Trust supporting S016909, available at:
http://waterboards.ca.gov/water_issues/programs/delta_watermaster/docs/reports/attach_k.pdf.
[107] *Turner v. James Canal Co.* (1909) 155 Cal. 82, 91; *Chowchilla Farms Inc. v. Martin* (1933) 219 Cal. 1, 19; see also Cal. Water Code, § 1201.

Coupling this difficulty with the language of the Delta Protection Act and the Area of Origin statutes enacted in concert with the development and implementation of the Projects, in-Delta diverters have argued that they are entitled to divert water from the "Delta pool" for agricultural use, without regard to whether "natural flow" is intermingled with previously stored Project water and without regard to whether salty water would invade the "Delta pool" but for Project operations designed to repel salt intrusion.[108] In *State Water Resources Control Board Cases*, the Court of Appeal held that the Projects have the paramount right to reservoir releases of lawfully stored water, notwithstanding the protections provided by the Area of Origin statutes and the Delta Protection Act.[109] Therefore, the "natural flow" available to in-Delta riparians does not extend to any water stored and released by the Projects (water that is "foreign in time"), unless delivery of such water is specifically contracted from the paramount right holder.[110]

V. Conclusion

It is possible to hold both riparian and appropriative rights to use water on a single parcel of riparian land. However, riparian and appropriative rights are validated according to different legal requirements. The exercise of any surface water right in California is subject to the reasonable and beneficial use provisions of the California constitution. As a result, *bona fide* water right claims require evidence of both the elements of the claimed right and the observation of the limitations inherent in the nature of the claimed right.

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[108] See, e.g.*, State Water Resources Control Board Cases* (2006) 39 Cal.Rptr.3d 189, 239-244.
[109] *Id.* at p. 255-267.
[110] *Ibid*.; see also *El Dorado, supra,* 142 Cal.App.4th 937 at 967, 976; *Phelps, supra,* 157 Cal.App.4th 89, 105-111.

ATTACHMENT 4

Daily Full Natural Flows for July 2018

Report generated: July 20, 2018 07:57

Daily Full Natural Flows for July 2018

Day	TRINITY AT CLAIR ENGLE (CLE)	LAKE SHASTA TOTAL INFLOW (SHA)	SACTO AT BEND BRIDGE (BND)	FEATHER AT OROVILLE (ORO)	YUBA AT SMARTVILLE (YRS)	AMERICAN AT FOLSOM (FOL)	COSUMNES AT MICH BAR (MHB)	MOKELUMNE AT PARDEE (MKM)
01	329	1,836	3,382	1,916	489	922	60	92
02	33	2,815	5,616	2,410	480	1,228	58	170
03	-250	3,443	4,828	1,728	586	640	56	145
04	121	3,360	3,853	1,286	456	306	54	92
05	-61	3,139	5,006	2,160	479	386	53	108
06	195	3,099	2,904	1,634	510	435	53	152
07	117	3,157	4,537	1,444	455	385	52	90
08	134	3,191	3,928	1,821	436	433	48	154
09	-11	2,598	4,344	1,291	436	358	47	30
10	201	3,227	4,221	1,445	397	358	46	42
11	405	3,040	4,602	973	507	588	44	123
12	201	2,858	4,272	1,469	524	418	43	120
13	296	3,661	3,765	1,503	347	373	42	77
14	372	3,131	3,011	1,387	464	992	42	154
15	57	3,185	4,862	1,043	510	471	41	36
16	21	2,668	3,722	1,153	417	199	41	101
17	365	3,210	4,587	1,452	448	840	39	103
18	88	2,886	4,622	1,160		190	37	
19	189	2,764	3,172			411	35	
20								
21								
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23								
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26								
27								
28								
29								
30								
31								
Total To Date (in AC-FT)	5,558	113,591	157,161	54,100	15,751	19,702	1,767	3,548
Daily Average (in CFS)	147	3,014	4,170	1,515	467	523	47	105
Historic Monthly Average (in CFS)	724	3,994	5,090	2,465	946	1,097	75	544
% of Historic Average	20	75	82	61	49	48	63	19

Daily Full Natural Flows for July 2018

Day	STANISLAUS AT GOODWIN (GDW)	TUOLUMNE AT DON PEDRO (TLG)	MERCED AT MCCLURE (MRC)	SAN JOAQUIN AT MILLERTON (MIL)	KINGS AT PINE FLAT (PNF)	KAWEAH AT TERMINUS (TRM)	TULE AT SUCCESS (SCC)	KERN AT ISABELLA (ISB)
01	712	1,310	465	1,439	1,326	225	13	522
02	548	600	344	1,440	705	122	16	515
03	833	1,044	355	1,254	1,283	144	4	550
04	132	373	352	1,302	1,234	126	27	492
05	487	1,067	221	1,321	1,135	53	25	493
06	531	306	363	832	1,104	248	24	467
07	462	918	306	1,015	1,717	116	17	449
08	452	262	207	1,587	1,064	104	25	419
09	382	494	233	595	1,025	130	21	405
10	436	249	221	826	1,022	150	32	453
11	625	872	269	998	908	147	28	474
12	419	414	217	1,195	1,143	-11	21	557
13	386	352	268	1,746	1,444	236	37	574
14	379	890	256	1,717	1,513	123	42	700
15	386	614	372	1,530	1,301	195	39	611
16	309	489	257	1,226	1,155	42	42	638
17	482	448	198	871	1,206	127	46	515
18	389	361	264	968	580	142	44	562
19		798			1,312	121	51	497
20								
21								
22								
23								
24								
25								
26								
27								
28								
29								

30
31

Total To Date (in AC-FT)

16,562	23,526	10,251	43,363	43,986	5,038	1,099	19,623

Daily Average (in CFS)

464	624	287	1,215	1,167	134	29	521

Historic Monthly Average (in CFS)

912	2,204	1,057	3,023	2,930	570	78	1,198

% of Historic Average

51	28	27	40	40	23	37	43

Notes

- Full Natural Flow" or "Umimpaired Runoff" represents the natural water production of a river basin, unaltered by upstream diversions, storage, or by export or import of water to or from other watersheds. Gauged flows at the given measurement points are increased or decreased to account for these upstream operations. The flows reported here are based on calculations done by project operators on the respective rivers, the US Army Corps of Engineers and/or Snow Surveys.

- Daily Full Natural Flow (FNF) calculations are based on less data than is available at the completion of each month. The sum of daily FNF reported here will not exactly match the calculated monthly FNF reported on the seasonal and water year reports. Due to the lag between the effect of upstream operations and downstream flow measurements, calculated daily FNF will fluctuate from day to day.

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ATTACHMENT 5

Instream Flow Studies for the Protection
of Public Trust Resources:

A Prioritized Schedule and Estimate of Costs

Submitted In Accordance with the
Requirements of Water Code Section 85087

December 2010

STATE OF CALIFORNIA
Arnold Schwarzenegger, Governor

CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY
Linda S. Adams, Secretary

**STATE WATER RESOURCES
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Instream Flow Studies for the Protection of Public Trust Resources:

A Prioritized Schedule and Estimate of Costs

Executive Summary

Chapter 5 of the 2009-10 Seventh Extraordinary Session (SB X7 1, Simitian) directs the State Water Resources Control Board (State Water Board) to submit to the Legislature, by December 31, 2010, a prioritized schedule and estimate of costs to complete instream flow studies for two categories of rivers and streams, by two specific deadlines:

1) high priority rivers and streams in the Delta watershed that were not covered in the Board's "Final Report on Development of Flow Criteria for the Sacramento-San Joaquin Delta Ecosystem" by 2012; and
2) all major rivers and streams outside the Sacramento River watershed by 2018.

The definition of the two stream categories is ambiguous. There are a number of tributaries that are both in the Delta watershed and outside the Sacramento River watershed, including the San Joaquin, Calaveras, Cosumnes, and Mokelumne Rivers. The State Water Board interprets the first category to mean all Delta and Sacramento River tributaries not covered under the Board's "Final Report on Development of Flow Criteria for the Sacramento-San Joaquin Delta Ecosystem." Two additional schedules are prioritized for "all major rivers and streams outside the Sacramento River watershed."

This report identifies 138 rivers and streams for instream flow studies. The total estimated cost to conduct scientific instream flow studies for the high priority rivers and streams tributary to the Delta is $32.46 million. The total estimated cost to conduct scientific instream flow studies for the high priority rivers and streams outside the Delta watershed is $107.25 million. The detailed schedules and costs are preceded with a few short discussions on the timelines given in the directive, the organization of schedules, the cost estimates for instream flow studies, and cost estimates for the next logical step: setting instream flow objectives.

I.   Timelines for Instream Flow Studies

To comply with requirements of Chapter 5/X7 2009, the Board provides three schedules in this report:

Schedule 1 is for High Priority Rivers and Streams Tributary to the Sacramento River and Delta. Schedules 2 and 3 are for High Priority Rivers and Streams Outside the Sacramento River and Delta Watershed that Support Anadromous Species and Nonanadromous species respectively. Although the Chapter 5/X7 2009 calls for a

completion date for Schedule 1 waterbodies in 2012 and a completion date for Schedule 2 and Schedule 3 waterbodies in 2018, the State Water Board notes, that these deadlines are unrealistic. An instream flow study rooted in sound science requires at least three years of sampling and monitoring. The 2012 deadline would allow for a maximum of one and a half years of study. Realistically, completing instream flow studies and preparing flow recommendations for all rivers and streams listed in this report is a project that will take substantial time to complete.

II. Organization of Schedules and Prioritization Criteria

In developing these schedules, the State Water Board has coordinated with the Department of Fish and Game (as required by Water Code Section 85087) as well as the Regional Water Resources Control Boards (Regional Water Boards). To prioritize the schedules, the State Water Board determined that those streams which serve as habitat for threatened and endangered California anadromous fish, such as coho and chinook salmon and steelhead trout, should be prioritized for instream flow studies. Some of the rivers and streams listed may no longer support anadromous populations. These water bodies are included in the list as candidates for restoration of anadromous populations. Inland streams that do not generally support anadromous populations are prioritized in a separate schedule. Rivers and streams which are located within the habitat range of declining native amphibian and reptile populations, such as the California Red-Legged Frog and Western Pond Turtle, are noted. The presence of these species across all three schedules demonstrates a shared ecological concern between different regions of the state.

- ***Schedule 1 – High Priority Rivers and Streams Tributary to the Sacramento River and Delta.*** There are two priority groups in this schedule. Priority 1 includes rivers and streams that serve as habitat for spring-run chinook salmon. Spring-run Chinook are more adversely affected by lack of flow than fall-run Chinook because they enter fresh waterways as the dry season begins.

- ***Schedule 2 – High Priority Rivers and Streams Outside the Sacramento River and Delta Watershed that Support Anadromous Species***. There are two priority groups in this schedule. Priority 1 includes rivers and streams that serve as habitat for either Coho Salmon, or Southern California Steelhead. Coho salmon are more sensitive than Chinook or Steelhead. Their range is limited to the North Coast, where they are federally listed as threatened, and the Central Coast where they are federally listed as endangered. Southern California Steelhead are federally listed as endangered.

- ***Schedule 3 – High Priority Rivers and Streams Outside the Sacramento River and Delta Watershed that Support Non-Anadromous Species.*** The rivers and streams in this schedule do not generally serve as habitat for the anadromous species used to prioritize the rest of the schedules. There are two priority groups in this schedule. Priority 1 includes rivers and streams that serve as habitat for the Lahontan Cutthroat Trout, a federally listed threatened species, as well as the Lost

River, which is the sole habitat of the Lost River Sucker, a federally listed endangered species. All other rivers and streams in Schedule 3 list species that are endemic to the Lahontan region and are sensitive according to the California Natural Diversity Database.

Table A summarizes the total estimated costs to conduct these instream flow studies. The specific rivers and streams identified for study are listed in alphabetical order within Table B, C and D.

III. Cost Estimates for Contracted Instream Flow Studies

Given the ecological diversity of the watersheds represented in this list, a generic cost estimate to complete instream flow studies state-wide is difficult to determine. The studies required for any given stream would need to be tailored on a case-by-case basis after the stream has been physically examined. Scientific studies would need to be accomplished through contracted consultants. This means that there are two distinct costs associated with this endeavor: (1) staffing costs to manage the contracts and coordinate the studies, and (2) costs associated with the actual contracted activities themselves. Contracted activities that may need to occur in an instream flow study are flow/habitat modeling, spawning gravel studies, fish passage studies, water temperature monitoring/modeling, developing timing of pulse flows, and compilation of hydrology. The length of study also factors into the cost. Some streams may require longer study periods than others, depending on the complexities of the habitat.

The staffing required to oversee the consultants and manage the contracts also depends on the complexity of the studies required. Out of necessity, the cost estimates included in this report are highly generalized. Each stream is rated on an estimated range of costs:

- *High Cost Range:* the contract cost estimate of instream flow studies is in a range of $800,000 - $2 million. For this category, the State Water Board would require one staff position, costing $150,000 annually to manage the studies for two rivers. Using one individual, over an average three year study period, amounts to $450,000 in staffing costs to manage the study contracts for two rivers or streams.

- *Mid Cost Range:* the contract cost estimate of instream flow studies is in a range of $400,000 – $800,000. For this category, the State Water Board would require one staff position, costing $150,000 annually to manage the contracts for studies of three rivers or streams. Over an average three year study period, consequently, one position and $450,000 would be needed, for three rivers or streams.

- *Low Cost Range:* the contract cost estimate of instream flow studies is in a range of $150,000 - $400,000. For this category, the State Water Board would require one staff position, costing $150,000 annually to manage the studies of four rivers or streams. Over an average three year, study period, consequently, the State Water

Board would need $450,000 to fund a staff position to manage the study contracts for four rivers or streams.

The dollar amount in each schedule summary is based on the high end of each cost estimate range. Staffing and staff cost estimates are prorated to the number of rivers and streams in each priority grouping as described above.

Potential Cost Savings and Existing Studies

The cost estimates included in this report do not reflect studies that already may be in existence for certain streams that would reduce the costs of conducting the instream flow studies. Significant cost savings would be achieved by partnering with organizations already undertaking studies and relying upon existing studies and information that has already been collected and, in some cases, also analyzed. For example, information on instream flow needs in the American River is available in a Surface Water Resources, Inc. report prepared for the Water Forum: *A Draft Policy Document for the Lower American River Flow Management Standard.* The cost for instream flow studies in the American River may, therefore, be far less than the high cost estimate of $800,000 to $2 million, if the State Water Board can rely upon the information summarized in this report. Contacting stakeholders and reviewing existing information are, therefore, necessary first steps prior to initiating any new studies.

IV. Cost Estimates for Setting Instream Flow Objectives

Streamflow studies do not result in additional streamflow. If existing streamflows are insufficient to meet environmental needs, voluntary or regulatory actions are necessary to ensure that the flows are made available. After conducting instream flow studies, the next logical step[1] would be to set instream flow objectives as part of the regulatory framework needed to prevent further ecological damage to the Delta or other California rivers and streams. Streamflow objectives can be set administratively either as part of the State Water Board's planning processes, which would then require subsequent implementation actions, or directly as the result of a regulatory water rights action taken to amend specific water right permits and licenses. In either case, the activity would require compliance with: (1) the California Environmental Quality Act (CEQA), (2) the Water Code, and (3) the Administrative Procedures Act, as well as other regulatory requirements. A wide range of costs could occur as a result of these processes. A simple case with a smaller watershed and limited water use would cost approximately $600,000. A larger watershed with more complex water use issues would cost several million dollars.

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[1] The Board notes that partnering with other agencies and organizations may open opportunities for potential solutions that have not been tried before. The point of this section is that further steps beyond the completion of studies will likely be required to protect flows.

Summary of Cost Estimates (Table A)

	Contract Oversight Staffing Estimate	Contracted Scientific Studies Estimate	Total Cost Estimate for Studies and Study Oversight
Schedule 1 (Table B) **High-priority Rivers and Streams Tributary to the Sacramento River and Delta**			
Priority Group 1	$4.16 million	$26.4 million	$30.56 million
Priority Group 2	$300,000	$1.6 million	$1.9 million
	Total Estimated Costs for Schedule 1		**$32.46 million**
Schedule 2 (Table C) **High Priority Rivers and Streams that Support Anadromous Species**			
Priority Group 1	$10.39 million	$60.8 million	$71.19 million
Priority Group 2	$2.36 million	$13.2 million	$15.56 million
	Total Estimated Costs for Schedule 2		**$86.75 million**
Schedule 3 (Table D) **High Priority Rivers and Streams that Support Only Non-Anadromous Species**			
Priority Group 1	$1.12 million	$4.8 million	$5.92 million
Priority Group 2	$2.17 million	$12.4 million	$14.57 million
	Total Estimated Costs for Schedule 3		**$20.5 million**

V.   Detailed Stream Lists with Instream Flow Studies Cost Estimate Range
Schedule 1 (Table B) High Priority Rivers and Streams Tributary to the Sacramento River and Delta

Water Body	Priority Group	Threatened, Endangered, and Sensitive Aquatic Species Present (or Historically Present) and Other Rationale for Inclusion	Estimated Cost Range for Contracted Studies and Potential Cost Savings [1]
American River	1	▪ Central Valley Spring Chinook Salmon, Fall Chinook Salmon, Central Valley Steelhead Trout, Sierra Nevada Yellow-Legged Frog, Foothill Yellow Legged-Frog, California Red-Legged Frog, Western Pond Turtle ▪ Stream identified by NMFS in 2009 Draft Recovery Plan ▪ Stream identified by USFWS in 2001 Restoration Plan	▪ High ($800,000 - $2,000,000) ▪ As noted in the text of this report, there are studies underway for lower American River by the Water Forum. Anticipated release of a Draft EIR in summer 2011.
Antelope Creek (Tributary to Sacramento River near Red Bluff)	1	▪ Central Valley Spring Chinook Salmon, Central Valley Steelhead Trout, Foothill Yellow-Legged Frog, California Red-Legged Frog, Western Pond Turtle ▪ Stream identified by NMFS in 2009 Draft Recovery Plan ▪ Stream identified by USFWS in 2001 Restoration Plan	▪ Mid ($400,000 - $800,000)
Battle Creek (Tributary to Sacramento River)	1	▪ Sacramento River Winter Chinook Salmon, Central Valley Spring Chinook Salmon, Central Valley Steelhead Trout, Green Sturgeon, Foothill Yellow-Legged Frog, California Red-Legged Frog, Western Pond Turtle ▪ Stream identified by NMFS in 2009 Draft Recovery Plan ▪ Stream identified by USFWS in 2001 Restoration Plan	▪ Mid ($400,000 - $800,000)
Bear River (Tributary to Feather River)	1	▪ Central Valley Spring Chinook Salmon, Central Valley Steelhead Trout, Sierra Nevada Yellow-Legged Frog, Foothill Yellow-Legged Frog, Western Pond Turtle ▪ Stream identified by NMFS in 2009 Draft Recovery Plan ▪ Stream identified by DFG in 2008 Priority Streams List	▪ Low ($150,000 - $400,000)
Big Chico Creek	1	▪ Sacramento River Winter Chinook Salmon, Central Valley Spring Chinook Salmon, Central Valley Steelhead Trout, Foothill Yellow-Legged Frog, California Red-Legged Frog, Western Pond Turtle ▪ Stream identified by NMFS in 2009 Draft Recovery Plan ▪ Stream identified by USFWS in 2001 Restoration Plan	▪ Low ($150,000 - $400,000)

[1] Note: until all stakeholders for each stream are contacted, and an evaluation of existing information is complete, a true picture of potential cost savings will not be possible.

Water Body	Priority Group	Threatened, Endangered, and Sensitive Aquatic Species Present (or Historically Present) and Other Rationale for Inclusion	Estimated Cost Range for Contracted Studies and Potential Cost Savings [1]
Lower Butte Creek	1	▪ Central Valley Spring Chinook Salmon, Central Valley Steelhead Trout, Foothill Yellow-Legged Frog, California Red-Legged Frog, Western Pond Turtle ▪ Stream identified by NMFS in 2009 Draft Recovery Plan ▪ Stream identified by USFWS in 2001 Restoration Plan ▪ Stream identified by DFG in 2008 Priority Streams List	▪ Mid ($400,000 - $800,000)
Calaveras River	2	▪ Fall Chinook Salmon, Central Valley Steelhead Trout, Sierra Nevada Yellow-Legged Frog, Foothill Yellow-Legged Frog, California Red-Legged Frog, Western Pond Turtle ▪ Stream identified by NMFS in 2009 Draft Recovery Plan ▪ Stream identified by USFWS in 2001 Restoration Plan	▪ Mid ($400,000 - $800,000)
Clear Creek	1	▪ Central Valley Spring Chinook Salmon, Central Valley Steelhead Trout ▪ Stream identified by NMFS in 2009 Draft Recovery Plan ▪ Stream identified by USFWS in 2001 Restoration Plan	▪ Low ($150,000 - $800,000)
Cosumnes River	2	▪ Fall Chinook Salmon, Central Valley Steelhead Trout, Foothill Yellow-Legged Frog, California Red-Legged Frog, Western Pond Turtle ▪ Stream identified by NMFS in 2009 Draft Recovery Plan ▪ Stream identified by USFWS in 2001 Restoration Plan	▪ Mid ($400,000 - $800,000)
Cottonwood Creek (two forks, tributary to Sacramento River)	1	▪ Central Valley Spring Chinook Salmon, Central Valley Steelhead Trout, Foothill Yellow-Legged Frog, California Red-Legged Frog, Western Pond Turtle ▪ Stream identified by NMFS in 2009 Draft Recovery Plan ▪ Stream identified by USFWS in 2001 Restoration Plan	▪ Low ($150,000 - $400,000)
Cow Creek (Tributary to Sacramento River)	1	▪ Fall Chinook Salmon, Central Valley Spring Chinook Salmon, Central Valley Steelhead Trout, Foothill Yellow-Legged Frog, California Red-Legged Frog, Western Pond Turtle ▪ Stream identified by NMFS in 2009 Draft Recovery Plan ▪ Stream identified by USFWS in 2001 Restoration Plan	▪ Mid ($400,000 - $800,000)
Deer Creek (Tributary to Sacramento River)	1	▪ Central Valley Spring Chinook Salmon, Central Valley Steelhead Trout, Foothill Yellow-Legged Frog, California Red-Legged Frog, Western Pond Turtle ▪ Stream identified by NMFS in 2009 Draft Recovery Plan ▪ Stream identified by USFWS in 2001 Restoration Plan	▪ Mid ($400,000 - $800,000)

Water Body	Priority Group	Threatened, Endangered, and Sensitive Aquatic Species Present (or Historically Present) and Other Rationale for Inclusion	Estimated Cost Range for Contracted Studies and Potential Cost Savings [1]
Fall River	1	▪ Sacramento River Winter Chinook Salmon, Central Valley Spring Chinook Salmon, Central Valley Steelhead Trout ▪ Stream identified by NMFS in 2009 Draft Recovery Plan	▪ Low ($150,000 - $400,000)
Lower Feather River	1	▪ Central Valley Spring Chinook Salmon, Central Valley Steelhead Trout ▪ Stream identified by NMFS in 2009 Draft Recovery Plan ▪ Stream identified by USFWS in 2001 Restoration Plan	▪ Low ($150,000 - $800,000)
Hat Creek	1	▪ Sacramento River Winter Chinook Salmon, Central Valley Spring Chinook Salmon, Central Valley Steelhead Trout ▪ Stream identified by NMFS in 2009 Draft Recovery Plan	▪ Low ($150,000 - $400,000)
Little Sacramento - Above Shasta	1	▪ Sacramento River Winter Chinook Salmon, Central Valley Spring Chinook Salmon, Central Valley Steelhead Trout ▪ Stream identified by NMFS in 2009 Draft Recovery Plan	▪ Mid ($400,000 - $800,000)
McCloud River	1	▪ Sacramento River Winter Chinook Salmon, Central Valley Spring Chinook, Central Valley Steelhead Trout ▪ Stream identified by NMFS in 2009 Draft Recovery Plan	▪ Mid ($400,000 - $800,000)
Merced River	1	▪ Central Valley Spring Chinook, Fall Chinook Salmon, Central Valley Steelhead Trout, Yosemite Toad, Sierra Nevada Yellow-Legged Frog, Foothill Yellow-Legged Frog, California Red-Legged Frog, Western Pond Turtle ▪ Stream identified by NMFS in 2009 Draft Recovery Plan ▪ Stream identified by USFWS in 2001 Restoration Plan ▪ Stream identified by DFG in 2008 Priority Streams List	▪ High ($800,000 - $2,000,000)
Mill Creek (Tributary to Sacramento River)	1	▪ Central Valley Spring Chinook Salmon, Central Valley Steelhead Trout, Foothill Yellow-Legged Frog, California Red-Legged Frog, Western Pond Turtle ▪ Stream identified by NMFS in 2009 Draft Recovery Plan ▪ Stream identified by USFWS in 2001 Restoration Plan	▪ High ($800,000 - $2,000,000)
Mokelumne River	1	▪ Central Valley Spring Chinook Salmon, Fall Chinook Salmon, Central Valley Steelhead Trout, Sierra Nevada Yellow-Legged Frog, California Red-Legged Frog, Western Pond Turtle ▪ Stream identified by NMFS in 2009 Draft Recovery Plan ▪ Stream identified by USFWS in 2001 Restoration Plan	▪ Mid ($400,000 - $800,000)
Pit River	1	▪ Sacramento River Winter Chinook Salmon, Central Valley Spring Chinook, Central Valley Steelhead Trout ▪ Stream identified by NMFS in 2009 Draft Recovery Plan	▪ Mid ($400,000 - $800,000)

Water Body	Priority Group	Threatened, Endangered, and Sensitive Aquatic Species Present (or Historically Present) and Other Rationale for Inclusion	Estimated Cost Range for Contracted Studies and Potential Cost Savings[1]
Interdam Sacramento – Shasta to Keswick	1	• Sacramento River ESU Winter Chinook Salmon, Central Valley Spring Chinook, Central Valley Steelhead Trout • Stream identified by NMFS in 2009 Draft Recovery Plan	• Mid ($400,000 - $800,000)
Upper Sacramento - - Keswick to Red Bluff	1	• Sacramento River Winter Chinook Salmon, Central Valley Spring Chinook Salmon, Central Valley Steelhead Trout • Stream identified by NMFS in 2009 Draft Recovery Plan • Stream identified by USFWS in 2001 Restoration Plan	• Mid ($400,000 - $800,000)
Lower San Joaquin (below Merced River)	1	• Central Valley Spring Chinook Salmon, Fall Chinook Salmon, Central Valley Steelhead Trout, Green Sturgeon, Foothill Yellow-Legged Frog, California Red-Legged Frog, Western Pond Turtle • Stream identified by NMFS in 2009 Draft Recovery Plan • Stream identified by USFWS in 2001 Restoration Plan	• High ($800,000 - $2,000,000)
Upper San Joaquin River	1	• Central Valley Spring Chinook Salmon, Fall Chinook Salmon, Central Valley Steelhead Trout, Green Sturgeon, Sierra Nevada Yellow-Legged Frog, Foothill Yellow-Legged Frog, California Red-Legged Frog, Western Pond Turtle • Stream identified by NMFS in 2009 Draft Recovery Plan • Stream identified by USFWS in 2001 Restoration Plan	• High ($800,000 - $2,000,000)
Stanislaus River	1	• Central Valley Spring Chinook Salmon, Fall Chinook Salmon, Central Valley Steelhead Trout, Yosemite Toad, Sierra Nevada Yellow-Legged Frog, California Red-Legged Frog, Western Pond Turtle • Stream identified by NMFS in 2009 Draft Recovery Plan • Stream identified by USFWS in 2001 Restoration Plan	• High ($800,000 - $2,000,000)
Tuolumne River	1	• Central Valley Spring Chinook Salmon, Fall Chinook Salmon, Central Valley Steelhead Trout, Steelhead Trout, Yosemite Toad, Sierra Nevada Yellow-Legged Frog, Foothill Yellow-Legged Frog, California Red Legged Frog, Western Pond Turtle • Stream identified by NMFS in 2009 Draft Recovery Plan • Stream identified by USFWS in 2001 Restoration Plan • Stream identified by DFG in 2008 Priority Streams List	• High ($800,000 - $2,000,000)
Yuba River	1	• Central Valley Spring Chinook Salmon, Central Valley Steelhead Trout • Stream identified by NMFS in 2009 Draft Recovery Plan • Stream identified by USFWS in 2001 Restoration Plan	• Mid ($400,000 - $800,000)

Schedule 2 (Table C) High Priority Rivers and Streams that Support Anadromous Species

Water Body	Priority Group	Threatened, Endangered, and Sensitive Aquatic Species Present (or Historically Present) and Other Rationale for Inclusion	Estimated Cost Range for Contracted Studies and Potential Cost Savings[2]
Alameda Creek	2	- Winter Steelhead Trout, Foothill Yellow-Legged Frog, California Red-Legged Frog, Western Pond Turtle - Stream identified by CEMAR in 2007 Watershed Evaluation	Low ($150,000 - $400,000)
Albion River	1	- Coho Salmon, Winter Steelhead Trout, Foothill Yellow-Legged Frog, California Red-Legged Frog, Western Pond Turtle - Stream identified by DFG in 2004 Recovery Plan - Stream identified by NMFS in 2010 Recovery Plan	Mid ($400,000 - $800,000)
Aptos Creek	1	- Coho Salmon, Winter Steelhead Trout, Foothill Yellow-Legged Frog, California Red-Legged Frog, Western Pond Turtle - Stream identified by DFG in 2004 Recovery Plan - Stream identified by NMFS in 2010 Recovery Plan - Low water levels in summer months	Mid ($400,000 - $800,000)
Arroyo de la Cruz (San Luis Obispo County)	2	- Winter Steelhead Trout, Foothill Yellow-Legged Frog, California Red-Legged Frog, Western Pond Turtle - Watershed may be developed in the near future	Low ($150,000 - $400,000)
Arroyo Siquit	1	- Southern Steelhead Trout, California Red-Legged Frog - Stream identified by NMFS in 2009 Public Review Draft Recovery Plan	Low ($150,000 - $400,000)
Bear Creek (Tributary to West Fork San Gabriel)	1	- Southern Steelhead Trout, Western Pond Turtle - Stream identified by NMFS in 2009 Public Review Draft Recovery Plan	Low ($150,000 - $400,000)
Bear River (Humboldt County)	1	- Coho Salmon, Chinook Salmon, Steelhead Trout, Foothill Yellow-Legged Frog, Northwestern Salamander, Western Pond Turtle - Stream identified by DFG in 2004 Recovery Plan	Low ($150,000 - $400,000)
Big River (Two Forks)	1	- Coho Salmon, Winter Steelhead Trout, Foothill Yellow-Legged Frog, California Red-Legged Frog, Western Pond Turtle - Stream identified by DFG in 2004 Recovery Plan	High ($800,000 - $2,000,000)

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[2] Note: until all stakeholders for each stream are contacted, and an evaluation of existing information is complete, a true picture of potential cost savings will not be possible.

Water Body	Priority Group	Threatened, Endangered, and Sensitive Aquatic Species Present (or Historically Present) and Other Rationale for Inclusion	Estimated Cost Range for Contracted Studies and Potential Cost Savings[2]
		• Stream identified by NMFS in 2010 Recovery Plan	
Big Sur River	2	• Winter Steelhead Trout, California Red-Legged Frog, Western Pond Turtle • Stream identified by DFG in 2008 Priority Streams List	• High ($800,000 - $2,000,000)
Carmel River	2	• Winter Steelhead Trout, California Red-Legged Frog, Western Pond Turtle • Stream identified by DFG in 2008 Priority Streams List	• Mid ($400,000 - $800,000)
Carpinteria Creek	1	• Southern Steelhead Trout, Foothill Yellow-Legged Frog, California Red-Legged Frog, Western Pond Turtle • Stream identified by DFG in 2008 Priority Streams List • Stream identified by NMFS in 2009 Public Review Draft Recovery Plan	• Low ($150,000 - $400,000)
Conejo Creek	1	• Southern Steelhead Trout, California Red-Legged Frog • Stream identified by NMFS in 2009 Public Review Draft Recovery Plan	• Low ($150,000 - $400,000)
Coyote Creek (Marin County)	2	• Winter Steelhead Trout, California Red-Legged Frog, Western Pond Turtle • Stream identified by CEMAR in 2007 Watershed Evaluation	• Low ($150,000 - $400,000)
Dos Pueblos Canyon Creek	1	• Southern Steelhead Trout, California Red-Legged Frog, Western Pond Turtle • Stream identified by DFG in 2008 Priority Streams List • Stream identified by NMFS in 2009 Public Review Draft Recovery Plan	• Low ($150,000 - $400,000)
Dume Creek (Zuma Canyon, Los Angeles County)	1	• Southern Steelhead Trout, California Red-Legged Frog, Western Pond Turtle • Stream identified by NMFS in 2009 Public Review Draft Recovery Plan	• Low ($150,000 - $400,000)
South Fork Eel River	1	• Coho Salmon, Fall Chinook Salmon, Steelhead Trout, Foothill Yellow-Legged Frog, Northwestern, Salamander, Western Pond Turtle • Stream identified by DFG in 2004 Recovery Plan	• High ($800,000 - $2,000,000)
Middle Fork Eel River	1	• Coho Salmon, Chinook Salmon, Winter and Summer Steelhead Trout, Foothill Yellow-Legged Frog, Northwestern Salamander, Western Pond Turtle • Stream identified by DFG in 2004 Recovery Plan	• High ($800,000 - $2,000,000)

Water Body	Priority Group	Threatened, Endangered, and Sensitive Aquatic Species Present (or Historically Present) and Other Rationale for Inclusion	Estimated Cost Range for Contracted Studies and Potential Cost Savings[2]
Lower Eel River	1	▪ Coho Salmon, Chinook Salmon, Steelhead Trout, Green Sturgeon, Foothill Yellow-Legged Frog, Northwestern Salamander, Western Pond Turtle ▪ Stream identified by DFG in 2004 Recovery Plan	▪ Mid ($400,000 - $800,000) ▪
Middle Main Eel River	1	▪ Coho Salmon, Chinook Salmon, Steelhead Trout, Foothill Yellow-Legged Frog, Northwestern Salamander, Western Pond Turtle ▪ Stream identified by DFG in 2004 Recovery Plan	▪ Mid ($400,000 - $800,000) ▪
North Fork Eel River	2	▪ Chinook Salmon, Steelhead Trout, Foothill Yellow-Legged Frog, Northwestern Salamander, Western Pond Turtle	▪ Mid ($400,000 - $800,000) ▪
Upper Main Eel River	1	▪ Coho Salmon, Chinook Salmon, Steelhead Trout, Foothill Yellow-Legged Frog, Northwestern Salamander, Western Pond Turtle ▪ Stream identified by DFG in 2004 Recovery Plan	▪ Low ($150,000 - $400,000)
Escondido Canyon Creek (Los Angeles County)	1	▪ Southern Steelhead Trout, California Red-Legged Frog, Western Pond Turtle ▪ Stream identified by NMFS in 2009 Public Review Draft Recovery Plan	▪ Low ($150,000 - $400,000)
Fish Fork (Tributary to San Gabriel)	1	▪ Southern Steelhead Trout, Western Pond Turtle	▪ Low ($150,000 - $400,000)
Garcia River	1	▪ Coho Salmon, Pink Salmon, Winter Steelhead Trout, California Red-Legged Frog, Northwestern Salamander, Western Pond Turtle ▪ Stream identified by DFG in 2004 Recovery Plan ▪ Stream identified by NMFS in 2010 Recovery Plan	▪ Mid ($400,000 - $800,000) ▪
Gazos Creek	1	▪ Coho Salmon, Winter Steelhead Trout, Foothill Yellow-Legged Frog, California Red-Legged Frog, Western Pond Turtle ▪ Stream identified by DFG in 2004 Recovery Plan ▪ Stream identified by NMFS in 2010 Recovery Plan	▪ Low ($150,000 - $400,000)
Guadalupe River	2	▪ Winter Steelhead Trout, California Red-Legged Frog, Western Pond Turtle ▪ Stream identified by CEMAR in 2007 Watershed Evaluation	▪ Mid ($400,000 - $800,000) ▪
Gualala River	1	▪ Coho Salmon, Winter Steelhead Trout, California Red-Legged Frog, Foothill Yellow-Legged Frog, Western Pond	▪ Mid ($400,000 - $800,000) ▪

Water Body	Priority Group	Threatened, Endangered, and Sensitive Aquatic Species Present (or Historically Present) and Other Rationale for Inclusion	Estimated Cost Range for Contracted Studies and Potential Cost Savings[2]
		Turtle ▪ Stream identified by DFG in 2004 Recovery Plan ▪ Stream identified by NMFS in 2010 Recovery Plan	
Hopper Canyon Creek	1	▪ Southern Steelhead Trout, California Red-Legged Frog, Foothill Yellow-Legged Frog, Arroyo Toad, Western Pond Turtle	▪ Low ($150,000 - $400,000)
Middle Klamath River	1	▪ Coho Salmon, Winter and Summer Steelhead Trout, Green Sturgeon, Foothill Yellow-Legged Frog, Western Pond Turtle ▪ Stream identified by DFG in 2004 Recovery Plan	▪ High ($800,000 - $2,000,000)
Lower Klamath River	1	▪ Coho Salmon, Winter and Summer Steelhead Trout, Green Sturgeon, Shortnose Sucker, Foothill Yellow-Legged Frog, Western Pond Turtle ▪ Stream identified by DFG in 2004 Recovery Plan	▪ Mid ($400,000 - $800,000) ▪
Lagunitas Creek	1	▪ Coho Salmon, Winter Steelhead Trout, Foothill Yellow-Legged Frog, California Red-Legged Frog, Western Pond Turtle ▪ Stream identified by DFG in 2004 Recovery Plan ▪ Stream identified by NMFS in 2010 Recovery Plan	▪ Mid ($400,000 - $800,000) ▪
Lake Casitas Tributaries	1	▪ Southern Steelhead Trout, California Red-Legged Frog, Yellow-Legged Frog, Western Pond Turtle	▪ Mid ($400,000 - $800,000) ▪
Little River	1	▪ Coho Salmon, Chinook Salmon, Steelhead Trout, California Red-Legged Frog, Foothills Yellow-Legged Frog, Northwestern Salamander, Western Pond Turtle ▪ Stream identified by DFG in 2004 Recovery Plan	▪ Mid ($400,000 - $800,000) ▪
Los Alisos Canyon Creek	1	▪ Southern Steelhead Trout, California Red-Legged Frog, Western Pond Turtle	▪ Low ($150,000 - $400,000)
Malibu Creek	1	▪ Southern Steelhead Trout, Tidewater Goby, California Red-Legged Frog, Western Pond Turtle ▪ Stream identified by NMFS in 2009 Public Review Draft Recovery Plan	▪ Low ($150,000 - $400,000)
Matilija Creek (Two Forks)	1	▪ Southern Steelhead Trout, Foothill Yellow-Legged Frog, California Red-Legged Frog, Western Pond Turtle, Arroyo Toad ▪ Stream identified by NMFS in 2009 Public Review Draft Recovery Plan	▪ Mid ($400,000 - $800,000) ▪

Water Body	Priority Group	Threatened, Endangered, and Sensitive Aquatic Species Present (or Historically Present) and Other Rationale for Inclusion	Estimated Cost Range for Contracted Studies and Potential Cost Savings[2]
Mattole River	1	- Coho Salmon, Chinook Salmon, Steelhead Trout, Foothill Yellow-Legged Frog, Northwestern Salamander, Western Pond Turtle - Stream identified by DFG in 2004 Recovery Plan - Stream identified by DFG in 2008 Priority Streams List	- High ($800,000 - $2,000,000) - Streamflow enhancement projects in the Mattole Headwaters are in progress by Trout Unlimited.
Murietta Canyon Creek	1	- Southern Steelhead Trout, California Red-Legged Frog, Yellow-Legged Frog, Western Pond Turtle, Arroyo Toad - Stream identified by NMFS in 2009 Public Review Draft Recovery Plan	Low ($150,000 - $400,000)
Napa River	2	- Winter Steelhead Trout, Chinook Salmon, Foothill Yellow-Legged Frog, California Red-Legged Frog, Western Pond Turtle - Stream identified by CEMAR in 2007 Watershed Evaluation	High ($800,000 - $2,000,000)
Navarro River	1	- Coho Salmon, Winter Steelhead Trout, Foothill Yellow-Legged Frog, Western Pond Turtle - Stream identified by DFG in 2004 Recovery Plan - Stream identified by NMFS in 2010 Recovery Plan - Stream identified by DFG in 2008 Priority Streams List	High ($800,000 - $2,000,000)
Noyo River	1	- Coho Salmon, Steelhead Trout, Foothill Yellow-Legged Frog, California Red-Legged Frog, Northwestern Salamander, Western Pond Turtle - Stream identified by DFG in 2004 Recovery Plan - Stream identified by NMFS in 2010 Recovery Plan	Low ($150,000 - $400,000)
Otay River	1	- Southern Steelhead Trout, Arroyo Toad, Western Pond Turtle - Stream identified by NMFS in 2009 Public Review Draft Recovery Plan	- Mid ($400,000 - $800,000)
Piru Creek (Incl. Lockwood Creek)	1	- Southern Steelhead Trout, California Red-Legged Frog, Foothill Yellow-Legged Frog, Arroyo Toad, Western Pond Turtle - Stream identified by NMFS in 2009 Public Review Draft Recovery Plan	Low ($150,000 - $400,000)
Redwood Creek (Marin County)	1	- Coho Salmon, Winter Steelhead Trout, California Red-Legged Frog, Foothill Yellow-Legged Frog, Western Pond Turtle - Stream identified by DFG in 2004 Recovery Plan - Stream identified by NMFS in 2010 Recovery Plan	Low ($150,000 - $400,000)

Water Body	Priority Group	Threatened, Endangered, and Sensitive Aquatic Species Present (or Historically Present) and Other Rationale for Inclusion	Estimated Cost Range for Contracted Studies and Potential Cost Savings[2]
		- Stream identified by CEMAR in 2007 Watershed Evaluation - Stream identified by DFG in 2008 Priority Streams List	
Russian River (Lower, Middle, and Upper)	1	- Coho Salmon, Fall Chinook Salmon, Steelhead Trout, Foothill Yellow-Legged Frog, California Red-Legged Frog, Western Pond Turtle - Stream identified by DFG in 2004 Recovery Plan - Stream identified by NMFS in 2010 Recovery Plan	- High ($800,000 - $2,000,000) - Streamflow enhancement projects are in progress by Trout Unlimited for Lower Russian River Tributaries: Grape Creek, Mill Creek, Dutch Bill Creek, Green Valley Creek, Mark West Creek.
Salinas River	2	- Winter Steelhead Trout, Foothill Yellow-Legged Frog, California Red-Legged Frog, Western Pond Turtle - Watershed significant to both habitat and economy, but with no instream flow requirements	- Mid ($400,000 - $800,000)
Salmon River	2	- Coho Salmon, Chinook Salmon, Steelhead Trout, Foothill Yellow-Legged Frog, Western Pond Turtle - Stream identified by DFG in 2004 Recovery Plan	- Mid ($400,000 - $800,000)
San Antonio Creek (Santa Barbara County)	1	Southern Steelhead Trout, Foothill Yellow-Legged Frog, California Red-Legged Frog, Western Pond Turtle	Low ($150,000 - $400,000)
San Benito River	2	Winter Steelhead Trout, Foothill Yellow-Legged Frog, California Red-Legged Frog, Western Pond Turtle	- Mid ($400,000 - $800,000)
San Dieguito Creek	1	- Southern Steelhead Trout, Western Pond Turtle - Stream identified by NMFS in 2009 Public Review Draft Recovery Plan	Low ($150,000 - $400,000)
San Francisquito Creek	2	- Winter Steelhead Trout, California Red-Legged Trout, Western Pond Turtle - Stream identified by CEMAR in 2007 Watershed Evaluation	Low ($150,000 - $400,000)
San Gabriel River (Main Stem, North Fork, West Fork, East Fork)	1	- Southern Steelhead Trout, Western Pond Turtle - Stream identified by NMFS in 2009 Public Review Draft Recovery Plan	High ($800,000 - $2,000,000)
San Geronimo Creek	1	- Coho Salmon, Winter Steelhead Trout, Foothill Yellow-Legged Frog, California Red-Legged Frog, Western Pond Turtle - Stream identified by DFG in 2004 Recovery Plan	Low ($150,000 - $400,000)
San Gregorio Creek	1	Coho Salmon, California Red-Legged Frog, Western Pond	Low ($150,000 - $400,000)

Water Body	Priority Group	Threatened, Endangered, and Sensitive Aquatic Species Present (or Historically Present) and Other Rationale for Inclusion	Estimated Cost Range for Contracted Studies and Potential Cost Savings[2]
		Turtle ▪ Stream identified by NMFS in 2010 Recovery Plan ▪ Stream identified by DFG in 2008 Priority Streams List	▪ Studies underway by American Rivers and Stillwater.
San Juan Creek (Incl. Arroyo Trabuco)	1	▪ Southern Steelhead Trout, California Red-Legged Frog, Arroyo Toad, Western Pond Turtle ▪ Stream identified by NMFS in 2009 Public Review Draft Recovery Plan	▪ Mid ($400,000 - $800,000) ▪
San Lorenzo River	2	▪ Coho Salmon, Winter Steelhead Trout, Foothill Yellow-Legged Frog, California Red-Legged Frog, Western Pond Turtle ▪ Stream identified by DFG in 2004 Recovery Plan ▪ Stream identified by NMFS in 2010 Recovery Plan	▪ Mid ($400,000 - $800,000) ▪
San Luis Rey River	1	▪ Southern Steelhead Trout, California Red-Legged Frog, Arroyo Toad, Western Pond Turtle ▪ Stream identified by NMFS in 2009 Public Review Draft Recovery Plan	▪ Mid ($400,000 - $800,000) ▪
San Mateo Creek	1	▪ Southern Steelhead Trout, Arroyo Toad, Western Pond Turtle ▪ Stream identified by NMFS in 2009 Public Review Draft Recovery Plan	▪ Mid ($400,000 - $800,000) ▪
San Onofre Creek	1	▪ Southern Steelhead Trout, Arroyo Toad, Western Pond Turtle ▪ Stream identified by NMFS in 2009 Public Review Draft Recovery Plan	▪ Low ($150,000 - $400,000)
San Vicente Creek (Santa Cruz)	1	▪ Coho Salmon, Winter Steelhead Trout, Foothill Yellow-Legged Frog, California Red-Legged Frog, Western Pond Turtle ▪ Stream identified by DFG in 2004 Recovery Plan ▪ Stream identified by NMFS in 2010 Recovery Plan	▪ Low ($150,000 - $400,000)
Santa Anita Canyon Creek	1	▪ Southern Steelhead, California Red-Legged Frog, Western Pond Turtle ▪ Stream identified by NMFS in 2009 Public Review Draft Recovery Plan	▪ Low ($150,000 - $400,000)
Santa Clara River	1	▪ Southern Steelhead Trout, California Red-Legged Frog, Foothill Yellow-Legged Frog, Arroyo Toad, Western Pond Turtle ▪ Stream identified by NMFS in 2009 Public Review Draft	▪ High ($800,000 - $2,000,000)

Water Body	Priority Group	Threatened, Endangered, and Sensitive Aquatic Species Present (or Historically Present) and Other Rationale for Inclusion	Estimated Cost Range for Contracted Studies and Potential Cost Savings[2]
		Recovery Plan	
Santa Margarita River	1	▪ Southern Steelhead Trout, Arroyo Toad, Western Pond Turtle ▪ Stream identified by DFG in 2008 Priority Streams List ▪ Stream identified by NMFS in 2009 Public Review Draft Recovery Plan	▪ Mid ($400,000 - $800,000) ▪
Santa Maria River	1	▪ Southern Steelhead Trout, California Red-Legged Frog, Western Pond Turtle ▪ Stream identified by DFG in 2008 Priority Streams List ▪ Stream provides steelhead migratory access to Sisquoc River ▪ Stream identified by NMFS in 2009 Public Review Draft Recovery Plan	▪ Mid ($400,000 - $800,000) ▪
Santa Paula Creek	1	▪ Southern Steelhead Trout, California Red-Legged Frog, Foothill Yellow-Legged Frog, Arroyo Toad, Western Pond Turtle ▪ Stream identified by NMFS in 2009 Public Review Draft Recovery Plan	▪ Low ($150,000 - $400,000)
Santa Rosa Creek	2	▪ Winter Steelhead Trout, California Red-Legged Frog, Western Pond Turtle ▪ Creek often dry in lower reaches	▪ Mid ($400,000 - $800,000) ▪
Santa Ynez River	1	▪ Southern Steelhead Trout, Tidewater Goby, Foothill Yellow-Legged Frog, California Red-Legged Frog, Arroyo Toad, Western Pond Turtle ▪ Stream identified by NMFS in 2009 Public Review Draft Recovery Plan	▪ Mid ($400,000 - $800,000) ▪
Scott River	1	▪ Coho Salmon, Chinook Salmon, Steelhead Trout, Scott Bar Salamander, Long-toed Salamander, Foothill Yellow-Legged Frog ▪ Stream identified by DFG in 2004 Recovery Plan ▪ Stream identified by DFG in 2008 Priority Streams List ▪ Recent stream de-watering events	▪ High ($800,000 - $2,000,000)
Sespe Creek (Incl. tributaries)	1	▪ Southern Steelhead Trout, California Red-Legged Frog, Foothill Yellow-Legged Frog, Arroyo Toad, Western Pond Turtle ▪ Stream identified by NMFS in 2009 Public Review Draft Recovery Plan	▪ High ($800,000 - $2,000,000)

Water Body	Priority Group	Threatened, Endangered, and Sensitive Aquatic Species Present (or Historically Present) and Other Rationale for Inclusion	Estimated Cost Range for Contracted Studies and Potential Cost Savings[2]
Shasta River	1	▪ Coho Salmon, Chinook Salmon, Steelhead Trout, Shasta Salamander, Long-toed Salamander ▪ Stream identified by DFG in 2004 Recovery Plan ▪ Stream identified by DFG in 2008 Priority Streams List	▪ High ($800,000 - $2,000,000)
Sisar Creek	1	▪ Southern Steelhead Trout, California Red-Legged Frog, Foothill Yellow-Legged Frog, Arroyo Toad, Western Pond Turtle ▪ Stream identified by NMFS in 2009 Public Review Draft Recovery Plan	▪ Low ($150,000 - $400,000)
Sisquoc River (Incl. La Brea Creek (Two Forks))	1	▪ Southern Steelhead Trout, Foothill Yellow-Legged Frog, California Red-Legged Frog, Western Pond Turtle ▪ Stream identified by NMFS in 2009 Public Review Draft Recovery Plan	▪ Mid ($400,000 - $800,000) ▪
Smith River	1	▪ Coho Salmon, Winter and Summer Steelhead Trout, Green Sturgeon, Chinook Salmon, Foothill Yellow-Legged Frog, Northwestern Salamander, Western Pond Turtle ▪ Stream identified by DFG in 2004 Recovery Plan	▪ High ($800,000 - $2,000,000)
Solstice Creek	1	▪ Southern Steelhead Trout, California Red-Legged Frog, Western Pond Turtle ▪ Stream identified by NMFS in 2009 Public Review Draft Recovery Plan	▪ Low ($150,000 - $400,000)
Sonoma Creek	2	▪ Winter Steelhead Trout, Foothill Yellow-Legged Frog, California Red-Legged Frog, Western Pond Turtle	▪ Mid ($400,000 - $800,000) ▪
Soquel Creek	1	▪ Coho Salmon, Steelhead Trout, Foothill Yellow-Legged Frog, California Red-Legged Frog, Western Pond Turtle ▪ Stream identified by NMFS in 2010 Recovery Plan ▪ Watershed adjudicated but without instream flow requirements	▪ Low ($150,000 - $400,000)
Suisun Creek	2	▪ Winter Steelhead Trout, California Red-Legged Frog, Western Pond Turtle ▪ Stream identified by CEMAR in 2007 Watershed Evaluation	▪ Low ($150,000 - $400,000)
Sweetwater Creek (San Diego County)	1	▪ Southern Steelhead Trout, California Red-Legged Frog, Arroyo Toad, Western Pond Turtle ▪ Stream identified by NMFS in 2009 Public Review Draft Recovery Plan	▪ Low ($150,000 - $400,000)
Topanga Canyon Creek	1	▪ Southern Steelhead Trout, California Red-Legged Frog,	▪ Low ($150,000 - $400,000)

Water Body	Priority Group	Threatened, Endangered, and Sensitive Aquatic Species Present (or Historically Present) and Other Rationale for Inclusion	Estimated Cost Range for Contracted Studies and Potential Cost Savings[2]
		Western Pond Turtle • Stream identified by NMFS in 2009 Public Review Draft Recovery Plan	
Trancas Canyon	1	• Southern Steelhead Trout, California Red-Legged Frog, Western Pond Turtle	• Low ($150,000 - $400,000)
Sweetwater Creek (San Diego County)	1	• Southern Steelhead Trout, California Red-Legged Frog, Arroyo Toad, Western Pond Turtle • Stream identified by NMFS in 2009 Public Review Draft Recovery Plan	• Low ($150,000 - $400,000)
Topanga Canyon Creek	1	• Southern Steelhead Trout, California Red-Legged Frog, Western Pond Turtle • Stream identified by NMFS in 2009 Public Review Draft Recovery Plan	• Low ($150,000 - $400,000)
Trancas Canyon	1	• Southern Steelhead Trout, California Red-Legged Frog, Western Pond Turtle	• Low ($150,000 - $400,000)
Trinity River (Lower, Middle and Upper)	1	• Coho Salmon, Winter and Summer Steelhead Trout, Fall and Spring Chinook Salmon, Foothill Yellow-Legged Frog, Long-toed Salamander, Western Pond Turtle • Stream identified by DFG in 2004 Recovery Plan	• High ($800,000 - $2,000,000)
South Fork Trinity River	1	• Coho Salmon, Winter and Summer Steelhead Trout, Fall and Spring Chinook Salmon, Foothill Yellow-Legged Frog, Western Pond Turtle • Stream identified by DFG in 2004 Recovery Plan	• Mid ($400,000 - $800,000) •
Van Duzen River	1	• Coho Salmon, Chinook Salmon, Steelhead Trout, Foothill Yellow-Legged Frog, Northwestern Salamander, Western Pond Turtle • Stream identified by DFG in 2004 Recovery Plan	• Mid ($400,000 - $800,000) •
Ventura River	1	• Southern Steelhead Trout California Red-Legged Frog, Foothill Yellow-Legged Frog, Arroyo Toad, Western Pond Turtle • Stream identified by NMFS in 2009 Public Review Draft Recovery Plan	• High ($800,000 - $2,000,000)
Waddell Creek	1	• Coho Salmon, Winter Steelhead Trout, Foothill Yellow-Legged Frog, California Red-Legged Frog, Western Pond Turtle • Stream identified by DFG in 2004 Recovery Plan	• Low ($150,000 - $400,000)

Water Body	Priority Group	Threatened, Endangered, and Sensitive Aquatic Species Present (or Historically Present) and Other Rationale for Inclusion	Estimated Cost Range for Contracted Studies and Potential Cost Savings[2]
		▪ Stream identified by NMFS in 2010 Recovery Plan	
Winchuck River	1	▪ Coho Salmon, Winter Steelhead Trout, Chinook Salmon, Cutthroat Trout, Foothill Yellow-Legged Frog, Northwestern Salamander, Western Pond Turtle ▪ Stream identified by DFG in 2004 Recovery Plan	▪ Mid ($400,000 - $800,000) ▪

Schedule 3 (Table D)
High Priority Rivers and Streams that Support Only Non-Anadromous Species

Water Body	Priority Group	Threatened, Endangered, or Sensitive Aquatic Species Present (or Historically Present) and Other Rationale for Inclusion	Estimated Cost Range for Contracted Studies and Potential Cost Savings[3]
Buckeye Creek	1	▪ Lahontan Cutthroat Trout, Sierra Nevada Yellow-Legged Frog, Yosemite Toad ▪ East Walker River watershed identified by USFWS in 1994 Recover Plan	▪ Low ($150,000 - $400,000)
Cow Head Slough	2	▪ Cow Head Lake Tui Chub ▪ Stream identified by USFWS in 1998 Recovery Plan	▪ Low ($150,000 - $400,000)
Deep Creek	2	▪ Mojave Tui Chub, California Red-Legged Frog, Sierra Madre Yellow-Legged Frog, Arroyo Toad, Western Pond Turtle ▪ Stream identified by NPS in 2004 Workshop to Revisit Recovery Plan ▪ Mojave River watershed identified by USFWS in 1984 Recovery plan.	▪ Low ($150,000 - $400,000)
Escondido Creek (San Diego County)	2	▪ Western Pond Turtle ▪ Stream provides habitat for species classified as sensitive per the California Natural Diversity Database	▪ Low ($150,000 - $400,000)
Green Creek	1	▪ Lahontan Cutthroat Trout, Sierra Nevada Yellow-Legged Frog, Yosemite Toad ▪ East Walker River watershed identified by USFWS in 1994 Recover Plan	▪ Low ($150,000 - $400,000)
Hot Creek	2	▪ Owens Sucker, California Floater Freshwater Mussel ▪ Stream provides habitat for species classified as sensitive	▪ Low ($150,000 - $400,000)

[3] Note: until all stakeholders for each stream are contacted, and an evaluation of existing information is complete, a true picture of potential cost savings will not be possible.

Water Body	Priority Group	Threatened, Endangered, or Sensitive Aquatic Species Present (or Historically Present) and Other Rationale for Inclusion	Estimated Cost Range for Contracted Studies and Potential Cost Savings[3]
		per the California Natural Diversity Database	
Independence Creek	1	▪ Lahontan Cutthroat Trout, Sierra Nevada Yellow-Legged Frog ▪ Little Truckee River watershed identified by USFWS in 1994 Recovery Plan	▪ Low ($150,000 - $400,000) ▪ Flow studies in progress by the Department of Water Resources.
Lee Vining Creek	2	▪ Sierra Nevada Yellow-Legged Frog, Yosemite Toad, Mount Lyell Salamander ▪ Stream provides habitat for species classified as sensitive per the California Natural Diversity Database	▪ Mid ($400,000 - $800,000) ▪
Little Rock (Littlerock) Creek (Eastern LA County)	2	▪ Sierra Madre Yellow-Legged Frog, Arroyo Toad ▪ Stream provides habitat for species classified as sensitive per the California Natural Diversity Database	▪ Mid ($400,000 - $800,000) ▪
Little Truckee River	1	▪ Lahontan Cutthroat Trout, Sierra Nevada Yellow-Legged Frog ▪ Little Truckee River Watershed identified by USFWS in 1994 Recovery Plan	▪ Mid ($400,000 - $800,000) ▪
Los Peñasquitos Canyon Creek	2	▪ Arroyo Toad, Western Pond Turtle ▪ Stream provides habitat for species classified as sensitive per the California Natural Diversity Database	▪ Low ($150,000 - $400,000)
Lost River	1	▪ Shortnose Sucker, Lost River Sucker, Western Pond Turtle ▪ Stream provides habitat for species classified as sensitive per the California Natural Diversity Database	▪ Mid ($400,000 - $800,000) ▪
Mammoth Creek	2	▪ Owens Sucker, California Floater Freshwater Mussel ▪ Stream provides habitat for species classified as sensitive per the California Natural Diversity Database	▪ Low ($150,000 - $400,000)
Mill Creek (Mono Basin)	2	▪ Sierra Nevada Yellow-Legged Frog, Yosemite Toad, Mount Lyell Salamander ▪ Stream provides habitat for species classified as sensitive per the California Natural Diversity Database	▪ Low ($150,000 - $400,000)
Mojave River and Tributaries	2	▪ Mojave Tui Chub, California Red-Legged Frog, Sierra Madre Yellow-Legged Frog, Arroyo Toad, Western Pond Turtle ▪ Mojave River watershed identified by USFWS in 1984 Recovery plan.	▪ High ($800,000 - $2,000,000)
West Fork Mojave River	2	▪ Mojave Tui Chub, California Red-Legged Frog, Sierra Madre Yellow-Legged Frog, Arroyo Toad, Western Pond	▪ High ($800,000 - $2,000,000)

Water Body	Priority Group	Threatened, Endangered, or Sensitive Aquatic Species Present (or Historically Present) and Other Rationale for Inclusion	Estimated Cost Range for Contracted Studies and Potential Cost Savings[3]
		Turtle ▪ Mojave River watershed identified by USFWS in 1984 Recovery plan.	
Owens River and Tributaries	2	▪ Owens Tui Chub, Owens Speckled Dace, Owens Sucker, Owens Pupfish, Northern Leopard Frog, Sierra Nevada Yellow-Legged Frog ▪ Stream provides habitat for species classified as sensitive per the California Natural Diversity Database	▪ High ($800,000 - $2,000,000)
Pine Creek (Tributary to Eagle Lake, Lassen County)	2	▪ Eagle Lake Rainbow Trout ▪ Stream provides habitat for species classified as sensitive per the California Natural Diversity Database	▪ Mid ($400,000 - $800,000)
Reverse Creek	2	▪ Sierra Nevada Yellow-Legged Frog, Yosemite Toad, Mount Lyell Salamander ▪ Stream provides habitat for species classified as sensitive per the California Natural Diversity Database	▪ Low ($150,000 - $400,000)
Rush Creek	2	▪ Sierra Nevada Yellow-Legged Frog, Yosemite Toad, Mount Lyell Salamander ▪ Stream provides habitat for species classified as sensitive per the California Natural Diversity Database	▪ Mid ($400,000 - $800,000)
Robinson Creek	1	▪ Lahontan Cutthroat Trout, Sierra Nevada Yellow-Legged Frog, Yosemite Toad ▪ East Walker River watershed identified by USFWS in 1994 Recover Plan	▪ Low ($150,000 - $400,000)
Sagehen Creek	1	▪ Lahontan Cutthroat Trout, Sierra Nevada Yellow-Legged Frog ▪ Little Truckee River Watershed identified by USFWS in 1994 Recovery Plan	▪ Low ($150,000 - $400,000) ▪ Flow studies in progress by the Department of Water Resources.
Virginia Creek	1	▪ Lahontan Cutthroat Trout, Sierra Nevada Yellow-Legged Frog, Yosemite Toad ▪ East Walker River watershed identified by USFWS in 1994 Recover Plan	▪ Low ($150,000 - $400,000)
East Walker River	1	▪ Lahontan Cutthroat Trout, Sierra Nevada Yellow-Legged Frog, Yosemite Toad ▪ East Walker River watershed identified by USFWS in 1994 Recover Plan	▪ Mid ($400,000 - $800,000)

VI. Public Workshop and Possible Next Steps

On November 2, 2010, the State Water Board issued a Notice of Opportunity for Public Comment and Notice of Public Workshop regarding an earlier draft version of this report. The notice for the workshop requested information on:
   (1) Whether there are streams that should be added to the list;
   (2) Whether there are existing and adequate streamflow studies for streams that are on the list; and
   (3) Whether there is other information available on likely costs that will help inform the State Water Board.

The State Water Board received 12 comment letters by the November 10th deadline, all of which are posted and available for viewing on the State Water Board's website at: http://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/ .

On November 16, 2010, the State Water Board held the public workshop. Three individuals provided verbal comments before a quorum to the State Water Board. Additional changes made to this report as a result of the comments received include:

- The addition of San Gregorio Creek in San Mateo County. This creek was recommended as an addition by The Nature Conservancy and noted in the Trout Unlimited (TU) comment letter as having instream flow studies in progress. It was identified as a priority stream in the 2008 DFG list for instream flow studies and the 2010 NMFS Coho Recovery Plan.

- Streamflow enhancement projects in process for lower Russian River tributaries were added to the cost estimate column of Schedule 2. The organizations working on these enhancement projects may have study information that can defray our initial cost estimate, though a detailed examination would be needed.

- The rationale for including the specific rivers and streams under each Schedule was expanded.

The most effective way for the state to use limited resources towards improving instream flows is to partner with stakeholders and other organizations to avoid duplicative studies and supplement work already being done. For each water body, the following six steps are recommended before the initiation of any new studies:

1. A review and analysis of existing studies and literature.
2. A physical site visit to specific locations.
3. The identification and inclusion of stakeholders.
4. An analysis of known fisheries impacts and/or water quality impairments.
5. The development of an initial list of scientific studies that may be required.
6. The development of a list of water right users and water rights.

VII. Conclusions

In accordance with Chapter 5 of the 2009-10 Seventh Extraordinary Session, the State Water Board developed a prioritized schedule and estimate of costs to complete instream flow studies for:

(1)   high priority rivers and streams in the Delta watershed that were not covered in the Board's "Final Report on Development of Flow Criteria for the Sacramento-San Joaquin Delta Ecosystem" by 2012; and

(2)   all major rivers and streams outside the Sacramento River watershed by 2018.

The purpose of this report is to inform the Legislature as to the complexities and resources involved in completing instream flow studies and to identify waterbodies that serve as habitat for threatened and endangered species that may benefit from instream flow studies. Most of the rivers and streams identified in this report were previously identified in recovery strategies by other state and federal agencies and third party non-governmental organizations. More research is required before this report can serve as an official plan, and even then it will need to be continually updated as new information is discovered and priorities change. The most effective way to use limited resources is for the state to serve as a liaison between the stakeholders already engaged in flow studies and to supplement those studies wherever it is determined to be necessary.

This report identifies 138 rivers and streams for instream flow studies. The total estimated cost to conduct scientific instream flow studies for the 2012 deadline is $32.46 million. The total estimated cost to conduct scientific instream flow studies for the 2018 deadline is $107.25 million.

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ATTACHMENT 6

Executive Summary

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Executive Summary

The Sacramento-San Joaquin River Delta is the grand confluence of California's waters, the place where the state's largest rivers merge in a web of channels—and in a maze of controversy. The Delta is a zone where the wants of a modern society come into collision with each other and with the stubborn limitations of a natural system. In 2009, seeking an end to decades of conflict over water, the Legislature established the Delta Stewardship Council with a mandate to resolve long-standing issues. The first step toward that resolution is the document you have before you, the Delta Plan.

Though more than 50 miles inland from the Golden Gate, Delta waters rise and fall with ocean tides. The Delta is in fact the upstream, mostly freshwater portion of the San Francisco Estuary, the largest estuarine system on the West Coast of the Americas, and one of California's prime natural assets. It is a major stop on the Pacific Flyway and the portal through which important fish species, including anadromous Chinook salmon, pass on their way to and from their spawning grounds in the interior.

The system of waters in which the Delta is so central has changed dramatically since California became a state. Rivers have been dammed and aqueducts built. Natural flows and fluxes have been disrupted to support cities and make the Central Valley the fruit basket and salad bowl of the nation. Approximately half of the water that historically flowed into and through the Delta is now diverted for human use, never reaching the sea. Much of this diversion occurs at points upstream, before the rivers come down to the Delta; but the last and largest draws take place in the Delta itself. On the southeast edge of the region, near Byron, two sets of mighty pumps extract water for shipment as far south as San Diego.

Two-thirds of California's people and 4.5 million acres of farmland receive some part of their water from the Delta.

The Delta landscape we know is itself the result of a great transformation, from a primeval wetland complex to an archipelago of diked islands, where soils that once grew vast thickets of tules now yield bountiful corn, alfalfa, tomatoes, and many other crops. The Delta is home to about 12,000 people on farms and in small historic communities, and to about half a million in the larger cities that are

pressing into the region from the fringe. More millions come to it for boating, fishing, hunting, bird watching, even windsurfing on its 700 miles of channels. Steeped in history, combining notes of the American heartland and of Holland, the Delta looks and feels like no other place in California. This is a land that people love.

It is not doing so well.

The very shape of the modern Delta is in danger. Farming of peat-rich ground like this always leads to oxidation, the literal vanishing of soil, and thus to subsidence. Many Delta islands now lie 15 feet or more below sea level and depend on aging dikes to prevent the water in adjacent channels from pouring in. Higher river flows in winter or spring, predicted results of climate change, will add to the pressure, and a great earthquake, sooner or later, will shake the region like a paint can on a mixer. Encroaching urbanization, meanwhile, puts more people and property on dangerous ground.

After years of slow decline, the condition of the Delta's watery ecosystem, as measured especially by the population of wild salmon and other native fishes, has gone critical. The list of causes begins, but does not end, with all those water withdrawals, a kind of tax that leaves the system in a condition of chronic drought. The specific, peculiar manner in which the last large gulps of water are withdrawn adds to the ecological cost. The continual introduction of alien aquatic species from around the world is altering the web of life, often at the expense of native and other valued species. Pollution from the vast and busy watershed does its share of harm.

Today, all those who depend on or value the Delta are, in a word, afraid. Delta residents face the possibility of floods from the east when the rivers flow strongly and of salinity intrusion from the west if they flow too feebly. Fishermen, both commercial and recreational, fret about the future of salmon and other species. Water suppliers that receive water from the Delta find those supplies insecure, subject to

Steeped in history, combining notes of the American heartland and of Holland, the Delta looks and feels like no other place in California. This is a land that people love.

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interruption by weather vagaries, levee failures, or pumping restrictions imposed in the desperate attempt to stem the decline of fish.

The Coequal Goals, the Delta Stewardship Council, and the Delta Plan

Since the middle 1980s, California has been looking for ways to secure the natural and human values of the Delta while maintaining its place in the state's water plumbing. These efforts have generally started in hope and ended in impasse. In recent years environmentalists turned to the courts, using the blunt tool of the federal Endangered Species Act to force curtailment of water exports at certain times. In reaction, water suppliers south of the Delta have complained of "regulatory drought."

In 2009 the Legislature made its latest, most determined bid to find solutions, passing the Delta Reform Act and associated bills. First and foremost, it declared that State policy toward the Delta must henceforth serve two "coequal goals":

■ Providing a more reliable water supply for California, and

■ Protecting, restoring, and enhancing the Delta ecosystem.

These goals, the Legislature added, must be met in a manner that:

- Protects and enhances the unique cultural, recreational, natural resource, and agricultural values of the Delta as an evolving place.

By affirming the equal status of ecosystem health and water supply reliability, the Legislature changed the terms of the conversation. It changed them further with the following pronouncement: "The policy of the state of California is to reduce reliance on the Delta in meeting California's future water supply needs." Here was recognition that, for the sake of the water system and the Delta both, a partial weaning of the one from the other is required.

The Delta Stewardship Council is the body entrusted with giving practical meaning to these directives. Publication of this Delta Plan completes its first assignment. The product of eight drafts, almost 100 public meetings, and nearly 10,000 comments, the Delta Plan pulls together in one place the steps that need to be taken to meet the coequal goals—measures that, in one way or another, could affect almost everyone in California. The Plan is to be revised every 5 years, or sooner as circumstances change.

The Delta Plan contains 87 provisions, some broad and some narrowly technical, some novel, some commonsensically familiar. What, in essence, does the Plan propose be done differently? At the risk of oversimplification, we can say that it asks California and Californians to do six large things:

- In order to improve and secure our water supply, while taking pressure off the Delta, we must use water more efficiently in cities and on farms, and develop alternative, usually local, sources.

- We must also get much better at capturing and storing the surplus water that nature provides in the wettest years, building reserves that can be drawn on in dry ones.

- To revitalize the Delta ecosystem, we must provide adequate seaward flows in Delta channels, on a schedule more closely mirroring historical rhythms: what the Plan calls natural, functional flows.

- We must also bring back generous wetlands and riparian zones in the Delta for the benefit of fish and birds.

- To preserve the Delta as a place, we must restrict new urban development to those peripheral areas already definitely earmarked for such growth, while supporting farming and recreation in the Delta's core.

- And we must floodproof the Delta, as far as feasible, mainly by improving levees and by providing more overflow zones where swollen rivers can spread without doing harm.

What about today's headline issue concerning the Delta—the proposed construction of tunnels to improve the way water destined for export southwards reaches the pump intakes near Byron? This initiative is part of what is called the Bay Delta Conservation Plan (BDCP). The BDCP is a different and more narrowly focused undertaking than the Delta Plan, into which, if certain conditions are met, it will be fused (see section, A Better System: Delta Conveyance).

The Delta Plan is *California's* plan for the Delta, prepared in consultation with, and to be carried out by, all agencies in the field: the State Water Resources Control Board, ultimate arbiter of water rights and water quality; the California Department of Water Resources, the state's water planner and also operator of the great State Water Project; the California Department of Fish and Wildlife, responsible for the welfare of the living system of the Delta; the Delta Protection Commission, which oversees land use and development on low-lying Delta islands; and many more agencies, State and local. Add to the list federal players like the Bureau of Reclamation, which runs the Central Valley Project; the U.S. Fish and Wildlife Service; the National Marine Fisheries Service; and the U.S. Army Corps of Engineers. Their cooperation has been promised, and it is vital.

The working parts of the Plan are 73 *Recommendations* and 14 *Policies*. *Recommendations* call attention to tasks being done or to be done by others. *Policies* are legal requirements that anyone undertaking a significant project in the Delta must meet. See the sidebar, From Plan to Reality, for more on the mechanics of realizing the Plan and pages ES-15 to ES-35 for a survey of all 87 provisions.

Where Is the Money?

The Legislature sees "adequate and secure funding" as a need "inherent in the coequal goals." In order to know what this entails, we need to form a clearer picture of the costs of the work now proposed for the Delta or on its behalf and how those costs might be met. This first edition of the Delta Plan proposes research toward that clarity.

FROM PLAN TO REALITY

The Legislature instructed the Delta Stewardship Council to "direct efforts across state agencies." This "direction" has three distinct aspects.

First of all, the Council is to **coordinate**. It will chair a high-powered committee dedicated to implementing the Plan. The heads of key State and local agencies will be at that table, together with federal representatives. This body will meet for the first time in fall 2013. Agency staffs will work with that of the Council daily.

Second, the Council is to **keep track of progress**. Using specific performance metrics contained in the Plan, and guided by the Delta Science Program (see sidebar, Science at the Center), it will monitor what is actually being done toward Plan goals, and what changes of course may be indicated. The results will be widely publicized.

Third, in certain key areas, the Council can be called upon to **block damaging actions**. The Plan provisions that can trigger this authority are called Policies. To avoid premature encroachment on the work of other agencies, the Legislature devised an indirect path leading to Council intervention.

Actions subject to these Policies are called "covered actions," but the Council itself cannot declare an action to be covered. It is the proposing agency that makes this determination. Legal standards apply, however, and if an action is questionably deemed not to be covered, the Council or any other party can take the agency to court.

Once an action is determined to be covered, the proposing agency must make sure it is in line with the Policies of the Delta Plan, filing a Certification of Consistency with contents specified in Delta Plan **Governance Policy 1**. If the agency says the action is consistent but another party or citizen thinks it is not, the opponent can then appeal to the Delta Stewardship Council. A Council member or the Council's Executive Officer may initiate the appeal.

SCIENCE AT THE CENTER

The Delta Reform Act mandates that the Delta Plan be based on the best available scientific knowledge of our day. It must, moreover, be open to change as knowledge changes—and as paper proposals meet the test of reality. The results of every action are to be closely tracked, so that corrections can be made in a timely way—a process, much discussed but not sufficiently practiced, known as adaptive management.

To be more than a buzzword, adaptive management must bring two things to bear: new information, and a readiness to let new information disrupt old plans. Both, in the past, have been in scant supply.

Though Delta knowledge has expanded hugely in recent years, it is often a challenge to pull that data together and draw conclusions from it. Studies are done by different agencies for specific purposes and in narrow contexts; findings can be hard to integrate. The Delta Science Program, a function of the Council, will seek to overcome these gaps, linking the whole community of scientists at work. Guided by a top-flight Delta Independent Science Board, it will prepare, by December 31, 2013, a companion to the Delta Plan called the Delta Science Plan (**Governance Recommendation 1**).

The Delta Science Plan will propose a collaborative structure for doing science in the Delta. It will suggest ways of improving communication, resolving conflicting results, and accommodating uncertainty. It will offer priorities: how to apportion attention between immediate practical questions, on the one hand, and research aimed at increasing long-term understanding, on the other. It will sketch a more integrated approach to monitoring, so that results from different settings can be compared, and consider how computer modeling of the intricate Delta system might be improved.

Once a year, the Council will bring scientists together to assess what has been learned and what changes in ongoing plans and projects the new knowledge may suggest. Another conference? Yes, but with a difference: These findings will feed directly into ongoing refinement of the Delta Plan.

First step is an inventory: How much is now actually being spent, by all the agencies involved, that can be chalked up to furthering the coequal goals? Second comes an assessment of costs: How much will it take to carry out the projects and programs described in the Delta Plan, and what might the sources of support be for each one? The third step must be a comparison of resources and needs, and a reckoning of gaps: What key elements lack probable funding, and what might be done to fill these holes? (**Funding Principles Recommendations 1 through 3**.)

Providing a More Reliable Water Supply for California...

The Delta's contribution to the overall statewide water supply is smaller than many people think. The proportion drawn directly from the Delta, mostly through the pumps near Byron, is only about 8 percent of the total. The bulk of California's water comes from more local sources, and always has.

Nevertheless, the Delta supply is important to many regions. Southern California imports about 25 percent of its water via the Byron pumps. The Tulare Lake Basin, the southern end of the Great Central Valley, gets 27 percent of its water by that route. Even the San Francisco Bay Area takes 16 percent of its supply from Delta pumps. On a more local scale, several water suppliers rely entirely on the Delta, and others have become dependent on this one overtaxed source to a risky degree.

In addition to water pulled directly from the Delta, a great deal is drawn from the Delta's tributary streams before they come down to sea level. San Francisco Bay Area cities reach far inland to tap the Tuolumne and Mokelumne Rivers in the Sierra Nevada, taking 27 percent of their water needs from these sources. Parts of the Central Valley tributary to the Delta get all of their water from that watershed by

California water planning is full of good intentions. If the laws and policies that are now on the books were consistently carried out, the state's water system—including that part that is tied to the Delta—would work much better.

definition, as do the people and farms of the Delta itself. (See also sidebar, The Problem with Numbers.)

The Delta Plan addresses water supply on three scales: California-wide, on the Delta watershed level, and in the areas that receive water from the Delta pumps. (See Figure ES-1, The Delta Watershed and Areas Receiving Delta Water.)

California water planning is full of good intentions. If the laws and policies that are now on the books were consistently carried out, the state's water system—including that part that is tied to the Delta—would work much better. The Delta Plan calls on *all* water suppliers to obey the many laws and guidelines that exist, and on the State's regulatory agencies to insist on compliance (**Water Resources Recommendation 1**).

THE PROBLEM WITH NUMBERS

In talking of California water, we put trust in numbers: flows, usages, capacities, trends. But some seemingly solid and much-quoted figures are little more than guesses. By and large, we do not truly know how much water we are using or how much we are saving through conservation efforts. We know less than we should about Delta inflows and outflows. We know little about groundwater except that water tables in too many places are dropping. What information is available is often packaged in inscrutable ways. The Delta Plan asks all the agencies and water suppliers involved to provide or demand better information, and to communicate it better (**Water Resources Policy 2, WR Recommendations 16 through 19**).

Whatever the outcome of some current debates, California's next large increment of water supply will not come from major new engineering but from water conservation, recycling, local stormwater capture, and reasonable use of aquifers (see section, A Better System: Storing Floods to Ride Out Droughts). These measures can yield an amount of water larger than the total that is drawn from the Delta today. State agencies in charge of water matters should systematically promote these practices, and *all* State agencies should model them in their own water usage. (**Water Resources Recommendations 6, 8, and 14**.)

Zooming in a bit from the statewide picture, the Delta Plan calls for all water users linked to the Delta—whether they take water from it directly, or tap the watershed—to reduce their draws. The State Water Resources Control Board should give special scrutiny to water use applications that could boost demand on the watershed. Urban and agricultural water suppliers are already required to write water management plans; these now should include "water supply reliability elements," discussing, among other things, how to deal with the cascading effects if Delta pumping were halted for as long as 3 years. (**Water Resources Recommendations 3, 4, 5, and 7**.)

The Plan speaks most directly to those suppliers that serve water within the Delta or pump water out of the region—including the State Water Project, the Central Valley Project, and by extension the many agricultural and urban water purveyors that are the customers of these giants. Any organization that receives water from the projects must do its share to reduce reliance on the Delta, setting specific reduction targets and actually putting measures in place.

The Delta Watershed and Areas Receiving Delta Water

Figure ES-1

The State Water Project is called on to write the corresponding provisions into contracts with its clients when these agreements are renewed or revised (**Water Resources Policies 1 and 2, WR Recommendation 2**).

A Better System: Storing Floods to Ride Out Droughts (and Give the Delta a Break)

The measures so far mentioned will take pressure off the Delta while actually increasing California's developed water supply. The further key to both goals is to harvest and store the water that is available from Central Valley rivers in the

wettest years, at the least environmental cost. The need is heightened by the fact of climate change, which stands to make rainy years all the wetter, and droughts all the more severe.

There are few opportunities left in California to build large new dams (or to raise the height of old dams), and the options that exist are dauntingly expensive. The California Department of Water Resources and the Bureau of Reclamation have been studying the possibilities. The Delta Plan urges the agencies to wrap up these studies, so that the State can decide the fate of these proposals once and for all (**Water Resources Recommendations 13 and 14**).

Much more water storage space exists right under our feet: in groundwater basins, or aquifers.

California began its history with a vast supply of water stored naturally in underground gravel fields and free for the taking via wells. In parts of the state, including most of the southern Central Valley, this endowment has been squandered, and groundwater levels have dropped, sometimes by hundreds of feet. One of the rationales for sending water south from the Delta has been to recharge aquifers, but not enough recharging has occurred. And the State's last comprehensive assessment of its groundwater situation was published in 1980—a third of a century ago.

The Delta Plan calls for a rededication to the conservative idea of using aquifers like bank accounts: to be filled up in wet times, in order that they may be drawn from in dry. It calls on the State to do the indispensable groundwater update, on local suppliers to write plans for sustainable groundwater management, and on the State Water Resources Control Board to stand ready to intervene in seriously overdrafted areas, if good local plans are not forthcoming, leading perhaps to the court procedure called groundwater adjudication. (**Water Resources Recommendations 9, 10, 11, and 14**.)

> *The Delta Plan calls for a rededication to the conservative idea of using aquifers like bank accounts: to be filled up in wet times, in order that they may be drawn from in dry.*

There is another tool for making the supply stretch further: the sale or trade of water between suppliers, especially in times of shortage. Existing rules governing such transfers are found cumbersome by some and insufficiently protective of water rights and the environment by others. The State Water Resources Control Board should reformulate the guidelines by mid-2016 (**Water Resources Recommendations 14 and 15**).

A Better System: Delta Conveyance

As noted, many of the state's water suppliers take their water from rivers at points upstream of the Delta. The two biggest, however—the State Water Project and the Central Valley Project—are different. Though most of the water they transport has its origin to the north, in the Sacramento River, their withdrawal points are deep in the Delta and well to the south, on the channel called Old River. Unlike most other water withdrawals, these affect the region not only by removing water but also by distorting flows.

The pumps at Byron have so much power that they essentially give the Delta a second mouth. In many channels, water runs backward at times, toward the pump intakes, not toward the sea. This situation is bad for salmon, Delta smelt, and other sensitive and legally protected species. Under the Bay Delta Conservation Plan, the Department of Water Resources and the federal Bureau of Reclamation are planning a kind of arterial bypass, segregating the water meant for the pumps at a new northern intake on the Sacramento River. The water corralled at this point would be sent to the pumps via a pair of tunnels. This arrangement

is intended to alleviate the backward flows that harm fish; in conjunction with major habitat improvements and other measures, it is supposed to bring endangered species far enough back from the brink to satisfy protective laws. Many Delta residents and environmentalists, though, fear that the new system will simply allow more water to be shipped south, doing, on balance, more harm than good.

The Delta Stewardship Council is not the author of the BDCP. Its role for now is to advise and to urge timely completion (**Water Resources Recommendation 12**). Later on, though, the Council may have a decisive say. Once the proposal is complete, the Department of Fish and Wildlife must declare that it meets the standards of the Delta Reform Act, and this declaration can in turn be appealed to the Council. If the Council does not concur, certain aspects of the BDCP will lose access to State funding. If all hurdles have been cleared, on the other hand, the BDCP will take its place as a component of the Delta Plan.

...and Protecting, Restoring, and Enhancing the Delta Ecosystem...

The effort to improve the fortunes of the Delta ecosystem has two components that are vital: guaranteeing adequate flows from the rivers feeding into and through Delta channels, and creating new wetlands and other habitats in partial replacement for what has been lost. Three other components are merely very important: combating harmful exotic species, improving the management of salmon hatcheries, and protecting and improving water quality.

Toward "Natural Functional Flows"

Humans have not only reduced the total quantity of runoff through the Delta toward the ocean but also have changed its timing, decreasing the historical torrents of spring and increasing the formerly feeble flows of autumn. In a natural system that evolved with wide variation, this shift toward a steady state is itself a source of harm.

> *Humans have not only reduced the total quantity of runoff through the Delta toward the ocean but also have changed its timing, decreasing the historical torrents of spring and increasing the formerly feeble flows of autumn.*

The minimum seaward flows to be maintained in Delta channels are set by the State Water Resources Control Board, according to season and year type (wet, above normal, below normal, dry, or critical). These required flows help fish; they also prevent saltwater intrusion. As a not-incidental side effect, the rules limit the amount of water that can be exported through the pumps.

The Water Board is now preparing to revise this flow regime, last updated in 2006. As a later step, the Water Board is to issue comparable flow standards for the major tributary rivers of the Delta. The Delta Plan recommends deadlines for these processes (mid-2014 and mid-2018). The adopted regulations will become elements of the Plan. The Delta Stewardship Council can be called upon to review any project that could affect Delta flows in the light of adopted flow criteria (**Ecosystem Restoration Policy 1, ER Recommendation 1**).

Habitat Restoration

In its primeval state, the Delta was no uniform sea of reeds but a vast mesh of habitats including tule marsh threaded with rivers and sloughs, perched lakes filled by floods and very high tides, natural levees with big trees on them, and seasonal overflow basins behind the levees. Most of this mosaic has disappeared, converted to fifty large and many small leveed islands. Evidence of what was remains in agricultural soils of uncommon quality (and fragility).

The old scene will never return, but careful habitat restoration projects can help to reverse the region's

ecological decline. Biologists have spent years locating the likeliest areas for such revival. The Delta Plan incorporates the latest thinking, essentially the Conservation Strategy drafted in 2011 by the Department of Fish and Wildlife (formerly the Department of Fish and Game).

Since the heart of the Delta is now well below sea level, due to subsidence, the suitable restoration sites are mostly found near Delta margins, where the soil surface is still high enough to permit marsh plants and riparian vegetation to take root. The Plan outlines six such zones: the Yolo Bypass, the floodplain west of Sacramento into which the Sacramento River spills in wet years; the Cache Slough Complex, where the Bypass rejoins the body of the Delta; a nexus in the eastern Delta, where the Mokelumne River and the Cosumnes River add their strands to the Delta's web; a zone in the southern Delta along the San Joaquin River; a collection of small tracts at the western apex of the Delta, where it narrows to meet Suisun Bay; and finally the Suisun Marsh, fringing that bay to the north. This fresh-to-brackish water marsh, the largest wetland in California, is mostly managed by hunting clubs for seasonal waterfowl ponds, but sizeable areas should be restored to full tidal action. The existing plan for Suisun Marsh, written by the San Francisco Bay Conservation and Development Commission, is 36 years old and does not take into account, for example, probable sea level rise.

The Delta Plan calls for the habitat restorations in the Conservation Strategy to be carried out by the Department of Fish and Wildlife and by the Delta Conservancy, a body established for such purposes in 2009; and it calls for a plan update for Suisun Marsh. The Delta Stewardship Council can be appealed to, if necessary, to block development or any other intrusion that might interfere with a restoration site. (**Ecosystem Restoration Policies 2 and 3, ER Recommendations 2, 3, and 5**.)

Much of the remaining good habitat in the Delta is found in strips along the water side of levees, and the Delta Plan looks to protect and widen these green margins. When levees are rebuilt or altered, the possibility of shifting them farther away from the water should always be explored. The growth of trees along the waterline should be encouraged. However, authority over many levees lies with the U.S. Army Corps of Engineers, and the Corps requires removal of trees and shrubs, on the theory that root systems have a weakening effect. (The matter is debated.) Given the value of tall vegetation for habitat, the Delta Plan asks the Corps to exempt Delta levees from this rule, where appropriate. (**Ecosystem Restoration Policy 4 and ER Recommendation 4**.)

Exotic Species

One of the less-visible forces to buffet the Delta ecosystem is the proliferation of nonnative aquatic species—fish, crustaceans, plants, and even the microscopic floating animals of zooplankton. Some were introduced deliberately; others arrived by random routes including the discharge of bilgewater from oceangoing ships and the dumping of goldfish bowls.

New arrivals keep appearing. Some of these intruders affect the system little, but other species, notably certain aquatic plants and filter-feeding clams, transform the web of life profoundly. The Delta Plan prohibits actions that could bring in new exotics or improve conditions for exotics that are here, and endorses the measures the Department of Fish and Wildlife is already planning to take against them. (**Ecosystem Restoration Policy 5, ER Recommendation 7**.)

Among the exotics are game species introduced in the nineteenth century and well-loved by fishermen: striped, largemouth, and smallmouth bass. It has become apparent that these voracious game fish are helping to deplete salmon, Delta smelt, and other species in trouble. The Delta Plan asks the Department of Fish and Wildlife to change angling rules to permit heavier fishing and somewhat suppress the bass population (**Ecosystem Restoration Recommendation 6**).

Management of Hatchery Fish

When dams on many rivers cut off spawning grounds for salmon and steelhead trout, hatcheries were built to compensate. Now there is worry that hatchery-raised salmon, less genetically diverse than their wild cousins, may mix with and reduce the fitness of the wild strains. Various solutions are proposed, including capturing wild fish to add their eggs to hatchery stock. The Delta Plan asks the Department of Fish and Wildlife and the U.S. Fish and Wildlife Service to put these ideas and recommendations into effect (**Ecosystem Restoration Recommendations 8 and 9**).

Water Quality

Pollution from the watershed is bad for the Delta ecosystem and for water users. The Delta Plan urges the responsible agencies—the State Water Resources Control Board, the Central Valley Regional Water Quality Control Board, and the San Francisco Bay Regional Water Quality Control Board—to protect "beneficial uses" of water in the Delta and Suisun Bay. Various ongoing projects of planning, rulemaking, and construction should be brought to conclusion. All agencies should look at water quality when weighing actions covered under the Delta Plan. Special attention should be paid to pollution that might degrade habitat restoration sites. (**Water Quality Recommendations 1 through 12**.)

...In a Way that Protects and Enhances the Values of the Delta as an Evolving Place

Because of its role in greater systems—the San Francisco Estuary, the state water plumbing—the Delta is a subject of statewide debate. The conversation can seem to take place over the heads of the people who actually live in the region; and it can seem to overlook the lasting values of the place that is: its thriving agriculture, the beauty of its countryside, its cultural heritage, and its recreational bounty. The Delta Plan strives to redress this balance without promising what is probably impossible: the retention of the landscape exactly as it is today.

Honorific labels do not protect valuable assets, but they can help us recognize them. The Delta Plan asks that the Delta be declared a National Heritage Area by Congress and that Highway 160, its north-south artery, be designated a National Scenic Byway by the U.S. Department of Transportation (**Delta-as-Place Recommendations 1 and 2**).

Many Delta people fear that their concerns will be brushed aside as new water facilities and habitat restorations get under way. While deference cannot be guaranteed,

the Delta Plan calls on the agencies to respect local plans in siting such projects, to minimize conflict when possible, and to buy land from willing sellers when they can (**Delta-as-Place Policy 2, DP Recommendation 4**).

The distinctive Delta landscape has been much altered by urban encroachment, often entailing higher flood risk. The Delta Protection Commission, created in 1992 and strengthened by the Delta Reform Act of 2009, oversees development in the core area called the Primary Zone: Local decisions affecting this zone can be appealed to the Commission and overturned by it. However, this authority does not extend to the peripheral Secondary Zone, where the development pressure is strongest. The Delta Plan tightens control further, steering new development to the 26,000 acres in the Peripheral Zone that are already earmarked for urbanization in local plans. Small housing developments that may occur outside these limits must meet high flood control standards (**Delta-as-Place Policy 1, Risk Reduction Policy 2**). (See Figure ES-2, Delta Communities.)

A little more bustle might actually benefit 11 historic small towns or settlements within the Delta, known as the legacy communities. Most are spaced along the Sacramento River: Freeport, Clarksburg, Hood, Courtland, Locke, Walnut Grove, Ryde, Isleton, and Rio Vista. Knightsen and Bethel Island are near the lower channel of the San Joaquin River. Planners at all levels should respect the character, and promote the vitality, of these places (**Delta-as-Place Recommendation 3**).

The Delta Protection Commission has written an Economic Sustainability Plan containing numerous ideas for the support of the region's farm economy, parks and recreation, and roads and infrastructure. The Delta Plan adapts many of these as **Delta-as-Place Recommendations 5 through 19**.

Flood Risk Reduction

In its primeval state, most of the Delta was wetland and slightly above sea level. Since levees created the modern islands and cultivation began, soils have subsided deeply. Many Delta tracts are strikingly below the level of the water in adjacent channels; rising sea level will make the differential worse. While the occasional levee break is part of Delta lore, multiple failures could bring disaster to the Delta landscape, economy, and ecosystem.

The Delta Plan urges all agencies in the Delta to plan for emergencies and to join forces in a regional response consortium, as proposed by the Delta Multi-Hazard Coordination Task Force. Every responsible party, public and private, should allocate money for flood prevention and reaction. Utilities should plan to minimize interruptions of service. The Department of Water Resources should expand its stockpiles of stone and earth for the use of all when breaches require rapid plugging. Higher levels of private flood insurance should be required, and the State should gain immunity from lawsuits related to flooding beyond its power to prevent. (**Risk Reduction Recommendations 1, 9, and 10**.)

It is estimated that only about half the Delta's acreage is adequately protected. There is not enough money for all the desirable improvements, nor is there a mechanism for sharing costs among all who benefit.

Delta Communities
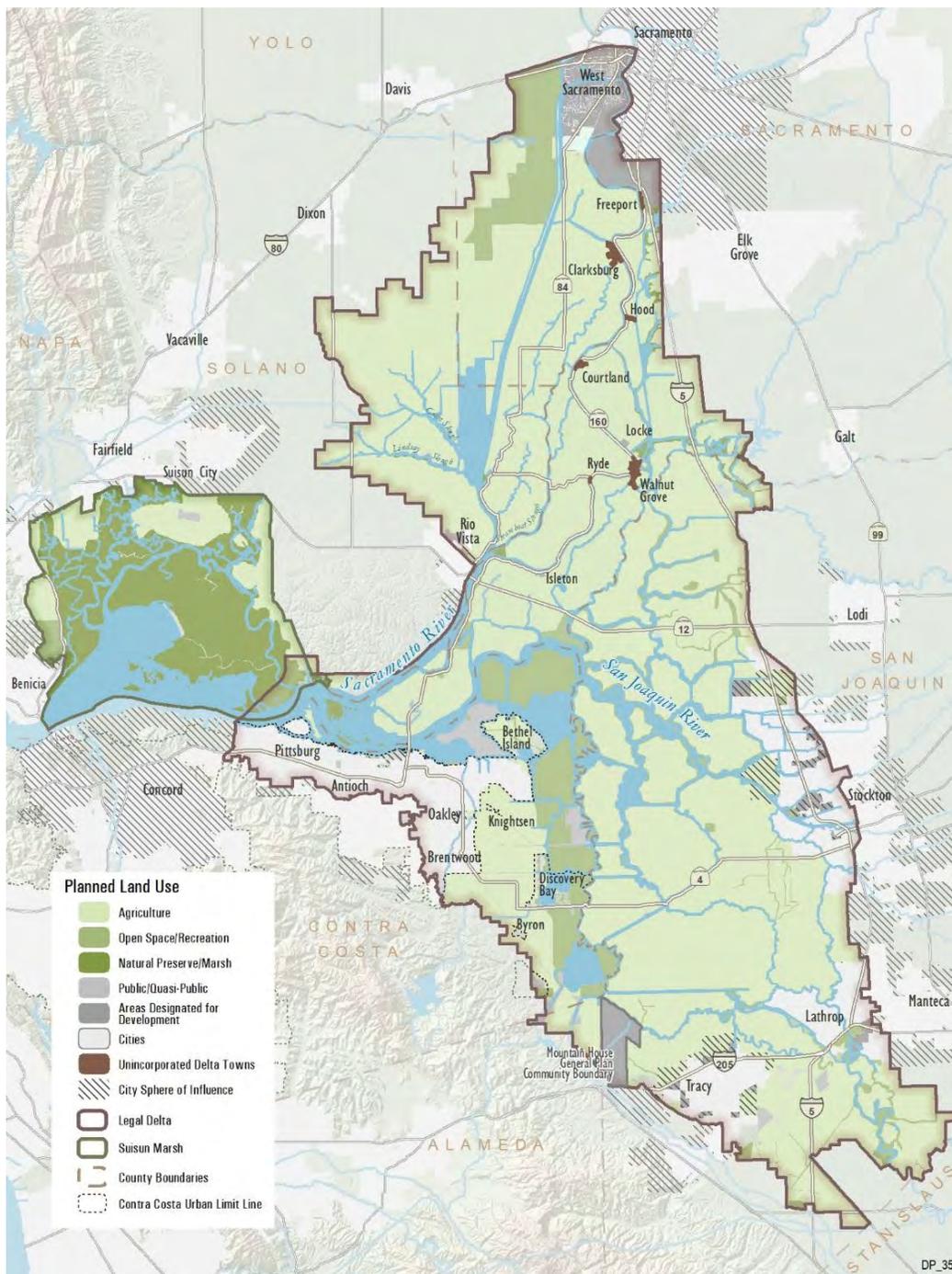
There are more than 1,000 miles of Delta levees. The State is directly responsible for about one-third of the system; nearly 70 local Reclamation Districts are in charge of the rest. It is estimated that only about half the Delta's acreage is adequately protected. There is not enough money for all the desirable improvements, nor is there a mechanism for sharing costs among all who benefit. The Delta Plan calls on the Legislature to establish a locally based Delta Flood Risk Management Assessment District to raise money for combined defenses. Public and private utilities, too, should invest in defense of their facilities and lines. (**Risk Reduction Recommendations 2 and 3**.)

The State contributes massively to levee costs throughout the Delta, but on a not very systematic basis. The Legislature directed the Delta Stewardship Council to set priorities for these investments. **Risk Reduction Policy 1** offers broad principles. Urban areas come first; special attention must be paid to levees guarding roads and energy facilities. The channels through which water flows toward export pumps require protection, as does the pipeline that brings Sierra water across the Delta for the East Bay Municipal Utility District. Levees on the western islands, whose failure could bring salinity deep into the Delta, are also of high concern.

A more detailed study is to follow. Building on work being done by the Department of Water Resources, the Council will assess, island by island, the state of levees, the degree of subsidence, the extent and value of assets to be protected, and the cost of long-term defense. The result, due at the end of 2014, will be a tiered priority list for the expenditure of State levee funds (**Risk Reduction Recommendation 4**).

To take pressure off the levee system, floodwaters need room to move and to spread without causing harm (and often to the benefit of plants, birds, and fish). Two such safety valves already exist at the Yolo Bypass and the Cosumnes-Mokelumne floodplain; a third such zone is proposed for the lower San Joaquin River at Paradise Cut. The Delta Plan urges expansion of the flood relief system, and requires that

present or potential overflow areas be kept free of encroachments. Levee setbacks are also encouraged. (**Risk Reduction Policies 3 and 4, RR Recommendations 5 through 8**.)

Given time, land subsidence can actually be reversed. Experimental plots show that soils can be deepened by growing tules in shallowly flooded fields, at a rate of a little over an inch a year. The tule plots also fix a lot of atmospheric carbon and thus do their bit toward slowing climate change. The Delta Plan encourages expansion of this work (**Delta-as-Place Recommendation 7**).

Finding the Way Through

When the first Spanish explorers took their boats into the Sacramento-San Joaquin River Delta, they were feeling their way. They could see the channel they were in, as far as the next bend or junction of sloughs. They had a general idea of where they were going. Between the near and the far, though, were mysteries. Which waterways connected to others, which petered out in the marshes? Where was the real way through?

> *Tangible marks of progress may at first be as subtle as shifting shoreline features seen from a Delta boat.*

This first edition of the Delta Plan is a little like such an exploration. A short reach of channel is visible; another stretch can be assessed from local information. After that, the route is a matter of educated guesswork.

The Delta Plan can be fairly specific about steps to be taken in the next 5 years. The Delta Science Plan is already under way. The in-depth study of levees will begin by fall 2013. The Interagency Implementation Committee will meet by

the end of the year. Just around the next bend, the State Water Resources Control Board will adopt its momentous new flow rules; a final decision on Delta conveyance (the Bay Delta Conservation Plan) looms beyond that.

It will not have escaped the reader how many of these measures seem rather abstract, involving studies, rule-making, the gathering of information, the refining of procedures, the testing of powers—not so much doing as planning, and even planning how to plan. This is simply the phase we are in. Tangible marks of progress may at first be as subtle as shifting shoreline features seen from a Delta boat. Here, though, are some markers to look for. We will be doing well if, in a few years' time:

- Many urban and rural water suppliers that draw on the Delta have taken real steps to reduce that reliance, with measured, reported results.

- Flows in Delta channels, controlled under new State Water Resources Control Board rules, are looking a good deal more like the historical ones.

- Several new habitat restoration projects in the Delta have moved from the planning to the construction stage.

- Subsidence reversal planting has expanded from the small pilot projects seen today.

- Measurably less acreage of Delta waters is dominated by nonnative water plants.

- Stocks of endangered fish are showing a rebound.

- Key levees have been strengthened, especially in the environs of Stockton and Sacramento.

- No further rural farmland has been lost to urbanization.

The next edition of the Delta Plan, due in 2018 or sooner, will be a little longer on specifics and a little shorter on question marks. A few more miles of the channel ahead will have come into view. New uncertainties, no doubt, will have

replaced old. The captains will continue to disagree. But, just as it was in the old days, the route through the Delta will be the one way forward.

Beyond all local debates and confusions, the destination is clear. We want a Delta landscape that remains essentially itself while adapting gradually and gracefully to a future marked by climate change and sea level rise. We want a Delta ecosystem that works markedly better than today's, reflected partly in a resurgence of native fish. And we want an end to the endless wrangling about Delta flows and plumbing—a truce that can only be achieved if the entire California water system undergoes a measure of reform.

> *In solving the "Delta problem," we will not only be doing right by a treasured land- and waterscape. We will be putting the entire state of California on a sounder development path.*

Driven by cost, environmental concern, and sheer practicality, the water world is already shifting away from reliance on distant dams and aqueducts and toward trust in conservation, local sources, and better use of groundwater storage. This change is reflected in the fact, startling to many, that California's total water consumption has not climbed in recent years; in fact, despite our increasing population, use has slightly dropped. The Delta Plan gives a push to trends already under way.

In solving the "Delta problem," we will not only be doing right by a treasured land- and waterscape. We will be putting the entire state of California on a sounder development path.

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Delta Plan Policies and Recommendations

The Delta Plan contains a set of regulatory policies that will be enforced by the Delta Stewardship Council's appellate authority and oversight. The Delta Plan also contains priority recommendations, which are nonregulatory but call out actions essential to achieving the coequal goals.

POLICY OR RECOMMENDATION NUMBER	SHORT TITLE	POLICY/RECOMMENDATION LANGUAGE
Chapter 2		
G P1 (23 CCR section 5002)	Detailed Findings to Establish Consistency with the Delta Plan	*(a) This policy specifies what must be addressed in a certification of consistency filed by a State or local public agency with regard to a covered action. This policy only applies after a "proposed action" has been determined by a State or local public agency to be a covered action because it is covered by one or more of the regulatory policies contained in Article 3. Inconsistency with this policy may be the basis for an appeal.* *(b) Certifications of consistency must include detailed findings that address each of the following requirements:* *(1) Covered actions, in order to be consistent with the Delta Plan, must be consistent with this regulatory policy and with each of the regulatory policies contained in Article 3 implicated by the covered action. The Delta Stewardship Council acknowledges that in some cases, based upon the nature of the covered action, full consistency with all relevant regulatory policies may not be feasible. In those cases, the agency that files the certification of consistency may nevertheless determine that the covered action is consistent with the Delta Plan because, on whole, that action is consistent with the coequal goals. That determination must include a clear identification of areas where consistency with relevant regulatory policies is not feasible, an explanation of the reasons why it is not feasible, and an explanation of how the covered action nevertheless, on whole, is consistent with the coequal goals. That determination is subject to review by the Delta Stewardship Council on appeal;* *(2) Covered actions not exempt from CEQA must include applicable feasible mitigation measures identified in the Delta Plan's Program EIR (unless the measure(s) are within the exclusive jurisdiction of an agency other than the agency that files the certification of consistency), or substitute mitigation measures that the agency that files the certification of consistency finds are equally or more effective;* *(3) As relevant to the purpose and nature of the project, all covered actions must document use of best available science;* *(4) Ecosystem restoration and water management covered actions must include adequate provisions, appropriate to the scope of the covered action, to assure continued implementation of adaptive management. This requirement shall be satisfied through both of the following:* *(A) An adaptive management plan that describes the approach to be taken consistent with the adaptive management framework in Appendix 1B, and* *(B) Documentation of access to adequate resources and delineated authority by the entity responsible for the implementation of the proposed adaptive management process.*

POLICY OR RECOMMENDATION NUMBER	SHORT TITLE	POLICY/RECOMMENDATION LANGUAGE
		(c) A conservation measure proposed to be implemented pursuant to a natural community conservation plan or a habitat conservation plan that was:
		(1) Developed by a local government in the Delta; and
		(2) Approved and permitted by the California Department of Fish and Wildlife prior to May 16, 2013
		is deemed to be consistent with sections 5005 through 5009 of this Chapter if the certification of consistency filed with regard to the conservation measure includes a statement confirming the nature of the conservation measure from the California Department of Fish and Wildlife.
G R1	Development of a Delta Science Plan	*The Delta Stewardship Council's Delta Science Program should develop a Delta Science Plan by December 31, 2013. The Delta Science Program should work with the Interagency Ecological Program, Bay Delta Conservation Plan, California Department of Fish and Wildlife, and other agencies to develop the Delta Science Plan. To ensure that best science is used to develop the Delta Science Plan, the Delta Independent Science Board should review the draft Delta Science Plan.* *The Delta Science Plan should address the following:* ▪ *A collaborative institutional and organizational structure for conducting science in the Delta* ▪ *Data management, synthesis, scientific exchange, and communication strategies to support adaptive management and improve the accessibility of information* ▪ *Strategies for addressing uncertainty and conflicting scientific information* ▪ *The prioritization of research and balancing of the short-term immediate science needs with science that enhances comprehensive understanding of the Delta system over the long term* ▪ *Identification of existing and future needs for refining and developing numerical and simulation models along with enhancing existing Delta conceptual models (e.g., the Interagency Ecological Program (IEP) Pelagic Organism Decline (POD) and the Delta Regional Ecosystem Restoration Implementation Plan (DRERIP) models)* ▪ *An integrated approach for monitoring that incorporates existing and future monitoring efforts* ▪ *An assessment of financial needs and funding sources to support science*
Chapter 3		
WR P1 (23 CCR section 5003)	Reduce Reliance on the Delta through Improved Regional Water Self-Reliance	*(a) Water shall not be exported from, transferred through, or used in the Delta if all of the following apply:*
		(1) One or more water suppliers that would receive water as a result of the export, transfer, or use have failed to adequately contribute to reduced reliance on the Delta and improved regional self-reliance consistent with all of the requirements listed in paragraph (1) of subsection (c);
		(2) That failure has significantly caused the need for the export, transfer, or use; and
		(3) The export, transfer, or use would have a significant adverse environmental impact in the Delta.

POLICY OR RECOMMENDATION NUMBER	SHORT TITLE	POLICY/RECOMMENDATION LANGUAGE
		(b) For purposes of Water Code section 85057.5(a)(3) and section 5001(j)(1)(E) of this Chapter, this policy covers a proposed action to export water from, transfer water through, or use water in the Delta, but does not cover any such action unless one or more water suppliers would receive water as a result of the proposed action.
		(c) (1) Water suppliers that have done all of the following are contributing to reduced reliance on the Delta and improved regional self-reliance and are therefore consistent with this policy:
		(A) Completed a current Urban or Agricultural Water Management Plan (Plan) which has been reviewed by the California Department of Water Resources for compliance with the applicable requirements of Water Code Division 6, Parts 2.55, 2.6, and 2.8;
		(B) Identified, evaluated, and commenced implementation, consistent with the implementation schedule set forth in the Plan, of all programs and projects included in the Plan that are locally cost effective and technically feasible which reduce reliance on the Delta; and
		(C) Included in the Plan, commencing in 2015, the expected outcome for measurable reduction in Delta reliance and improvement in regional self-reliance. The expected outcome for measurable reduction in Delta reliance and improvement in regional self-reliance shall be reported in the Plan as the reduction in the amount of water used, or in the percentage of water used, from the Delta watershed. For the purposes of reporting, water efficiency is considered a new source of water supply, consistent with Water Code section 1011(a).
		(2) Programs and projects that reduce reliance could include, but are not limited to, improvements in water use efficiency, water recycling, stormwater capture and use, advanced water technologies, conjunctive use projects, local and regional water supply and storage projects, and improved regional coordination of local and regional water supply efforts.
WR R1	Implement Water Efficiency and Water Management Planning Laws	*All water suppliers should fully implement applicable water efficiency and water management laws, including urban water management plans (Water Code section 10610 et seq.); the 20 percent reduction in statewide urban per capita water usage by 2020 (Water Code section 10608 et seq.); agricultural water management plans (Water Code section 10608 et seq. and 10800 et seq.); and other applicable water laws, regulations, or rules.*
WR R2	Require SWP Contractors to Implement Water Efficiency and Water Management Laws	*The California Department of Water Resources should include a provision in all State Water Project contracts, contract amendments, contract renewals, and water transfer agreements that requires the implementation of all State water efficiency and water management laws, goals, and regulations, including compliance with Water Code section 85021.*
WR R3	Compliance with Reasonable and Beneficial Use	*The State Water Resources Control Board should evaluate all applications and petitions for a new water right or a new or changed point of diversion, place of use, or purpose of use that would result in new or increased long-term average use of water from the Delta watershed for consistency with the constitutional principle of reasonable and beneficial use. The State Water Resources Control Board should conduct its evaluation consistent with Water Code sections 85021, 85023, 85031, and other provisions of California law. An applicant or*

POLICY OR RECOMMENDATION NUMBER	SHORT TITLE	POLICY/RECOMMENDATION LANGUAGE
		petitioner should submit to the State Water Resources Control Board sufficient information to support findings of consistency, including, as applicable, its urban water management plan, agricultural water management plan, and environmental documents prepared pursuant to the California Environmental Quality Act.
WR R4	Expanded Water Supply Reliability Element	*Water suppliers that receive water from the Delta watershed should include an expanded water supply reliability element, starting in 2015, as part of the update of an urban water management plan, agricultural water management plan, integrated water management plan, or other plan that provides equivalent information about the supplier's planned investments in water conservation and water supply development. The expanded water supply reliability element should detail how water suppliers are reducing reliance on the Delta and improving regional self-reliance consistent with Water Code section 85201 through investments in local and regional programs and projects, and should document the expected outcome for a measurable reduction in reliance on the Delta and improvement in regional self-reliance. At a minimum, these plans should include a plan for possible interruption of water supplies for up to 36 months due to catastrophic events impacting the Delta, evaluation of the regional water balance, a climate change vulnerability assessment, and an evaluation of the extent to which the supplier's rate structure promotes and sustains efficient water use.*
WR R5	Develop Water Supply Reliability Element Guidelines	*The California Department of Water Resources, in consultation with the Delta Stewardship Council, the State Water Resources Control Board, and others, should develop and approve, by December 31, 2014, guidelines for the preparation of a water supply reliability element so that water suppliers can begin implementation of WR R4 by 2015.*
WR R6	Update Water Efficiency Goals	*The California Department of Water Resources and the State Water Resources Control Board should establish an advisory group with other State agencies and stakeholders to identify and implement measures to reduce impediments to achievement of statewide water conservation, recycled water, and stormwater goals by 2014. This group should evaluate and recommend updated goals for additional water efficiency and water resource development by 2018. Issues such as water distribution system leakage should be addressed. Evaluation should include an assessment of how regions are achieving their proportional share of these goals.*
WR R7	Revise State Grant and Loan Priorities	*The California Department of Water Resources, the State Water Resources Control Board, the California Department of Public Health, and other agencies, in consultation with the Delta Stewardship Council, should revise State grant and loan ranking criteria by December 31, 2013, to be consistent with Water Code section 85021 and to provide a priority for water suppliers that includes an expanded water supply reliability element in their adopted urban water management plans, agricultural water management plans, and/or integrated regional water management plans.*
WR R8	Demonstrate State Leadership	*All State agencies should take a leadership role in designing new and retrofitted State-owned and -leased facilities, including buildings and California Department of Transportation facilities, to increase water efficiency, use recycled water, and incorporate stormwater runoff capture and low-impact development strategies.*

POLICY OR RECOMMENDATION NUMBER	SHORT TITLE	POLICY/RECOMMENDATION LANGUAGE
WR R9	Update Bulletin 118, California's Groundwater Plan	*The California Department of Water Resources, in consultation with the Bureau of Reclamation, U.S. Geological Survey, the State Water Resources Control Board, and other agencies and stakeholders should update Bulletin 118 information using field data, California Statewide Groundwater Elevation Monitoring (CASGEM), groundwater agency reports, satellite imagery, and other best available science by December 31, 2014, so that this information can be included in the next California Water Plan Update and be available for inclusion in 2015 urban water management plans and agricultural water management plans. The Bulletin 118 update should include a systematic evaluation of major groundwater basins to determine sustainable yield and overdraft status; a projection of California's groundwater resources in 20 years if current groundwater management trends remain unchanged; anticipated impacts of climate change on surface water and groundwater resources; and recommendations for State, federal, and local actions to improve groundwater management. In addition, the Bulletin 118 update should identify groundwater basins that are in a critical condition of overdraft.*
WR R10	Implement Groundwater Management Plans in Areas that Receive Water from the Delta Watershed	*Water suppliers that receive water from the Delta watershed and that obtain a significant percentage of their long-term average water supplies from groundwater sources should develop and implement sustainable groundwater management plans that are consistent with both the required and recommended components of local groundwater management plans identified by the California Department of Water Resources Bulletin 118 (Update 2003) by December 31, 2014.*
WR R11	Recover and Manage Critically Overdrafted Groundwater Basins	*Local and regional agencies in groundwater basins that have been identified by the California Department of Water Resources as being in a critical condition of overdraft should develop and implement a sustainable groundwater management plan, consistent with both the required and recommended components of local groundwater management plans identified by the California Department of Water Resources Bulletin 118 (Update 2003), by December 31, 2014. If local or regional agencies fail to develop and implement these plans, the State Water Resources Control Board should take action to determine if the continued overuse of a groundwater basin constitutes a violation of the State's Constitution Article X, Section 2, prohibition on unreasonable use of water and whether a groundwater adjudication is necessary to prevent the destruction of or irreparable injury to the quality of the groundwater, consistent with Water Code sections 2100 and 2101.*
WR R12	Complete Bay Delta Conservation Plan	*The relevant federal, State, and local agencies should complete the Bay Delta Conservation Plan, consistent with the provisions of the Delta Reform Act, and receive required incidental take permits by December 31, 2014.*
WR R13	Complete Surface Water Storage Studies	*The California Department of Water Resources should complete surface water storage investigations of proposed off-stream surface storage projects by December 31, 2012, including an evaluation of potential additional benefits of integrating operations of new storage with proposed Delta conveyance improvements, and recommend the critical projects that need to be implemented to expand the state's surface storage.*
WR R14	Identify Near-term Opportunities for Storage, Use, and Water Transfer Projects	*The California Department of Water Resources, in coordination with the California Water Commission, Bureau of Reclamation, State Water Resources Control Board, California Department of Public Health, the Delta Stewardship Council, and other agencies and stakeholders, should conduct a survey to identify projects throughout California that could be implemented within the next 5 to 10 years to expand existing surface and groundwater storage facilities, create new storage, improve operation of existing Delta conveyance*

POLICY OR RECOMMENDATION NUMBER	SHORT TITLE	POLICY/RECOMMENDATION LANGUAGE
		facilities, and enhance opportunities for conjunctive use programs and water transfers in furtherance of the coequal goals. The California Water Commission should hold hearings and provide recommendations to the California Department of Water Resources on priority projects and funding.
WR R15	Improve Water Transfer Procedures	The California Department of Water Resources and the State Water Resources Control Board should work with stakeholders to identify and recommend measures to reduce procedural and administrative impediments to water transfers and protect water rights and environmental resources by December 31, 2016. These recommendations should include measures to address potential issues with recurring transfers of up to 1 year in duration and improved public notification for proposed water transfers.
WR P2 (23 CCR section 5004)	Transparency in Water Contracting	(a) The contracting process for water from the State Water Project and/or the Central Valley Project must be done in a publicly transparent manner consistent with applicable policies of the California Department of Water Resources and the Bureau of Reclamation referenced below. (b) For purposes of Water Code section 85057.5(a)(3) and section 5001(j)(1)(E) of this Chapter, this policy covers the following: (1) With regard to water from the State Water Project, a proposed action to enter into or amend a water supply or water transfer contract subject to California Department of Water Resources Guidelines 03-09 and/or 03-10 (each dated July 3, 2003), which are attached as Appendix 2A; and (2) With regard to water from the Central Valley Project, a proposed action to enter into or amend a water supply or water transfer contract subject to section 226 of P.L. 97-293, as amended or section 3405(a)(2)(B) of the Central Valley Project Improvement Act, Title XXXIV of Public Law 102-575, as amended, which are attached as Appendix 2B, and Rules and Regulations promulgated by the Secretary of the Interior to implement these laws.
WR R16	Supplemental Water Use Reporting	The State Water Resources Control Board should require water rights holders submitting supplemental statements of water diversion and use or progress reports under their permits or licenses to report on the development and implementation of all water efficiency and water supply projects and on their net (consumptive) use.
WR R17	Integrated Statewide System for Water Use Reporting	The California Department of Water Resources, in coordination with the State Water Resources Control Board, California Department of Public Health, California Public Utilities Commission, California Energy Commission, Bureau of Reclamation, California Urban Water Conservation Council, and other stakeholders, should develop a coordinated statewide system for water use reporting. This system should incorporate recommendations for inclusion of data needed to better manage California's water resources. The system should be designed to simplify reporting; reduce the number of required reports where possible; be made available to the public online; and be integrated with the reporting requirements for the urban water management plans, agricultural water management plans, and integrated regional water management plans. Water suppliers that export water from, transfer water through, or use water in the Delta watershed should be full participants in the data base.

POLICY OR RECOMMENDATION NUMBER	SHORT TITLE	POLICY/RECOMMENDATION LANGUAGE
WR R18	California Water Plan	*The California Department of Water Resources, in consultation with the State Water Resources Control Board, and other agencies and stakeholders, should evaluate and include in the next and all future California Water Plan updates information needed to track water supply reliability performance measures identified in the Delta Plan, including an assessment of water efficiency and new water supply development, regional water balances, improvements in regional self-reliance, reduced regional reliance on the Delta, and reliability of Delta exports, and an overall assessment of progress in achieving the coequal goals.*
WR R19	Financial Needs Assessment	*As part of the California Water Plan Update, the California Department of Water Resources should prepare an assessment of the state's water infrastructure. This should include the costs of rehabilitating/replacing existing infrastructure, an assessment of the costs of new infrastructure, and an assessment of needed resources for monitoring and adaptive management for these projects. The California Department of Water Resources should also consider a survey of agencies that may be planning small-scale projects (such as storage or conveyance) that improve water supply reliability.*
Chapter 4		
ER P1 (23 CCR section 5005)	Delta Flow Objectives	*(a) The State Water Resources Control Board's Bay Delta Water Quality Control Plan flow objectives shall be used to determine consistency with the Delta Plan. If and when the flow objectives are revised by the State Water Resources Control Board, the revised flow objectives shall be used to determine consistency with the Delta Plan.* *(b) For purposes of Water Code section 85057.5(a)(3) and section 5001(j)(1)(E) of this Chapter, the policy set forth in subsection (a) covers a proposed action that could significantly affect flow in the Delta.*
ER R1	Update Delta Flow Objectives	*Development, implementation, and enforcement of new and updated flow objectives for the Delta and high-priority tributaries are key to the achievement of the coequal goals. The State Water Resources Control Board should update the Bay Delta Water Quality Control Plan objectives as follows:* *(a) By June 2, 2014, adopt and implement updated flow objectives for the Delta that are necessary to achieve the coequal goals.* *(b) By June 2, 2018, adopt, and as soon as reasonably possible, implement flow objectives for high-priority tributaries in the Delta watershed that are necessary to achieve the coequal goals.[1]* *Flow objectives could be implemented through several mechanisms including negotiation and settlement, Federal Energy Regulatory Commission relicensing, or adjudicative proceeding.[2]* *Prior to the establishment of revised flow objectives identified above, the existing Bay Delta Water Quality Control Plan objectives shall be used to determine consistency with the Delta Plan. After the flow objectives are revised, the revised objectives shall be used to determine consistency with the Delta Plan.*

[1] SWRCB staff should work with the Council and DFW to determine priority streams. As an illustrative example, priority streams could include the Merced River, Tuolumne River, Stanislaus River, Lower San Joaquin River, Deer Creek (tributary to Sacramento River), Lower Butte Creek, Mill Creek (tributary to Sacramento River), Cosumnes River, and American River. Implementation through hearings is expected to take longer than the deadline shown here.

[2] Implementation through adjudicative proceedings or FERC relicensing is expected to take longer than the deadline shown here.

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ER P2 (23 CCR section 5006)	Restore Habitats at Appropriate Elevations	*(a) Habitat restoration must be carried out consistent with Appendix 3, which is Section II of the Draft Conservation Strategy for Restoration of the Sacramento-San Joaquin Delta Ecological Management Zone and the Sacramento and San Joaquin Valley Regions (California Department of Fish and Wildlife 2011). The elevation map attached as Appendix 4 should be used as a guide for determining appropriate habitat restoration actions based on an area's elevation. If a proposed habitat restoration action is not consistent with Appendix 4, the proposal shall provide rationale for the deviation based on best available science.* *(b) For purposes of Water Code section 85057.5(a)(3) and section 5001(j)(1)(E) of this Chapter, this policy covers a proposed action that includes habitat restoration.*
ER P3 (23 CCR section 5007)	Protect Opportunities to Restore Habitat	*(a) Within the priority habitat restoration areas depicted in Appendix 5, significant adverse impacts to the opportunity to restore habitat as described in section 5006, must be avoided or mitigated.* *(b) Impacts referenced in subsection (a) will be deemed to be avoided or mitigated if the project is designed and implemented so that it will not preclude or otherwise interfere with the ability to restore habitat as described in section 5006.* *(c) Impacts referenced in subsection (a) shall be mitigated to a point where the impacts have no significant effect on the opportunity to restore habitat as described in section 5006. Mitigation shall be determined, in consultation with the California Department of Fish and Wildlife, considering the size of the area impacted by the covered action and the type and value of habitat that could be restored on that area, taking into account existing and proposed restoration plans, landscape attributes, the elevation map shown in Appendix 4, and other relevant information about habitat restoration opportunities of the area.* *(d) For purposes of Water Code section 85057.5(a)(3) and section 5001(j)(1)(E) of this Chapter, this policy covers proposed actions in the priority habitat restoration areas depicted in Appendix 5. It does not cover proposed actions outside those areas.*
ER P4 (23 CCR section 5008)	Expand Floodplains and Riparian Habitats in Levee Projects	*(a) Levee projects must evaluate and where feasible incorporate alternatives, including the use of setback levees, to increase floodplains and riparian habitats. Evaluation of setback levees in the Delta shall be required only in the following areas (shown in Appendix 8): (1) The Sacramento River between Freeport and Walnut Grove, the San Joaquin River from the Delta boundary to Mossdale, Paradise Cut, Steamboat Slough, Sutter Slough; and the North and South Forks of the Mokelumne River, and (2) Urban levee improvement projects in the cities of West Sacramento and Sacramento.* *(b) For purposes of Water Code section 85057.5(a)(3) and section 5001(j)(1)(E) of this Chapter, this policy covers a proposed action to construct new levees or substantially rehabilitate or reconstruct existing levees.*
ER R2	Prioritize and Implement Projects that Restore Delta Habitat	*Bay Delta Conservation Plan implementers, California Department of Fish and Wildlife, California Department of Water Resources, and the Delta Conservancy should prioritize and implement habitat restoration projects in the areas shown on Figure 4-8. Habitat restoration projects should ensure connections between areas being restored and existing habitat areas and other elements of the landscape needed for the full life cycle of the species that will benefit from the restoration project.*

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		Where possible, restoration projects should also emphasize the potential for improving water quality. Restoration project proponents should consult the California Department of Public Health's Best Management Practices for Mosquito Control in California. ■ *Yolo Bypass. Enhance the ability of the Yolo Bypass to flood more frequently to provide more opportunities for migrating fish, especially Chinook salmon, to use this system as a migration corridor that is rich in cover and food.* ■ *Cache Slough Complex. Create broad nontidal, freshwater, emergent-plant-dominated wetlands that grade into tidal freshwater wetlands, and shallow subtidal and deep open-water habitats. Also, return a significant portion of the region to uplands with vernal pools and grasslands.* ■ *Cosumnes River–Mokelumne River confluence. Allow these unregulated and minimally regulated rivers to flood over their banks during winter and spring frequently and regularly to create seasonal floodplains and riparian habitats that grade into tidal marsh and shallow subtidal habitats.* ■ *Lower San Joaquin River floodplain. Reconnect the floodplain and restore more natural flows to stimulate food webs that support native species. Integrate habitat restoration with flood management actions, when feasible.* ■ *Suisun Marsh. Restore significant portions of Suisun Marsh to brackish marsh with land-water interactions to support productive, complex food webs to which native species are adapted and to provide space to adapt to rising sea level action. Use information from adaptive management processes during the Suisun Marsh Habitat Management, Preservation, and Restoration Plan's implementation to guide future habitat restoration projects and to inform future tidal marsh management.* ■ *Western Delta/Eastern Contra Costa County. Restore tidal marsh and channel margin habitat at Dutch Slough and western islands to support food webs and provide habitat for native species.*
ER R3	Complete and Implement Delta Conservancy Strategic Plan	*As part of its Strategic Plan and subsequent Implementation Plan or annual work plans, the Delta Conservancy should:* ■ *Develop and adopt criteria for prioritization and integration of large-scale ecosystem restoration in the Delta and Suisun Marsh, with sustainability and use of best available science as foundational principles.* ■ *Develop and adopt processes for ownership and long-term operations and management of land in the Delta and Suisun Marsh acquired for conservation or restoration.* ■ *Develop and adopt a formal mutual agreement with the California Department of Water Resources, California Department of Fish and Wildlife, federal interests, and other State and local agencies on implementation of ecosystem restoration in the Delta and Suisun Marsh.* ■ *Develop, in conjunction with the Wildlife Conservation Board, the California Department of Water Resources, California Department of Fish and Wildlife, Bay Delta Conservation Plan implementers, and other State and local agencies, a plan and protocol for acquiring the land necessary to achieve ecosystem restoration consistent with the coequal goals and the Ecosystem Restoration Program Conservation Strategy.*

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		▪ *Lead an effort, working with State and federal fish agencies, to investigate how to better use habitat credit agreements to provide credit for each of these steps: (1) acquisition for future restoration; (2) preservation, management, and enhancement of existing habitat; (3) restoration of habitat; and (4) monitoring and evaluation of habitat restoration projects.* ▪ *Work with the California Department of Fish and Wildlife and the U.S. Fish and Wildlife Service to develop rules for voluntary safe harbor agreements with property owners in the Delta whose actions contribute to the recovery of listed threatened or endangered species.*
ER R4	Exempt Delta Levees from the U.S. Army Corps of Engineers' Vegetation Policy	*Considering the ecosystem value of remaining riparian and shaded riverine aquatic habitat along Delta levees, the U.S. Army Corps of Engineers should agree with the California Department of Fish and Wildlife and the California Department of Water Resources on a variance that exempts Delta levees from the U.S. Army Corps of Engineers' levee vegetation policy where appropriate.*
ER R5	Update the Suisun Marsh Protection Plan	*The San Francisco Bay Conservation and Development Commission should update the Suisun Marsh Protection Plan and relevant components of the Suisun Marsh Local Protection Program to adapt to sea level rise and ensure consistency with the Suisun Marsh Preservation Act, the Delta Reform Act, and the Delta Plan.*
ER P5 (23 CCR section 5009)	Avoid Introductions of and Habitat Improvements for Invasive Nonnative Species	*(a) The potential for new introductions of or improved habitat conditions for nonnative invasive species, striped bass, or bass must be fully considered and avoided or mitigated in a way that appropriately protects the ecosystem.* *(b) For purposes of Water Code section 85057.5(a)(3) and section 5001(j)(1)(E) of this Chapter, this policy covers a proposed action that has the reasonable probability of introducing or improving habitat conditions for nonnative invasive species.*
ER R6	Regulate Angling for Nonnative Sport Fish to Protect Native Fish	*The California Department of Fish and Wildlife should develop, for consideration by the Fish and Game Commission, proposals for new or revised fishing regulations designed to increase populations of listed fish species through reduced predation by introduced sport fish. The proposals should be based on sound science that demonstrates these management actions are likely to achieve their intended outcome and include the development of performance measures and a monitoring plan to support adaptive management.*
ER R7	Prioritize and Implement Actions to Control Nonnative Invasive Species	*The California Department of Fish and Wildlife and other appropriate agencies should prioritize and fully implement the list of "Stage 2 Actions for Nonnative Invasive Species" and accompanying text shown in Appendix J taken from the* Conservation Strategy for Restoration of the Sacramento–San Joaquin Delta Ecological Management Zone and the Sacramento and San Joaquin Valley Regions *(DFG 2011). Implementation of the Stage 2 actions should include the development of performance measures and monitoring plans to support adaptive management.*
ER R8	Manage Hatcheries to Reduce Genetic Risk	*As required by the National Marine Fisheries Service, all hatcheries providing listed fish for release into the wild should continue to develop and implement scientifically sound Hatchery and Genetic Management Plans (HGMPs) to reduce risks to those species. The California Department of Fish and Wildlife should provide annual updates to the Delta Stewardship Council on the status of HGMPs within its jurisdiction.*

EXECUTIVE SUMMARY

POLICY OR RECOMMENDATION NUMBER	SHORT TITLE	POLICY/RECOMMENDATION LANGUAGE
ER R9	Implement Marking and Tagging Program	*By December 2014, the California Department of Fish and Wildlife, in cooperation with the U.S. Fish and Wildlife Service and the National Marine Fisheries Service, should revise and begin implementing its program for marking and tagging hatchery salmon and steelhead to improve management of hatchery and wild stocks based on recommendations of the California Hatchery Scientific Review Group, which considered mass marking, reducing hatchery programs, and mark selective fisheries in developing its recommendations.*
Chapter 5		
DP R1	Designate the Delta as a National Heritage Area	*The Delta Protection Commission should complete its application for designation of the Delta and Suisun Marsh as a National Heritage Area, and the federal government should complete the process in a timely manner.*
DP R2	Designate State Route 160 as a National Scenic Byway	*The California Department of Transportation should seek designation of State Route 160 as a National Scenic Byway, and prepare and implement a scenic byway plan for it.*
DP P1 (23 CCR section 5010)	Locate New Urban Development Wisely	*(a) New residential, commercial, and industrial development must be limited to the following areas, as shown in Appendix 6 and Appendix 7:* *(1) Areas that city or county general plans as of May 16, 2013, designate for residential, commercial, and industrial development in cities or their spheres of influence;* *(2) Areas within Contra Costa County's 2006 voter-approved urban limit line, except no new residential, commercial, and industrial development may occur on Bethel Island unless it is consistent with the Contra Costa County general plan effective as of May 16, 2013;* *(3) Areas within the Mountain House General Plan Community Boundary in San Joaquin County; or* *(4) The unincorporated Delta towns of Clarksburg, Courtland, Hood, Locke, Ryde, and Walnut Grove.* *(b) Notwithstanding subsection (a), new residential, commercial, and industrial development is permitted outside the areas described in subsection (a) if it is consistent with the land uses designated in county general plans as of May 16, 2013, and is otherwise consistent with this Chapter.* *(c) For purposes of Water Code section 85057.5(a)(3) and section 5001(j)(1)(E) of this Chapter, this policy covers proposed actions that involve new residential, commercial, and industrial development that is not located within the areas described in subsection (a). In addition, this policy covers any such action on Bethel Island that is inconsistent with the Contra Costa County general plan effective as of May 16, 2013. This policy does not cover commercial recreational visitor-serving uses or facilities for processing of local crops or that provide essential services to local farms, which are otherwise consistent with this Chapter.* *(d) This policy is not intended in any way to alter the concurrent authority of the Delta Protection Commission to separately regulate development in the Delta's Primary Zone.*

POLICY OR RECOMMENDATION NUMBER	SHORT TITLE	POLICY/RECOMMENDATION LANGUAGE
DP P2 (23 CCR section 5011)	Respect Local Land Use When Siting Water or Flood Facilities or Restoring Habitats	*(a) Water management facilities, ecosystem restoration, and flood management infrastructure must be sited to avoid or reduce conflicts with existing uses or those uses described or depicted in city and county general plans for their jurisdictions or spheres of influence when feasible, considering comments from local agencies and the Delta Protection Commission. Plans for ecosystem restoration must consider sites on existing public lands, when feasible and consistent with a project's purpose, before privately owned sites are purchased. Measures to mitigate conflicts with adjacent uses may include, but are not limited to, buffers to prevent adverse effects on adjacent farmland.* *(b) For purposes of Water Code section 85057.5(a)(3) and section 5001(j)(1)(E) of this Chapter, this policy covers proposed actions that involve the siting of water management facilities, ecosystem restoration, and flood management infrastructure.*
DP R3	Plan for the Vitality and Preservation of Legacy Communities	*Local governments, in cooperation with the Delta Protection Commission and Delta Conservancy, should prepare plans for each community that emphasize its distinctive character, encourage historic preservation, identify opportunities to encourage tourism, serve surrounding lands, or develop other appropriate uses, and reduce flood risks.*
DP R4	Buy Rights of Way from Willing Sellers When Feasible	*Agencies acquiring land for water management facilities, ecosystem restoration, and flood management infrastructure should purchase from willing sellers, when feasible, including consideration of whether lands suitable for proposed projects are available at fair prices.*
DP R5	Provide Adequate Infrastructure	*The California Department of Transportation, local agencies, and utilities should plan infrastructure, such as roads and highways, to meet needs of development consistent with sustainable community strategies, local plans, the Delta Protection Commission's Land Use and Resource Management Plan for the Primary Zone of the Delta, and the Delta Plan.*
DP R6	Plan for State Highways	*The Delta Stewardship Council, as part of the prioritization of State levee investments called for in Water Code section 85306, should consult with the California Department of Transportation as provided in Water Code section 85307(c) to consider the effects of flood hazards and sea level rise on State highways in the Delta.*
DP R7	Subsidence Reduction and Reversal	*The following actions should be considered by the appropriate State agencies to address subsidence reversal:* ▪ *State agencies should not renew or enter into agricultural leases on Delta or Suisun Marsh islands if the actions of the lessee promote or contribute to subsidence on the leased land, unless the lessee participates in subsidence reversal or reduction programs.* ▪ *State agencies currently conducting subsidence reversal projects in the Delta on State-owned lands should investigate options for scaling up these projects if they have been deemed successful. The California Department of Water Resources should develop a plan, including funding needs, for increasing the extent of their subsidence reversal and carbon sequestration projects to 5,000 acres by January 1, 2017.* ▪ *The Delta Stewardship Council, in conjunction with the California Air Resources Board (CARB) and the Delta Conservancy, should investigate the opportunity for the development of a carbon market whereby Delta farmers could receive credit for carbon sequestration by reducing subsidence and growing native marsh and wetland plants. This investigation should include the potential for developing offset protocols applicable to these types of plants for subsequent adoption by the CARB.*

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DP R8	Promote Value-added Crop Processing	*Local governments and economic development organizations, in cooperation with the Delta Protection Commission and the Delta Conservancy, should encourage value-added processing of Delta crops in appropriate locations.*
DP R9	Encourage Agritourism	*Local governments and economic development organizations, in cooperation with the Delta Protection Commission and the Delta Conservancy, should support growth in agritourism, particularly in and around legacy communities. Local plans should support agritourism where appropriate.*
DP R10	Encourage Wildlife-friendly Farming	*The California Department of Fish and Wildlife, the Delta Conservancy, and other ecosystem restoration agencies should encourage habitat enhancement and wildlife-friendly farming systems on agricultural lands to benefit both the environment and agriculture.*
DP R11	Provide New and Protect Existing Recreation Opportunities	*Water management and ecosystem restoration agencies should provide recreation opportunities, including visitor-serving business opportunities, at new facilities and habitat areas whenever feasible; and existing recreation facilities should be protected, using California State Parks' Recreation Proposal for the Sacramento-San Joaquin Delta and Suisun Marsh and Delta Protection Commission's Economic Sustainability Plan for the Sacramento-San Joaquin Delta as guides.*
DP R12	Encourage Partnerships to Support Recreation and Tourism	*The Delta Protection Commission and Delta Conservancy should encourage partnerships between other State and local agencies, and local landowners and business people to expand recreation, including boating, promote tourism, and minimize adverse impacts to nonrecreational landowners.*
DP R13	Expand State Recreation Areas	*California State Parks should add or improve recreation facilities in the Delta in cooperation with other agencies. As funds become available, it should fully reopen Brannan Island State Recreation Area, complete the park at Delta Meadows-Locke Boarding House, and consider adding new State parks at Barker Slough, Elkhorn Basin, the Wright-Elmwood Tract, and south Delta.*
DP R14	Enhance Nature-based Recreation	*The California Department of Fish and Wildlife, in cooperation with other public agencies, should collaborate with nonprofits, private landowners, and business partners to expand wildlife viewing, angling, and hunting opportunities.*
DP R15	Promote Boating Safety	*The California Department of Boating and Waterways should coordinate with the U.S. Coast Guard and State and local agencies on an updated marine patrol strategy for the region.*
DP R16	Encourage Recreation on Public Lands	*Public agencies owning land should increase opportunities, where feasible, for bank fishing, hunting, levee-top trails, and environmental education.*
DP R17	Enhance Opportunities for Visitor-serving Businesses	*Cities, counties, and other local and State agencies should work together to protect and enhance visitor-serving businesses by planning for recreation uses and facilities in the Delta, providing infrastructure to support recreation and tourism, and identifying settings for private visitor-serving development and services.*
DP R18	Support the Ports of Stockton and West Sacramento	*The ports of Stockton and West Sacramento should encourage maintenance and carefully designed and sited development of port facilities.*

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DP R19	Plan for Delta Energy Facilities	*The California Energy Commission and California Public Utilities Commission should cooperate with the Delta Stewardship Council as described in Water Code section 85307(d) to identify actions that should be incorporated in the Delta Plan by 2017 to address the needs of Delta energy development, storage, and distribution.*
Chapter 6		
WQ R1	Protect Beneficial Uses	*Water quality in the Delta should be maintained at a level that supports, enhances, and protects beneficial uses identified in the applicable State Water Resources Control Board or regional water quality control board water quality control plans.*
WQ R2	Identify Covered Action Impacts	*Covered actions should identify any significant impacts to water quality.*
WQ R3	Special Water Quality Protections for the Delta	*The State Water Resources Control Board or regional water quality control board should evaluate and, if appropriate, propose special water quality protections for priority habitat restoration areas identified in recommendation ER R2 or other areas of the Delta where new or increased discharges of pollutants could adversely impact beneficial uses.*
WQ R4	Complete Central Valley Drinking Water Policy	*The Central Valley Regional Water Quality Control Board should complete the Central Valley Drinking Water Policy by July 2013.*
WQ R5	Complete North Bay Aqueduct Alternative Intake Project	*The California Department of Water Resources should complete the North Bay Aqueduct Alternate Intake Project Environmental Impact Report by December 31, 2012, and begin construction as soon as possible thereafter.*
WQ R6	Protect Groundwater Beneficial Uses	*The State Water Resources Control Board should complete development of a Strategic Workplan for protection of groundwater beneficial uses, including groundwater use for drinking water, by December 31, 2012.*
WQ R7	Participation in CV-SALTS	*The State Water Resources Control Board and Central Valley Regional Water Quality Control Board should consider requiring participation by all relevant water users that are supplied water from the Delta or the Delta watershed or discharge wastewater to the Delta or the Delta watershed to participate in the Central Valley Salinity Alternatives for Long-Term Sustainability Program.*
WQ R8	Completion of Regulatory Processes, Research, and Monitoring for Water Quality Improvement	*The State Water Resources Control Board and the San Francisco Bay and Central Valley Regional Water Quality Control Boards are currently engaged in regulatory processes, research, and monitoring essential to improving water quality in the Delta. In order to achieve the coequal goals, it is essential that these ongoing efforts be completed and, if possible, accelerated, and that the Legislature and Governor devote sufficient funding to make this possible. The Delta Stewardship Council specifically recommends that:* ■ *The State Water Resources Control Board should complete development of the proposed policy for nutrients for inland surface waters of the State of California by January 1, 2014.* ■ *The State Water Resources Control Board and the San Francisco Bay and Central Valley Regional Water Quality Control Boards should prepare and begin implementation of a study plan for the development of objectives for nutrients in the Delta and Suisun Marsh by January 1, 2014. Studies needed for development of Delta and Suisun Marsh nutrient objectives should be completed by January 1, 2016. The water boards should*

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		adopt and begin implementation of nutrient objectives, either narrative or numeric, where appropriate, for the Delta and Suisun Marsh by January 1, 2018.
		▪ *The State Water Resources Control Board and the Central Valley Regional Water Quality Control Board should complete the Central Valley Pesticide Total Maximum Daily Load and Basin Plan Amendment for diazinon and chlorpyrifos by January 1, 2013.*
		▪ *The State Water Resources Control Board and the Central Valley Regional Water Quality Control Board should prioritize and accelerate the completion of the Central Valley Pesticide Total Maximum Daily Load and Basin Plan Amendment for pyrethroids by January 1, 2016.*
		▪ *The State Water Resources Control Board and the San Francisco Bay and Central Valley Regional Water Quality Control Boards have completed Total Maximum Daily Load and Basin Plan Amendments for methylmercury, and efforts to support their implementation should be coordinated. Parties identified as responsible for current methylmercury loads or proponents of projects that may increase methylmercury loading in the Delta or Suisun Marsh should participate in control studies or implement site-specific study plans that evaluate practices to minimize methylmercury discharges. The Central Valley Regional Water Quality Control Board should review these control studies by December 31, 2018, and determine control measures for implementation starting in 2020.*
WQ R9	Implement Delta Regional Monitoring Program	*The State Water Resources Control Board and Regional Water Quality Control Boards should work collaboratively with the California Department of Water Resources, California Department of Fish and Wildlife, and other agencies and entities that monitor water quality in the Delta to develop and implement a Delta Regional Monitoring Program that will be responsible for coordinating monitoring efforts so Delta conditions can be efficiently assessed and reported on a regular basis.*
WQ R10	Evaluate Wastewater Recycling, Reuse, or Treatment	*The Central Valley Regional Water Quality Control Board, consistent with existing water quality control plan policies and water rights law, should require responsible entities that discharge wastewater treatment plant effluent or urban runoff to Delta waters to evaluate whether all or a portion of the discharge can be recycled, otherwise used, or treated in order to reduce contaminant loads to the Delta by January 1, 2014.*
WQ R11	Manage Dissolved Oxygen in Stockton Ship Channel	*The State Water Resources Control Board and the Central Valley Regional Water Quality Control Board should complete Phase 2 of the Total Maximum Daily Load and Basin Plan Amendment for dissolved oxygen in the Stockton Deep Water Ship Channel by January 1, 2015.*
WQ R12	Manage Dissolved Oxygen in Suisun Marsh	*The State Water Resources Control Board and the San Francisco Bay Regional Water Quality Control Board should complete the Total Maximum Daily Load and Basin Plan Amendment for dissolved oxygen in Suisun Marsh wetlands by January 1, 2014.*

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Chapter 7		
RR R1	Implement Emergency Preparedness and Response	The following actions should be taken by January 1, 2014, to promote effective emergency preparedness and response in the Delta: - Responsible local, State, and federal agencies with emergency response authority should consider and implement the recommendations of the Sacramento-San Joaquin Delta Multi-Hazard Coordination Task Force (Water Code section 12994.5). Such actions should support the development of a regional response system for the Delta. - In consultation with local agencies, the California Department of Water Resources should expand its emergency stockpiles to make them regional in nature and usable by a larger number of agencies in accordance with California Department of Water Resources' plans and procedures. The California Department of Water Resources, as a part of this plan, should evaluate the potential of creating stored material sites by "over-reinforcing" west Delta levees. - Local levee-maintaining agencies should consider developing their own emergency action plans, and stockpiling rock and flood-fighting materials. - State and local agencies and regulated utilities that own and/or operate infrastructure in the Delta should prepare coordinated emergency response plans to protect the infrastructure from long-term outages resulting from failures of the Delta levees. The emergency procedures should consider methods that also would protect Delta land use and ecosystem.
RR R2	Finance Local Flood Management Activities	The Legislature should create a Delta Flood Risk Management Assessment District with fee assessment authority (including over State infrastructure) to provide adequate flood control protection and emergency response for the regional benefit of all beneficiaries, including landowners, infrastructure owners, and other entities that benefit from the maintenance and improvement of Delta levees, such as water users who rely on the levees to protect water quality. This district should be authorized to: - Identify and assess all beneficiaries of Delta flood protection facilities. - Develop, fund, and implement a regional plan of flood management for both project and nonproject levees of the Delta, including the maintenance and improvement of levees, in cooperation with the existing reclamation districts, cities, counties, and owners of infrastructure and other interests protected by the levees. - Require local levee-maintaining agencies to conduct annual levee inspections per the California Department of Water Resources subventions program guidelines, and update levee improvement plans every 5 years. - Participate in the collection of data and information necessary for the prioritization of State investments in Delta levees consistent with RR P1. - Notify residents and landowners of flood risk, personal safety information, and available systems for obtaining emergency information before and during a disaster on an annual basis. - Potentially implement the recommendations of the Sacramento-San Joaquin Delta Multi-Hazard Coordination Task Force (Water Code section 12994.5) in conjunction with local, State, and federal agencies, and maintain the resulting regional response system

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		and components and procedures on behalf of SEMS jurisdictions (reclamation district, city, county, and State) that would jointly implement the regional system in response to a disaster event. ■ *Identify and assess critical water supply corridor levee operations, maintenance, and improvements.*
RR R3	Fund Actions to Protect Infrastructure from Flooding and Other Natural Disasters	■ *The California Public Utilities Commission should immediately commence formal hearings to impose a reasonable fee for flood and disaster prevention on regulated privately owned utilities with facilities located in the Delta. Publicly owned utilities should also be encouraged to develop similar fees. The California Public Utilities Commission, in consultation with the Delta Stewardship Council, the California Department of Water Resources, and the Delta Protection Commission, should allocate these funds among State and local emergency response and flood protection entities in the Delta. If a new regional flood management agency is established by law, a portion of the local share would be allocated to that agency.* ■ *The California Public Utilities Commission should direct all regulated public utilities in their jurisdiction to immediately take steps to protect their facilities in the Delta from the consequences of a catastrophic failure of levees in the Delta, to minimize the impact on the State's economy.* ■ *The Governor, by Executive Order, should direct State agencies with projects or infrastructure in the Delta to set aside a reasonable amount of funding to pay for flood protection and disaster prevention. The local share of these funds should be allocated as described above.*
RR P1 (23 CCR section 5012)	Prioritization of State Investments in Delta Levees and Risk Reduction	(a) *Prior to the completion and adoption of the updated priorities developed pursuant to Water Code section 85306, the interim priorities listed below shall, where applicable and to the extent permitted by law, guide discretionary State investments in Delta flood risk management. Key priorities for interim funding include emergency preparedness, response, and recovery as described in paragraph (1), as well as Delta levees funding as described in paragraph (2).* (1) *Delta Emergency Preparedness, Response, and Recovery: Develop and implement appropriate emergency preparedness, response, and recovery strategies, including those developed by the Delta Multi-Hazard Task Force pursuant to Water Code section 12994.5.* (2) *Delta Levees Funding: The priorities shown in the following table are meant to guide budget and funding allocation strategies for levee improvements. The goals for funding priorities are all important, and it is expected that over time, the California Department of Water Resources must balance achievement of those goals. Except on islands planned for ecosystem restoration, improvement of nonproject Delta levees to the Hazard Mitigation Plan (HMP) standard may be funded without justification of the benefits. Improvements to a standard above HMP, such as that set by the U.S. Army Corps of Engineers under Public Law 84-99, may be funded as befits the benefits to be provided, consistent with the California Department of Water Resources' current practices and any future adopted investment strategy.*

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Priorities for State Investment in Delta Integrated Flood Management

Categories of Benefit Analysis

Goals	Localized Flood Protection	Levee Network	Ecosystem Conservation
1	Protect existing urban and adjacent urbanizing areas by providing 200-year flood protection.	Protect water quality and water supply conveyance in the Delta, especially levees that protect freshwater aqueducts and the primary channels that carry fresh water through the Delta.	Protect existing and provide for a net increase in channel-margin habitat.
2	Protect small communities and critical infrastructure of statewide importance (located outside of urban areas).	Protect floodwater conveyance in and through the Delta to a level consistent with the State Plan of Flood Control for project levees.	Protect existing and provide for net enhancement of floodplain habitat.
3	Protect agriculture and local working landscapes.	Protect cultural, historic, aesthetic, and recreational resources (Delta as Place).	Protect existing and provide for net enhancement of wetlands.

(b) For purposes of Water Code section 85057.5(a)(3) and section 5001(j)(1)(E) of this Chapter, this policy covers a proposed action that involves discretionary State investments in Delta flood risk management, including levee operations, maintenance, and improvements. Nothing in this policy establishes or otherwise changes existing levee standards.

RR R4	Actions for the Prioritization of State Investments in Delta Levees	*The Delta Stewardship Council, in consultation with the California Department of Water Resources, the Central Valley Flood Protection Board, the Delta Protection Commission, local agencies, and the California Water Commission, should develop funding priorities for State investments in Delta levees by January 1, 2015. These priorities shall be consistent with the provisions of the Delta Reform Act in promoting effective, prioritized strategic State investments in levee operations, maintenance, and improvements in the Delta for both levees that are a part of the State Plan of Flood Control and nonproject levees. Upon completion, these priorities shall be considered for incorporation into the Delta Plan.*

The priorities should identify guiding principles, constraints, recommended cost share allocations, and strategic considerations to guide Delta flood risk reduction investments,

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		supported by, at a minimum, the following actions to be conducted by the California Department of Water Resources, consistent with available funding:
		
		■ An assessment of existing Delta levee conditions. This should include the development of a Delta levee conditions map based on sound data inputs, including, but not limited to:
		
		  ■ Geometric levee assessment
		  ■ Flow and updated stage-frequency analysis
		
		■ An island-by-island economics-based risk analysis. This analysis should consider, but not be limited to, values related to protecting:
		
		  ■ Island residents/life safety
		  ■ Property
		  ■ Value of Delta islands' economic output, including agriculture
		  ■ State water supply
		  ■ Critical local, State, federal, and private infrastructure, including aqueducts, state highways, electricity transmission lines, gas/petroleum pipelines, gas fields, railroads, and deep water shipping channels
		  ■ Delta water quality
		  ■ Existing ecosystem values and ecosystem restoration opportunities
		  ■ Recreation
		  ■ Systemwide integrity
		
		■ An ongoing assessment of Delta levee conditions. This should include a process for updating Delta levee assessment information on a routine basis.
		
		This methodology should provide the basis for the prioritization of State investments in Delta levees. It should include, but not be limited to, the public reporting of the following items:
		
		■ Tiered ranking of Delta islands, based on economics-based risk analysis values
		■ Delta levee conditions status report, including a levee conditions map
		■ Inventory of Delta infrastructure assets

RR P2
(23 CCR section 5013)
	Require Flood Protection for Residential Development in Rural Areas	(a) New residential development of five or more parcels shall be protected through flood-proofing to a level 12 inches above the 100-year base flood elevation, plus sufficient additional elevation to protect against a 55-inch rise in sea level at the Golden Gate, unless the development is located within:
		
		  (1) Areas that city or county general plans, as of May 16, 2013, designate for development in cities or their spheres of influence;
		
		  (2) Areas within Contra Costa County's 2006 voter-approved urban limit line, except Bethel Island;
		
		  (3) Areas within the Mountain House General Plan Community Boundary in San Joaquin County; or
		
		  (4) The unincorporated Delta towns of Clarksburg, Courtland, Hood, Locke, Ryde, and Walnut Grove, as shown in Appendix 7.
		
		(b) For purposes of Water Code section 85057.5(a)(3) and section 5001(j)(1)(E) of this Chapter, this policy covers a proposed action that involves new residential development of five or more parcels that is not located within the areas described in subsection (a).

POLICY OR RECOMMENDATION NUMBER	SHORT TITLE	POLICY/RECOMMENDATION LANGUAGE
RR P3 (23 CCR section 5014)	Protect Floodways	(a) *No encroachment shall be allowed or constructed in a floodway, unless it can be demonstrated by appropriate analysis that the encroachment will not unduly impede the free flow of water in the floodway or jeopardize public safety.* (b) *For purposes of Water Code section 85057.5(a)(3) and section 5001(j)(1)(E) of this Chapter, this policy covers a proposed action that would encroach in a floodway that is not either a designated floodway or regulated stream.*
RR P4 (23 CCR section 5015)	Floodplain Protection	(a) *No encroachment shall be allowed or constructed in any of the following floodplains unless it can be demonstrated by appropriate analysis that the encroachment will not have a significant adverse impact on floodplain values and functions:* (1) *The Yolo Bypass within the Delta;* (2) *The Cosumnes River-Mokelumne River Confluence, as defined by the North Delta Flood Control and Ecosystem Restoration Project (McCormack-Williamson), or as modified in the future by the California Department of Water Resources or the U.S. Army Corps of Engineers (California Department of Water Resources 2010); and* (3) *The Lower San Joaquin River Floodplain Bypass area, located on the Lower San Joaquin River upstream of Stockton immediately southwest of Paradise Cut on lands both upstream and downstream of the Interstate 5 crossing. This area is described in the Lower San Joaquin River Floodplain Bypass Proposal, submitted to the California Department of Water Resources by the partnership of the South Delta Water Agency, the River Islands Development Company, Reclamation District 2062, San Joaquin Resource Conservation District, American Rivers, the American Lands Conservancy, and the Natural Resources Defense Council, March 2011. This area may be modified in the future through the completion of this project.* (b) *For purposes of Water Code section 85057.5(a)(3) and section 5001(j)(1)(E) of this Chapter, this policy covers a proposed action that would encroach in any of the floodplain areas described in subsection (a).* (c) *This policy is not intended to exempt any activities in any of the areas described in subsection (a) from applicable regulations and requirements of the Central Valley Flood Protection Board.*
RR R5	Fund and Implement San Joaquin River Flood Bypass	*The Legislature should fund the California Department of Water Resources and the Central Valley Flood Protection Board to evaluate and implement a bypass and floodway on the San Joaquin River near Paradise Cut that would reduce flood stage on the mainstem San Joaquin River adjacent to the urban and urbanizing communities of Stockton, Lathrop, and Manteca in accordance with Water Code section 9613(c).*
RR R6	Continue Delta Dredging Studies	*The current efforts to maintain navigable waters in the Sacramento River Deep Water Ship Channel and Stockton Deep Water Ship Channel, led by the U.S. Army Corps of Engineers and described in the Delta Dredged Sediment Long-Term Management Strategy (USACE 2007, Appendix K), should be continued in a manner that supports the Delta Plan and the coequal goals. Appropriate dredging throughout other areas in the Delta for maintenance purposes, or that would increase flood conveyance and provide potential material for levee maintenance or subsidence reversal should be implemented in a manner that supports the Delta Plan and coequal goals. Coordinated use of dredged material in levee improvement, subsidence reversal, or wetland restoration is encouraged.*

POLICY OR RECOMMENDATION NUMBER	SHORT TITLE	POLICY/RECOMMENDATION LANGUAGE
RR R7	Designate Additional Floodways	*The Central Valley Flood Protection Board should evaluate whether additional areas both within and upstream of the Delta should be designated as floodways. These efforts should consider the anticipated effects of climate change in its evaluation of these areas.*
RR R8	Develop Setback Levee Criteria	*The California Department of Water Resources, in conjunction with the Central Valley Flood Protection Board, the California Department of Fish and Wildlife, and the Delta Conservancy, should develop criteria to define locations for future setback levees in the Delta and Delta watershed.*
RR R9	Require Flood Insurance	*The Legislature should require an adequate level of flood insurance for residences, businesses, and industries in floodprone areas.*
RR R10	Limit State Liability	*The Legislature should consider statutory and/or constitutional changes that would address the State's potential flood liability, including giving State agencies the same level of immunity with regard to flood liability as federal agencies have under federal law.*
Chapter 8		
FP R1	Conduct Current Spending Inventory	*An inventory of current State and federal spending on programs and projects that do or may achieve the coequal goals will be conducted. Data sources to be used include the CALFED cross-cut budget, State bond balance reports, and the annual State budget, among others. Consideration will be given to selecting an independent agency (which could include a non governmental organization) to conduct the inventory.*
FP R2	Develop Delta Plan Cost Assessment	*Costs will be assigned to the projects and programs proposed in the Delta Plan (Chapters 2 through 7) and sources of funding will be identified.*
FP R3	Identify Funding Gaps	*Current State and federal funding gaps will be identified that are determined to hinder progress toward meeting the coequal goals.*

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ATTACHMENT 7

Phase 4 of Bay-Delta Effort: Overview & Background

Method to Develop Flow Criteria for Priority Tributaries to the Bay-Delta Workshop

Erin Ragazzi

March 19, 2014

Presentation Outline

- Definitions
- General Background on State Water Board & Authority
- Phase 4 Overview – Flow Objectives for Priority Tributaries (Sacramento River focus)
- Next Steps
- Resources

DEFINITIONS

Flow Criteria

Flow Objective

Public Trust

Beneficial Uses

Flow Criteria
(focus of today's workshop)

- The range of instream flow needed to ensure the viability of aquatic dependent species, and to support geomorphic processes that create and maintain habitat

- Provide the technical basis for the development of flow objectives

- Do not consider competing uses of water

- Do not have regulatory effect

Flow Objectives

- The quantity of instream flow required to maintain ecologically sustainable watersheds, while concurrently <u>balancing</u> all beneficial uses of water

- State Water Board determination that has regulatory effect

- Tributary-specific flow objectives will be developed as a component of tributary-specific policies

Public Trust

- The State Water Board is responsible for the protection of public trust uses, including commerce, navigation, recreation, and habitat for fish and wildlife, which are held in trust for the public.

- The State Water Board must consider these responsibilities when planning and allocating water resources, and protect public trust uses whenever feasible.

Beneficial Uses of Water

- Beneficial uses of water, pertaining to water rights include: domestic; irrigation; power; municipal; mining; industrial; fish and wildlife preservation and enhancement; aquaculture; recreational; stock watering; water quality; frost protection; and heat control.
  - California Code of Regulations (CCR) §659-672

Beneficial Uses of Water (con't)

- Water quality control plans (basin plans) also designate beneficial uses
- Beneficial uses of waters of the state that "may be protected against quality degradation include, but are not limited to: domestic, municipal, agricultural and industrial supply; power generation; recreation; aesthetic enjoyment; navigation; and preservation and enhancement of fish, wildlife, and other aquatic resources or preserves" - Water Code §13050
- Examples: water contact recreation, cold and warm freshwater habitat, cold and warm water spawning habitat, agricultural supply, commercial and sport fishing, etc.

State Water Board Background & Authority

State Water Board's Mission

To preserve, enhance and restore the quality of California's water resources, and ensure their proper allocation and efficient use for the benefit of present and future generations

Authorities

- Dual authorities (water allocation and water quality protection) to provide comprehensive protection of California's waters
- Protect and enforce water quality standards (beneficial uses + water quality objectives + antidegradation)
- Protect public trust resources
- Balancing role

Recent History

- 2009 Delta Reform Act (Senate Bill X7-1)
  - Water Code §§ 85086 & 85087

Water Code (Delta Reform Act)

§85086

"For the purpose of informing planning decisions for the Delta Plan and the Bay Delta Conservation Plan, the board shall, **pursuant to its public trust obligations, develop new flow criteria for the Delta ecosystem necessary to protect public trust resources"**

§85087

"The board [...] shall submit to the Legislature a prioritized schedule and estimate of costs to complete instream flow studies for the Delta and for high priority rivers and streams in the Delta watershed [...] and for all major rivers and streams outside the Sacramento River watershed [...]"

History Continued

- 2010: State Water Board submittal to Legislature – *Instream Flow Studies for the Protection of Public Trust Resources: A Prioritized Schedule and Estimate of Costs*
  - Included 138 rivers and streams (28 Delta tributaries)
  - Determined which rivers and streams should be prioritized for instream flow studies

  http://www.waterboards.ca.gov/publications_forms/publications/legislative/docs/2011/instream_flow2010.pdf

- 2010: State Water Board completed report: *Development of Flow Criteria for the Sacramento-San Joaquin Delta Ecosystem*

History Continued

- 2013: Delta Stewardship Council's Final Delta Plan
  - Co-equal goals:
    - Provide a more reliable water supply for California
    - Protect, restore, and enhance the Delta ecosystem
  - Directs State Water Board "By June 2, 2018, adopt, and as soon as reasonably possible, implement flow objectives for high-priority tributaries in the Delta watershed that are necessary to achieve the coequal goals"

State Water Board Bay-Delta Activities

- <u>Phase 1</u>: Bay-Delta Plan review and update of the San Joaquin River flow and southern Delta salinity objectives and program of implementation

- <u>Phase 2</u>: Comprehensive review and update of other components of the Bay-Delta Plan and program of implementation

- <u>Phase 3</u>: Amendment of water rights and other measures to implement changes to the Bay-Delta Plan resulting from Phases 1 and 2

- **<u>Phase 4:</u> Development and implementation of flow criteria and flow objectives for priority tributaries to the Sacramento-San Joaquin Delta watershed, with a focus on the Sacramento River watershed**

Phase 4 Goal

- Focus on Sacramento River watershed
- Establish and implement flow objectives for a minimum of five priority tributaries in the Bay-Delta watershed by 2018 – as policies for water quality control
- Work to continue on remaining priority tributaries thereafter
- Consistent with Delta Stewardship Council's *Final Delta Plan*

Phase 4 Objectives

- Achieve characteristics of a natural hydrograph
  - Inter-annual variability
  - Intra-annual events
- Restore natural fluvial processes
  - Inundate floodplains
  - Flush fines
  - Maintain channel habitat
- Restore natural high flow recession rates
  - Prevent juvenile salmonid stranding
  - Promote riparian seed dispersal
  - Trigger natural species reproduction patterns

Phase 4 Objectives

- Restore self-sustaining resilient populations of anadromous salmonids and other native species
- Preserve existing beneficial uses of water to the maximum extent possible
- Minimize impacts to water right holders

Phase 4 Process

1. Development of non-binding flow criteria (**discussion of this workshop**)

2. Development of flow objectives and implementation plans

3. Development of policies for water quality control

4. Implementation of policies through conditioning of water rights and other measures as appropriate

Policies for Water Quality Control (Water Code §§13140-13147)

- Tributary-specific
- Include flow objective(s), implementation plan, and adaptive management
- Principles, guidelines, and requirements for maintaining instream flows and habitat connectivity to protect public trust resources, while minimizing impacts on other beneficial uses of water
- Complement or enhance existing efforts to make significant positive progress towards protection of public trust resources and other beneficial uses of water

Flow Criteria Method Objectives

- Leverage limited resources available to conduct needed studies over large geographic area

- Applicable to bulk of each tributary's watershed

- Address multiple species or life stages and fluvial processes

- Responsive to critical and time-sensitive need to address flow-related impacts contributing to the decline of threatened and endangered species

Major Tributaries of the
Sacramento River and
North Bay-Delta Watershed:
Phase 4 Priorities

Legend

CV Chinook Salmon Critical Habitat
CV Steelhead Critical Habitat
Tributaries
Reservoirs
San Francisco Bay
Sacramento-San Joaquin River Delta

0 10 20   40   60   80
Miles

Scale: 1:1,800,000
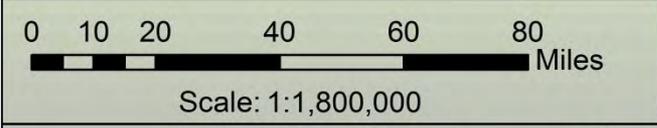
Sources: CA SWRCB,
National Marine Fisheries
Service, ESRI

CALIFORNIA
Water Boards
STATE WATER RESOURCES CONTROL BOARD
REGIONAL WATER QUALITY CONTROL BOARDS
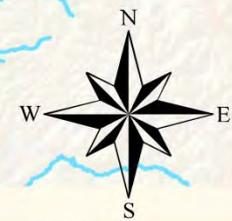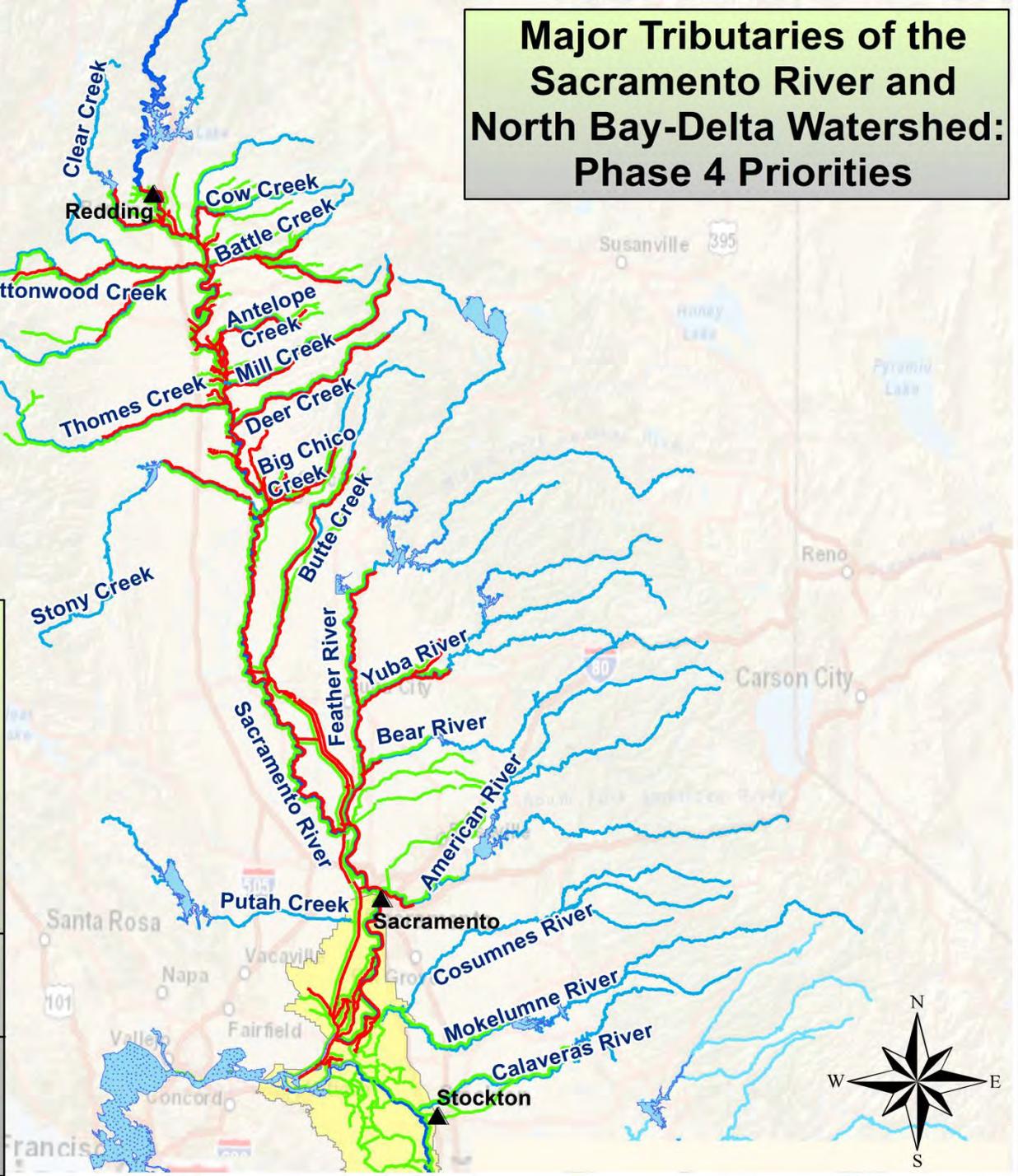
Major Tributaries in the Phase 4 Planning Area (in alphabetical order)

American River	Clear Creak	Mill Creek
Antelope Creek	Cosumnes River	Mokelumne River
Auburn Ravine	Cottonwood Creek	Paynes Creek
Battle Creek	Cow Creek	Sacramento River (below Keswick)
Bear River	Deer Creek	Stony Creek
Big Chico Creek	Dry Creek	Thomes Creek
Butte Creek	Feather River	Yuba River
Calaveras River	McClure Creek	

Flow Objectives to be developed as part of Phase 1 Bay-Delta Plan Update

Merced River
San Joaquin River
Stanislaus River
Tuolumne River

Flow Criteria Development (to date)

- July 2013: State Water Board submitted *Request for Recommendation of Method to Develop Flow Criteria for Priority Tributaries to the Sacramento-San Joaquin Delta* to the Delta Science Program
  - Scientifically Defensible
  - Cost-effective
  - Applicable to the bulk of each tributary's watershed
  - Can be implemented in a timely fashion

Flow Criteria Development (to date)

- February 2014: Delta Science Program transmitted the report developed by an independent review committee - *Recommendations for Determining Regional Instream Flow Criteria for Priority Tributaries to the Sacramento-San Joaquin Delta*

Phase 4 Next Steps

- Public Comment Period ends at Noon (12:00 pm) on April 18, 2014
- Staff will review comments received to develop a recommendation for the State Water Board regarding its process to develop instream flow criteria for priority tributaries as part of the Phase 4 process
  - Staff recommendation to be incorporated into Phase 4 Strategy document

Phase 4 Next Steps (con't)

- Develop *Strategy for Establishing Flows for Tributaries to the Bay-Delta* (Phase 4 Strategy); Anticipate Strategy will contain:
  - Goals and objectives of Phase 4 effort
  - Overview of process
  - Flow criteria methodology
  - Priority Tributaries

  - <u>Timeframe</u>: Draft Strategy anticipated for release for public comment in Fall 2014

Phase 4 Resources

- Phase 4 Webpage:

  http://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/flow_objectives/index.shtml

- To receive email subscriptions:

  http://www.waterboards.ca.gov/resources/email_subscriptions/

  - Select "State Water Resources Control Board"
  - Enter email address and full name
  - Under Categories, select "Water Rights Topics"
  - Select "Delta Watershed Flow Objectives (Phase 4 of Bay-Delta effort)"
  - Click "Subscribe" button at top

Method to Develop Flow Criteria for Priority Tributaries to the Bay-Delta Workshop

March 19, 2014

ATTACHMENT 8

State Water Resources Control Board

NOTICE OF PUBLIC WORKSHOP

METHOD TO DEVELOP FLOW CRITERIA FOR
PRIORITY TRIBUTARIES TO THE BAY-DELTA

Wednesday, March 19, 2014 – 9:00 a.m.
Joe Serna Jr. – Cal/EPA Headquarters Building
Coastal Hearing Room
1001 I Street, Second Floor
Sacramento, CA 95814

NOTICE IS HEREBY GIVEN that the State Water Resources Control Board (State Water Board) will hold a public workshop to receive information and solicit public input on the Delta Stewardship Council – Delta Science Program's (Delta Science Program) Recommendation on the Method to Develop Flow Criteria for Priority Tributaries to the San Francisco Bay/ Sacramento – San Joaquin Delta Estuary (Bay-Delta). This will be an information workshop only and no State Water Board action will be taken.

BACKGROUND

On July 31, 2013, the State Water Board submitted a document to the Delta Science Program to request assistance in identifying one or more scientifically defensible methods to develop flow criteria for priority tributaries to the Bay-Delta. In response, the Delta Science Program evaluated a variety of methods which could be used for this purpose, and has provided a recommendation to the State Water Board. The State Water Board plans to use the recommendation to inform the Phase 4 process of developing flow criteria and establishing flow objectives for a minimum of five priority tributaries in the Bay-Delta watershed by June 2018.

The State Water Board is conducting water quality control planning and flow-related work in the Bay-Delta watershed in four phases as outlined below. The first three phases involve developing and implementing updates to the *2006 Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary* (Bay-Delta Plan):

Phase 1:   Bay-Delta Plan review and update of the San Joaquin River Flow and Southern Delta Salinity Objectives and associated program of implementation;

Phase 2:   Comprehensive review and update of other components of the Bay-Delta Plan and associated program of implementation;

Phase 3:   Amendment of water rights and other measures to implement changes to the Bay-Delta Plan resulting from Phases 1 and 2; and

Phase 4:   Development and implementation of tributary-specific policies for water quality control, including the development of flow criteria and flow objectives for priority tributaries to the Bay-Delta, with a focus on the Sacramento River watershed.

Phase 4 includes: 1) development of non-binding flow criteria; 2) development of flow objectives[1] and implementation plans; 3) development of policies that incorporate flow objectives, methods for adaptive management, and implementation plans; and 4) implementation of policies through conditioning of water rights and other measures as appropriate.

The State Water Board's current focus and the purpose of this public workshop is the methods to be used for development of non-binding flow criteria. Flow criteria, as referred to in Phase 4, provide the technical basis for the development of flow objectives, but do not have regulatory effect. Flow criteria do not consider the costs of providing this water or the competing uses for water. Flow criteria will identify the range of instream flows needed to ensure the viability of aquatic species and support fluvial processes. Flow criteria should consider the needs of each tributary's flow dependent aquatic organisms and emphasize the protection of threatened or endangered species, or species likely to become threatened or endangered in the foreseeable future.

WORKSHOP OVERVIEW

The State Water Board will hold a public workshop to receive information and solicit input on the Delta Science Program's recommendation of the method that the State Water Board should use to develop flow criteria for priority tributaries to the Bay-Delta (Phase 4). State Water Board staff will present a brief overview of Phase 4, including the goals and anticipated timelines for the Phase 4 process. Dr. Cliff Dahm, the Delta Science Program's independent review committee chair, will present an overview of the recommendation and findings. The public may review and comment on the recommendation from the Delta Science Program or provide alternative recommendations of methods to develop flow criteria for priority tributaries to the Bay-Delta. To ensure a productive and efficient public workshop, the discussion will focus on the potential method(s) to develop flow criteria for priority tributaries to the Bay-Delta. The workshop discussion is not intended to focus on policy questions or implementation.

AVAILABILITY OF DOCUMENTS

Additional information on Phase 4 of the Bay-Delta effort, including a copy of the document submitted to the DSP, and a copy of the DSP's written recommendation, can be found on the Phase 4 webpage at:
http://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/flow_objectives/index.shtml

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[1] Flow objectives, with regulatory effect, will be established to provide balanced protection of all applicable beneficial uses and public trust resources.

SUBMISSION OF WRITTEN COMMENTS

The State Water Board encourages interested parties and persons to submit their comments in writing. Comment letters regarding the workshop topic **must be received by 12:00 p.m. (noon) on Friday, April 18, 2014**. Please send comment letters to Jeanine Townsend, Clerk to the Board, by email at: commentletters@waterboards.ca.gov (15 megabytes, or less, in size); by fax: (916) 341-5620; or by mail, addressed to:

Jeanine Townsend,
Clerk to the Board
State Water Resources Control Board
1001 I Street, 24th Floor
Sacramento, CA 95814

Please indicate the subject line **"Comment Letter – Board Workshop: Recommendations for Developing Instream Flow Criteria for Priority Tributaries (Phase 4)."** Persons delivering hard copies of comment letters must check in with lobby security personnel, who can contact Ms. Townsend at (916) 341-5600.

PROCEDURAL MATTERS

The workshop will be informal. While a quorum of the State Water Board may be present, the State Water Board will not take formal action at the workshop. There will be no sworn testimony or cross-examination of participants, but the State Water Board and its staff may ask clarifying questions. No final action will be taken until a subsequent, noticed State Water Board meeting.

The workshop is an opportunity for interested persons to provide input to the State Water Board. To ensure a productive and efficient workshop, oral comments will be limited to five (5) minutes or otherwise at the discretion of the State Water Board Chair. To ensure a productive and efficient workshop, participants with common comments are encouraged to coordinate and provide oral comments as a group. **For those wishing to organize and present comments as a group, please contact Mr. Daniel Schultz by March 12, 2014 at (916) 323-9392 to ensure that adequate time is allotted.** So that all commenters have an opportunity to participate, presentations and questions may be time-limited.

WEBCAST OF WORKSHOP

A broadcast of the meeting will be available via the Internet and can be accessed at: http://www.calepa.ca.gov/broadcast/.

PARKING AND ACCESSIBILITY

For directions to the Cal/EPA Building and public parking information, please refer to the following website at: http://www.calepa.ca.gov/EPAbldg/location.htm.

The Cal/EPA building is accessible to persons with disabilities. Individuals who require special accommodations are requested to contact Ms. Michele Villados, at (916) 341-5881, at least five working days prior to the meeting. Persons with hearing or speech impairments may contact us using the California Relay Service Telecommunications Device for the Deaf (TDD) at (800) 735-2929 or voice line at (800) 735-2922.

Due to enhanced security precautions at the Cal/EPA Building, all visitors are required to register with security staff prior to attending any meeting. To sign in and receive a visitor's badge, visitors must go to the Visitor and Environmental Services Center, located just inside and to the left of the Cal/EPA Building's main public entrance. Depending on their destination and the building's security level, visitors may be asked to show valid picture identification. Valid picture identification can take the form of a current driver's license, military identification card, or state or federal identification card. Depending on the size and number of meetings scheduled on any given day, the security check-in could take up to 15 minutes. Please allow adequate time to sign in before being directed to the workshop.

QUESTIONS REGARDING THE WORKSHOP

Questions concerning this notice may be directed to Mr. Daniel Schultz, Senior Environmental Scientist, at (916) 323-9392 or by email at: Daniel.Schultz@waterboards.ca.gov.

February 19, 2014
Date

Jeanine Townsend
Clerk to the Board

ATTACHMENT 9

Note to Readers:

This report, required by Water Code section 85086(c) (2009 Delta Reform Act) in 2010, suggests the flows that would be needed in the Delta ecosystem if fishery protection was the sole purpose for which its waters were put to beneficial use. In keeping with the narrow focus of the legislation, this report only presents a technical assessment of flow and operational requirements to provide fishery protection under existing conditions.

We know however, that there are many other important beneficial uses that these waters support such as municipal and agricultural water supply and recreational uses. The State Water Board is required by law to establish flow and other objectives that ensure the reasonable protection of beneficial uses. In order for any flow objective to be reasonable, the State Water Board must consider and balance all competing uses of water in its decision-making. More broadly, the State Water Board will factor in relevant water quality, water rights and habitat needs as it considers potential changes to its Bay-Delta objectives. Any attempts to portray the recommendations contained in this report as an indicator of future State Water Board decision-making ignores this critical, multi-dimensional balancing requirement and misrepresents current efforts to analyze the water supply, economic, and hydropower effects of a broad range of alternatives. This report represents only one of many factors that will need to be balanced by the State Water Board as it updates the Bay-Delta Water Quality Control Plan. For more current information on the State Water Board's Bay-Delta Plan update efforts, please visit http://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/.

State Water Resources Control Board
California Environmental Protection Agency

Development of Flow Criteria for the Sacramento-San Joaquin Delta Ecosystem

Prepared Pursuant to the Sacramento-San Joaquin Delta Reform Act of 2009

August 3, 2010

STATE WATER RESOURCES
CONTROL BOARD
P.O. Box 100
Sacramento, CA 95812-0100
(916) 341-5250
http://www.waterboards.ca.gov

State Water Resources Control Board
California Environmental Protection Agency

**Development of Flow Criteria for the Sacramento-San Joaquin Delta
Ecosystem**

Prepared Pursuant to the Sacramento-San Joaquin Delta Reform Act of 2009

Report prepared by:

Phil Crader, Senior Environmental Scientist
Les Grober, Environmental Program Manager
Adam Ballard, Senior Environmental Scientist
Chris Foe, Staff Environmental Scientist
Diane Riddle, Staff Environmental Scientist
David La Brie, Engineering Associate
Mark Gowdy, Water Resources Control Engineer
Erin Mahaney, Senior Staff Counsel

With assistance from:

Barbara Leidigh, Senior Staff Counsel
Lucas Sharkey, Water Resources Control Engineer
Jean McCue, Water Resources Control Engineer
Dramy Saechao, Office Technician
Stephen Craig, Associate Information Systems Analyst
Duran Fiack, Student Assistant

Acknowledgements

The State Water Resources Control Board (State Water Board or Board) acknowledges the following for their contributions and participation in the Board's Delta Flow Criteria proceding:

- The professors, researchers, and staff from various resource agencies that comprise the Delta Environmental Flows Group (DEFG) for providing valuable information and insights that informed the Delta flow criteria informational proceeding, and whose work was cited liberally throughout this report
- The UC Davis Delta Solutions Group, a subset of the DEFG for providing additional insights in their reports on habitat variability, flow presecriptions, and ecosystem investments
- The California Department of Fish and Game for working collaboratively with the State Water Board on development of species life history requirements and for reviewing portions of the draft report
- The United States Fish and Wildflie Service and National Marine Fisheries Service for reviewing portions of the draft report
- All the participants of the proceeding for providing information and serving on panels to answer questions during the proceeding

The State Water Board, however, is responsible for any errors and for all interpretations of the information in this report.

STATE WATER RESOURCES CONTROL BOARD
RESOLUTION NO. 2010-0039

DETERMINING DELTA FLOW CRITERIA PURSUANT TO THE DELTA REFORM ACT

WHEREAS:

1. Water Code section 85086, contained in the Sacramento-San Joaquin Delta Reform Act of 2009 (Stats. 2009 (7th Ex. Sess.) ch. 5) (commencing with Wat. Code, § 85000), requires the State Water Resources Control Board (State Water Board) to develop, within nine months of enactment of the statute, new flow criteria for the Sacramento-San Joaquin Delta (Delta) ecosystem that are necessary to protect public trust resources. The purpose of the flow criteria is to inform planning decisions for the Delta Plan and the Bay Delta Conservation Plan. The statute specifies that the flow criteria shall not predetermine any issue that may arise in the State Water Board's subsequent consideration of a permit.

2. In accordance with Water Code section 85086, subdivision (c)(1), the State Water Board conducted a public process in the form of an informational proceeding to collect information used to develop the flow criteria. The State Water Board conducted the informational proceeding on March 22-24, 2010, and considered the information submitted in connection with that proceeding in developing the flow criteria.

3. The State Water Board has prepared a report determining flow criteria for the Delta ecosystem necessary to protect public trust resources. In developing the flow criteria, the State Water Board reviewed existing water quality objectives and used the best available scientific information. The flow criteria include the volume, timing, and quality of flow necessary under different hydrologic conditions.

THEREFORE BE IT RESOLVED THAT:

1. In accordance with the Delta Reform Act, the State Water Board approves the report determining new flow criteria for the Delta ecosystem that are necessary to protect public trust resources.

2. The Executive Director is directed to submit the Delta flow criteria report to the Delta Stewardship Council for its information within 30 days of the adoption of this resolution.

CERTIFICATION

The undersigned Clerk to the Board does hereby certify that the foregoing is a full, true, and correct copy of a resolution duly and regularly adopted at a meeting of the State Water Board held on August 3, 2010.

AYE: Chairman Charles R. Hoppin
               Vice Chair Frances Spivy-Weber
               Board Member Arthur G. Baggett, Jr.
               Board Member Tam M. Doduc
               Board Member Walter G. Pettit

NAY: None

ABSENT: None

ABSTAIN: None

_____

Jeanine Townsend
Clerk to the Board

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Acronyms and Abbreviations

AFRP	Anadromous Fish Restoration Program
AR	American Rivers
Bay-Delta	San Francisco Bay/Sacramento-San Joaquin Delta Estuary including Suisun Marsh
Bay-Delta Plan	Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary
BDCP	Bay Delta Conservation Program
CCWD	Contra Costa Water District
Central Valley Regional Board	Central Valley Regional Water Quality Control Board
CEQA	California Environmental Quality Act
CESA	California Endangered Species Act
cfs	cubic feet per second
Council	Delta Stewardship Council
CSPA	California Sportfishing Protection Alliance
CVP	Central Valley Project
CWIN	California Water Impact Network
DEFG	Delta Environmental Flows Group
Delta	Confluence of the Sacramento River and San Joaquin River (as defined in Water Code section 12220)
Delta Plan	Delta Stewardship Council comprehensive, long-term management plan for the Delta
Delta Reform Act	Sacramento-San Joaquin Delta Reform Act of 2009
DFG	California Department of Fish and Game
DO	dissolved oxygen
DOI	United States Department of the Interior
DSM2	Delta Simulation Model
DWR	California Department of Water Resources
DWSC	Stockton Deep Water Ship Channel
E/I	Export/Inflow ratio
EC	Electrical Conductivity
EDF	Environmental Defense Fund
ESA	Endangered Species Act
FERC	Federal Energy Regulatory Commission
FMWG	Fisheries Management Work Group
FMWT	Fall mid-water trawl
IEP	Interagency Ecological Program
LSZ	Low Salinity Zone
MAF	million acre-feet
mg/L	milligrams per liter
mmhos/cm	millimhos per centimeter
NAS	National Academy of Sciences
NCCPA	State Natural Community Conservation Planning Act
NDOI	Net Delta Outflow Index
NEPA	National Environmental Policy Act
NHI	Natural Heritage Institute

NMFS	National Marine Fisheries Service
NRDC	Natural Resources Defense Council
OCAP	Long-Term Operations Criteria and Plan for Coordination of the Central Valley Project and the State Water Project
OMR	Old and Middle River
Opinion	Biological Opinion
PCFFA	Pacific Coast Federation of Fishermen's Associations
POD	Pelagic Organism Decline
ppt	parts per thousand
psu	practical salinity unit
PTM	Particle Tracking Model
RMP	Regional Monitoring Program
RPA	Reasonable and Prudent Alternatives
San Francisco Regional Board	San Francisco Bay Regional Water Quality Control Board
SB 1	Senate Bill No. 1 of the 2009-2010 Seventh Extraordinary Session (Stats. 2009 (7th Ex. Sess.) ch. 5, § 39)
SFWC	State and Federal Water Contractors
SJRA	San Joaquin River Agreement
SJRGA	San Joaquin River Group Authority
SJRRP	San Joaquin River Restoration Program
SRWTP	Sacramento Regional Wastewater Treatment Plant
State Water Board	State Water Resources Control Board
SWG	Smelt Working Group
SWP	State Water Project
TBI	The Bay Institute
TNC	The Nature Conservancy
USACE	U.S. Army Corps of Engineers
USBR	United States Bureau of Reclamation
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
VAMP	Vernalis Adaptive Management Plan
WOMT	Water Operations Management Team

1. Executive Summary

The Sacramento-San Joaquin Delta (Delta) is a critically important natural resource for California and the nation. It is both the hub of California's water supply system and the most valuable estuary and wetlands on the western coast of the Americas. The Delta is in ecological crisis, resulting in high levels of conflict that affect the sustainability of existing water policy in California. Several species of fish have been listed as protected species under the California Endangered Species Act (CESA) and under the federal Endangered Species Act (ESA). These two laws and other regulatory constraints have restricted water diversions from the Delta in an effort to prevent further harm to the protected species.

In November 2009, California enacted a comprehensive package of four policy bills and a bond measure intended to meet California's growing water challenges by adopting a policy of sustainable water supply management to ensure a reliable water supply for the State and to restore the Delta and other ecologically sensitive areas. One of these bills, Senate Bill No. 1 (SB 1) (Stats. 2009 (7th Ex. Sess.) ch 5, § 39) contains the Sacramento-San Joaquin Delta Reform Act of 2009 (Delta Reform Act), Water Code section 85000 et seq. The Delta Reform Act establishes a Delta Stewardship Council (Council), tasked with developing a comprehensive, long-term management plan for the Delta, known as the Delta Plan, and providing direction to multiple state and local agencies that take actions related to the Delta. The comprehensive bill package also sets water conservation policy, requires increased groundwater monitoring, and provides for increased enforcement against illegal water diversions.

The Delta Reform Act requires the State Water Board to use a public process to develop new flow criteria for the Delta ecosystem. During this process, participants cautioned the the State Water Board on the limitations of any flow criteria (Fleenor *et al.*, 2010):

> "How much water do fish need?" has been a common refrain in Delta water management for many years… it is highly unlikely that any fixed or predetermined prescription will be a "silver bullet". The performance of native and desirable fish populations in the Delta requires much more than fresh water flows. Fish need enough water of appropriate quality over the temporal and spatial extent of habitats to which they adapted their life history strategies. Typically, this requires habitat having a particular range of physical characteristics, appropriate variability, adequate food supply and a diminished set of invasive species. While folks ask "How much water do fish need?" they might well also ask, "How much habitat of different types and locations, suitable water quality, improved food supply and fewer invasive species that is maintained by better governance institutions, competent implementation and directed research do fish need?" The answers to these questions are interdependent. We cannot know all of this now, perhaps ever, but we do know things that should help us move in a better direction, especially the urgency for being proactive. We do know that current policies have been disastrous for desirable fish. It took over a century to change the Delta's ecosystem to a less desirable state; it will take many decades to put it back together again with a different physical, biological, economic, and institutional environment."

The State Water Board concurs with this cautionary note. The State Water Board further cautions that flow and physical habitat interact in many ways, but they are not interchangeable.

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The best available science suggests that current flows are insufficient to protect public trust resources.

1.1 Legislative Directive and State Water Board Approach

Legislative Directive
Water Code section 85086 (See Appendix B), contained in the Delta Reform Act, was enacted as part of the comprehensive package of water legislation adopted in November 2009. Water Code section 85086 requires the State Water Resources Control Board (State Water Board) to use the best available scientific information gathered as part of a public process conducted as an informational proceeding to develop new flow criteria for the Delta ecosystem to protect public trust resources. The purpose of the flow criteria is to inform planning decisions for the Delta Plan and the BDCP. The Legislature intended to establish an accelerated process to determine the instream flow needs of the Delta in order to facilitate the planning decisions required to meet the objectives of the Delta Plan. Accordingly, Water Code section 85086 requires the State Water Board to develop the flow criteria within nine months of enactment of the statute and to submit its flow criteria determinations to the Council within 30 days of their development.

State Water Board Approach
In determining the extent of protection to be afforded public trust resources through the development of the flow criteria, the State Water Board considered the broad goals of the planning efforts the criteria are intended to inform, including restoring and promoting viable, self-sustaining populations of aquatic species. Given the accelerated time frame in which to develop the criteria, the State Water Board's approach to developing criteria was limited to review of instream needs in the Delta ecosystem, specifically fish species and Delta outflows, while also receiving information on hydrodynamics and major tributary inflows. The State Water Board's flow criteria determinations are accordingly limited to protection of aquatic resources in the Delta.

Limitations of State Water Board Approach
When setting flow objectives with regulatory effect, the State Water Board reviews and considers all the effects of the flow objectives through a broad inquiry into all public trust and public interest concerns. For example, the State Water Board would consider other public trust resources potentially affected by Delta outflow requirements and impose measures for the protection of those resources, such as requiring sufficient water for cold water pool in reservoirs to maintain temperatures in Delta tributaries. The State Water Board would also consider a broad range of public interest matters, including economics, power production, human health and welfare requirements, and the effects of flow measures on non-aquatic resources (such as habitat for terrestrial species). The limited process adopted for this proceeding does not include this comprehensive review.

The State Water Board's Public Trust Responsibilities in this Proceeding
Under the public trust doctrine, the State Water Board must take the public trust into account in the planning and allocation of water resources, and to protect public trust uses whenever feasible. (*National Audubon Society v. Superior Court* (1983) 33 Cal.3d 419, 446.) Public trust values include navigation, commerce, fisheries, recreation, scenic, and ecological values. "[I]n determining whether it is 'feasible' to protect public trust values like fish and wildlife in a particular instance, the [State Water] Board must determine whether protection of those values, or what level of protection, is 'consistent with the public interest.'" (*State Water Resources*

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Control Bd. Cases (2006) 136 Cal.App.4th 674, 778.) The State Water Board does not make any determination regarding the feasibility of the public trust criteria and consistency with the public interest in this report.

In this forum, the State Water Board has not considered the allocation of water resources, the application of the public trust to a particular water diversion or use, water supply impacts, or any balancing between potentially competing public trust resources (such as potential adverse effects of increased Delta outflow on the maintenance of coldwater resources for salmonids in upstream areas). Any such application of the State Water Board's public trust responsibilities, including any balancing of public trust values and water rights, would be conducted through an adjudicative or regulatory proceeding. Instead, the State Water Board's focus here is solely on identifying public trust resources in the Delta ecosystem and determining the flow criteria, as directed by Water Code section 85086.

Future Use of This Report

None of the determinations in this report have regulatory or adjudicatory effect. Any process with regulatory or adjudicative effect must take place through the State Water Board's water quality control planning, water rights processes, or public trust proceedings in conformance with applicable law. In the State Water Board's development of Delta flow objectives with regulatory effect, it must ensure the reasonable protection of beneficial uses, which may entail balancing of competing beneficial uses of water, including municipal and industrial uses, agricultural uses, and other environmental uses. The State Water Board's evaluation will include an analysis of the effect of any changed flow objectives on the environment in the watersheds in which Delta flows originate, the Delta, and the areas in which Delta water is used. It will also include an analysis of the economic impacts that result from changed flow objectives.

Nothing in either the Delta Reform Act or in this report amends or otherwise affects the water rights of any person. In carrying out its water right responsibilities, the State Water Board may impose any conditions that in its judgment will best develop, conserve, and utilize in the public interest the water to be appropriated. In making this determination, the State Water Board considers the relative benefit to be derived from all beneficial uses of the water concerned and balances competing interests.

The State Water Board has continuing authority over water right permits and licenses it issues. In the exercise of that authority and duty, the State Water Board may, if appropriate, amend terms and conditions of water right permits and licenses to impose further limitations on the diversion and use of water by the water right holder to protect public trust uses or to meet water quality and flow objectives in Water Quality Control Plans it has adopted. The State Water Board must provide notice to the water permit or license holder and an opportunity for hearing before it may amend a water right permit or license.

If the DWR and/or the USBR in the future request the State Water Board to amend the water right permits for the State Water Project (SWP) and/or the Central Valley Project (CVP) to move the authorized points of diversion for the projects from the southern Delta to the Sacramento River, Water Code section 85086 directs the State Water Board to include in any order approving a change in the point of the diversion of the projects appropriate Delta flow criteria. At that time, the State Water Board will determine appropriate permit terms and conditions. That decision will be informed by the analysis in this report, but will also take many other factors into consideration, including any newly developed scientific information, habitat conditions at the time, and other policies of the State, including the relative benefit to be derived from all

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beneficial uses of water. The flow criteria in this report are not pre-decisional in regard to any State Water Board action. (See e.g., Wat. Code, § 85086, subd. (c)(1).)

The information in this report illustrates to the State Water Board the need for an integrated approach to management of the Delta. Best available science supports that it is important to directly address the negative effects of other stressors, including habitat, water quality, and invasive species, that contribute to higher demands for water to protect public trust resources. The flow criteria highlight the continued need for the BDCP to develop an integrated set of solutions and to implement non flow measures to protect public trust resources.

1.2   Summary Determinations

This report contains the State Water Board's determinations as to the flows that protect public trust resources in the Delta, under the narrow circumstances analyzed in this report. As required, the report includes the volume, timing, and quality of flow for protection of public trust resources under different hydrologic conditions. The flow criteria represent a technical assessment only of flow and operational requirements that provide fishery protection under existing conditions. The flow criteria contained in this report do not represent flows that might be protective under other conditions. The State Water Board recognizes that changes in existing conditions may alter the need for flow. Changes in existing conditions that may affect flow needs include, but are not limited to, reduced reverse flows in Delta channels, increased tidal habitat, improved water quality, reduced competition from invasive species, changes in the point of diversion of the SWP and CVP, and climate change.

Flow Criteria and Conclusions
The numeric criteria determinations in this report must be considered in the following context:

- The flow criteria in this report do not consider any balancing of public trust resource protection with public interest needs for water.
- The State Water Board does not intend that the criteria should supersede requirements for health and safety such as the need to manage water for flood control.
- There is sufficient scientific information to support the need for increased flows to protect public trust resources; while there is uncertainty regarding specific numeric criteria, scientific certainty is not the standard for agency decision making.

The State Water Board has considered the testimony presented during the Board's informational proceeding to develop flow criteria and to support the following summary conclusions. Several of these summary conclusions rely in whole or in part on conclusions and recommendations made to the State Water Board by the Delta Environmental Flows Group (DEFG)[1] and the University of California at Davis Delta Solutions Group[2].

1. The effects of non-flow changes in the Delta ecosystem, such as nutrient composition, channelization, habitat, invasive species, and water quality, need to be addressed and integrated with flow measures.

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[1] The Delta Environmental Flows Group of experts consists of William Bennett, Jon Burau, Cliff Dahm, Chris Enright, Fred Feyrer, William Fleenor, Bruce Herbold, Wim Kimmerer, Jay Lund, Peter Moyle, and Matthew Nobriga.

[2] The Delta Solutions Group consists of William Bennett, William Fleenor, Jay Lund, and Peter Moyle.

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2. Recent Delta flows are insufficient to support native Delta fishes for today's habitats.[3] Flow modification is one of the immediate actions available although the links between flows and fish response are often indirect and are not fully resolved. Flow and physical habitat interact in many ways, but they are not interchangeable.

3. In order to preserve the attributes of a natural variable system to which native fish species are adapted, many of the criteria developed by the State Water Board are crafted as percentages of natural or unimpaired flows. These criteria include:

    - 75% of unimpaired Delta outflow from January through June;
    - 75% of unimpaired Sacramento River inflow from November through June; and
    - 60% of unimpaired San Joaquin River inflow from February through June.

    It is not the State Water Board's intent that these criteria be interpreted as precise flow requirements for fish under current conditions, but rather they reflect the general timing and magnitude of flows under the narrow circumstances analyzed in this report. In comparison, historic flows over the last 18 to 22 years have been:

    - approximately 30% in drier years to almost 100% of unimpaired flows in wetter years for Delta outflows;
    - about 50% on average from April through June for Sacramento River inflows; and
    - approximately 20% in drier years to almost 50% in wetter years for San Joaquin River inflows.

4. Other criteria include: increased fall Delta outflow in wet and above normal years; fall pulse flows on the Sacramento and San Joaquin Rivers; and flow criteria in the Delta to help protect fish from mortality in the central and southern Delta resulting from operations of the State and federal water export facilities.

5. The report also includes determinations regarding variability and the natural hydrograph, floodplain activation and other habitat improvements, water quality and contaminants, cold water pool management, and adaptive management:
    - Criteria should reflect the frequency, duration, timing, and rate of change of flows, and not just volumes or magnitudes. Accordingly, whenever possible, the criteria specified above are expressed as a percentage of the unimpaired hydrograph.

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[3] This statement should not be construed as a critique of the basis for existing regulatory requirements included in the 2006 Bay-Delta Plan and biological opinions. Those requirements were developed pursuant to specific statutory requirements and considerations that differ from this proceeding. Particularly when developing water quality objectives, the State Water Board must consider many different factors including what constitutes reasonable protection of the beneficial use and economic considerations. In addition, the biological opinions for the SWP and CVP Operations Criteria and Plan were developed to prevent jeopardy to specific fish species listed pursuant to the federal Endangered Species Act; in contrast, the flow criteria developed in this proceeding are intended to halt population decline and increase populations of certain species.

- Inflows should generally be provided from tributaries to the Delta watershed in proportion to their contribution to unimpaired flow unless otherwise indicated.
- Studies and demonstration projects for, and implementation of, floodplain restoration, improved connectivity and passage, and other habitat improvements should proceed to provide additional protection of public trust uses and potentially allow for the reduction of flows otherwise needed to protect public trust resources in the Delta.
- The Central Valley and San Francisco Regional Water Quality Control Boards should continue developing Total Maximum Daily Loads (TMDLs) for all listed pollutants and adopting programs to implement control actions.
- The Central Valley Regional Water Quality Control Board should require additional studies and incorporate discharge limits and other controls into permits, as appropriate, for the control of nutrients and ammonia.
- Temperature and water supply modeling and analyses should be conducted to identify conflicting requirements to achieve both flow and cold water temperature goals.
- A strong science program and a flexible management regime are critical to improving flow criteria. The State Water Board should work with the Council, the Delta Science Program, BDCP, the Interagency Ecological Program (IEP), and others to develop the framework for adaptive management that could be relied upon for the management and regulation of Delta flows.
- The numeric criteria included in this report are all criteria that are only appropriate for the current physical system and climate; as other factors change the flow needs advanced in this report will also change. As physical changes occur to the environment and our understanding of species needs improves, the long-term flow needs will also change. Actual flows should be informed by adaptive management.
- Only the underlying principles for the numeric criteria and other measures are advanced as long term criteria.

6. Past changes in the Delta may influence migratory cues for some fishes. These cues are further scrambled by a reverse salinity gradient in the south Delta. It is important to establish seaward gradients and create more slough networks with natural channel geometry. Achieving a variable more complex estuary requires establishing seasonal gradients in salinity and other water quality variables and diverse habitats throughout the estuary. These goals in turn encourage policies which establish internal Delta flows that create a tidally-mixed upstream- downstream gradient (without cross-Delta flows) in water quality. Continued through-Delta conveyance is likely to continue the need for in-Delta flow requirements and restrictions to protect fish within the Delta.

7. Restoring environmental variability in the Delta is fundamentally inconsistent with continuing to move large volumes of water through the Delta for export. The drinking and agricultural water quality requirements of through-Delta exports, and perhaps even some current in-Delta uses, are at odds with the water quality and variability needs of desirable Delta species.

8. The Delta ecosystem is likely to dramatically shift within 50 years due to large scale levee collapse. Overall, these changes are likely to promote a more variable, heterogeneous estuary. This changed environment is likely to be better for desirable estuarine species; at least it is unlikely to be worse.

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9. Positive changes in the Delta ecosystem resulting from improved flow or flow patterns will benefit humans as well as fish and wildlife.

10. In order to prevent further channelization of riparian corridors and infill of wetland habitats, the Delta Stewardship Council should consider developing a plan to coordinate land use policy within the Delta between the city, county, State, and federal governments.

Ecosystems are complex; there are many factors that affect the quality of the habitat that they provide. These factors combine in ways that can amplify the effect of the factors on aquatic resources. The habitat value of the Delta ecosystem for favorable species can be improved by habitat restoration, contaminant and nutrient reduction, changes in diversions, control of invasive species, and island flooding. Each of these non-flow factors has the potential to interact with flow to affect available aquatic habitat in Delta channels.

The State Water Board supports the most efficient use of water that can reasonably be made. The flow improvements that the State Water Board identifies in this report as being necessary to protect public trust resources illustrate the importance of addressing the negative effects of these other stressors that contribute to higher than necessary demands for water to provide resource protection. Future habitat improvements or changes in nutrients and contaminants, for example, may change the response of fishes to flow. Addressing other stressors directly will be necessary to assure protection of public trust resources and could change the demands for water to provide resource protection in the future. Uncertainty regarding the effects of habitat improvement and other stressors on flow demands for resource protection highlights the need for continued study and adaptive management to respond to changing conditions.

The flow criteria identified in this report highlight the need for the BDCP to develop an integrated set of solutions, to address ecosystem flow needs, including flow and non-flow measures. Although flow modification is an action that can be implemented in a relatively short time in order to improve the survival of desirable species and protect public trust resources, public trust resource protection cannot be achieved solely through flows – habitat restoration also is needed. One cannot substitute for the other; both flow improvements and habitat restoration are essential to protecting public trust resources.

1.3   Background and Next Steps

Informational Proceeding
The State Water Board held an informational proceeding on March 22, 23, and 24, 2010, to receive scientific information from technical experts on the Delta outflows needed to protect public trust resources. The State Water Board also received information at the proceeding on flow criteria for inflow to the Delta from the Sacramento and San Joaquin rivers and Delta hydrodynamics. The State Water Board did not solicit information on the need for water for other beneficial uses, including the amount of water needed for human health and safety, during the informational proceeding. Nor did the State Water Board consider other policy considerations, such as the state goal of providing a decent home and suitable living environment for every Californian.

Analytical Methods
The State Water Board received a wide range of recommendations for the volume, quantity and timing of flow necessary to protect public trust resources. Recommendations were also

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received on non-flow related measures. State Water Board determinations of flow criteria rely upon four types of information:

- Unimpaired flows
- Historical impaired inflows that supported more desirable ecological conditions
- Statistical relationships between flow and native species abundance
- Ecological functions-based analysis for desirable species and ecosystem attributes

The State Water Board emphasizes, however, information based on ecological functions, followed by information on statistical relationships between flow and native species abundance.

In all cases, the flow criteria contained in this report are those supported by the best available scientific information submitted into the record for this proceeding. The conceptual bases for all of the criteria in this report are supported by scientific information on function-based species or ecosystem needs. In other words, there is sufficiently strong scientific evidence to support the need for flows necessary to support particular functions. This does not necessarily mean that there is scientific evidence to support *specific* numeric criteria. Criteria are therefore divided into two categories: Category "A" criteria have more and better scientific information, with less uncertainty, to support specific numeric criteria than do Category "B" criteria. The State Water Board followed the following steps to develop flow criteria and other measures:

1. Establish general goals and objectives for protection of public trust resources in the Delta
2. Identify species to include based on ecological, recreational, or commercial importance.
3. Review and summarize species life history requirements
4. Summarize numeric and other criteria for each of: Delta outflow, Sacramento River inflow, San Joaquin River inflow, and Hydrodynamics, including Old and Middle River flows
5. Review other flow-related and non-flow measures that should be considered
6. Provide summary determinations for flow criteria and other measures

In developing its flow criteria, the State Water Board reviewed the life history requirements of the following pelagic and anadromous species:

- Chinook Salmon (various runs)
- American Shad.
- Longfin Smelt
- Delta Smelt
- Sacramento Splittail
- Starry Flounder
- Bay Shrimp
- Zooplankton

The flow criteria needed to protect public trust resources are more than just the sum of each species-specific flow need. The State Water Board also considered the following issues to make its flow criteria determinations:

- Variability, flow paths, and the natural hydrograph
- Floodplain activation and other habitat improvements

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- Water quality and contaminants
- Cold water pool management
- Adaptive management

The Board also made other specific determinations for other measures based on review of these issues.

Regulatory Authority of the State Water Board
The State Water Board was established in 1967 as the State agency with jurisdiction to administer California's water resources. The State Water Board is responsible for water allocation as well as for water quality planning and water pollution control. In carrying out its water quality planning functions under both State and federal law, the State Water Board formulates and adopts state policy for water quality control, which includes water quality principles and guidelines for long-range resource planning, water quality objectives, and other principles and guidelines deemed essential by the State Water Board for water quality control. The State Water Board has adopted a Water Quality Control Plan for the Delta (Bay-Delta Plan). The plan is implemented in part through conditions imposed in both water quality and water right permits.

The State Water Board administers the water rights program for the State, including issuing water right permits. More than two-thirds of the residents of California and more than two million acres of highly productive farmlands receive water exported from the Delta, primarily, although not exclusively, through the SWP and CVP. In addition to the SWP and CVP, there are many other diversions from the Delta and from tributaries to the Delta including the East Bay Municipal Utilities District, the San Francisco Public Utilities Commission, and Contra Costa Water District, to name a few.

Regulatory Actions by Other Agencies
In addition to the State Water Board, other state and federal agencies have authority to take regulatory action that can affect Delta inflows, outflows, and hydrodynamics. As indicated below, the United States Fish and Wildlife Service (USFWS), the National Marine Fisheries Service (NMFS), and the California Department of Fish and Game (DFG) have authority to impose regulatory conditions that affect water diversions from the Delta. The Federal Energy Regulatory Commission (FERC) also has authority over non-federal hydropower projects that can change the timing and quantity of inflows to the Delta. Over the next six years, there are 16 hydropower projects on tributaries to the Sacramento and San Joaquin rivers with potential to affect Delta tributary flows that have ongoing or pending proceedings before the FERC.

Next Steps
The State Water Board will submit its flow criteria determinations to the Council for its information within 30 days of completing its determinations as required by Water Code section 85086.

The flow criteria contained in this report will be submitted to the Council to inform the Delta Plan. The Council is required to develop the Delta Plan to implement the State's co-equal goals of providing a more reliable water supply for California and protecting, restoring, and enhancing the Delta ecosystem. The Council is to develop the Delta Plan by January 2012.

The flow criteria will also inform the BDCP. The BDCP is a multispecies conservation plan being developed pursuant to the ESA and the State Natural Community Conservation Planning Act (NCCPA), administered by the USFWS and the NMFS and the DFG, respectively. The

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CESA and the federal ESA generally prohibit the "take" of species protected pursuant to the acts. Both acts contain provisions that allow entities to seek approvals from the resources agencies, which approvals allow limited take of protected species under some circumstances. The BDCP is intended to meet all regulatory requirements necessary for USFWS and NMFS to issue Incidental Take Permits to allow incidental take of all proposed covered species as a result of covered activities undertaken by DWR, certain SWP contractors, and Mirant Corporation, and to issue biological opinions under the ESA to authorize incidental take for covered actions undertaken by USBR and CVP contractors. The BDCP is also intended to address all of the requirements of the NCCPA for aquatic, wetland, and terrestrial covered species of fish, wildlife, and plants and Delta natural communities affected by BDCP actions and is intended to provide sufficient information for DFG to issue permits under the CESA for the taking of the species proposed for coverage under the BDCP.

Finally, the flow criteria in this report will also inform the State Water Board's on-going and subsequent proceedings, including the review and development of flow objectives in the San Joaquin River, a comprehensive update to the 2006 Bay-Delta Plan, and the associated water rights proceedings to implement these Bay-Delta Plan updates.

2. Introduction

The purpose of this report is to identify new flow criteria for the Sacramento-San Joaquin Delta (Delta) ecosystem to protect public trust resources in accordance with the Delta Reform Act of 2009, Water Code § 85000 et seq. The flow criteria, which do not have any regulatory or adjudicative effect, may be used to inform planning decisions for the new Delta Plan being prepared by the newly created Delta Stewardship Council (Council) and the Bay Delta Conservation Plan (BDCP). The public trust resources that are the subject of this proceeding include those resources affected by flow, namely, native and valued resident and migratory aquatic species, habitats, and ecosystem processes. The State Water Resources Control Board (State Water Board or Board) has developed flow criteria to protect these resources that incorporate measures regarding Delta outflows and Delta inflows and has recommended other measures relevant to the protection of public trust resources. After approval by the State Water Board, this report will be submitted to the Council.

3. Purpose and Background

3.1   *Background and Scope of Report*

Pursuant to Water Code section 85086, subdivision (c), enacted on November 12, 2009, in Senate Bill No. 1 of the 2009-2010 Seventh Extraordinary Session (Stats. 2009 (7th Ex. Sess.) ch. 5, § 39) (SB 1), the State Water Board is required to "develop new flow criteria for the Delta ecosystem necessary to protect public trust resources." The purpose of this report is to comply with the Legislature's mandate to the State Water Board.

Given the limited amount of time the State Water Board had to develop the criteria, the Board initially focused on Delta outflow conditions as a primary driver of ecosystem functions in the Delta. In determining the extent of protection to be afforded public trust resources through the development of the flow criteria, the State Water Board considered the broad goals of the planning efforts the criteria are intended to inform, including restoring and promoting viable, self-sustaining populations of aquatic species. The specific goals for protection are discussed in more detail below.

The notice for this proceeding focused the proceeding on Delta outflows. During the proceeding, however, the State Water Board received useful information from participants regarding Sacramento River inflows, San Joaquin River inflows, and Delta hydrodynamics (including Old and Middle River flows, San Joaquin River at Jersey Point flows, and San Joaquin River inflow to export ratios) that is relevant to protection of public trust resources in the Delta ecosystem. The hydrodynamic criteria included in this reportare largely dependent on exports and on San Joaquin River inflows, and do not directly affect the outflows considered in this proceeding. The State Water Board believes, however, that this information should be transmitted to the Council for its use in informing the Delta Plan and BDCP. Because the notice for the proceeding focused on Delta outflows, and some of the participants did not submit scientific information on inflows and hydrodynamics for the State Water Board's consideration, the record for inflows and hydrodynamics may not be as complete, and the analyses for these flow parameters accordingly may be limited. As a result, these criteria do not constitute formal criteria within the scope of the informational proceeding as noticed, but instead are submitted to the Council with the acknowledgement that they are based on the limited information received by the State Water Board.

3.1.1 The Legislative Requirements

In November 2009, legislation was enacted comprising a comprehensive water package for California. In general, the legislation is designed to achieve a reliable water supply for future generations and to restore the Delta and other ecologically sensitive areas. The package includes a bond bill and four policy bills, one of which is SB 1.

In the Delta Reform Act, the Legislature found and declared, among other matters, that:

> "The Sacramento-San Joaquin Delta watershed and California's water infrastructure are in crisis and existing Delta policies are not sustainable. Resolving the crisis requires fundamental reorganization of the state's management of Delta watershed resources. (Wat. Code, § 85001, subd. (a).)

> By enacting this division, it is the intent of the Legislature to provide for the sustainable management of the Sacramento-San Joaquin Delta ecosystem, to provide for a more reliable water supply for the state, to protect and enhance the quality of water supply from the Delta, and to establish a governance structure that will direct efforts across state agencies to develop a legally enforceable Delta Plan." (Wat. Code, § 85001, subd. (c).)

Among other provisions, SB 1 establishes the Delta Stewardship Council, which is charged with responsibility to develop, adopt, and commence implementation of a Delta Plan, a comprehensive, long-term management plan for the Delta, by January 1, 2012. The legislation also establishes requirements for inclusion of the BDCP, a multispecies conservation plan, into the Delta Plan. For purposes of informing the planning efforts for the Delta Plan and BDCP, SB 1 requires the State Water Board, pursuant to its public trust obligations, to develop new flow criteria for the Delta ecosystem necessary to protect public trust resources. (Wat. Code, § 85086, subd. (c).) Regarding the flow criteria, the Legislature provided that the flow criteria shall:

- include the volume, quality, and timing of water necessary for the Delta ecosystem;

- be developed within nine months of enactment of SB 1;

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- be submitted to the Council within 30 days of completion;

- inform planning decisions for the Delta Plan and the BDCP;

- be based on a review of existing water quality objectives and the use of the best available scientific information;

- be developed in a public process by the State Water Board as a result of an informational proceeding conducted under the board's regulations set forth at California Code of Regulations, title 23, sections 649-649.5, in which all interested persons have an opportunity to participate.

- not be considered predecisional with regard to any subsequent State Water Board consideration of a permit, including any permit in connection with a final BDCP;

- inform any State Water Board order approving a change in the point of diversion of the State Water Project or the federal Central Valley Project from the southern Delta to a point on the Sacramento River;

3.1.2 The State Water Board's Public Trust Obligations

As stated above, SB 1 requires the State Water Board to develop new flow criteria to protect public trust resources in the Delta ecosystem pursuant to the Board's public trust obligations. The purpose of the public trust is to protect commerce, navigation, fisheries, recreation, ecological values, and fish and wildlife habitat. Under the public trust doctrine, the State of California has sovereign authority to exercise continuous supervision and control over the navigable waters of the state and the lands underlying those waters. (*National Audubon Society v. Superior Court* (*Audubon*) (1983) 33 Cal.3d 419.) A variant of the public trust doctrine also applies to activities that harm a fishery in non-navigable waters. (*People v. Truckee Lumber Co.* (1897) 116 Cal. 397, see *California Trout, Inc. v. State Water Resources Control Board* (1989) 207 Cal.App.3d 585, 630.)

In *Audubon*, the California Supreme Court held that California water law is an integration of the public trust doctrine and the appropriative water right system. (*Audubon*, *supra*, 33 Cal.3d at p. 426.) The state has an affirmative duty to take the public trust into account in the planning and allocation of water resources. The public trust doctrine requires the State Water Board to consider the effect of a diversion or use of water on streams, lakes, or other bodies of water, and "preserve, so far as consistent with the public interest, the uses protected by the trust." (*Audubon, supra*, 33 Cal.3d at p. 447.) Thus, before the State Water Board approves a water diversion, it must consider the effect of the diversion on public trust resources and avoid or minimize any harm to those resources where feasible. (*Id.* at p. 426.) Even after an appropriation has been approved, the public trust imposes a duty of continuing supervision. (*Id.* at p. 447*.)*

The purpose of this proceeding is to receive scientific information and develop flow criteria pursuant to the State Water Board's public trust obligations. In this forum, the State Water Board will not consider the allocation of water resources, the application of the public trust to a particular water diversion or use, or any balancing between potentially competing public trust resources. The State Water Board has also not considered minimum or maximum flows needed to protect public health and safety. Any such application of the State Water Board's public trust responsibilities, including any balancing of public trust values and water rights, would be conducted through an adjudicative or regulatory proceeding. Instead, the State Water Board's focus here is solely on identifying public trust resources in the Delta ecosystem within the scope of SB 1 and determining the flows necessary to protect those resources.

3.1.3 Public Process

The Water Code directs the State Water Board to develop the flow criteria in a public process in the form of an informational proceeding conducted pursuant to the Board's regulations. (Wat. Code, § 85086, subd. (c)(1); Cal. Code Regs., tit. 23, §§ 649-649.5.) The State Water Board conducted this informational proceeding to receive the best available scientific information to use in carrying out its mandate to develop new flow criteria for the Delta ecosystem necessary to protect public trust resources. (Wat. Code, § 85086, subd. (c)(1).) On December 16, 2009, the State Water Board issued the notice for the public informational proceeding to develop the flow criteria. For the informational proceeding, the State Water Board required the participants to submit a Notice of Intent to Appear by January 5, 2010. The State Water Board received 55 Notices of Intent to Appear for the informational proceeding.

On January 7, 2010, the State Water Board conducted a pre-proceeding conference to discuss the procedures for the informational proceeding mandated by Water Code section 85086, subdivision (c). Topics for the pre-proceeding conference included coordination of joint presentations, use of presentation panels, time limits on presentations, and electronic submittal of written information. The conference was used only to discuss procedural matters and did not address any substantive issues.

On January 29, 2010, the State Water Board issued a revised notice amending certain procedural requirements and posted a preliminary list of reference documents. Written testimony, exhibits, and written summaries, along with lists of witnesses and lists of exhibits, were due on February 16, 2010. The State Water Board gave participants and interested parties an opportunity to submit written questions regarding the written testimony, exhibits, and written summaries by March 9, 2010. All submittals were posted on the State Water Board's website.

On March 22 through 24, the State Water Board held the public informational proceeding to develop flow criteria for the Delta ecosystem. The State Water Board received a technical introduction by the Delta Environmental Flows Group (DEFG)[4] at the beginning of the proceeding. The group prepared two documents and an associated list of references that were submitted as State Water Board exhibits:

- Key Points on Delta Environmental Flows for the State Water Resources Control Board, February 2010
- Changing Ecosystems: a Brief Ecological History of the Delta, February 2010

A subset of the group, the UC Davis Delta Solutions Group, prepared three additional papers (which were also submitted as State Water Board exhibits):

- Habitat Variability and Complexity in the Upper San Francisco Estuary
- On Developing Prescriptions for Freshwater Flows to Sustain Desirable Fishes in the Sacramento-San Joaquin Delta

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[4] The Delta Environmental Flows Group consists of William Bennett, Jon Burau, Cliff Dahm, Chris Enright, Fred Feyrer, William Fleenor, Bruce Herbold, Wim Kimmerer, Jay Lund, Peter Moyle, and Matthew Nobriga. This group of professors, researchers, and staff from various resource agencies was assembled by State Water Board staff with the intent of informing the Delta flow criteria informational proceeding.

- Ecosystem Investments for the Sacramento-San Joaquin Delta: Development of a Portfolio Framework

Over the course of the hearing, the State Water Board received information from expert witnesses in response to questions posed by Board members. The expert witnesses, representing various participants, as well as experts from the DEFG, were grouped into five panels in order to focus the discussions on specific aspects of the Delta flow criteria. These panels addressed the following topics: hydrology, pelagic fish, anadromous fish, other stressors, and hydrodynamics.

At the conclusion of the informational proceeding, participants were given approximately 20 days to submit closing comments. On July 21, 2010, the draft report was released for public review and comment.

3.1.4 Scope of This Report

Due to the limited nine-month time period in which the State Water Board must develop new flow criteria, the notice for the informational proceeding requested information on what volume, quality, and timing of Delta outflows are necessary under different hydrological conditions to protect public trust resources pursuant to the State Water Board's public trust obligations and the requirements of SB 1. Delta outflows are of critical importance to various ecosystem functions, water supply, habitat restoration, and other planning issues. The effect of Delta outflows in protecting public trust resources necessarily involves complex interactions with other flows in the Delta and with non-flow parameters including water quality and the physical configuration of the Delta. This report recognizes the role of source inflows used to meet Delta outflows, Delta hydrodynamics, tidal action, hydrology, water diversions, water project operations, and cold water pool storage in upstream reservoirs, and relies upon information submitted on these related topics to inform its determinations.

The State Water Board intends that the flow criteria developed in this proceeding should meet the following general goal regarding the protection of public trust resources:

- Halt the population decline and increase populations of native species as well as species of commercial and recreational importance by providing sufficient flow and water quality at appropriate times to promote viable life stages of these species.

To meet this goal, the State Water Board also sought to develop criteria that are comprehensive and that can be implemented without undue complexity. This report is limited to consideration of flow criteria needed under the existing physical conditions, so therefore does not consider or anticipate changes in habitat or modification of water conveyance facilities. The State Water Board does, however, identify other measures that should be considered in conjunction with, and to complement, the flow criteria.

A number of factors outside the scope of the legislative mandate to develop new flow criteria could affect public trust resources and some other factors could affect the interaction of flows with the environment. These factors include contaminants, water quality parameters, future habitat restoration measures, water conveyance facilities modification, and the presence of non-native species.

3.1.5 Concurrent State Water Board Processes

The State Water Board has a number of ongoing proceedings that may be informed by the development of flow criteria. Some of these proceedings will result in regulatory requirements

that affect flow, or otherwise affect the volume, quality, or timing of flows into, within, or out of the Delta. In July 2008, the State Water Board adopted a strategic work plan for actions to protect beneficial uses of the San Francisco Bay/Delta (Bay-Delta). In accordance with the work plan, the State Water Board recently completed a periodic review of the 2006 Water Quality Control Plan for the Bay-DeltaEstuary (Bay-Delta Plan) that recommended the Delta Outflow objectives, as well as other flow objectives, for further review in the water quality control planning process. Currently, the State Water Board is in the process of reviewing the southern Delta salinity and the San Joaquin River flow objectives contained in the Bay-Delta Plan.

Clean Water Act Water Quality Certifications
Several non-federal hydropower projects with potential to affect Delta tributary flows have ongoing or pending proceedings before the Federal Energy Regulatory Commission (FERC) that will result in the issuance of new licenses that will govern operations for the 30-50 year term. The relicensing process allows state and federal agencies to prescribe conditions to achieve certain objectives such as state water quality standards and the protection of listed species. New license conditions may include instreams flows requirements or other conditions to protect aquatic species. For example, the new license for the Oroville Dam will require changes in minimum flow requirements and changes in facilities and operations to meet certain water temperature requirements to protect Chinook salmon, steelhead, and green sturgeon. By 2016, more than 25 Delta tributary dams will go through the relicensing process.

The State Water Board will rely upon the FERC license application and the National Environmental Policy Act (NEPA) and California Environmental Quality Act (CEQA) documents prepared for the projects, and may require submittal of additional data or studies, to inform its Clean Water Act Section 401 Water Quality Certifications for the projects. The Board's water quality certification will be issued as soon as possible after the environmental documents and any other needed studies are complete, after which FERC will issue a new license. The conditions in the water quality certification are mandatory and must be included in the FERC license.

Information developed as part of the relicensing of these projects will be used to inform on-going Bay Delta proceedings, and any information developed in the State Water Board's Bay Delta proceedings will be used to inform the two water quality certifications.

Table 1 summarizes the dams, tributaries, and license expiration dates for FERC projects in the Delta watershed. Several of these projects are upstream of major dams and reservoirs in the Sacramento and San Joaquin river watershed so operational changes would have little or no direct effect upon Delta flows.

Table 1. Delta Watershed FERC Projects

River	Dam(s)	Storage Capacity (acre-feet)	Owner	Status of Proceeding	FERC License Expiration
Feather	Oroville	3.5 million	Department of Water Resources (DWR)	Near completion	January 2007
West Branch Feather	Philbrook, Round Valley	6,200	Pacific Gas and Electric Company (PG&E)	Near Completion	October 2009
South Feather	Little Grass Valley	90,000	South Feather Water and Power Agency	Near completion	March 2009
Upper North Fork Feather	Lake Almanor	1.1 million	PG&E	Near Completion	October 2004
Pit River	McCloud, Iron Canyon,Pit 6, 7	110,000	PG&E	Ongoing	July 2011
North Yuba	New Bullards Bar	970,000	Yuba County Water Agency	Pre-Licensing meetings started	March 2016
Middle and South Yuba, Bear	Yuba-Bear Project, 10+ dams	210,000	Nevada Irrigation District	Ongoing	April 2013
Middle & South Yuba, Bear	Drum-Spaulding Project, 10+ dams	150,000	PG&E	Ongoing	April 2013
Middle Fork American River	French Meadows, Hell Hole	340,000	Placer County Water Agency	Ongoing	February 2013
South Fork American River	Loon Lake, Slab Creek	400,000	Sacramento Municipal Utility District	Near completion	July 2007
South Fork American River	Chili Bar	1,300	PG&E	Near completion	July 2007
Tuolumne	New Don Pedro	2 million	Turlock Irrigation District	To commence late 2010	April 2016
Merced	New Exchequer/ McSwain	1 million	Merced Irrigation District	Ongoing	February 2014
Merced	Merced Falls	650	PG&E	Ongoing	February 2014
San Joaquin	Mammoth Pool	120,000	Southern California Edison	Near Completion	November 2007
San Joaquin	Huntington, Shaver, Florence	320,000	Southern California Edison	Near Completion	February 2009

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3.1.6 Delta Stewardship Council and Use of This Report

In accordance with the legislative requirements described above, the State Water Board will submit this report, containing its Delta flow criteria determinations, to the Council within 30 days after this report has been completed. This report will be deemed complete on the date the State Water Board adopts a resolution approving transmittal of the report to the Council.

Additionally, SB 1 requires any order approving a change in the point of diversion of the State Water Project (SWP) or the Central Valley Project (CVP) from the southern Delta to a point on the Sacramento River to include appropriate flow criteria and to be informed by the analysis in this report. (Wat. Code, § 85086, subd. (c)(2).) The statute also specifies, however, that the criteria shall not be considered predecisional with respect to the State Water Board's subsequent consideration of a permit. (*Id.*, § 85086, subd. (c)(1).) Thus, any process with regulatory or adjudicative effect must take place through the State Water Board's water quality control planning or water rights processes in conformance with applicable law. Any person who wishes to introduce information produced during this informational proceeding, or the State Water Board's ultimate determinations in this report, into a later rulemaking or adjudicative proceeding must comply with the rules for submission of information or evidence applicable to that proceeding.

3.2 Regulatory Setting

3.2.1 History of Delta Flow Requirements

The State Water Rights Board (a predecessor to the State Water Board) first had an opportunity to consider flow requirements in the Delta when it approved water rights for much of the U.S. Bureau of Reclamation's (USBR) CVP in Water Right Decision 990 (D-990) (adopted in 1961), but it did not impose any fish protection conditions in D-990. In 1967, the State Water Rights Board included fish protections in D-1275 approving the water right permits for the SWP. Effective December 1, 1967, the State Water Rights Board and the State Water Quality Control Board were merged in a new agency, the State Water Board, which exercises both the water quality and water rights adjudicatory and regulatory functions of the state. The State Water Board adopted a new water quality control policy for the Delta and Suisun Marsh in October 1968, in Resolution 68-17. The resolution specified that the objectives would be implemented through conditions on the water rights of the CVP and SWP.

To implement the water quality objectives, the State Water Board adopted Water Right Decision 1379 (D-1379) in 1971[5]. D-1379 established new water quality requirements in both the SWP and CVP permits, including fish flows, and rescinded the previous SWP requirements from D-1275 and D-1291. D-1379 was stayed by the courts and eventually was superseded by Water Right Decision 1485 (D-1485).

In April 1973, in Resolution 73-16, the State Water Board adopted a water quality control plan to supplement the State water quality control policies for the Delta.

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[5] In 1971, the State Water Board approved interim regional water quality control plans for the entire State, including the Delta and Suisun Marsh. Subsequently, the State Water Board approved long-term objectives for the Delta and Suisun Marsh in the regional plans for the Sacramento-San Joaquin Delta Basin and the San Francisco Bay Basin.

In August 1978, the State Water Board adopted both D-1485 and the 1978 Delta Plan. Together the 1978 Delta Plan and D-1485 revised existing objectives for flow and salinity in the Delta's channels and ordered USBR and DWR to meet the objectives. In 1987, the State Water Board commenced proceedings to review the 1978 Delta Plan and D-1485. The Board held a hearing at numerous venues in California and released a draft water quality control planin 1988, but subsequently withdrew it and resumed further proceedings.

In 1991, the State Water Board adopted the 1991 water quality control plan. This is the first Bay-Delta plan to adopt objectives for dissolved oxygen (DO) and temperature. The 1991 Bay-Delta plan did not amend either the flow or water project operations objectives adopted in the 1978 Delta Plan.[6] The United States Environmental Protection Agency (USEPA) approved the objectives in the plan for salinity for municipal, industrial, and agricultural uses, and approved the new DO objectives for fish and wildlife, but disapproved the Delta outflow objectives for the protection of fish and wildlife carried over from the 1978 Delta Plan. The USEPA adopted its own Delta outflow standards in 1994 to supersede the State's objectives.

In the summer of 1994, after the USEPA had initiated its process to develop standards for the Delta, the State and federal agencies with responsibility for management of Bay-Delta resources signed a Framework Agreement, agreeing that: (1) the State Water Board would update and revise its 1991 Bay-Delta Plan to meet federal requirements and would initiate a water right proceeding to implement the plan, after which the USEPA would withdraw its fish and wildlife objectives; (2) a group would be formed to coordinate operations of the SWP and CVP with all regulatory requirements in the Delta; and (3) the State and federal governments would undertake a joint long-term solution finding process to resolve issues in the Bay-Delta. In December 1994, representatives of the State and federal governments, water users, and environmental interests agreed to the implementation of a Bay-Delta protection plan. The plan and institutional documents to implement it are contained in a document titled "Principles for Agreement on Bay-Delta Standards between the State of California and the Federal Government." This is commonly referred to as the "Bay-Delta Accord" or "Principles Agreement."

In 1995 the State Water Board adopted the 1995 Bay-Delta Plan, which is consistent with the Principles Agreement.[7] In response to a water right change petition filed by DWR and USBR, the State Water Board then adopted Water Right orders that temporarily allowed DWR and USBR to operate the SWP and CVP in accordance with the 1995 Plan while the State Water Board conducted water right proceedings for a water right decision that would implement the 1995 Bay-Delta Plan. The hearing commenced in 1998 and concluded in 1999. During the 1998-99 water right hearing, DWR and USBR and their water supply contractors negotiated with a number of parties. In 1999, the State Water Board adopted Decision 1641 (D-1641) and subsequently revised D-1641 in 2000.

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[6] After adopting the 1991 Plan, the State Water Board conducted a proceeding to establish interim water right requirements for the protection of public trust uses in the Delta. The State Water Board released a draft water right decision known as "Decision 1630" (D-1630), but did not adopt it.

[7] USEPA approved the 1995 Bay-Delta Plan. By approving the 1995 Bay-Delta Plan, the USEPA supplanted its own water quality standards with the standards in the 1995 Bay-Delta Plan. (*State Water Resources Control Board Cases* (2006) 136 Cal.App.4th 674,774-775 [39 Cal.Rptr.3d 189]; 33 U.S.C. § 1313(c)(2)(A),(c)(3).)

3.2.2 Current State Water Board Flow Requirements

The current Bay-Delta flow requirements are contained in the 2006 Bay-Delta Plan and in D-1641. D-1641 implements portions of the 1995 Bay-Delta Plan. D-1641 accepts the contribution that certain entities, through their agreements, will make to meet the flow-dependent water quality objectives in the 1995 Plan, and continues the responsibility of DWR and USBR for the remaining measures to meet the flow-dependent objectives and other responsibilities. In addition, D-1641 recognizes the San Joaquin River Agreement (SJRA) and approves, for a period of twelve years, the conduct of the Vernalis Adaptive Management Plan (VAMP) under the SJRA instead of meeting the San Joaquin River pulse flow objectives in the 1995 Plan. The 2006 Bay-Delta Plan is consistent with D-1641 and makes only minor changes to the 1995 Bay-Delta Plan, allowing the staged implementation of the San Joaquin River spring pulse flow objectives and other minor changes. The 2006 Bay-Delta Plan also identifies a number of issues requiring additional review and planning including: the pelagic organism decline (POD), climate change, Delta and Central Valley salinity, and San Joaquin River flows.

Current Delta outflow requirements, set forth in Tables 3 and 4 in both the 2006 Bay-Delta Plan and D-1641, take two basic forms based on water year type and season: 1) specific numeric Delta outflow requirements; and 2) position of X2, the horizontal distance in kilometers up the axis of the estuary from the Golden Gate Bridge to where the tidally averaged near-bottom salinity is 2 practical salinity units (psu). The Delta outflow requirements are expressed in Table 3 as a Net Delta Outflow Index (NDOI). The NDOI is a calculated flow expressed as Delta Inflow, minus net Delta consumptive use, minus Delta exports. Each component is calculated as described in the 2006 Bay-Delta Plan and D-1641. An electrical conductivity (EC) measurement of 2.64 mmhos/cm at Collinsville station C2 can be substituted for the NDOI during February through June. The most downstream location of either the maximum daily average or the 14-day running average of this EC level is commonly referred to as the position of "X2" in the Delta. Table 4 specifies EC measurements at two specific locations and alternatively allows an NDOI calculation at these locations.

3.2.3 Special Status Species

The California Endangered Species Act (CESA) states that all native species of fishes, amphibians, reptiles, birds, mammals, invertebrates, and plants, and their habitats, threatened with extinction and those experiencing a significant decline which, if not halted, would lead to a threatened or endangered designation, will be protected or preserved. The federal Endangered Species Act of 1973 (ESA) provides for the conservation of species that are endangered or threatened throughout all or a significant portion of their range, and the conservation of the ecosystems on which they depend. A number of species discussed in this report are afforded protections under CESA and ESA. These species and the protections are discussed below.

The longfin smelt (*Spirinchus thaleichthys*) is currently a candidate for threatened species status under the CESA. (DFG 1, p. 9.) In March 2009, the California Fish and Game Commission (Commission) made a final determination that the listing of longfin smelt as a threatened species was warranted and the rulemaking process to officially add the species to the CESA list of threatened species found in the California Code of Regulations was initiated. Upon completion of this rulemaking process, the longfin smelt's status will officially change from candidate to threatened. (DFG 1, p. 9.) Its status remains unresolved at the federal level. (USFWS 2009.) The delta smelt (*Hypomesus transpacificus*) is listed as endangered and threatened pursuant to the CESA and ESA, respectively. (DFG 1, p. 14; USFWS 1993.) In April 2010, the United States Fish and Wildlife Service (USFWS) considered a petition to reclassify the delta smelt from threatened to endangered. After review of all available scientific and

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commercial information, the USFWS found that reclassifying the delta smelt from a threatened to an endangered species is warranted, but precluded by other higher priority listing actions. (USFWS 2010.)

Sacramento winter-run Chinook salmon *(Oncorhynchus tshawytscha)* is listed as endangered pursuant to the CESA and ESA. (NMFS 1994; NMFS 2005; DFG 2010.) Central Valley spring-run Chinook salmon (*O. tshawytscha*) is listed as threatened pursuant to both the CESA and ESA. (NMFS 1999; NMFS 2005; DFG 2010.) Central Valley fall/late fall-run Chinook salmon (*O. tshawytscha*) are classified as species of special concern by the National Marine Fisheries Service (NMFS). (NMFS 2004.) Central Valley steelhead (*O. mykiss*) is listed as threatened under the ESA (NMFS 1998; NMFS 2006a.) Southern Distinct Population Segment of North American green sturgeon (*Acipenser medirostris*) is listed as threatened under the ESA. (NMFS 2006b.)

3.2.4 State Incidental Take Permit for Longfin Smelt

The CESA prohibits the take[8] of any species of wildlife designated as an endangered, threatened, or candidate species[9] by the Commission. The Department of Fish and Game (DFG), however, may authorize the take of such species by permit if certain conditions are met (Cal. Code Regs., tit 14, § 783.4). In 2009, DFG issued an Incidental Take Permit for Longfin Smelt to the DWR for the on-going and long-term operation of the SWP. The permit specifies a number of conditions, including two flow measures (Conditions 5.1 and 5.2) intended to minimize take of the longfin smelt and provide partial mitigation for the remaining take by: 1) minimizing entrainment; 2) improving estuarine processes and flow; 3) improving downstream transport of longfin smelt larvae; and 4) providing more water that is used as habitat (increasing habitat quality and quantity) by longfin smelt than would otherwise be provided by the SWP.

Longfin Smelt Incidental Take Permit (2009), p. 9-10, Condition 5.1.
This Condition is not likely to occur in many years.   To protect adult longfin smelt migration and spawning during December through February period, the Smelt Working Group (SWG) or DFG SWG personnel staff shall provide Old and Middle River (OMR) flow advice to the Water Operations Management Team (WOMT) and to Director of DFG weekly. The SWG will provide the advice when either: 1) the cumulative salvage index (defined as the total longfin smelt salvage at the CVP and SWP in the December through February period divided by the immediately previous FMWT longfin smelt annual abundance index) exceeds five (5); or 2) when a review of all abundance and distribution survey data and other pertinent biological factors that influence the entrainment risk of adult longfin smelt indicate OMR flow advise is warranted. Permittee shall ensure the OMR flow requirement is met by maintaining the OMR flow 14-day running average is no more negative than -5,000 cfs and the initial 5-day running average is not more negative than -6,250 cfs. During any time OMR flow restrictions for the USFWS's 2008 Biological Opinion for delta smelt are being implemented, this condition (5.1) shall not result in additional OMR flow requirements for protection of adult longfin smelt. Once spawning has been detected in the system, this Condition terminates and 5.2 begins. Condition 5.1 is not required or would cease if previously required when river flows are 1) > 55,000 cfs in

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[8] Pursuant to Fish and Game Code section 86, "'Take' means hunt, pursue, catch, capture, or kill, or attempt to hunt, pursue, catch, capture or kill."

[9] "Candidate species" are species of wildlife that have not yet been placed on the list of endangered species or the list of threatened species, but which are under formal consideration for listing pursuant to Fish and Game Code section 2074.2

the Sacramento River at Rio Vista; or 2) > 8,000 cfs in the San Joaquin River at Vernalis. If flows go below 40,000 cfs in the Sacramento River at Rio Vista or 5,000 cfs in the San Joaquin River at Vernalis, the OMR flow in Condition 5.1 shall resume if triggered previously. Review of survey data and other pertinent biological factors that influence the entrainment risk of adult longfin smelt may result in a recommendation to relax or cease an OMR flow requirement.

Longfin Smelt Incidental Take Permit (2009), p. 10-11, Condition 5.2.
To protect larval and juvenile longfin smelt during January -June period, the SWG or DFG SWG personnel shall provide OMR flow advice to the WOMT and the DFG Director weekly. The OMR flow advice shall be an OMR flow between -1,250 and -5,000 cfs and be based on review of survey data, including all of the distributional and abundance data, and other pertinent biological factors that influence the entrainment risk of larval and juvenile longfin smelt. When a single Smelt Larval Survey (SLS) or 20 mm Survey sampling period results in: 1) longfin smelt larvae or juveniles found in 8 or more of the 12 SLS or 20mm stations in the central and south Delta (Stations 809, 812, 901, 910, 912, 918, 919) or, 2) catch per tow exceeds 15 longfin smelt larvae or juveniles in 4 or more of the 12 survey stations listed above, OMR flow advice shall be warranted. Permittee shall ensure the OMR flow requirement is met by maintaining the OMR flow 14-day running average no more negative than the required OMR flow and the 5-day running average is within 25% of the required OMR. This Conditions OMR flow requirement is likely to vary throughout Jan through June. Based on prior analysis, DFG has identified three likely scenarios that illustrate the typical entrainment risk level and protective measures for larval smelt over the period: High Entrainment Risk Period - Jan through Mar OMR range from -1,250 to -5,000 cfs; Medium Entrainment Risk Period - April and May OMR range from -2000 to -5,000 cfs, and Low Entrainment Risk Period - June OMR -5,000 cfs. When river flows are: 1) greater than 55,000 cfs in the Sacramento River at Rio Vista; or 2) greater than 8,000 cfs in the San Joaquin River at Vernalis, the Condition would not trigger or would be relaxed if triggered previously. Should flows go below 40,000 cfs in Sacramento River at Rio Vista or 5,000 cfs in the San Joaquin River at Vernalis, the Condition shall resume if triggered previously. In addition to river flows, the SWG or DFG SWG personnel review of all abundance and distribution survey data and other pertinent biological factors that influence the entrainment risk of longfin smelt may result in a recommendation by DFG to WOMT to relax or cease an OMR flow requirement.

3.2.5 Biological Opinions

In 2008 and 2009, the USBR and the DWR concluded consultations regarding the effects of continued long-term operations of the Central CVP and SWP with the USFWS and the NMFS, respectively. Those consultations led to the issuance of biological opinions that require implementation of reasonable and prudent alternatives (RPAs) to avoid jeopardizing the continued existence and potential for recovery of delta smelt (*Hypomesus transpacificus*), Sacramento River winter-run Chinook salmon *(Oncorhynchus tshawytscha)*, Central Valley spring-run Chinook salmon (*O. tshawytscha*), Central Valley steelhead (*O. mykiss*), Southern Distinct Population Segment of North American green sturgeon (*Acipenser medirostris*), and Southern Resident killer whales *(Orcinus orca).*

Pursuant to Section 7 of the ESA, federal agencies must insure that their actions do not jeopardize the continued existence of threatened or endangered species or adversely modify their designated critical habitat. The regulations (50 CFR 402.02) implementing Section 7 of the ESA define RPAs as alternative actions, identified during formal consultation, that: 1) can be implemented in a manner consistent with the intended purpose of the action; 2) can be implemented consistent with the scope of the action agency's legal authority and jurisdiction; 3) are economically and technologically feasible; and, 4) would, the USFWS or NMFS believes,

avoid the likelihood of jeopardizing the continued existence of listed species or resulting in the destruction or adverse modification of critical habitat. (USFWS 2008, p.279.)

Numerous anthropogenic and other factors (e.g., pollutants and non-native species) that may adversely affect listed fish species in the region are not under the direct control of the CVP or the SWP and as such are not addressed in the biological opinions.

USFWS Biological Opinion

On December 15, 2008, the USFWS issued a biological opinion on the Long-Term Operational Criteria and Plan (OCAP) for coordination of the CVP and SWP (UFWS Opinion). The RPA in the USFWS Opinion, divided into six actions, applies to delta smelt and focuses primarily on managing flow regimes to reduce entrainment of delta smelt and on the extent of suitable water conditions in the Delta, as well as on construction or restoration of habitat. (USFWS 2008, pp.329-381.) Flow related components of the RPA include:

- A fixed duration action to protect pre-spawning adult delta smelt from entrainment during the first flush, and to provide advantageous hydrodynamic conditions early in the migration period. This action limits exports so that the average daily net OMR flow is no more negative than -2,000 cubic-feet per second (cfs) for a total duration of 14 days, with a 5-day running average no more negative than -2,500 cfs (within 25 percent) (Action 1, p.329).

- An adaptive process to continue to protect pre-spawning adults from entrainment and, to the extent possible, from adverse hydrodynamic conditions after the action identified above. The range of net daily OMR flows will be more no more negative than -1,250 to -5,000 cfs. From the onset of this action through its termination, the Delta Smelt Working Group would provide weekly recommendations for specific net OMR flows based upon review of the sampling data, from real-time salvage data at the CVP and SWP, and utilizing the most up-to-date technological expertise and knowledge relating population status and predicted distribution to monitored variables of flow and turbidity. The USFWS will make the final determination (Action 2, p.352).

- Upon completion of Actions 1 and 2 or when Delta water temperatures reach 12°C (based on a 3-station average of daily average water temperature at Mossdale, Antioch, and Rio Vista) or when a spent female delta smelt is detected in the trawls or at the salvage facilities, the projects shall operate to maintain net OMR flows no more negative than -1,250 to -5000 cfs based on a 14-day running average with a simultaneous 5-day running average within 25% of the applicable 14-day OMR flow requirement. Action continues until June 30th or when Delta water temperatures reach 25°C, whichever comes first (Action 3, p.357).

- Improve fall habitat, both quality and quantity, for delta smelt through increasing Delta outflow during fall (fall X2). Subject to adaptive management, provide sufficient Delta outflow to maintain average X2 for September and October no greater (more eastward) than 74 km in the fall following wet years and 81km in the fall following above normal years. The monthly average X2 must be maintained at or seaward of these values for each individual month and not averaged over the two month period. In November, the inflow to CVP/SWP reservoirs in the Sacramento Basin will be added to reservoir releases to provide an added increment of Delta inflow and to augment Delta outflow up

- To minimize entrainment of larval and juvenile delta smelt at the State and federal south Delta export facilities or from being transported into the south and central Delta, where they could later become entrained, do not install the Head of Old River Barrier (HORB) if delta smelt entrainment is a concern. If installation of the HORB is not allowed, the agricultural barriers would be installed as described in the Project Description of the biological opinion. If installation of the HORB is allowed, the Temporary Barrier Project flap gates would be tied in the open position until May 15 (Action 5, p. 377).

- Implement habitat restoration activities designed to improve habitat conditions for delta smelt by enhancing food production and availability to supplement the benefits resulting from the flow actions described above. DWR shall implement a program to create or restore a minimum of 8,000 acres of intertidal and associated subtidal habitat in the Delta and Suisun Marsh. The restoration efforts shall begin within 12 months of signature of this biological opinion and be completed within a 10 year period (Action 6, p. 379).

NMFS Biological Opinion

On June 4, 2009, NMFS issued its Biological and Conference Opinion on the OCAP (NMFS Opinion), which provides RPA actions to protect winter-run and spring-run Chinook salmon, Central Valley steelhead, green sturgeon, and killer whales from project effects in the Delta and upstream areas. (NMFS 3.) The RPA consists of five actions with a total of 72 subsidiary actions. Included within the RPA are actions related to: formation of technical teams, research and adaptive management, monitoring and reporting, flow management, temperature management, gravel augmentation, fish passage and reintroduction, gate operations and installation (Red Bluff Diversion Dam, Delta Cross Channel Gate, South Delta Improvement Program), funding for fish screening, floodplain and other habitat restoration, hatchery management, export restrictions, CVP and SWP fish collection facility modifications, and fish collection and handling. The flow related components of the opinion include:

- In the Sacramento River Basin – flow requirements for Clear Creek; release requirements from Whiskeytown Dam for temperature management; cold water pool management of Shasta Reservoir; development of flow requirements for Wilkins Slough; and restoration of floodplain habitat in the lower Sacramento River basin to better protect Chinook salmon, steelhead, and green sturgeon. (*Id at* pp.587-611.)

- In the American River - flow requirements and cold water pool management requirements to provide protection for steelhead. (*Id at* pp. 611-619.)

- In the San Joaquin River Basin – cold water pool management, floodplain inundation flows, and flow requirements for the Stanislaus River (NMFS 3, pp. 619-628, Appendix 2-E) and an interim minimum flow schedule for the San Joaquin River at Vernalis during April and May effective through 2011 for the protection of steelhead. (*Id at* pp. 641-645.)

- In the Delta – Delta Cross-Channel Gate operational requirements; net negative flow requirements toward the export pumps in Old and Middle rivers; and export limitations based on a ratio of San Joaquin River flows to combined SWP and CVP export during April and May for the protection of Chinook salmon and steelhead. (*Id. at* pp. 628-660.)

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It is important to note that the flow protections described in the project description and RPA are the minimum flows necessary to avoid jeopardy. (NMFS written summary, p.3.) In addition, NMFS considered provision of water to senior water rights holders to be non-discretionary for purposes of the ESA as it applies to Section 7 consultation with the USBR, which constrained development of RPA Shasta storage actions and flow schedules. San Joaquin River flows at Vernalis were constrained by the NMFS Opinion's scope extending only to CVP New Melones operations. Operations on other San Joaquin tributaries were not within the scope of the consultation. (*Id.*)

Recent Litigation

Both the USFWS Opinion and the NMFS Opinion are the subject of ongoing litigation in the United States District Court for the Eastern District of California. Plaintiffs challenged the validity of the opinions under various legal theories, including claims under the ESA and the NEPA. Most recently, this year plaintiffs Westlands Water District and San Luis Delta Mendota Water Authority sought preliminary injunctions against the implementation of certain RPAs identified by NMFS and USFWS in their biological opinions for the protection of Delta smelt and Central Valley steelhead and salmonids. In May 2010, Judge Wanger issued a ruling concluding that injunctive relief was appropriate with respect to the NMFS biological opinion PRA Action IV.2.1, which limits pumping based on San Joaquin River inflow from April 1 through May 31, and RPA Action IV.2.3, which imposes restrictions on negative OMR flows in generally between January 1 and June 15. Later that month, he also ruled that injunctive relief was appropriate with respect to RPA Component 2 of Action 3 of the USFWS Opinion, which requires net OMR flows to remain between -1,250 and -5,000 cfs during a certain period for the protection of larval and juvenile delta smelt. The validity of the biological opinions likely will continue to be litigated in the foreseeable future, creating uncertainty about implementation of the RPAs.

3.3   Environmental Setting

Figure 1 is a map of the Bay-Delta Estuary that was included in the 2006 Bay-Delta Plan. The map depicts the location of monitoring stations used to collect baseline water quality data for the Bay-Delta Estuary and stations used to monitor compliance with water quality objectives set forth in the Bay-Delta Plan.
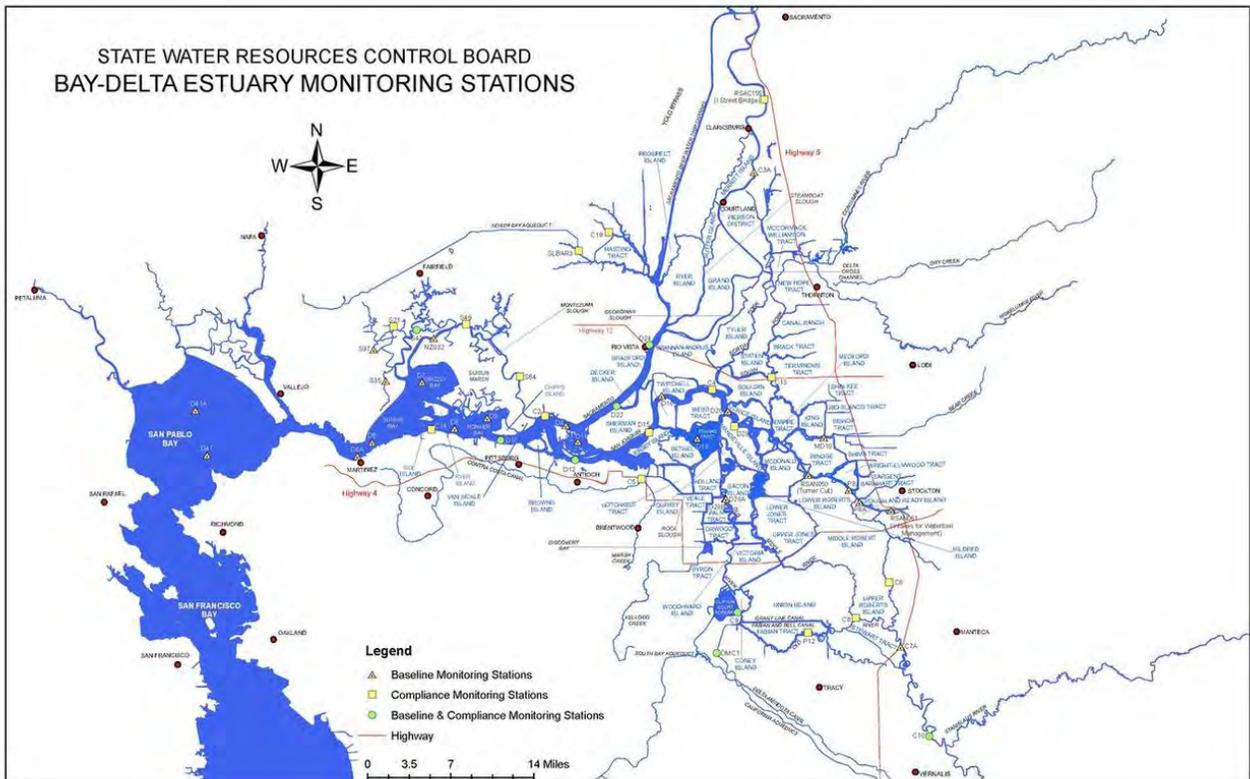
Figure 1. Map of the Bay-Delta Estuary

3.3.1 Physical Setting

The Delta is located where California's two major river systems, the Sacramento and San Joaquin rivers, converge from the north and south and are joined by several tributaries from the Central Sierras to the east, before flowing westward through the San Francisco Bay to the Pacific Ocean. The Sacramento and San Joaquin rivers drain water from the Central Valley Basin, which includes about 40 percent of California's land area.

Outflow from the Delta enters Suisun Bay just west of the confluence of the Sacramento and San Joaquin rivers. Suisun Marsh, which is located along the north shore of Suisun Bay, is one of the few major marshes remaining in California and is the largest remaining brackish wetland in Western North America. The marsh is subject to tidal influence and is directly affected by Delta outflow. Suisun Marsh covers approximately 85,000 acres of marshland and water ways and provides a unique diversity of habitats for fish and wildlife.

The Old Delta

The Delta formed as a freshwater marsh through the interaction of river inflow and the strong tidal influence of the Pacific Ocean and San Francisco Bay. The growth and decay of tules and other marsh plants resulted in the deposition of organic material, creating layers of peat that formed the soils of the marsh. Hydraulic mining during the Gold Rush era washed large amounts of sediment into the rivers, channels and bays, temporarily burying the wetlands. The former wetland areas were reclaimed into more than 60 islands and tracts that are devoted primarily to farming. A network of levees protects the islands and tracts from flooding, because most of the islands lie near or below sea level due to the erosion and oxidation of the peat soils.

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As shown in Figure 2 (Courtesy, Chris Enright, DWR, using Atwater data), prior to reclamation, the channels in the Delta were connected in a dendritic, or tree-like, pattern and may have included 5 to 10 times as many miles of interconnected channels as it does today, with largely unidirectional flow.

Figure 2. The Old Delta (*ca.* 1860).

The Recent Delta
Today's Delta covers about 738,000 acres, of which about 48,000 acres are water surface area, and is interlaced with about 700 miles of waterways. As shown in Figure 3 (Courtesy, Chris Enright, DWR, using Atwater data), today's remaining Delta waterways have been greatly modified to facilitate the bi-directional movement of water and the river banks have been armored to protect against erosion, thus changing the geometry of the stream channels and eliminating most of the natural vegetation and habitat of the aquatic and riparian environment. The interconnected geometry and channelized sloughs of the present Delta result in much less variability in water quality than the past dendritic pattern, and today's mostly open ended sloughs results in water quality and habitat being relatively homogenous throughout the system. (Moyle et al. 2010.)

Figure 3. The Recent Delta

The Changing Delta
The Delta Environmental Flows Group (DEFG 2) describes in *Changing Ecosystems: a Brief Ecological History of the Delta* how the Delta has undergone significant physical and biological modification over the past 150 years. Initial development occurred during the Gold Rush when large amounts of sediment washed into the Delta, followed by diking and dredging of rivers. This was followed by increasing diversions and developments, including fixing of levees and channels, and most recently with large-scale dam development and diversions from the Delta. The Moyle et al. history also suggests what is likely to happen in the future:

> "The Delta ecosystem is likely to dramatically shift again within 50 years due to large-scale levee collapse in the Delta and Suisun Marsh. Major levee failures are inevitable due to continued subsidence, sea level rise, increasing frequency of large floods, and high probability of earthquakes. These significant changes will create large areas of open water and increased salinity intrusion, as well as new tidal and subtidal marshes. Other likely changes include reduced freshwater inflow during prolonged droughts, altered hydraulics from reduced export pumping, and additional alien invaders (e.g., zebra and quagga mussels). The extent and effects of all these changes are unknown but much will depend on how the estuary is managed in response to change or even before change takes place. Overall, these major changes in the estuary's landscape are likely to promote a more variable, heterogeneous estuary, especially in the Delta and Suisun Marsh. This changed environment is likely to be better for desirable estuarine species; at least it is unlikely to be worse."

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3.3.2 Hydrology/Hydrodynamics

California's climate and hydrology are Mediterranean, which is characterized by most precipitation falling during the winter-spring wet season, a dry season extending from late spring through early fall, and high inter-annual variation in total runoff. The life history strategies of all native estuarine Delta fishes are adapted to natural variability. (Moyle and Bennett 2008, as cited in Fleenor et al. 2010.) Although the unimpaired flow record does not indicate precise, or best, flow requirements for fish under current conditions, the general timing (e.g., seasonality), magnitudes, and directions of flows seen in the unimpaired flow record are likely to remain important for native species under contemporary and future conditions. (Fleenor et al. 2010.)

Inflow to the Delta comes primarily from the Central Valley Basin's Sacramento and San Joaquin river systems and is chiefly derived from winter and spring runoff originating in the Cascade and Sierra Nevada mountains, with minor amounts from the Coast Ranges. Precipitation totals vary annually with about 80 percent of the total occurring between the end of October and the beginning of April. Snow storage in the high Sierra delays the runoff from that area until the snow melts in April, May, and June. Normally, about half of the annual runoff from the Central Valley Basin occurs during this period. In recent years, the Sacramento River contributed roughly 75 to 80% of the Delta inflow in most years, while the San Joaquin River contributed about 10 to 15%. The minor flows of the Mokelumne, Cosumnes, and Calaveras rivers, which enter into the eastern side of the Delta, contributed the remainder of the inflow to the Delta.

Net Delta outflow represents the difference between the sum of freshwater inflows from tributaries to the Delta and the sum of exports and net in-Delta consumptive uses. (Kimmerer 2004, DOI 1, p.17.) As noted above, the majority of the freshwater flow into the Delta occurs in winter and spring; however, upstream storage and diversions have reduced the winter-spring flow and increased flow in summer and early fall. (Figure 4, Kimmerer 2002b; Kimmerer 2004; DOI 1, p. 16.) The April-June reductions are largely the result of the San Joaquin River diversions. (Fleenor et al. 2010.) During the summer-fall dry season the Delta channels essentially serve as a conveyance system for moving water from reservoirs in the north to the CVP and SWP export facilities, as well as the smaller Contra Costa Water District facility, for subsequent delivery to farms and cities in the San Joaquin Valley, southern California, and/or other areas outside the watershed. (Kimmerer 2002b.) Figure 5 shows the reduction in annual Delta outflow as a percentage of unimpaired outflow. The combined effects of water exports and upstream diversions reduced average annual net outflow from the Delta from unimpaired conditions by 33% and 48% during the 1948 – 1968 and 1986 – 2005 periods, respectively. (Fleenor et al. 2010.)
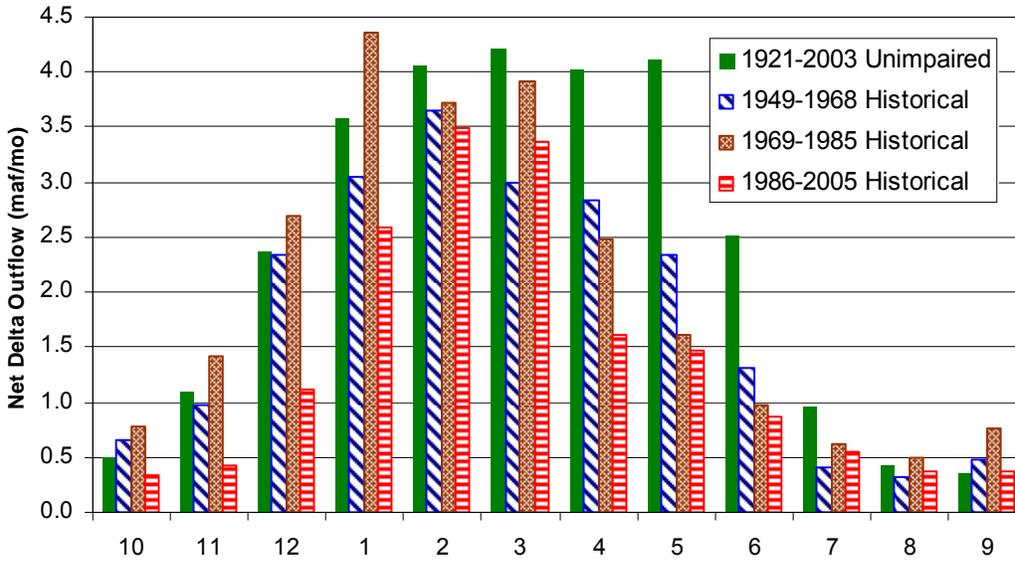
This figure shows monthly average net delta outflows (in million acre-feet per month) compared to the unimpaired flows from 1921-2003. Unimpaired flow data is from DWR (2006) and other from Dayflow web site. (Source: Fleenor et al. 2010, Figure 7.)

Figure 4. Monthly Average Net Delta Outflows from Fleenor et al. 2010
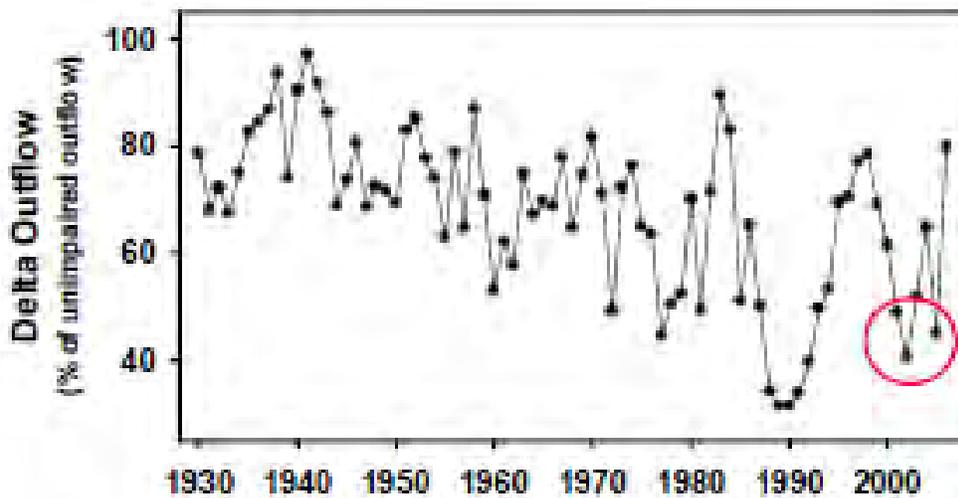
Delta outflow shown as a percentage of unimpaired outflow (1930-2005); in the last decade annual outflow is reduced by more than 50% in 2001, 2002, and 2005. (Source: TBI 2007, as cited in DOI 1, p. 17.)

Figure 5. Delta Outflow as a Percent of Unimpaired Outflow from TBI 2007

Delta outflows and the position of X2 are closely and inversely related, with a time lag of about two weeks. (Jassby et al. 1995; Kimmerer 2004.) A time series of the annual averages for January to June of X2 and Delta outflow is depicted in Figure 6. X2 is defined as the horizontal distance in kilometers up the axis of the estuary from the Golden Gate Bridge to where the tidally averaged near-bottom salinity is 2 practical salinity units (psu). (Jassby et al. 1995,

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Kimmerer 2002a.) The position of X2 roughly equates to the center of the low salinity zone (defined as salinity of 0.5 to 6 psu). (Kimmerer 2002a.) The X2 objectives in the 2006 Bay-Delta Plan were designed to restore a more natural hydrograph and salinity pattern by requiring maintenance of the low salinity zone at specified points and durations based on the previous month's Eight River Index. (State Water Board 2006a.) The relationships between outflow and several measures of the health of the Bay-Delta Estuary have been known for some time (Jassby *et al.* 1995) and are the basis for the current X2 objectives.
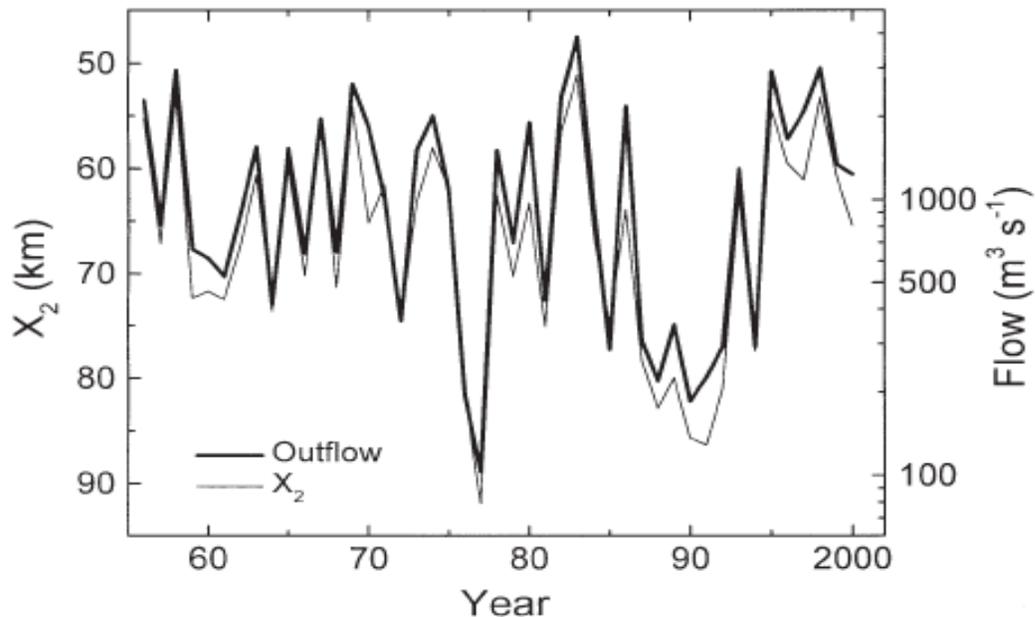
Time series of X2 (thin line, left axis, scale reversed) and flow (heavy line, right axis, log scale), annual averages for January to June; flow data from DWR; X2 calculated as in Jassby et al. (1995) (Source: Kimmerer 2002a, Figure 3).

Figure 6. X2 and Delta Outflow for January to June from Kimmerer 2002a

Both Delta outflow and the position of X2 have been altered as a result of numerous factors including development and operation of upstream storage and diversions, land use changes, and increasing water demand. Hydrodynamic simulations conducted by Fleenor et al. (2010) indicate that the position of X2 has been skewed eastward in the recent past, as compared to unimpaired conditions and earlier impaired periods, and that the variability of salinity in the western Delta and Suisun Bay has been significantly reduced (Figure 7). The higher X2 values shown in this figure (refer to Point 'B') indicate the low salinity zone is farther upstream for a more prolonged period of time. Point 'B' demonstrates that during the period from 1986 to 2005 the position of X2 was located upstream of 71 km nearly 80% of the time, as opposed to unimpaired flows which were equally likely to place X2 upstream or downstream of the 71 km location (50% probability). (Fleenor *et al.* 2010.) Historically, X2 exhibited a wide seasonal range tracking the unimpaired Delta outflows; however, seasonal variation in X2 range has been reduced by nearly 40%, as compared to pre-dam conditions. (TBI 2003, as cited in DOI 1, pp. 21-22.)
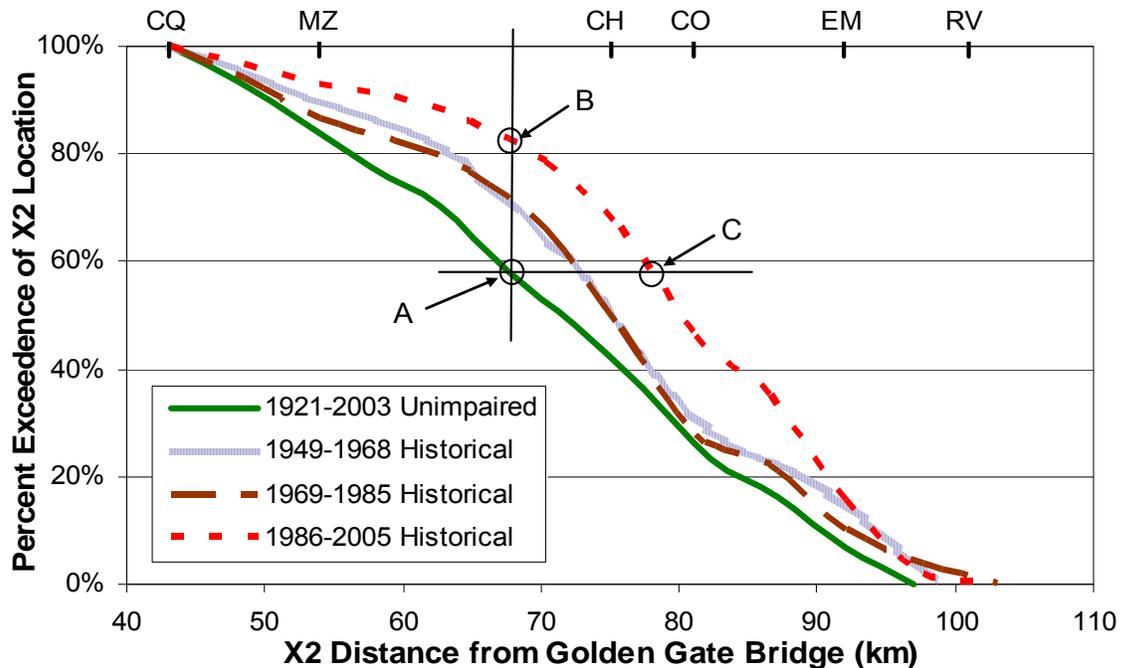
This graph shows the cumulative probability distributions of daily X2 locations showing unimpaired flows (green solid line) and three historical periods, 1949-1968 (light solid blue line), 1969-1985 (long-dashed brown line) and 1986-2005 (short-dashed red line), illustrating progressive reduction in salinity variability from unimpaired conditions. Paired letters indicate geographical landmarks: CQ, Carquinez Bridge; MZ, Martinez Bridge; CH, Chipps Island; CO, Collinsville; EM, Emmaton; and RV, Rio Vista (Source: Fleenor et al. 2010, Figure 8).

Figure 7. Cumulative Probability of Daily X2 Locations from Fleenor *et al*. 2010

In their key points on Delta environmental flows for the State Water Board, the DEFG (DEFG 1) noted that the recent flow regimes both harm native species and encourage non-native species and provided the following justification:

> "The major river systems of the arid western United States have highly variable natural flow regimes. The present-day flow regimes of western rivers, including the Sacramento and San Joaquin, are highly managed to increase water supply reliability for agriculture, urban use, and flood protection (Hughes et al. 2005, Lund et al. 2007). Recent Delta inflow and outflow regimes appear to both harm native species and encourage non-native species. Inflow patterns from the Sacramento River may help riverine native species in the north Delta, but inflow patterns from the San Joaquin River encourage non-native species. Ecological theory and observations overwhelmingly support the argument that enhancing variability and complexity across the estuarine landscape will support native species. However, the evidence that flow stabilization reduces native fish abundance in the upper estuary (incl. Delta) is circumstantial:
>
> 1) High winter-spring inflows to the Delta cue native fish spawning migrations (Harrell and Sommer 2003; Grimaldo et al. 2009), improve the reproductive success of resident native fishes (Meng et al. 1994; Sommer et al. 1997; Matern et al. 2002; Feyrer 2004), increase the survival of

juvenile anadromous fishes migrating seaward (Sommer *et al.* 2001; Newman 2003), and disperse native fishes spawned in prior years (Feyrer and Healey 2003; Nobriga et al. 2006).

2) High freshwater outflows (indexed by X2) during winter and spring provide similar benefits to species less tolerant of freshwater including starry flounder, bay shrimp, and longfin smelt (Kimmerer 2002; Kimmerer *et al.* 2009). Freshwater flows provide positive benefits to native fishes across a wide geographic area through various mechanisms including larval-juvenile dispersal, floodplain inundation, reduced entrainment, and increased up-estuary transport flows. Spring Delta inflows and outflow have declined since the early 20th century, but average winter-spring X2 has not had a time trend during the past 4-5 decades (Kimmerer 2004).

3) The estuary's fish assemblages vary along the salinity gradient (Matern et al. 2002; Kimmerer 2004), and along the gradient between predominantly tidal and purely river flow. In tidal freshwater regions, fish assemblages also vary along a gradient in water clarity and submerged vegetation (Nobriga et al. 2005; Brown & Michniuk 2007), and smaller scale, gradients of flow, turbidity, temperature and other habitat features (Matern et al. 2002; Feyrer & Healey 2003). Generally, native fishes have their highest relative abundance in Suisun Marsh and the Sacramento River side of the Delta, which are more spatially and temporally variable in salinity, turbidity, temperature, and nutrient concentration and form than other regions.

4) In both Suisun Marsh and the Delta, native fishes have declined faster than non-native fishes over the past several decades (Matern et al. 2002; Brown and Michniuk 2007). These declines have been linked to persistent low fall outflows (Feyrer et al. 2007) and the proliferation of submerged vegetation in the Delta (Brown and Michniuk 2007). However, many other factors also may be influencing native fish declines including differences in sensitivity to entrainment (sustained or episodic high "fishing pressure" as productivity declines), and greater sensitivity to combinations of food-limitation and contaminants, especially in summer-fall when many native fishes are near their thermal limits.

The weight of the circumstantial evidence summarized above strongly suggests flow stabilization harms native species and encourages non-native species, possibly in synergy with other stressors such as nutrient loading, contaminants, and food limitation."

Diversion and Use

Irrigation is the primary use of water in the Sacramento and San Joaquin river watershed. Water is used to a lesser extent to meet municipal, industrial, environmental, and instream needs. Water is also exported from the Central Valley Basin for many of these same purposes. Local irrigation districts, municipal utility districts, county agencies, private companies and corporations, and State and federal agencies have developed surface water projects throughout the basin to control and conserve the natural runoff and provide a reliable water supply for beneficial uses. Many of these projects are used to produce hydroelectric power and to

enhance recreational opportunities. Flood control systems, water storage facilities, and diversion works exist on all major streams in the basin, altering the timing, location, and quantity of water and the habitat associated with the natural flow patterns of the basin. (State Water Board 1999.)

The major surface water supply developments of the Central Valley include the CVP, other federal projects built by the USBR and the U.S. Army Corps of Engineers (USACE), the SWP, and numerous local projects (including several major diversions). The big rim dams, developed mostly since the 1940s, dramatically changed river flow patterns. The dams were built to provide flood protection and a reliable water supply. Collection of water to storage decreased river flows in winter and spring, and changed the timing of high flow periods (except for extreme flood flows). The San Joaquin River has lost most of its natural summer flows because the majority of the water is exported via the Friant project or diverted from the major tributaries for use within the basin. Even though natural flows have been substantially reduced, agricultural return flows during the summer have actually resulted in higher flows than would have occurred under unimpaired conditions at times. Winter and spring flows collected to storage by the State and federal projects in the Sacramento Basin are released in the late spring and throughout the summer and fall, largely to be rediverted from the Delta for export. The federal pumping plants in the southern Delta started operating in the 1950s, exporting water into the Delta-Mendota Canal. The State pumps and the California Aqueduct started operating in the late 1960s, further increasing exports from the Delta. (Moyle, et al. 2010.)

In-Delta Diversions and Old and Middle River Reverse Flows

The USBR and the DWR are the major diverters in the Delta. The USBR exports water from the Delta at the Tracy Pumping Plant and the Contra Costa Water District diverts CVP water at Rock Slough and Old River under a water supply contract with the USBR. The DWR exports from the Delta at the Banks Delta Pumping Plant and Barker Slough to serve the SWP contractors. Operation of the CVP and SWP Delta export facilities are coordinated to meet water quality and flow standards set by the Board, the USACE, and by fisheries agencies. In addition, there are approximately 1,800 local diversions within the Delta that amount to a combined potential instantaneous flow rate of more than 4,000 cfs. (State Water Board 1999.)

Net OMR reverse flows are now a regular occurrence in the Delta (Figure 8). Net OMR reverse flows are caused by the fact that the major freshwater source, the Sacramento River, enters on the northern side of the Delta while the two major pumping faciltes, the SWP and CVP, are located in the south (Figure 1). This results in a net water movement across the Delta in a north-south direction along a web of channels including Old and Middle rivers instead of the more natural pattern from east to west or from land to sea. Net OMR is calculated as half the flow of the San Joaquin River at Vernalis minus the combined SWP and CVP pumping rate. (CCWD closing comments, p. 2.) A negative value, or a reverse flow, indicates a net water movement across the Delta along Old and Middle river channels to the State and Federal pumping facilities. Fleenor *et al* (2010) has documented the change in both the magnitude and frequency of net OMR reverse flows as water development occurred in the Delta (Figure 8). The 1925-2000 unimpaired line in Figure 8 represents the best estimate of "quasi-natural" or net OMR values before most modern water development. (Fleenor et al. 2010.) The other three lines represent changes in the frequency and magnitude of net OMR flows with increasing development. Net OMR reverse flows are estimated to have occurred naturally about 15% of the time before most modern water development, including construction of the major pumping facilities in the South Delta (point A, Figure 8). The magnitude of net OMR reverse flows was seldom more negative than a couple of thousand cfs. In contrast, between1986-2005 net OMR

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reverse flows had become more frequent than 90 percent of the time (Point B). The magnitude of net OMR reverse flows may now be as much as -12,000 cfs. High net OMR reverse flows have several negative ecological consequences. First, net reverse OMR flows draw fish, especially the weaker swimming larval and juvenile forms, into the SWP and CVP export facilities. The export facilities have been documented to entrain most species of fish present in the upper estuary. (Brown *et al*. 1996,.) Approximately 110 million fish were salvaged at the SWP pumping facilities and returned to the Delta over a 15 year period, (Brown et al. 1996.) However, this number underestimates the actual number of fish entrained, as it does not include losses at the CVP nor does it account for fish less than 20 mm in length which are not collected and counted at the fish collection facilities. Second, net OMR reverse flows reduce spawning and rearing habitat for native species, like delta smelt. Any fish that enters the Central or Southern Delta has a high probability of being entrained and lost at the pumps. (Kimmerer and Nobriga, 2008.) This has restricted their habitat to the western Delta and Suisun and Grizzly bays. Third, net OMR reverse flows have led to a confusing environment for migrating juvenile salmon leaving the San Joaquin Basin. Through-Delta exports reduce salinity in the central and southern Delta and as a result juvenile salmon migrate from higher salinity in the San Joaquin River to lower salinity in the southern Delta, contrary to the natural historical conditions and their inherited migratory cues. Finally, net OMR reverse flows reduce the natural variability in the Delta by drawing Sacramento River water across and into the Central Delta. The UC Davis Delta Solutions Group recommends:

> "Achieving a variable, more complex estuary requires establishing seaward gradients in salinity and other water quality variables…These goals in turn encourage policies which… establish internal Delta flows that create a tidally-mixed, upstream-downstream gradient (without cross-Delta flows) in water quality… and … restoring environmental variability in the Delta is fundamentally inconsistent with continuing to move large volumes of water through the Delta for export. The drinking and agricultural water quality requirements of through-Delta exports, and perhaps even some current in-Delta uses, are at odds with the water quality and variability needs of desirable Delta species."
> (Moyle et al., 2010.)

Net OMR reverse flow restrictions are included in the USFWS Opinion (Actions 1 through 3), the NMFS Opinion (Action IV.2.3), and the DFG Incidental Take Permit (Conditions 5.1 and 5.2) for the protection of delta smelt, salmonids, and longfin smelt, respectively. (NMFS 3. p. 648; USFWS 2008, DFG 2009.) Additional net OMR reverse flow restrictions are recommended in this report for protection of longfin and delta smelt and Chinook salmon.

Further north in the Delta, the Delta Cross Channel is used to divert a portion of the Sacramento River flow into the interior Delta channels. The purpose of the Delta Cross Channel is to preserve the quality of water diverted from the Sacramento River by conveying it to southern Delta pumping plants through eastern Delta channels rather than allowing it to flow through more saline western Delta channels. The Delta Cross Channel is also operated to protect fish and wildlife beneficial uses (specifically Chinook salmon), while recognizing the need for fresh water to be moved through the system. With a capacity of 3,500 cfs, the Delta Cross Channel can divert a significant portion of the Sacramento River flows into the eastern Delta, particularly in the fall.
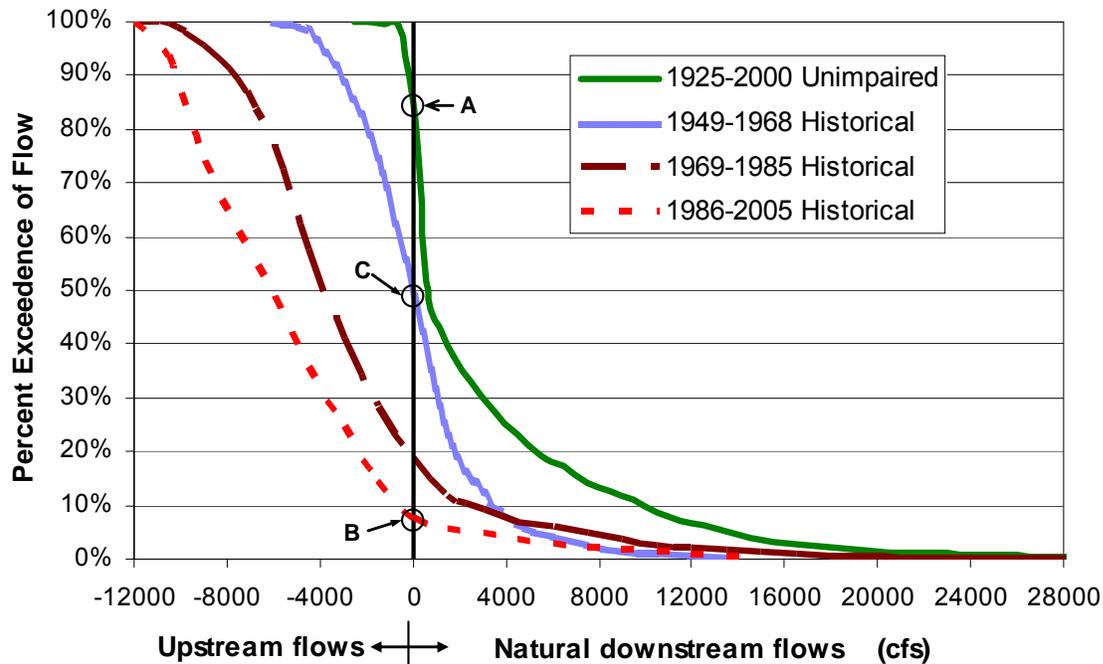
Cumulative probability distribution of sum of Old and Middle River flows (cfs) resulting from through Delta conveyance showing unimpaired flows (green solid line) and three historical periods, 1949-1968 (solid light blue line), 1969-1985 (long-dashed brown line) and 1986-2005 (short-dashed red line) (Source: Fleenor et al. 2010. Figure 9).

Figure 8. OMR Cumulative Probability Flows from Fleenor et al. 2010

3.3.3 Water Quality

Water quality in the Delta may be negatively impacted by contaminants in sediments and water, low DO levels, and blue green algal blooms. Additionally, changes in hydrology and hydrodynamics affect water quality. The conversion of tidal wetlands to leveed Delta islands has altered the tidal exchange and prism. These changes can contribute to spatial and temporal shifts in salinity and other physical and chemical water quality parameters (temperature, DO, contaminants, etc.).

Contaminants

The Delta and San Francisco Bay are listed under section 303(d) of the Federal Clean Water Act as impaired for a variety of toxic contaminants that may contribute to reduced population abundance of important fish and invertebrates. The contaminants include: organophosphate and pyrethrin pesticides, mercury, selenium and unknown toxicity. In addition, low DO levels periodically develop in the San Joaquin River in the Stockton Deep Water Ship Channel (DWSC) and in Old and Middle rivers. The low DO levels in the DWSC inhibit the upstream migration of adult fall-run Chinook salmon and adversely impact other resident aquatic organisms. The Central Valley and San Francisco Regional Boards are systematically developing Total Maximum Daily Loads (TMDLs) for all listed pollutants and adopting programs to implement control actions.

There is concern that a number of non-303(d) listed contaminants, such as ammonia, pharmaceuticals, endocrine disrupting compounds and blue-green algal blooms could also limit biological productivity and impair beneficial uses. More work is needed to determine their

impact on the aquatic community. Sources of these contaminants include: agricultural, municipal, and industrial wastewater; urban storm water discharges; discharges from wetlands; and channel dredging activities.

Ammonia has emerged as a contaminant of special concern in the Delta. Recent hypotheses are that ammonia is causing toxicity to delta smelt, other local fish, and zooplankton, and is reducing primary production rates in the Sacramento River below the Sacramento Regional Wastewater Treatment Plant (SRWTP) and in Suisun Bay. A third, newer, hypothesis is that ammonia and nitrogen to phosphorus ratios have altered phytoplankton species composition, and these changes have had a detrimental effect on zooplankton and fish population abundance. (Glibert, 2010.)

The SRWTP is the primary source of ammonia to the Delta. (Jassby 2008.) The SRWTP has converted the Delta from a nitrate to an ammonia dominated nitrogen system. (Foe et al. 2010.) Seven-day flow-through bioassays by Werner et al. (2008, 2009) have demonstrated that ammonia concentrations in the Delta are not acutely toxic to delta smelt. Monthly nutrient monitoring by Foe *et al.* (2010) has demonstrated that ammonia concentrations are below the recommended USEPA (1999) chronic criterion for the protection of juvenile fish. Results from the nutrient monitoring suggest that ammonia-induced toxicity to fish is not regularly occurring in the Delta.

Elevated ammonia concentrations inhibit nitrate uptake and that appears to be one factor preventing spring diatom blooms from developing in Suisun Bay. (Dugdale et al. 2007; Wilkerson et al. 2006.) One of the primary hypotheses for the POD is a decrease in the availability of food at the base of the food web. (Sommer et al. 2007.) Staff from the San Francisco Regional Board has informed the Central Valley Regional Board that ammonia may be impairing aquatic life beneficial uses in Suisun Bay (letter to Kathy Harder with the Central Valley Regional Board from Bruce Wolfe of the San Francisco Regional Board dated June 4, 2010).

Ammonia concentrations are higher in the Sacramento River below the SRWTP than in Suisun Bay. This led to a hypothesis that ammonia might be inhibiting nitrate uptake and reducing primary production rates in the Sacramento River and downstream Delta, as occurs in Suisun Bay. Experimental results for the Sacramento River are more ambiguous than for Suisun Bay. (Parker *et al.*, 2010.) Five-day cubitainer grow out experiments conducted using water collected above and below the SRWTP usually demonstrated more chlorophyll in water collected below the SRWTP. Short-term bottle primary production rate measurements conducted using water collected above and below the SRWTP also demonstrate no decrease in the rate when normalized by the amount of chlorophyll in the bottle. However, effluent dosed into upstream Sacramento River water at environmentally realistic concentrations does show a decrease in primary production. Elevated ammonia concentrations consistently decrease nitrate uptake. Whether the shift in nitrogen utilization indicates that different algal species are beginning to grow in the ammonia rich water is not known. A recent paper by Glibert (2010) demonstrates significant correlations between the form and concentration of nutrients discharged by the SRWTP, and changes in phytoplankton, zooplankton, and fish abundance in the Delta.

Salinity

Elevated salinity can impair the uses of water by municipal, industrial, and agricultural users and by organisms that require lower salinity levels. There are at least three factors that may cause salinity levels to exceed water quality objectives in the Delta: saltwater intrusion from the Pacific

Ocean and San Francisco Bay moving into the Delta on high tides during periods of relatively low flows of fresh water through the Delta; salts from agricultural return flows, municipalities, and other sources carried into the southern and eastern Delta with the waters of the San Joaquin River; and localized increases in salinity due to irrigation return flows into dead-end sloughs and low-capacity channels (null zones). The effects of saltwater intrusion are seen primarily in the western Delta. Due to the operation of the State and federal export pumping plants near Tracy, the higher salinity areas caused by salts in the San Joaquin River tend to be restricted to the southeast corner of the Delta. Null zones, and the localized areas of increased salinity associated with them, exist predominantly in three areas of the Delta: Old River between Sugar Cut and the CVP intake; Middle River between Victoria canal and Old River; and the San Joaquin River between the head of Old River and the City of Stockton.

Suspended Sediments and Turbidity

Turbidity in the Delta is caused by factors that include suspended material such as silts, clays, and organic matter coming from the major tributary rivers; planktonic algal populations; and sediments stirred up during dredging operations to maintain deep channels for shipping. Turbidity affects large river and estuarine fish assemblages because some fishes survive best in turbid (muddy) water, while other species do best in clear water. Studies suggest that changes in specific conductance and turbidity are associated with declines in upper estuary habitat for delta smelt, striped bass, and threadfin shad. Laboratory studies have shown that delta smelt require turbidity for successful feeding.

Turbidity in the Delta has decreased through time. The primary hypotheses to explain the turbidity decrease are: (1) reduced sediment supply; (2) sediment washout from very high inflows during the 1982 to 1983 El Nino; and (3) trapping of sediment by submerged aquatic vegetation. (Wright and Schoellhamer 2004, Jassby et al. 2005, Nobriga et al. 2005, and Brown and Michniuk 2007 as cited in Nobriga et al. 2008.)

Dissolved Oxygen

Low DO levels are found along the lower San Joaquin River and in certain localized areas of the Delta. Dissolved oxygen impairment is caused, in part, by loads of oxygen demanding substances such as dead algae or waste discharges. Low DO in the Delta occurs mainly in the late summer and coincides with low river flows and high temperatures. Fish vary greatly in their ability to tolerate low DO concentrations, based on the environmental conditions the species has evolved to inhabit. Salmonids are relatively intolerant of low DO concentrations. Within the lower San Joaquin River, DO concentrations can become sufficiently low to impair the passage and/or cause mortality of migratory salmonids. (DFG 3, p. 3; DOI 1, p. 25; TBI/NRDC 3, p. 26.)

The DWSC is a portion of the lower San Joaquin River between the City of Stockton and the San Francisco Bay that has been dredged to allow for the navigation of ocean-going vessels to the Port of Stockton. A 14-mile stretch of the DWSC, from the City of Stockton to Disappointment Slough, is listed as impaired for DO and, at times, does not meet the objectives set forth in the San Joaquin Riverwater quality control plan. Studies have identified three main contributing factors to the problem: loads of oxygen demanding substances that exert an oxygen demand (particularly the death and decay of algae); DWSC geometry, which reduces the assimilative capacity for loads of oxygen demanding substances by reducing the efficiency of natural re-aeration mechanisms and by magnifying the effect of oxygen demanding reactions; and, reduced flow through the DWSC, which reduces the assimilative capacity by reducing upstream inputs of oxygen and increasing the residence time for oxygen demanding reactions. (Central Valley Regional Board 2003.)

3.3.4 Biological Setting

The Bay-Delta Estuary is one of the largest, most important estuarine systems for fish and waterfowl production on the Pacific Coast of the United States. The Delta provides habitat for a wide variety of freshwater, estuarine, and marine fish species. Channels in the Delta range from dead-end sloughs to deep, open water areas that include several flooded islands that provide submerged vegetative shelter. The complex interface between land and water in the Delta provides rich and varied habitat for wildlife, especially birds. The Delta is particularly important to waterfowl migrating via the Pacific Flyway as these birds are attracted to the winter-flooded fields and seasonal wetlands. (State Water Board 1999.)

Existing Setting

A wide variety of fish are found throughout the waterways of the Central Valley and the Bay-Delta Estuary. About 90 species of fish are found in the Delta. Some species, such as the anadromous fish, are found in particular parts of the Bay-Delta Estuary and the tributary rivers and streams only during certain stages of their life cycle. The Delta's channels serve as a migratory route and nursery area for Chinook salmon, striped bass, white and green sturgeon, American shad, and steelhead trout. These anadromous fishes spend most of their adult lives either in the lower bays of the estuary or in the ocean, moving inland to spawn. Resident fishes in the Bay-Delta Estuary include delta smelt, longfin smelt, threadfin shad, Sacramento splittail, catfish, largemouth and other bass, crappie, and bluegill.

Food supplies for Delta fish communities consist of phytoplankton, zooplankton, benthic invertebrates, insects, and forage fish. The entrapment zone, where freshwater outflow meets and mixes with the more saline water of the Bay, concentrates sediments, nutrients, phytoplankton, some fish larvae, and other fish food organisms. Biological standing crop (biomass) of phytoplankton and zooplankton in the estuary has generally been highest in this zone. However, the overall productivity at the lower trophic levels has decreased over time. (State Water Board 1999.)

Non-Native and Invasive Species

Invasive aquatic organisms are known to have deleterious effects on the Delta ecosystem. These effects include reductions in habitat suitability, reductions in food supply, alteration of the aquatic food-web, and predation on or competition with native species. There are many notable examples of exotic species invasions in the Bay-Delta, so much so, that the Delta has been labeled "the most invaded estuary on earth."

Of particular importance potentially in the recent decline in pelagic organisms is the introduction of the Asian clam, *Corbula amurensis*. The introduction of the clam has lead to substantial declines in the lower trophic production of the Bay-Delta Estuary. In addition to reductions in planktonic production caused by *Corbula*, the planktonic food web composition has changed dramatically over the past decade or so. Once dominant copepods in the food web have declined leading to speculation that estuarine conditions have changed to favor alien species. The decrease in these desirable copepods may further increase the likelihood of larval fish starvation or result in decreased growth rates. (State Water Board 2008.)

The proliferation of invasive, aquatic weeds, such as *Egeria densa*, which filter out particulate materials and further reduce planktonic growth, are also having a impact on the Bay-Delta. Areas with low or no flow, such as warm, shallow, dead-end sloughs in the eastern Delta also support objectionable populations of plants during summer months including planktonic blue-green algae and floating and semi-attached aquatic plants such as water primrose, water

hyacinth, and *Egeria densa*. All of these plants contribute organic matter that reduces DO levels in the fall, and the floating and semi-attached plants interfere with the passage of small boat traffic. In addition, native fishes in the Bay-Delta face growing challenges associated with competition and predation by non-native fish. (State Water Board 1999; State Water Board 2008.)

Recent Species Declines

Historical fisheries within the Central Valley and the Bay-Delta Estuary were considerably different than the fisheries present today. Many native species have declined in abundance and distribution, while several introduced species have become well established. The Sacramento perch is believed to have been extirpated from the Delta; however, striped bass and American shad are introduced species that, until recently, have been relatively abundant and have contributed substantially to California's recreational fishery. (State Water Board 1999.)

In 2005, scientists with the Interagency Ecological Program (IEP) announced observations of a precipitous decline in several pelagic organisms in the Delta, beginning in 2002, in addition to declining levels of zooplankton. Zooplankton are the primary food source for older life stages of species such as delta smelt. The decline in pelagic organisms included delta smelt, striped bass, longfin smelt, and threadfin shad. Scientists hypothesized that at least three general factors may be acting individually, or in concert, to cause this recent decline in pelagic productivity: 1) toxic effects; 2) exotic species effects; and 3) water project effects. Scientists and resources agencies have continued to investigate the causes of the decline, and have prepared plans that identify actions designed to help stabilize the Delta ecosystem and improve conditions for pelagic fish species. (State Water Board 2008.)

In January of 2008, the Pacific Fisheries Management Council reported unexpectedly low Chinook salmon returns to California, particularly to the Central Valley, for 2007. Adult returns to the Sacramento River, the largest of Central Valley Chinook salmon runs, failed to meet resource management goals (122,000-180,000 spawners) for the first time in 15 years. (State Water Board 2008.) The Sacramento River fall Chinook salmon escapement to the Central Valley was estimated to be 88,000 adults in 2007; 66,000 in 2008; and 39,530 – the lowest on record -- in 2009. (PCFFA 2.) The NMFS concluded that poor ocean conditions were a major factor contributing to the low fall-run abundance; however, other conditions may exacerbate these effects. (State Water Board 2008.)

In April 2008, the Pacific Fisheries Management Council and the Commission adopted the most restrictive ocean and coastal salmon seasons ever for California by closing the ocean and coastal fishery to commercial and recreation fishing for the 2008 fishing season. The Commission further banned salmon fishing in all Central Valley rivers, with the exception of limited fishing on a stretch of the Sacramento River. (State Water Board 2008.) The ban on all salmon fishing was extended through the 2009 season, but the restrictions were eased somewhat for 2010.

3.3.5 How Flow-Related Factors Affect Public Trust Resources

Flow is important to sustaining the ecological integrity of aquatic ecosystems, including the public trust resources that are the subject of this proceeding. Flow affects water quality, food resources, physical habitat, and biotic interactions. Alterations in the natural flow regime affect aquatic biodiversity and the structure and function of aquatic ecosystems.

In its key points on Delta environmental flows for the State Water Board, the DEFG (DEFG 1) noted that:

- Flow related factors that affect public trust resources include more than just volumes of inflow and outflow and no single rate of flow can protect all public trust resources at all times. The frequency, timing, duration, and rate of change of flows, the tides, and the occurrence of overbank flows, all are important. Seasonal, interannual, and spatial variability in flows, to which native species are adapted, are as important as the quantity of flow. Biological responses to flows rest on combinations of quantity, timing, duration, frequency and how these inputs vary spatially in the context of a Delta that is geometrically complex, highly altered by humans, and fundamentally tidally driven.

- Recent flow regimes in the Delta have contributed to the decline of native species and encouraged non-native species. Flows into and within the estuary affect turbidity, salinity, aquatic plant communities, and nutrients that are important to both native and non-native species. However, flows and habitat structure are often mismatched and now favor non-native species.

- Flow is a major determinant of habitat and transport. The effects of flow on transport and habitat are controlled by the geometry of the waterways. Further, because the geometry of the waterways will change through time, flow regimes needed to maintain desired habitat conditions will also change through time. Delta inflow is an important factor affecting the biological resources of the Delta because inflow has a direct effect on flood plain inundation, in-Delta net channel flows, and net Delta outflows.

- Flow modification is one of the few immediate actions available to improve conditions to benefit native species. However, habitat restoration, contaminant and nutrient reduction, changes in diversions, control of invasive species, as well as flood plain inundation and island flooding all interact with flow to affect aquatic habitats.

4. Methods and Data

The notice for the informational proceeding requested scientific information on the volume, quality, and timing of water needed for the Delta ecosystem under different hydrologic conditions to protect public trust resources pursuant to the State Water Board's public trust obligations and the requirements of SB 1. Specifically, the notice focused on Delta outflows, but also requested information concerning the importance of the source of those flows and information concerning adaptive management, monitoring, and special study programs. In addition to the requested information concerning Delta outflows, the State Water Board also received information on Sacramento River inflows, San Joaquin River inflows, hydrodynamics including Old and Middle River flows, and other information that is relevant to protection of public trust resources in the Delta ecosystem. This section presents the recommendations received by the State Water Board and discusses approaches used to evaluate the recommendations and develop flow criteria responsive to SB1.

4.1 Summary of Participants' Submittals

Information submitted by interested parties over the course of this proceeding has resulted in the development of a substantive record; submittals are available on the State Water Board's website at:

http://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/deltaflow/entity_index.shtml

The exhibits include discussions pertaining to: the State Water Board's public trust obligations; methodologies that should be used to develop flow criteria; the importance of the source of flows when determining outflows; means by which uncertainty should be addressed; and specific recommendations concerning Delta outflows, Sacramento and San Joaquin river inflows, hydrodynamics, operation of the Delta Cross Channel Gates, and floodplain activation.

The State Water Board received a wide range of recommendations for the volume, quantity and timing of flow necessary to protect public trust resources. Delta outflow recommendations ranged from statements that the current state of scientific understanding does not support development of numeric Delta flow criteria that differ from the current outflow objectives included in D-1641 (DWR closing comments; SFWC closing comments) to flow volumes during above normal and wet water year types that are two to four times greater than currently required under D-1641 (TBI/NRDC closing comments; AR/NHI closing comments; EDF closing comments, CSPA closing comments; CWIN closing comments). Appendix A: Summary of Participant Recommendations, provides summary tables of the recommendations received for Delta outflows, Sacramento River inflows, San Joaquin River inflows, hydrodynamics, floodplain inundation, and Delta Cross Channel Gate closures.

4.2 Approach to Developing Flow Criteria

Fleenor et al. (2010) examined the following four approaches for prescribing environmental flows for the Delta:

- Unimpaired (quasi-natural) inflows
- Historical impaired inflows that supported more desirable ecological conditions
- Statistical relationships between flow and native species abundance
- The appropriate accumulation of flows estimated to provide specific ecological functions for desirable species and ecosystem attributes based on available literature.

Fleenor *et al.* (2010) concludes:

> "Generally, approaches that rely on data from the past will become more risky as the underlying changes in the Delta accumulate. However, since the objective is to provide flows for species which evolved under past conditions, information on past flows and life history strategies of fish provide considerable insight and context. Aggregate statistical approaches, which essentially establish correlations between past conditions and past species abundance, are likely to be less directly useful as the Delta changes. However, statistical approaches will continue to be useful, especially if developed for causal insights. More focused statistical relationships can be of more enduring value in the context of more causal models, even given underlying changes. In the absence of more process-based science, empirical relationships might be required for some locations and functions on an interim basis. Insights and information can be gained from each approach. Given the importance of the problem and the uncertainties involved,

the strengths of each approach should be employed to provide greater certainty or improve definition of uncertainties."

Among other things, the Fleenor report recommends:

1. Flow prescriptions should be supported preferably by causally or process-based science, rather than correlative empirical relationships or other statistical relationships without supporting ecological basis. Having a greater causal basis for flow prescriptions should make them more effective and readily adapted to improvements in knowledge and changing conditions in the Delta. A more explicit causal basis for flow prescriptions will also create incentives for improved scientific understanding of this system and its management as well as better integration of physical, chemical, and biological aspects of the problem.

2. Ongoing managed and unmanaged changes in the Delta will make any static set of flow standards increasingly irrelevant and obsolete for improving conditions for native fishes. Flows should be tied to habitat, fish, hydrologic, and other management conditions, as well as our knowledge of the system. Flows needed for fish native to the Delta will change.

Information received during this proceeding supports these conclusions and recommendations. The record for this proceeding contains a mix of data and analyses that uses the four approaches identified by Fleenor et al. (2010):

- Unimpaired flows
- Historical impaired inflows that supported more desirable ecological conditions
- Statistical relationships between flow and native species abundance
- Ecological functions-based analysis for desirable species and ecosystem attributes

All four types of information are relied upon to develop the flow criteria in this report. Emphasis, however, is placed on ecological function-based information, followed by information on statistical relationships between flow and native species abundance. In all cases, the criteria are supported by the best available scientific information submitted into the record for this proceeding. The species and ecosystem function-based needs assessments and criteria in this report are supported by references to specific scientific and empirical evidence, and cite to exhibits and testimony in the record or conclusions in published and peer reviewed articles. Criteria based upon statistical relationships between flow and native species abundance are also supported by references to specific scientific and empirical evidence, and cite to exhibits and testimony in the record or conclusions in published and peer reviewed articles.

Furthermore, the conceptual bases for all of the criteria in this report are supported by scientific information on function-based species or ecosystem needs. In other words, there is sufficiently strong scientific evidence to support the need for functional flows. This does not necessarily mean that there is scientific evidence to support *specific* numeric criteria. Recommendations are therefore divided into two categories: Category "A" criteria have more and better scientific information, with less uncertainty, to support specific numeric criteria than do Category "B" criteria. In all cases, the assumptions upon which the criteria are based are identified and discussed. The following steps were followed to develop flow criteria and other recommendations:

1. Establish general goals and objectives for protection of public trust resources in the Delta
2. Identify species to include based on ecological, recreational, or commercial importance
3. Review and summarize species life history requirements, including description of:
   - general life history and species needs
   - population distribution and abundance
   - population abundance and relationship to flow
   - specific population goals
   - species-specific basis for flow criteria
4. Summarize numeric and other criteria for each of: Delta outflows, Sacramento River inflows, San Joaquin River inflows, and hydrodynamics
5. Review other flow-related and non-flow measures that should be considered
6. Provide summary determinations for flow criteria and other measures

The following information was assembled and considered for each species, if available in the record for this proceeding:

- Life history information including timing of migrations
- Seasons or time periods when flow characteristics are most important
- Relationships of species abundance or habitat to Delta outflows, Delta inflows, hydrodynamics, or water quality parameters linked to flow, etc.
- Species environmental requirements (e.g., DO, temperature preferences, salinity, X2 location, turbidity, toxicity to specific pollutants, etc.)
- Relationship of species abundance to invasive species, to the extent possible
- Key quantifiable population responses or habitat characteristics linked to flow
- Mechanisms or hypotheses about mechanisms that link species abundance, habitat, and other metrics to flow or other variables

4.2.1 Biological and Management Goals

The goal of this report is discussed in Section 3.1.4 (Scope of this Report). The following biological and management goals are used to guide the development of criteria that support species life history requirements.

Biological Goals

- Depending on water year type or hydrologic condition, provide sufficient flow to increase abundance of desirable species that depend on the Delta (longfin smelt, delta smelt, starry flounder, bay shrimp, American shad, and zooplankton).

- Create shallow brackish water habitat for longfin smelt, delta smelt, starry flounder, bay shrimp, American shad, and zooplankton in Suisun Bay (and farther downstream).

- Provide floodplain inundation of appropriate timing and sufficient duration to enhance spawning and rearing opportunities to support Sacramento splittail, Chinook salmon, and other native species.

- Manage net OMR reverse flows and other hydrodynamic conditions to protect sensitive life stages of desirable species.

- Provide sufficient flow in the San Joaquin River to transport salmon smolts through the Delta during spring in order to contribute to attainment of the State Water Board's salmon protection water quality objective. (2009 Bay-Delta Plan, p. 14.)

- Provide sufficient flow in the Sacramento River to transport salmon smolts through the Delta during the spring in order to contribute to the attainment of the salmon protection water quality objective. (*Id.*)

- Provide sufficient flow in eastside streams that flow to the Delta, including the Mokelumne and Consumes rivers, to transport salmon smolts to the Delta during the spring in order to contribute to the attainment of the salmon protection water quality objective.

- Maintain water temperatures and DO in mainstem rivers that flow into the Delta and their tributaries at levels that will support adult Chinook salmon migration, egg incubation, smolting, and early-year and late-year juvenile rearing.

Management Goals

- Combine freshwater flows needed to protect species and ecosystem functions in a manner that is comprehensive, does not double count flows, uses an appropriate time step, and is well-documented

- Establish mechanisms to evaluate Delta environmental conditions, periodically review underpinnings of the biological objectives and flow criteria, and change biological objectives and flow criteria when warranted

- Periodically review new research and monitoring to evaluate the need to modify biological objectives and flow criteria

- Do not recommend overly complex flow criteria so as not to infer a greater understanding of specific numeric flow criteria than the available science supports

4.2.2 Selection of Species[10]

Information received during the informational proceeding links the abundance and habitat of several key species that live in, move through, or otherwise depend upon for their survival, the Delta and its ecosystem. DFG Exhibits 1 through 4 present information on the relationship between abundance and the quantity, quality, and timing of flow for the following species: (1) Chinook salmon, (2) Pacific herring, (3) longfin smelt, (4) prickly sculpin, (5) Sacramento splittail, (6) delta smelt, (7) starry flounder, (8) white sturgeon, (9) green sturgeon, (10) Pacific lamprey, (11) river lamprey, (12) bay shrimp, (13) mysid shrimp and a copepod, *Eurytemora affinis*, and (14) American shad. In general, the available data and information indicates:

- For many species, abundance is related to timing and quantity of flow (or the placement of X2).
- For many species, more flow translates into greater species production or abundance.
- Species are adapted to use the water resources of the Delta during all seasons of the year, yet for many species, important life history stages or processes consistently

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[10] This section is largely drawn from DFG exhibits 1 through 4.

coincide with the winter-spring seasons and its associated increased flows because this is the reproductive season for most native fishes, and the time that most salmonid fishes are emigrating.

- The source, quantity, quality, and timing of Central Valley tributary outflow affects the same characteristics of mainstem river flow into and through the Delta. Flows in all three of these areas, Delta outflows, tributary inflows, and hydrodynamics, influence production and survival of Chinook salmon in both the San Joaquin River and Sacramento River basins.
- Some invasive species negatively influence native species abundance.

This report is consistent with DFG's recommendation to establish flow criteria for species of priority concern that will benefit most by improving flow conditions. (DFG closing comments, p. 3.) Table 2 (from DFG closing comments p.4) identifies select species that have the greatest ecological, commercial, or recreational importance and are influenced by Delta inflows (including mainstem river tributaries) or Delta outflows. The table identifies the species life stage most affected by flows, the mechanism most affected by flows, and the time when flows are most important to the species.

Table 2. Species of Importance (from DFG closing comments p.4)

Priority Species	Life Stage	Mechanism	Time When Water Flows are Most Important	Reference
Chinook salmon (San Joaquin River basin)	Smolt	Outmigration	March – June	DFG Exhibit 1 – page 2; DFG Exhibit 3 – pages 7-10, 21-35.
Chinook salmon (Sacramento River basin)	Juvenile	Outmigration	November – June	DFG Exhibit 1 – page 1-2, 6-8
Chinook salmon (San Joaquin River tributaries)	Egg/fry	Temperature, DO, upstream barrier avoidance	October – March	DFG Exhibit 3, pages 2-4; DFG Exhibit 4
Longfin smelt	Egg	Freshwater-brackish habitat	December – April	DFG Exhibit 1 – page 2, 9-12
Longfin smelt	Larvae	Freshwater-brackish habitat; transport; turbidity	December – May	DFG Exhibit 1 – page 2, 9-12
Sacramento Splittail	Adults	Floodplain inundating flows	January – April	DFG Exhibit 1 – page 2, 13-14
Sacramento Splittail	Eggs and larvae	Floodplain habitat persistence	January – May	DFG Exhibit 1 – page 3, 13-14

Priority Species	Life Stage	Mechanism	Time When Water Flows are Most Important	Reference
Delta smelt	Larvae and Pre-adult	Transport; habitat	March – November September – November	DFG Exhibit 1 – page 2,14-15
Starry flounder	Settled juvenile; Juvenile-2 yr old	Estuary attraction; habitat	February – May	DFG Exhibit 1 – page 3, 15-16
Bay shrimp	Late-stage larvae and small juveniles	Transport	February – June	DFG Exhibit 1 – page 4; 22-25
Bay shrimp	Juveniles	Nursery habitat	April – June	DFG Exhibit 1 – page 4; 22-25
Mysid shrimp (zooplankton)	All	Habitat	March – November	DFG Exhibit 1 – page 5; 25-26
Eurytemora affinis (zooplankton)	All	Habitat	March – May	DFG Exhibit 1 – page 5; 25-26
American shad	Egg/larvae	Transport; dispersal; habitat	March – June	DFG Exhibit 1 – page 5; 26-28

While many species found in the Delta are of ecological, commercial, and/or recreational interest, specific flow needs for some of those species may not be directly addressed in this report because: they overlap with the needs of more sensitive species otherwise addressed in the report; the relationships between flow and abundance of those species are not well understood; or the needs of those species may be outside the scope of this report. For example, placement of X2 at certain locations in the Delta to protect longfin smelt or starry flounder will also protect striped bass (*Morone saxatilis*). Striped bass survival from egg to 38 mm is significantly increased as X2 shifts downstream in the estuary. (Kimmerer 2002a.) Kimmerer et al. (2009) showed that as X2 location moved downstream, several measures of striped bass survival and abundance significantly increased, as did several measures of striped bass habitat. Similarly, it is assumed that improved stream flow conditions for Chinook salmon will benefit steelhead, but additional work is needed to assure that these flow criteria are adequate for the protection of steelhead. Adult steelhead in the Central Valley migrate upstream beginning in June, peaking in September, and continuing through February or March. (Hallock *et al*. 1961, Bailey 1954, McEwan and Jackson 1996, as cited in SJRRP FMWG 2009.) Spawning occurs primarily from January through March, but may begin as early as December and may extend through April. (Hallock et al. 1961, as cited in McEwan and Jackson 1996.) Steelhead also rear in tributaries to the Delta throughout the year. Consequently, additional inflow criteria may be needed to protect steelhead at times when flows are not specifically recommended to protect Chinook salmon. As will be discussed in the species needs section for Chinook salmon, additional flow criteria may also be needed to protect various runs and life-stages of Chinook salmon. Adequate information is not currently available, however, upon which to base criteria.

Other species are influenced by very high and infrequent flows, far in excess of what could be provided by the State and federal water projects because they occur only during very wet years when project operations are not controlling. For example, white sturgeon are influenced by high winter and spring Delta and river flows (March-June Delta outflow greater than 60,000 cfs) that attract migrating adults, cue spawning, transport larvae, and enhance nursery habitat. These types of flows occur episodically in very wet years. Historical flow patterns combined with the unique life history (long-lived, late maturing, long intervals between spawning, high fecundity) result in infrequent strong recruitment.

There is adequate information in the record, and adequate time to evaluate life history requirements and develop species-specific flow criteria for the following species:

- Chinook Salmon (various runs) (primarily mirgration flows)
- American Shad
- Longfin Smelt
- Delta Smelt
- Sacramento Splittail
- Starry Flounder
- Bay Shrimp
- Zooplankton

4.2.3 Life History Requirements – Anadromous Species

Following are life history and species-specific requirements for Chinook Salmon (including Sacramento River winter-run, Central Valley spring-run, Central Valley fall-run, and Central Valley late fall-run) and American shad.

Chinook Salmon (Sacramento River Winter-Run, Central Valley Spring-Run, Central Valley Fall-Run, and Central Valley Late Fall-Run)

Status
Sacramento River winter-run Chinook salmon is listed as endangered pursuant to the ESA and the CESA. Central Valley spring-run Chinook salmon is listed as threatened pursuant to both the ESA and the CESA. Central Valley fall/late fall-run Chinook salmon are classified as species of special concern pursuant to the ESA.[11]

Life History[12]
Chinook salmon exhibit two generalized freshwater life history types (Healey 1991). Adult "stream-type" Chinook salmon enter freshwater up to several months before spawning, and juveniles reside in freshwater for a year or more, whereas "ocean-type" Chinook salmon spawn soon after entering freshwater and migrate to the ocean as fry or parr within their first year. Adequate instream flows and cool water temperatures are more critical for the survival of Chinook salmon exhibiting a stream-type life history due to over-summering by adults and/or juveniles.

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[11] Source: http://www.dfg.ca.gov/fish/Resources/Chinook/index.asp

[12] This section was largely extracted from NMFS 3, pages 76 through 79.

Chinook salmon typically mature between 2 and 6 years of age (Myers et al. 1998). Freshwater entry and spawning timing generally are thought to be related to local water temperature and flow regimes. Runs are designated on the basis of adult migration timing. However, distinct runs also differ in the degree of maturation of the fish at the time of river entry, thermal regime, and flow characteristics of their spawning sites, and the actual time of spawning (Myers et al. 1998). Both winter-run and spring-run tend to enter freshwater as immature fish, migrate far upriver, and delay spawning for weeks or months. Fall-run enter freshwater at an advanced stage of maturity, move rapidly to their spawning areas on the mainstem or lower tributaries of the rivers, and spawn within a few days or weeks of freshwater entry (Healey 1991).

During their upstream migration, adult Chinook salmon require streamflows sufficient to provide olfactory and other orientation cues used to locate their natal streams. Adequate streamflows are necessary to allow adult passage to upstream holding habitat. The preferred temperature range for upstream migration is 38ºF to 56ºF (Bell 1991, DFG 1998). Boles (1988) recommends water temperatures below 65ºF for adult Chinook salmon migration, and Lindley et al. (2004) report that adult migration is blocked when temperatures reach 70ºF, and that fish can become stressed as temperatures approach 70ºF.

Information on the migration rates of adult Chinook salmon in freshwater is scant and primarily comes from the Columbia River basin (Matter and Sanford 2003). Keefer et al. (2004) found migration rates of Chinook salmon ranging from approximately 10 kilometers (km) per day to greater than 35 km per day and to be primarily correlated with date, and secondarily with discharge, year, and reach, in the Columbia River basin. Matter and Sanford (2003) documented migration rates of adult Chinook salmon ranging from 29 to 32 km per day in the Snake River.

Adult Chinook salmon inserted with sonic tags and tracked throughout the Delta and lower Sacramento and San Joaquin rivers were observed exhibiting substantial upstream and downstream movement in a random fashion, for several days at a time, while migrating upstream (CALFED 2001). Adult salmonids migrating upstream are assumed to make greater use of pool and mid-channel habitat than channel margins (Stillwater Sciences 2004), particularly larger salmon such as Chinook salmon, as described by Hughes (2004). During their upstream migration, adults are thought to be primarily active during twilight hours.

Spawning Chinook salmon require clean, loose gravel in swift, relatively shallow riffles or along the margins of deeper runs, and suitable water temperatures, depths, and velocities for redd construction and adequate oxygenation of incubating eggs. Chinook salmon spawning typically occurs in gravel beds that are located at the tails of holding pools (USFWS 1995). The range of water depths and velocities in spawning beds that Chinook salmon find acceptable is very broad. The upper preferred water temperature for spawning Chinook salmon is 55ºF to 57ºF (Chambers 1956, Smith 1973, Bjornn and Reiser 1991, and Snider 2001).

Incubating eggs are vulnerable to adverse effects from floods, siltation, desiccation, disease, predation, poor gravel percolation, and poor water quality. Studies of Chinook salmon egg survival to hatching conducted by Shelton (1995) indicated 87% of fry emerged successfully from large gravel with adequate subgravel flow. The optimal water temperature for egg incubation ranges from 41ºF to 56ºF [44ºF to 54ºF (Rich 1997), 46ºF to 56ºF (NMFS 1997), and 41ºF to 55.4ºF (Moyle 2002)]. A significant reduction in egg viability occurs at water temperatures above 57.5ºF and total embryo mortality can occur at temperatures above 62ºF (NMFS 1997). Alderdice and Velsen (1978) found that the upper and lower temperatures resulting in 50% pre-hatch mortality were 61ºF and 37ºF, respectively, when the incubation

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temperature was held constant. As water temperatures increase, the rate of embryo malformations also increases, as well as the susceptibility to fungus and bacterial infestations. The length of development for Chinook salmon embryos is dependent on the ambient water temperature surrounding the egg pocket in the redd. Colder water necessitates longer development times as metabolic processes are slowed. Within the appropriate water temperature range for embryo incubation, embryos hatch in 40 to 60 days, and the yolk-sac fry remain in the gravel for an additional 4 to 6 weeks before emerging from the gravel.

During the 4 to 6 week period when alevins remain in the gravel, they utilize their yolk-sac to nourish their bodies. As their yolk-sac is depleted, fry begin to emerge from the gravel to begin exogenous feeding in their natal stream. Fry typically range from 25 mm to 40 mm at this stage. Upon emergence, fry swim or are displaced downstream (Healey 1991). The post-emergent fry disperse to the margins of their natal stream, seeking out shallow waters with slower currents, finer sediments, and bank cover such as overhanging and submerged vegetation, root wads, and fallen woody debris, and begin feeding on zooplankton, small insects, and other microcrustaceans. Some fry may take up residence in their natal stream for several weeks to a year or more, while others are displaced downstream by the stream's current. Once started downstream, fry may continue downstream to the estuary and rear there, or may take up residence in river reaches farther downstream for a period of time ranging from weeks to a year (Healey 1991).

Fry then seek nearshore habitats containing riparian vegetation and associated substrates important for providing aquatic and terrestrial invertebrates, predator avoidance, and slower velocities for resting (NMFS 1996). The benefits of shallow water habitats for salmonid rearing have been found to be more productive than the main river channels, supporting higher growth rates, partially due to higher prey consumption rates, as well as favorable environmental temperatures (Sommer et al. 2001).

When juvenile Chinook salmon reach a length of 50 to 57 mm, they move into deeper water with higher current velocities, but still seek shelter and velocity refugia to minimize energy expenditures (Healey 1991). Catches of juvenile salmon in the Sacramento River near West Sacramento exhibited larger-sized juveniles captured in the main channel and smaller-sized fry along the margins (USFWS 1997). When the channel of the river is greater than 9 to 10 feet in depth, juvenile salmon tend to inhabit the surface waters (Healey 1982). Migrational cues, such as increasing turbidity from runoff, increased flows, changes in day length, or intraspecific competition from other fish in their natal streams, may spur outmigration of juveniles from the upper Sacramento River basin when they have reached the appropriate stage of maturation (Kjelson et al. 1982, Brandes and McLain 2001).

As fish begin their emigration, they are displaced by the river's current downstream of their natal reaches. Similar to adult movement, juvenile salmonid downstream movement is crepuscular. Juvenile Chinook salmon migration rates vary considerably presumably depending on the physiological stage of the juvenile and hydrologic conditions. Kjelson *et al.* (1982) found Chinook salmon fry to travel as fast as 30 km per day in the Sacramento River, and Sommer et *al.* (2001) found travel rates ranging from approximately 0.5 miles up to more than 6 miles per day in the Yolo Bypass. As Chinook salmon begin the smoltification stage, they prefer to rear further downstream where ambient salinity is up to 1.5 to 2.5 parts per thousand (ppt, Healey 1980, Levy and Northcote 1981).

Fry and parr may rear within riverine or estuarine habitats of the Sacramento River, the Delta, and their tributaries (Maslin et al. 1997, Snider 2001). Within the Delta, juvenile Chinook

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salmon forage in shallow areas with protective cover, such as intertidal and subtidal mudflats, marshes, channels, and sloughs (McDonald 1960, Dunford 1975, Meyer 1979, Healey 1980). Cladocerans, copepods, amphipods, and larvae of diptera, as well as small arachnids and ants are common prey items (Kjelson et al. 1982, Sommer et al. 2001, MacFarlane and Norton 2002). Shallow water habitats are more productive than the main river channels, supporting higher growth rates, partially due to higher prey consumption rates, as well as favorable environmental temperatures (Sommer et al. 2001). Optimal water temperatures for the growth of juvenile Chinook salmon in the Delta are between 54°F to 57°F (Brett 1952). In Suisun and San Pablo bays, water temperatures reach 54°F by February in a typical year. Other portions of the Delta (*i.e.*, South Delta and Central Delta) can reach 70°F by February in a dry year. However, cooler temperatures are usually the norm until after the spring runoff has ended.

Within the estuarine habitat, juvenile Chinook salmon movements are dictated by the tidal cycles, following the rising tide into shallow water habitats from the deeper main channels, and returning to the main channels when the tide recedes (Levings 1982, Levy and Northcote 1982, Levings et al. 1986, Healey 1991). As juvenile Chinook salmon increase in length, they tend to school in the surface waters of the main and secondary channels and sloughs, following the tides into shallow water habitats to feed (Allen and Hassler 1986). In Suisun Marsh, Moyle et al. (1989) reported that Chinook salmon fry tend to remain close to the banks and vegetation, near protective cover, and in dead-end tidal channels. Kjelson et al. (1982) reported that juvenile Chinook salmon demonstrated a diel migration pattern, orienting themselves to nearshore cover and structure during the day, but moving into more open, offshore waters at night. The fish also distributed themselves vertically in relation to ambient light. During the night, juveniles were distributed randomly in the water column, but would school up during the day into the upper 3 meters of the water column. Available data indicate that juvenile Chinook salmon use Suisun Marsh extensively both as a migratory pathway and rearing area as they move downstream to the Pacific Ocean. Juvenile Chinook salmon were found to spend about 40 days migrating through the Delta to the mouth of San Francisco Bay and grew little in length or weight until they reached the Gulf of the Farallones (MacFarlane and Norton 2002). Based on the mainly oceantype life history observed (*i.e.*, fall-run), MacFarlane and Norton (2002) concluded that unlike other salmonid populations in the Pacific Northwest, Central Valley Chinook salmon show little estuarine dependence and may benefit from expedited ocean entry.

Population Distribution and Abundance
Four seasonal runs of Chinook salmon occur in the Central Valley, with each run defined by a combination of adult migration timing, spawning period, and juvenile residency and smolt migration periods. (Fisher 1994 as cited in Yoshiyama et al. 2001 p. 73.) The runs are named after the season when adults move upstream to migrate-- winter, spring, fall, and late-fall. The Sacramento River basin supports all four runs resulting in adult salmon being present in the basin throughout the year. (Stone 1883a; Rutter 1904; Healey 1991; Vogel and Marine 1991 as cited in Yoshiyama *et. al,* 2001 p. 73.) Historically, different runs occurred in the same streams staggered in time to correspond to the appropriate stream flow regime for which that species evolved, but overlapping. (Vogel and Marine 1991; Fisher 1994 as cited in Yoshiyama et al.*,* 2001, p. 73.) Typically, fall and late-fall runs spawn soon after entering natal streams and spring and winter runs typically "hold" for up to several months before spawning. (Rutter 1904; Reynolds and others 1993 as cited in Yoshiyama *et. al,* 2001, p. 73.) These runs and their life-cycle timing are summarized in Table 3 and described in more detail below.

Winter-Run - Due to a need for cool summer flows, Sacramento River winter-run originally likely only spawned in the upper Sacramento River tributaries, including the McCloud, Pit, Fall, and Little Sacramento rivers and Battle Creek. (NMFS 5, p. 16.) As a result of construction of

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Shasta and Keswick Dams, today all spawning habitat above Keswick Dam has been eliminated and approximately 47 of the 53 miles of habitat in Battle Creek has been eliminated. (Yoshiyama et al. 1996, as cited in NMFS 5, p. 16.) Currently, winter-run habitat is likely limited to the Sacramento River reach between Keswick Dam downstream of the Red Bluff Diversion Dam. (NMFS 5, p. 16.)

The winter-run population is currently very vulnerable due to its low population numbers and the fact that only one population exists. (Good et al. 2005, as cited in NMFS 5, p. 16.) In the late 1960s escapement was near 100,000 fish declining to fewer than 200 fish in the 1990s. (*Id.*) Recent escapement estimates from 2004 to 2006 averaged 13,700 fish. (DFG Website 2007, as cited in NMFS 5, p. 16.) However, in 2007 and 2008 escapements were less than 3,000 fish. Since 1998, hatchery produced winter-run have been released likely contributing to the observed increased escapement numbers. (Brown and Nichols 2003 as cited in NNFS 5, p. 16.) In addition, a temperature control device was installed on Shasta Dam in 1997 likely improving conditions for winter-run. (NMFS 5, p. 18.)

Spring-Run - Historically, spring-run were likely the most abundant salmonid in the Central Valley inhabiting headwater reaches of all major river systems in the Central Valley in the absence of natural migration barriers. (NMFS 5, p. 28.) Since the 1880s, construction of dams and other factors have significantly reduced the numbers and range of spring-run in the Central Valley. (*Id.*) Currently, the only viable populations occur on Mill, Deer, and Butte creeks, but those populations are small and isolated. (DFG 1998, as cited in NMFS 5, p. 28.) In addition, the Feather River Fish Hatchery which opened in 1967 produces spring-run salmon. However, significant hybridization of these hatchery fish with fall-run has occurred. (NMFS 5, p. 28-31.)

Historically, Central Valley spring-run numbers were estimated to be as large as 600,000 fish. (DFG 1998 as cited in NMFS 5, p. 28.) Nearly 50,000 spring-run adults were counted on the San Joaquin River prior to construction of Friant Dam. (Fry 1961 as cited in NMFS 5, p. 28.) Shortly after construction of Friant Dam, spring-run were extirpated on the San Joaquin River. (Yoshiyama et al. 1998 as cited in NMFS 5, p. 28.) Since 1970, estimates of spring-run populations in the Sacramento River have been as high as 30,000 fish and as low as 3,000 fish. (NMFS 5, p. 28.)

Fall-Run - Historically, fall run likely occurred in all Central Valley streams that had adequate flows during the fall months, even if the streams were intermittent during other parts of the year. (Yoshiyama *et. al* 2001, p. 74.) Due to their egg-laden and deteriorating physical condition, fall-run likely historically spawned in the valley floor and lower foothill reaches and probably were limited in their upstream migration. (Rutter 1904 as cited in Yoshiyama *et. al* 2001, p. 74.)

Currently, fall-run Chinook inhabit both the Sacramento and San Joaquin river basins and are currently the most abundant of the Central Valley races, contributing to large commercial and recreational fisheries in the ocean and popular sportfisheries in the freshwater streams. Fall-run Chinook are raised at five major Central Valley hatcheries which release more than 32 million smolts each year. In the past few years, there have been large declines in fall-run populations with escapements of 88,0000 and 66,000 fish in 2007 and 2008. (NMFS 2009, p. 4.) NMFS concluded that the recent declines were likely primarily due to poor ocean conditions in 2005 and 2006. (*Id.*) Other factors contributing to the decline of fall-run include: loss of spawning grounds due to dams and other factors, degradation of spawning habitat from water diversions, introduced species, altered sediment dynamics, hatchery practices, degraded water quality, and loss of riparian and estuarine habitat. (*Id.*)

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Late-Fall Run - Historically, late fall-run probably spawned in the mainstem Sacramento River and major tributary reaches and possibly in the San Joaquin River upstream of its tributaries. (Hatton and Clark 1942; Van Cleve 1945; Fisher 1994 as cited in Yoshiyama *et. al* 2001.) Today, late-fall run are mostly found in the upper Sacramento River where the river remains deep and cool enough in the summer for juvenile rearing. (Moyle 2002, p. 254.) The late fall-run has continued low, but potentially stable abundance. (NMFS 2009, p. 4.) Estimates from 1992 ranged from 6,700 to 9,700 fish and in 1998 were 9,717 fish. However, changes in estimation methods, lack of data, and hatchery influences make it difficult to accurately estimate abundance trends for this run. (*Id.*)

Table 3. Generalized Life History Timing of Central Valley Chinook Salmon Runs

	Migration Period	Peak Migration	Spawning Period	Peak Spawning	Juvenile Emergence Period	Juvenile Stream Residency
Sacramento River Basin Late Fall-Run	October–April	December	Early January–April	February–March	April-June	7-13 months
Winter-Run	December-July	March	Late April-early August	May-June	July-October	5-10 months
Spring-Run	March-September	May- June	Late August-October	Mid-September	November-March	3-15 months
Fall Run	June-December	September-October	Late September-December	October-November	December-March	1-7 months
San Joaquin (Tuolumne River) Fall-Run	October-early January	November	Late October-January	November	December-April	1-5 months

Source: Yoshiyama *et al.* (1998) as cited in Moyle 2002, p. 255.

Population Abundance and Relationship to Flow

Delta outflows and inflows affect rearing conditions and migration patterns for Chinook salmon in the Delta watershed. Freshwater flow serves as an important cue for upstream adult migration and directly affects juvenile survival and abundance as they move downstream through the Delta. (DOI 1, p. 23.) Decreased flows may decrease migration rates and increase exposure to unsuitable water quality and temperature conditions, predators, and entrainment at water diversion facilities. (DFG 1, p. 1.) For the most part, relationships between salmon survival and abundance have been developed using tributary inflows rather than Delta outflows, however, the Delta is an extension of the riverine environment until salmon reach the salt water interface. (DOI 1, p. 29.) Prior to development and channelization, the Delta provided hospitable habitat for salmon. With channelization and other development, the environment is no longer hospitable for salmon. As a result, the most beneficial Delta outflow pattern for salmon may currently be one that moves salmon through the Delta faster. (*d.*)

Salmon respond behaviorally to variations in flows. Monitoring shows that juvenile and adult salmon begin migrating during the rising limb of the hydrograph. (DOI 1, p. 30.) For juveniles, pulse flows appear to be more important than for adults. (*Id.*) For adults, continuous flows through the Delta and up to each of the natal tributaries appears to be more important. (*Id.*) Flows and water temperatures are also important to maintain populations with varied life history strategies in different year types to insure continuation of the species over different hydrologic

and other conditions. For salmon migrating as fry within a few days of emigration from redds, increased flows provide improved transport downstream and improved rearing habitat, and for salmon that stay in the rivers to rear, increased flows provide for increased habitat and food production. (DOI 1, 30.)

Population Abundance Goal
The immediate goal is to significantly improve survival of all existing runs of Chinook salmon that migrate through the Delta in order to facilitate positive population growth in the short term and subsequently achieve the narrative salmon protection objective identified in the 2006 Bay-Delta Plan to double the natural production of Chinook salmon from the average production from 1967 to 1991 consistent with the provisions of State and federal law. (State Water Board 2006a, p. 14.)

Species- Specific Recommendations
<u>Delta Outflow</u>
No specific Delta outflow criteria are recommended for Chinook salmon. Any flow needs would generally be met by the following inflow criteria and by the Delta outflow criteria determined for estuarine dependant species discussed elsewhere in this report.

<u>Sacramento River Inflows</u>
The 2006 Bay-Delta Plan includes flow objectives for the Sacramento River at Rio Vista for the protection of fish and wildlife beneficial uses from September through December ranging from 3,000 to 4,500 cfs. (State Water Board 2006a, p. 15.) These flow objectives are in part intended to provide attraction and transport flows and suitable habitat conditions for Chinook salmon. (State Water Board 2006b, p. 49.) The 2006 Bay-Delta Plan includes Delta outflow objectives for the remainder of the year, which effectively provide Sacramento River inflows. However, the Bay-Delta Plan does not include any specific Sacramento River flow requirements for the remainder of the year, including the critical spring period.

Habitat alterations in the Delta limit Sacramento River salmon production primarily through reduced survival during the outmigrant (smolt) stage. Decreases in flow through the estuary, increased temperatures, and the proportion of flow diverted through the Delta Cross Channel and Georgiana Slough on the Sacramento River are associated with lower survival in the Delta of marked juvenile fall-run Sacramento River salmon. (DOI 1, p. 24.) In 1981 (p. 17-18) and 1982 (p. 404), Kjelson et al. reported that flow was positively correlated with juvenile fall-run Chinook salmon survival through the Delta and that temperature was negatively correlated with survival. In testimony before the State Water Board in 1987 Kjelson presented additional analyses that again showed that survival of fall-run Chinook salmon smolts through the Delta between Sacramento and Suisun Bay was found to be positively correlated to flow and negatively correlated to water temperature. (p. 36.) Smolt survival increased with increasing Sacramento River flow at Rio Vista, with maximum survival observed at or above about 20,000 and 30,000 cfs from April through June (p. 36), while no apparent relationship was found at flows between 7,000 and 19,000 cfs (p. 27), suggesting a potential threshold response to flow. Smolt survival was also found to be highest when water temperatures were below 66ºF. (p. 61.) In addition to increased survival, juvenile abundance has also been found to be higher with greater Sacramento River flow. (DFG 3, pp. 1 and 6.) The abundance of juvenile Chinook salmon leaving the Delta at Chipps Island was found to be highest when Rio Vista flows averaged above 20,000 cfs from April through June. (*Id.*)

Dettman et al. (1987) reanalyzed data from the 1987 Kjelson experiments and found a positive correlation between an index of spawning returns, based on coded-wire tagged fish, and both

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June and July outflow from the Delta. (p. 1.) In 1989, Kjelson and Brandes updated and confirmed Kjelson's 1987 findings again reporting that survival of smolts through the Delta from Sacramento to Suisun Bay was highly correlated to mean daily Sacramento River flow at Rio Vista. (p. 113.) In the State Water Board's 1992 hearings, USFWS (1992) presented additional evidence, based on data collected from 1988 to 1991, that increased flow in the Delta may increase migration rates of both wild and hatchery fish migrating from the North Delta (Sacramento and Courtland) to Chipps Island. (DOI 1, p. 26.)

In 2001, Brandes and McLain confirmed the relationships between water temperature, flow, and juvenile salmonid survival. (p. 95.) In 2006, Brandes et al. updated findings regarding the relationship between Sacramento River flows and survival and found that the catch of Chinook salmon smolts surveyed at Chipps Island between April and June of 1978 to 2005 was positively correlated with mean daily Sacramento River flow at Rio Vista between April and June. (p. 41-46.)

In addition to the flow versus juvenile fall-run Chinook salmon survival relationships discussed above, several studies show that loss of migrating salmonids within Georgiana Slough and the interior Delta is approximately twice that of fish remaining in the mainstem Sacramento River. (Kjelson and Brandes 1989; Brandes and McLain 2001; Vogel 2004, 2008; and Newman 2008 as cited in NMFS 3, p. 640). Recent studies and modeling efforts have found that increasing Sacramento River flow such that tidal reversal does not occur in the vicinity of Georgiana Slough and at the Cross Channel Gates would lessen the proportion of fish diverted into channels off the mainstem Sacramento River. (Perry et al. 2008, 2009.) Thus, closing the Delta Cross Channel and increasing the flow on the Sacramento River to levels where there is no upstream flow from the Sacramento River entering Georgiana Slough on the flood tide during the juvenile salmon migration period (November to June) will likely reduce the number of fish that enter the interior Delta and improve survival. (DOI 1, p. 24.) To achieve no bidirectional flow in the mainstem Sacramento River near Georgiana Slough, flow levels of 13,000 (personal communication Del Rosario) to 17,000 cfs at Freeport are needed. (DOI 1, p. 24.)

Monitoring of emigration of juvenile Chinook salmon on the lower Sacramento River near Knights Landing also indicates a relationship between timing and magnitude of flow in the Sacramento River and the migration timing and survival of Chinook salmon approaching the Delta from the upper Sacramento River basin. (Snider and Titus 1998, 2000a, 2000b, 2000c, and subsequent draft reports and data as cited in DFG 1, p. 7.) The emigration timing of juvenile late fall, winter, and spring-run Chinook salmon from the upper Sacramento River basin depends on increases in river flow through the lower Sacramento River in fall, with significant precipitation in the basin by November to sustain downstream migration of juvenile Chinook salmon approaching the Delta. (Titus 2004 as cited in DFG 1, p. 7.) Sacramento River flows at Wilkins Slough of 15,000 to 20,000 cfs following major precipitation events are associated with increased emigration. (DFG 1, p. 7 and NMFS 7, p. 2-4.)

Delays in precipitation producing flows result in delayed emigration which may result in increased susceptibility to in-river mortality from predation and poor water quality conditions. (DFG 1, p. 7.) Allen and Titus (2004) suggest that the longer the delay in migration, the lower the survival of juvenile salmon to the Delta. (as cited in DFG 1, p. 7.) DFG indicates that juvenile Chinook salmon appear to need increases in Sacramento River flow that correspond to flows in excess of 20,000 cfs at Wilkins Slough by November with similar peaks continuing past the first of the year. (DFG 1, p. 7.) Pulse flows in excess of 15,000 to 20,000 cfs may also be necessary to erode sediment in the upper Sacramento River downstream of Shasta to create turbid inflow pulses to the Delta. (AR/NHI 1, p. 32.)

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Salmon are the only species considered for the Sacramento River inflow criteria; discussion of the flow criteria for Sacramento River inflows is therefore continued in Section 5.2, Sacramento River Inflow criteria.

<u>San Joaquin River Inflows</u>
Currently the Merced, Tuolumne, and Stanislaus river tributaries to the San Joaquin River support fall-run Chinook salmon. Historically spring-run also inhabited the basin. Pursuant to the San Joaquin River Restoration effort, there are plans to reintroduce spring-run Chinook salmon to the main-stem river beginning in 2012. Since the 1980s (1980-1989), San Joaquin basin fall-run Chinook salmon escapement numbers have declined from approximately 26,000 fish to 13,000 fish in the 2000s (2000-2008). (TBI/NRDC 3, p. 22.) Flow related conditions are believed to be a significant cause of this decline.

The 2006 Bay-Delta Plan includes flow objectives for the San Joaquin River at Vernalis, largely for the protection of fall-run Chinook salmon. The plan includes base flows during the spring (February through June with the exception of mid-April through mid-May) that vary between 700 and 3,420 cfs based on water year type and required location of X2. To improve juvenile fall-run Chinook salmon outmigration, the Plan also includes spring pulse flows (mid-April through mid-May) that vary between 3,110 and 8,620 cfs, however, those flows have never been implemented and have instead been replaced with the Vernalis Adaptive Management Plan (VAMP) flow targets for the past 10 years. The VAMP flows are lower than the pulse flow objectives and vary between 2,000 and 7,000 cfs based on existing flows and other conditions. (State Water Board 2006a, p. 24-26.) The 2006 Bay-Delta Plan also includes a flow objective of 1,000 to 2,000 cfs during October to support adult fall-run Chinook salmon migration. (State Water Board 2006b, p. 15-16.) The 2006 Bay-Delta Plan does not include any specific flow requirements during the remainder of the year. (State Water Board 2006b, pg. 50.)

Inflows from the San Joaquin River affect various life stages of Chinook salmon including adult migration, spawning, egg incubation, juvenile rearing, and juvenile emigration to the ocean. Evidence indicates that to maintain a viable Chinook salmon population, escapements should not decline below approximately 833 adult salmon per year (a total of 2,500 salmon in 3 years), and fluctuations in escapement between wet and dry years should be reduced by increasing dry year escapements and the percentages of hatchery fish should be reduced to no more than 10%. (Lindley and others 2007, as cited in CSPA 14, p. 3-4.) Mesick estimates that the Tuolumne River population is currently at a high risk of extinction (Mesick 2009); and that the Stanislaus and Merced river populations are also likely soon to be at a high risk of extinction due to high percentages of hatchery fish. (CSPA 7, p.4.)

Mesick estimates that the decline in escapement on the Tuolumne River from 130,000 salmon in the 1940s to less than 500 in recent years is primarily due to inadequate minimum instream flow releases from La Grange Dam in late winter and spring during non-flood years. (CSPA 14, p. 1.) Mesick suggests that escapement has been primarily determined by the rate of juvenile survival, which is primarily determined by the magnitude and duration of late winter and spring flows since the 1940s. (CSPA 14, p. 2.) Mesick indicates that other analyses show that spawner abundance, spawning habitat degradation, and the harvest of adult salmon in the ocean have not caused the decline in escapement. (CSPA 14, p. 1.)

Successful adult Chinook salmon migration depends on environmental conditions that cue the response to return to natal streams. Optimal conditions help to reduce straying and maintain egg viability and fecundity rates. (DFG 3, p. 2 and CSPA 7, p. 1.) Analyses of flow needs for

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the protection of adult fall-run migration conducted by Hallock and others from 1964 to 1967 indicate that the presence of Sacramento River water in the central and south Delta channels results in migration delays for both San Joaquin River and Sacramento River basin salmon. (Hallock et al., 1970 as cited in DOI 1, p. 25.) These analyses also show that reverse flows on the San Joaquin River delay and potentially hamper migration. (*Id.*) In addition, analyses by Hallock show that water temperatures in excess of 65° F and low DO conditions of less than 5 mg/l in the San Joaquin River near Stockton act as a barrier to adult migration. (as cited in AFRP 2005, p. 11.) Delayed migration may result in reduced gamete viability under elevated temperatures and mortality to adults prior to spawning. (AFRP 2005, p. 12.)

Mesick found that up to 58% of Merced River Hatchery Chinook salmon strayed to the Sacramento River Basin when flows in the San Joaquin River were less than 3,500 cfs for ten days in late October, but stray rates were less than 6% when flows were at least 3,500 cfs. (CSPA 14, p. 15 and CSPA 7, p. 1.) Mesick indicates that providing 1,200 cfs flows from the tributaries to the San Joaquin River (Merced, Tuolumne, and Stanislaus) for ten days in late October increases escapement by an average of 10%. (Mesick 2009 as cited in CSPA 7, p. 1.) The 2005 AFRP includes similar recommendations for flows of 1,000 cfs from each of the San Joaquin River tributaries. (AFRP, p. 12.) Such flows would likely improve DO conditions, temperatures, and olfactory homing fidelity for San Joaquin basin salmon. (Harden Jones 1968, Quinn et al. 1989, Quinn 1990 as cited in EDF 1, p. 48.) To achieve olfactory homing fidelity and continuous flows for adult migration, the physical source of this water is at least as important as the volume or rate of flow, especially given that the entire volume of the San Joaquin River during the fall period is typically diverted at the southern Delta export facilities. (EDF 1. p. 48.) Even in the absence of exports, it is necessary for the scent of the San Joaquin basin watershed to enter the Bay in order for adult salmonids to find their way back to their natal rivers. (NMFS 2009, p.407 as cited in EDF 1, p. 48.)

Outmigration success of juvenile Chinook salmon is affected by multiple factors, including water diversions and conditions related to flow. Data show that smolt survival and resulting adult production is better in wet years. (Kjelson and Brandes, 1989, SJRGA, 2007 as cited in DOI 1, p. 24.) VAMP analyses indicate that San Joaquin River flow at Vernalis is positively associated with the probability of survival for outmigrating smolts from Dos Reis (downstream of the Old River bifurcation) to the Delta (Jersey Point). (Newman, 2008 as cited in DOI 1, p. 24.) A positive relationship has also been shown between salmon survival indices and flow at Jersey Point for fish released at Jersey Point. (USFWS 1992, p. 21 as cited in DOI 1, p. 24.) Data indicate that maximum San Joaquin basin adult fall-run chinook salmon escapement may be achieved with flows exceeding 20,000 cfs at Vernalis during the smolt emigration period of April 15 through June 15. (2006 VAMP report page 65; DOI 1, p. 25.) As indicated below in Figure 9, DFG found that more spring flow from the San Joaquin River tributaries results in more juvenile salmon leaving the tributaries, more salmon successfully migrating to the South Delta, and more juvenile salmon surviving through the Delta. (DFG 3, p. 17.) DFG concludes that the primary mechanism needed to substantially produce more smolts at Jersey Point is to substantially increase the spring Vernalis flow level (magnitude, duration, and frequency) which will produce more smolts leaving the San Joaquin River tributaries, and produce more smolts surviving to, and through, the South Delta. (DFG 3, p. 17-18.) DFG indicates that random rare and unpredictable poor ocean conditions may cause stochastic high mortality of juvenile salmon entering the ocean, but that the overwhelming evidence is that more spring flow results in higher smolt abundance, and higher smolt abundance equates to higher adult production. (DFG 3, p.17.)

Mossdale & Chipps Island Smolt Comparison
Years 1988 to 2004
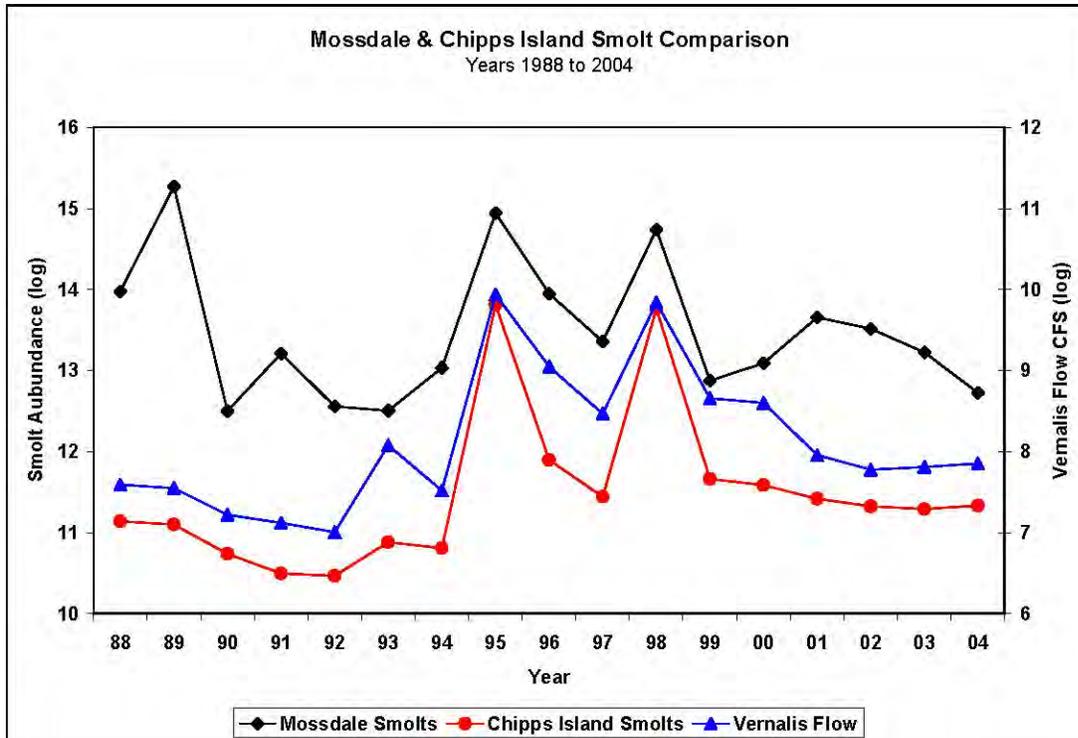
Note: This figure shows the relationship of smolt abundance (log transformed) at Mossdale to estimate smolt abundance at Chipps Island by average spring (3/15 to 6/15) Vernalis flow level (log transformed). To estimate the number of smolts at Chipps Island the smolt survival vs. flow level relationship developed by Dr. Hubbard was applied on a daily basis to the Mossdale smolt abundance and out-migration pattern. Smolt abundance at Chipps Island (or stated differently smolt survival through the Delta on an annual basis) can change by an order of magnitude pending Vernalis flow rate. (DFG 3, p. 16.)

Figure 9. Salmon Smolt Survival and San Joaquin River Vernalis Flows

Elevated flows during the smolt outmigration period function as an environmental cue to trigger migration, facilitate transport of juveniles downstream, improve migration corridor conditions to inundate floodplains, reduce predation and improve temperature and other water quality conditions; these are all functions that are currently extremely impaired on the San Joaquin River. (e.g., "Steelhead stressor matrix," NMFS 2009 as cited in TBI/NRDC 3, p. 7.) Under the 2006 Bay-Delta Plan, elevated flows are limited to approximately the mid-April to mid-May period. However, outmigration timing in the San Joaquin River basin occurs over a prolonged time frame from mid-March through June. (TBI/NRDC 3, p. 12-13.) This restricted window may impair population viability by limiting survival of fish that migrate outside of this time period, thus reducing the life history diversity and the genetic diversity of the population. (TBI/NRDC 3, p. 11-12.) Diverse migration timing increases population viability by making it more likely that at least some portion of the population is exposed to favorable ecological conditions in the Delta and into the ocean. (Smith et al. 1995 as cited in TBI/NRDC 3, p. 12.)

Temperature conditions in the San Joaquin River basin may limit smolt outmigration and survival. Lethal temperature thresholds for Pacific salmon depend, to some extent, on acclimation temperatures. (Myrick and Cech 2004 as cited in TBI/NRDC 3, p. 18.) Central Valley salmonids are generally temperature-stressed through at least some portion of their freshwater life-cycle. (e.g. Myrick and Cech 2004, 2005 as cited in TBI/NRDC 3, p. 18.) Lethal temperature effects commence in a range between 71.6° and 75.2° F (Baker et al.1995 as cited

in TBI/NRDC 3, p. 18), with sub-lethal effects occurring at lower temperatures. Access to food also affects temperature responses. When fish have adequate access to food, growth increases with increasing temperature, but when food is limited (which is typical), optimal growth occurs at lower temperatures. (TBI/NRDC 3, p 18.) Marine and Cech (2004) observed decreased growth, smoltification success, and predator avoidance at temperatures above 68° F and that fish reared at temperatures between 62.6° and 68° F experienced increased predation compared to fish reared at between 55.4° and 60.8° F. (as cited in TBI/NRDC 3, p. 18.) Several studies indicate that optimal rearing temperatures for Chinook salmon range from 53.6° to 62.6F (Richter and Kolmes 2005 as cited in TBI/NRDC 3, p. 18.) Mesick found that Tuolumne River smolt outmigration rates and adult recruitment were highest when water temperatures were at or below 59°F when smolts were migrating in the lower river. (Mesick 2009, p. 25.) Elevated temperatures may also affect competition between different species. (Reese and Harvey 2002 as cited in TBI/NRDC 3, p. 18.)

Temperature is determined by a number of factors including reservoir releases, channel geometry, and ambient air temperatures. As a result, a given flow may achieve different water temperatures depending on the other conditions listed above. Cain estimates that flows over 5,000 cfs in late spring (April to May) generally provide water temperatures (below 65° F) suitable for Chinook salmon, but that flows less than 5,000 cfs may be adequate to provide sufficient temperature conditions. (Cain 2003 as cited in TBI/NRDC 3, p 13-14.) Mesick indicates that salmon smolt survival can be improved by maintaining water temperatures near 59°F from March 15 to May 15 and as low as practical from May 16 to June 15. (CSPA 7, p. 2-3.) To maintain mean water temperatures near 59°F and maximum temperatures below 65°F from March 15 to May 15 in the tributaries downstream to the confluence with the San Joaquin River, Mesick indicates that flows need to be increased in response to average air temperature. (CSPA 7, p. 3.)

There are several different estimates for flow needs on the San Joaquin River during the spring period to improve or double salmon populations on the San Joaquin River. The USFWS's 2005 *Recommended Streamflow Schedules to Meet the AFRP Doubling Goal in the San Joaquin River Basin* (2005 AFRP) concludes that the declines in salmon in the San Joaquin River basin primarily resulted from reductions in the frequency and magnitude of spring flooding in the basin from 1992-2004 compared to the baseline period of 1967-1991. (2005 AFRP, p. 1.) The AFRP states that the most likely method to increase production of fall-run Chinook salmon is to increase flows from February to March to increase survival of juveniles in the tributaries and smolts in the mainstem and then to increase flows from April to mid-June to increase smolt survival through the Delta. (*Id.*) Using salmon production models for the San Joaquin River Basin, the AFRP provides recommendations for the amount of flow at Vernalis that would be needed to double salmon production in the San Joaquin River basin. On average, over the four month period of February to May, the AFRP recommends that flows range from less than 4,000 cfs in critical years to a little more than 10,000 cfs in wet years. From March through June, AFRP recommends that flows average between about 4,500 cfs in critical years to more than 12,000 cfs in wet years. (2005 AFRP, p. 8-10.)

Using a non-linear regression empirical data driven fall-run Chinook salmon production model, DFG developed flow recommendations for the San Joaquin River from March 15 through June 15 to double Chinook salmon smolt production. DFG developed a variety of modeling scenarios to evaluate the effects of various combinations of flow magnitudes and durations in order to identify the combination of flow levels varied by water year type to achieve doubling of juveniles. Base flows for the March 15 through June 15 period vary between 1,500 cfs in critical years to

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6,315 cfs in wet years. Pulse flow recommendations vary between 7,000 cfs and 15,000 cfs for durations of 31 to 70 days depending on water year type. (DFG 3, p. 34.)

In analyzing the relationship between Vernalis flow and cohort return ratios of San Joaquin River Chinook salmon, TBI/NRDC found that Vernalis average March through June flows of approximately 4,600 cfs corresponded to an equal probability for positive population growth or negative population growth. (TBI/NRDC 3, p. 24.) TBI/NRDC found that average March through June flows exceeding 5,000 cfs resulted in positive population growth in 84% of years with only 66% growth in years with flows less than 5,000 cfs. (*Id.)* TBI/NRDC found that flows of 6,000 cfs produced a similar response as the 5,000 cfs flows and flows of 4,000 cfs or lower resulted in significantly reduced population growth of only 37% of years. (*Id.)* The TBI/NRDC analysis suggests that 5,000 cfs may represent an important minimum flow threshold for salmon survival on the San Joaquin River. (*Id.*) Based on abundance to prior flow relationships, TBI/NRDC estimates that average March through June inflows of 10,000 cfs are likely to achieve the salmon doubling goal. (TBI/NRDC 3, p. 16-17.)

In addition to fall pulse flows for adult migration and spring flows to support juvenile emigration, additional flows on the San Joaquin River may be needed at other times of year to support Chinook salmon and their habitat. The 2006 Bay-Delta Plan does not include base flow objectives for the San Joaquin River. However, the Central Valley Regional Board's Water Quality Control Plan for the Sacramento and San Joaquin River Basins does include a year round DO objective of 5.0 mg/l at all times on the San Joaquin River within the Delta. (Central Valley Regional Board 2009,. III-5.0). The 2006 Bay-Delta Plan and the Central Valley Basin Plan also include a DO objective of 6.0 mg/L between Turner Cut and Stockton from September 1 through November 30. (*Id.*)

Current flow conditions on the San Joaquin River result in DO conditions below the existing DO objectives in the fall and winter in lower flow years. These conditions may result in delayed migration and mortality to San Joaquin River Chinook salmon, steelhead and other species. Increased flows would improve DO levels in the lower San Joaquin River. Additional flows at other times of year in the tributaries to the San Joaquin River would also provide improved conditions for steelhead inhabiting tributaries to the San Joaquin River (NMFS 3, p. 105) and would have additional benefits by reducing nutrients pollution and biological oxygen demand. (TBI/NRDC 3, p. 27.)

To reduce crowding of spawning adults during the fall, increased flows in the tributaries may also be needed from November through January to ensure protection of Chinook salmon. (AFRP, p. 12.) However, there is no evidence that increased flows would reduce spawner crowding or improve juvenile production. (*Id.*) Habitat modeling indicates that flows of up to 300 cfs on the San Joaquin River tributaries may provide optimum physical habitat during the fall. (AFRP 2005, p. 14.)

To maintain the ecosystem benefits of a healthy riparian forest, minimum flows and ramping rates for riparian recruitment may also be needed during late spring and early summer. (AFRP 2005, p. 14.) To protect over-summering steelhead and salmon, flows in the tributaries during the summer and fall are needed. To maintain minimal habitat of a suitable temperature (less than 65° F), flows between 150 and 325 cfs may be needed on each of the tributaries to the San Joaquin River. (AFRP 2005, pp. 14-15.)

The magnitude, duration, timing, and source of San Joaquin River inflows are important to San Joaquin River Chinook salmon migrating through the Delta and several different aspects of their

life history. Inflows are needed to provide appropriate conditions to cue upstream adult migration to the San Joaquin River and its tributaries, adult holding, egg incubation, juvenile rearing, emigration from the San Joaquin River and its tributaries, and other functions. San Joaquin River inflows are important during the fall to provide attraction flows and are especially important during juvenile emigration periods. Flows on tributaries to the San Joaquin River are also important for egg incubation and rearing, in addition to migration.

As with the Sacramento River inflows, Chinook salmon are the only species considered for the San Joaquin River inflow criteria; discussion of flow criteria for San Joaquin River inflows is therefore continued in Section 5.3, San Joaquin River inflow criteria.

Hydrodynamics
All Central Valley Chinook salmon must migrate out of the Delta as juveniles and back through the Delta as adults returning to spawn. In addition, many Central Valley Chinook salmon also rear in the Delta for a period of time. (DOI 1, p. 53.) Delta exports affect salmon migrating through and rearing in the Delta by modifying tidally dominated flows in the channels. It is, however, difficult to quantitatively evaluate the direct and indirect effects of these hydrodynamic changes. Delta exports can cause a false attraction flow drawing fish to the export facilities where direct mortality from entrainment may occur. (DOI 1, p. 29.) More important than direct entrainment effects, however, may be the indirect effects caused by export operations increasing the amount of time salmon spend in channelized habitats where predation is high. (*Id.*) Steady flows during drier periods (as opposed to pulse flows that occur during wetter periods) may increase these residence time effects. (DOI 1.)

Direct mortality from entrainment at the south Delta export facilities is most important for San Joaquin River and eastside tributary salmon (and steelhead). (DOI 1, p. 29.) Juvenile salmonids emigrate downstream on the San Joaquin River during the winter and spring. Salmonids from the Calaveras River basin and the Mokelumne River basin also use the lower San Joaquin River as a migration corridor. This lower reach of the San Joaquin River between the Port of Stockton and Jersey Point has many side channels leading toward the export facilities that draw water through the channels to the export pumps. (NMFS 3, p. 651.) Particle tracking model (PTM) simulations and acoustic tagging studies indicate that migrating fish may be diverted into these channels and may be affected by flow in these channels. (Vogel 2004, SJRGA 2006, p. 68, SJRGA 2007, pp. 76-77, and NMFS 3, p. 651.) Analyses indicate that tagged fish may be more likely to choose to migrate south toward the export facilities during periods of elevated diversions than when exports are reduced. (Vogel 2004.)

Similarly, salmon that enter the San Joaquin River through Georgiana Slough from the Sacramento River may also be vulnerable to export effects. (NMFS 3, p. 652.) While fish may eventually find their way out of the Central Delta channels after entering them, migratory paths through the Central Delta channels increase the length and time that fish take to migrate to the ocean increasing their exposure to predation, increased temperatures, contaminants, and unscreened diversions. (NMFS 3, p. 651-652.)

PTM analyses indicate that as net reverse flows in Old and Middle rivers increase from -2,500 cfs to -3,500 cfs, particle entrainment changes from 10% to 20% and then again to 40% when flows are -5,000 cfs and 90% when flows are -7,000 cfs. (*Id.*) Based on these findings, NMFS's Opinion includes requirements that exports be reduced to limit negative net Old and Middle river flows to -2,500 cfs to -5,000 cfs depending on the presence of salmonids from January 1 through June 15. (NMFS 3, p. 648.)

In addition to effects of net reverse flows in Old and Middle rivers, analyses concerning the effects of net reverse flows in the San Joaquin River at Jersey Point were also conducted and documented in the USFWS, 1995 *Working Paper on Restoration Needs, Habitat Restoration Actions to Double the Natural Production of Anadromous Fish in the Central Valley California* (1995Working Paper). These analyses show that net reverse flows at Jersey Point decrease the survival of smolts migrating through the lower San Joaquin River. (USFWS 1992b as cited in USFWS 1995b, p. 3Xe-19.) Net reverse flows on the lower San Joaquin River and diversions into the central Delta may also result in reduced survival for Sacramento River fall-run Chinook salmon. (USFWS 1995b, p. 3Xe-19) Based on these factors, the 1995 Working Paper includes a recommendation to maintain positive flows at Jersey Point of 1,000 cfs in critical and dry years, 2,000 cfs in below- and above-normal years, and 3,000 cfs in wet years from October 1 through June 30 to improve survival for all races and stocks of juvenile salmon and steelhead migrating through and rearing in the Delta. (*Id.*)

In addition to relationships between reverse flows and entrainment effects, flows on the San Joaquin River versus exports also appear to be an important factor in protecting San Joaquin River Chinook salmon. Various studies show that, in general, juvenile salmon released downstream of the effects of the export facilities (Jersey Point) have higher survival out of the Delta than those released closer to the export facilities. (NMFS 3-Appendix 3, p. 74.) Studies also indicate that San Joaquin basin Chinook salmon production increases when the ratio of spring flows to exports increases. (DFG 2005, SJRGA 2007 as cited in NMFS 3-Appendix 3, p. 74.) However, it should be noted that flow at Vernalis appears to be the controlling factor. Increased flows in the San Joaquin River in the Delta may also benefit Sacramento basin salmon by reducing the amount of Sacramento River water that is pulled into the central Delta and increasing the amount of Sacramento River water that flows out to the Bay. (NMFS 3, Appendix 3, p. 74-75.) Based on these findings, the NMFS Opinion calls for export restrictions from April 1 through May 31 with Vernalis flows to export ratios ranging from 1.0 to 4.0 based on water year type, with unrestricted exports above flows of 21,750 cfs at Vernalis, in addition to other provisions for health and safety requirements. (NMFS 3, Appendix 3, p.73-74.)

Analyses by TBI/NRDC indicate that Vernalis flow to export ratios above 1.0 during the San Joaquin basin juvenile salmon outmigration period in the spring consistently correspond to higher escapement estimates two and half years later, with more than 10,000 fish in 76% of years. (TBI/NRDC 4, p. 11.) Vernalis flows to export ratios of less than 1.0 correspond to lower escapement estimates two and half years later, with more than 10,000 fish in only 33% of years. (*Id.*) TBI/NRDC estimates that Vernalis flows to export ratios of greater than 4.0 would reach population abundance goals. (TBI/NRDC 4, pp. 11-12.)

Vernalis flows to export ratios also appear to be important during the fall period to provide improved migration conditions for adult fall-run San Joaquin basin Chinook salmon. Adult fall-run San Joaquin basin Chinook salmon migrate upstream through the Delta primarily during October when San Joaquin River flows are typically low. (AFRP 2005, p. 12.) As a result, when exports are high, little if any flow from the San Joaquin basin may make it out to the ocean to help guide San Joaquin basin salmon back to the basin to spawn. (*Id.*) Analyses indicate that increased straying occurs when more than 400% of the flow at Vernalis is exported at the Delta pumping facilities (equivalent to a Vernalis flow to export ratio of 0.25). (*Id.*) Straying rates decreased substantially when export rates were less than 300% of Vernalis flow. (*Id.*)

Export related criteria for salmon are provided in section 5.4, Hydrodynamic Recommendations.

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<u>Floodplain Flows</u>
Juvenile salmon will rear on seasonally inundated floodplains when available. Such rearing in the Central Valley, in the Yolo Bypass and the Cosumnes River floodplain, has been found to have a positive effect on growth and apparent survival of juvenile Central Valley salmon through the Delta. (Sommer *et al.* 2001 and Jeffres *et al.* 2005 as cited in DOI 1, p. 27 and Sommer *et al.* 2005 and Jeffres *et al.* 2008 as cited in NMFS 3, p. 609.) The increased growth rates may be due to increased temperatures and increased food supplies. (DOI 1, p. 27, DFG 3, p. 3.) Floodplain rearing provides conditions that promote larger and faster growth which improves outmigration, predator avoidance, and ultimately survival. (Stillwater Science 2003 as cited in DFG 3, p. 6.) Increased survival may also be related to the fact that ephemeral floodplain habitat and other side-channels provide better habitat conditions for juvenile salmon than intertidal river channels during high flow events when, in the absence of such habitat, juvenile salmon may be displaced to these intertidal areas. (Grosholz and Gallo 2006 as cited in DOI 1, p. 27 and Stillwater Science as cited in DFG 3, p. 6.) The improved growing conditions provided by floodplain habitat are also believed to improve ocean survival resulting in higher adult return rates. (Healy 1982, Parker 1971 as cited in DOI 1, p. 28.)

While floodplain habitat is generally beneficial to salmon, it may also be detrimental under certain conditions. Areas with engineered water control structures have comparatively higher rates of stranding. (Sommer *et al.* 2005 as cited in DOI 1, p. 28.) In addition, high temperatures, low DO, and other water quality conditions that may occur on floodplains may adversely affect salmon. (DFG 3, p. 6.) Reduced depth may also make salmon more susceptible to predation. (*Id.*) Water depths of 30 cm or more are believed to reduce the risk of avian predation. (Gawlik 2002 as cited in DFG 3, p. 6.) Further, the most successful native fish are those that use the floodplain for rearing, but leave before the floodplain becomes disconnected to the river. (Moyle *et al.* 2007, DFG 3, p. 6.) From a restoration perspective, projects should be designed to drain completely to minimize formation of ponds in order to avoid stranding. (Jones and Stokes, 1999 as cited in DOI 1, p. 28.) Bioenergetic modeling indicates that with regard to increased temperatures, increased food availability may be sufficient to offset increased metabolic demands from higher water temperatures. (DFG 3, p. 6.) However, as temperatures increase, juveniles may be unable to migrate to areas of lower temperatures due to reduced swimming ability. (DFG 3, p. 7.) As a result, as summer temperatures increase, floodplain habitat should also decrease. (*Id.*)

The timing of floodplain inundation for the protection of Central Valley Chinook salmon should generally occur from winter to mid-spring to coincide with the peak juvenile Chinook salmon outmigration period (which itself generally coincides with peak flows) and to avoid non-native access to the floodplain (which would generally occur in late-spring). (AR/NHI 1, p. 25.) The benefits of floodplain inundation generally increase with increasing duration, with even relatively short periods of two-weeks providing potential benefits to salmon. (Jeffres *et al.*, 2008 as cited in AR/NHI 1, p. 25.) Benefits to salmon may also increase with increasing inter-annual frequency of flooding. Repeated pulse flows and associated increased residence times may be associated with increased productivity which would benefit salmon growth rates and potentially reduce stranding. (*Id.*)

Table 4, developed by AR/NHI, provides estimated thresholds for inundating floodplain habitat under existing and potentially modified conditions. Inundation threshold refers to the discharge when floodwaters begin to inundate the floodplain. Target discharge is the amount of water necessary to produce substantial inundation and flow across the floodplain. (Source: AR/NHI 1, p. 30.)

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Floodplain inundation criteria for protection of salmon are provided in section 5.6.2, Floodplain Activation, under Other Measures.

Table 4. Inundation Thresholds for Floodplains and Side Channels at Various Locations Along the Sacramento River

Location	Stage (in feet)	Inundation Threshold (cfs)	Target Discharge (avg. cfs)	Gauge Location	Source
Freemont Weir Existing crest Proposed notch	33.5 17.5	56,000 23,100	63,000 35,000	Verona Verona	USGS USGS
Sutter Bypass Tisdale weir Tisdail with notch Lower Sutter Bypass	45.5 25	21,000 30,000	30,000	Colusa Verona	NOAA; Feyrer USGS
Upper Sacramento Meander belt side channels	Various	10,000	12,000	Red Bluff	USGS

American Shad (*Alosa sapidissima*)

Status
This species is not listed pursuant to either the ESA or CESA.

Life History[13]
The American shad (*Alosa sapidissima*) is an anadromous fish, introduced into California in the late 1880s, that has become an important sport fish within the San Francisco Estuary. American shad range from Alaska to Mexico and use major rivers between British Columbia and the Sacramento watershed for spawning. (Moyle 2002.)

American shad adults, at 3 to 5 years of age, return from the ocean and migrate into the freshwater reaches of the Sacramento and San Joaquin rivers during March through May, with peak migration occurring in May (Stevens *et al*. 1987). Within California, the major spawning run occurs in the Sacramento River up to Red Bluff and in the adjoining American, Feather, and Yuba rivers with lesser use of the Mokelumne, Cosumnes, and Stanislaus rivers and the Delta (Moyle 2002). Spawning takes place from May through early July (Stevens *et al*. 1987). Following their first spawning event, American shad will return annually to spawn up to seven years of age (Stevens *et al*. 1987). It is believed that river flow will affect the distribution of first time spawners, with numbers of newly mature adults spawning in rivers proportional to flows at the time of arrival (Stevens *et al*. 1987). Spawning takes place in the main channels of the rivers with flows washing negatively buoyant eggs downstream. Depending upon temperature, larvae hatch from eggs in 3 to 12 days and will remain planktonic for 4 weeks (Moyle 2002).

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[13] This section was largely extracted from DFG Exhibit 1, pages 26-27.

The lower Feather River and the Sacramento River from Colusa to the northern Delta provide the major summer nursery for larvae and juveniles. Flows drive the transport of young downstream, with wet years changing the location of the concentration of young and their nursery area further downstream into the northern Delta (Stevens *et al.* 1987). Out migration of young American shad through the Delta occurs from June through November (Stevens 1966). American shad spawned and rearing in the Delta and those that travel through the Delta during out migration are vulnerable to entrainment at the State and federal pumping facilities; catches at the facilities in some years have numbered in the millions (Stevens and Miller 1983). During migration to the ocean, young fish feed upon zooplankton, including copepods, mysids, and cladocerans, as well as amphipods (Stevens 1966, Moyle 2002). Most American shad migrate to the ocean by the end of their first year, but some remain in the estuary (Stevens *et al.* 1987).

Population Abundance and its Relationship to Flow
Year class strength correlates positively with river flow during the spawning and nursery period (April-June). (Stevens and Miller 1983.) American shad exhibit a weak but significant relationship to X2, (Kimmerer 2002a). After 1987, the relationship changed such that abundance increased per unit flow. (Kimmerer 2002a, Kimmerer 2009.) The X2 versus abundance relationship has remained intact into recent years. (Kimmerer *et al.* 2009.) In addition, Kimmerer *et al.* (2009) found that American shad had a habitat relationship (defined by salinity and Secchi depth) to X2 that appeared consistent with its relationship of abundance to X2 (i.e., slopes for abundance versus X2 and habitat versus X2 were similar), which provides some support for the idea that increasing quantity of habitat could explain the X2 relationship for this species (a possible causal mechanism for the abundance versus X2 relationship). Stevens and Miller (1983) determined that the apparent general effect of high flow on all of the species they examined, including American shad, is to increase the quality and quantity of nursery habitat and more widely disperse the young fish, thus reducing density-dependent mortality.

Population Goal
The immediate goal is to maintain viable populations of this species by providing sufficient flows to facilitate attraction of spawners, survival of eggs and larvae, and dispersal of young fish to suitable nursery habitats.

Species-Specific Recommendations
Delta Outflow
The DFG's current science-based conceptual model is that placement of X2 in Suisun Bay represents the best interaction of water quality and landscape for fisheries production given the current estuary geometry. (DFG 2, p. 6.) Maintaining X2 at 75 km and 64 km corresponds to net Delta outflows of approximately 11,400 cfs and 29,200 cfs, respectively. As noted by DFG, X2, in this instance, is a surrogate for tributary and mainstem river inflows to the Delta that support egg and larval survival. The species specific flow criteria to protect American shad shown in Table 5 are consistent with those submitted by DFG. (closing comments, p. 7.)

Inflows
No explicit recommendations for inflows to support American shad were identified in the record. The DFG provided outflow criteria for this species based on positioning X2 in Suisun Bay (DFG closing comments, p. 7); noting that in this instance X2 is a surrogate for tributary and mainstem river inflows. As noted above, year class strength correlates positively with river flow during the spawning and nursery period (April to June). (Steven and Miller 1983.) Flows must be sufficient to attract American shad spawners into Sacramento River tributaries, transport and disperse the young fish to suitable nursery habitat, and reduce the probability of entrainment of young fish

and their food organisms in water diversions. (DFG 1987 [Exh 23, p. 23].) Water development has reduced flows during the spring and early summer periods which are most critical in this respect. (*Id.*)   The spawning and nursery period, during which inflows appear to be most critical for this species, generally correspond to important periods for other more sensitive species (e.g., salmon outmigration, longfin smelt spawning and rearing). It is anticipated that by providing sufficient flows to meet the outflow criteria recommended above, favorable river conditions will be provided to support American shad spawning and rearing.

Old and Middle River Flows
American shad spawned and rearing in the Delta and those that travel through the Delta during out migration are vulnerable to entrainment at the State and Federal export facilities; in some years catches at the facilities have numbered in the millions. (Stevens and Miller 1983.) Although evaluations of screening efficiency comparable to studies for striped bass and salmon had not been completed for American shad, DFG believed in 1987 that larger fish in the fall were screened fairly efficiently, while screening efficiencies for newly metamorphosed juveniles in the late spring and early summer were quite low. (DFG 1987 [Exh 23, p. 20].) American shad are notoriously intolerant of handling. Tests have shown that losses of American shad that were successfully screened exceeded 50%during the summer months, with slightly lower mortalities during the cooler fall months. (DFG 1987 [Exh 23, p. 22].) These high handling mortalities suggest the only practical strategy for reducing losses may be pumping schedules that minimize shad entrainment. (*Id.*). However, no recommendations specific to American shad for net OMR flows or pumping restrictions were identified in the record. Net OMR flow criteria are intended to protect salmon, delta smelt, and longfin smelt populations and are also likely to reduce the number of American shad entrained at the export facilities. In addition, restrictions stipulated in the OCAP Biological Opinions (NMFS 3, pp. 648-653; USFWS 2008) will also reduce entrainment of American shad.

Table 5. Delta Outflows to Protect American Shad

Effect or Mechanism	Water Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Spawning; Nursery	All	--	--	--	$X2^1$ – 75 to 64 km (~11400 – 29200 cfs)			--	--	--	--	--	--
[1] For this species, X2 is a surrogate for tributary and mainstem river inflows to the Delta that support egg and larval survival. Source: DFG 1, p. 26; DFG 2, p. 6, DFG closing comments, p. 7.													

4.2.4 Life History Requirements – Pelagic Species

Following are life history and species-specific requirements for longfin smelt, Delta smelt, Sacramento splittail, starry flounder, Bay shrimp, and zooplankton

Longfin Smelt (*Spirinchus thaleichthys*)

Status
Longfin smelt is listed as a candidate for threatened status under the CESA. (DFG 2010.)

Life History
Longfin smelt are a native species that live two years with females reproducing in their second year. Both juveniles and adults feed on zooplankton. Longfin smelt is an anadromous, open water species moving between fresh and salt water. Adults spend time in San Francisco Bay and may go outside the Golden Gate for short periods. Adults aggregate in Suisun Bay and the

western Delta in late fall and migrate upstream to spawn in freshwater as water temperatures drop below 18°C. (Baxter *et al.* 2009.) The spawning habitat is between the confluence of the Sacramento and San Joaquin rivers (around Point Sacramento) to Rio Vista on the Sacramento side and Medford Island on the San Joaquin River. Spawning activity appears to decrease with distance from the low salinity zone, so the location of X2 influences how far spawning migrations extend into the Delta. (Baxter *et al.* 2009.) Spawning takes place between November and April with peak reproduction in January. Eggs are deposited on the bottom and hatch between December and May into buoyant larvae. Peak hatch is in February. Net Delta outflow transports the larvae and juvenile fish to higher salinity water.

Population Abundance and its Relationship to Flow
The population abundance of longfin smelt is positively correlated with spring Delta outflow and inversely related to net OMR spring reverse flows. The correlations are interpreted to mean that net Delta outflow and net reverse OMR flows are, at least partially, responsible for controlling the abundance of longfin smelt. Modifications in the two flow regimes are intended to begin to stabilize and increase the population abundance of longfin smelt. Each correlation is discussed below.

The population abundance of longfin smelt is positively related to Delta outflow during winter and spring. (Jassby *et al.* 1995; Rosenfield and Baxter 2007; Kimmerer 2002a; Kimmerer *et al.* 2009.) The statistically strongest outflow averaging period is January-June. The abundance relationships are from the fall mid-water trawl (FMWT) survey, the bay study mid-water trawl, and the bay study otter trawl. All three surveys show statistically significant positive relationships between the abundance of juveniles/adults and Delta outflow. There has been a decrease in the carrying capacity of the estuary since 1988, presumably because of the invasion of the clam *Corbula*, but the overall winter spring relationship is still statistically significant. More spring outflow results in more smelt as measured by all three indices. The biological basis for the spring outflow relationship is not known. Baxter et al. (2009) speculate that the larvae may benefit from increased downstream transport, increased food production, and a reduction in entrainment losses at the SWP and CVP pumps.

The population abundance of juvenile and adult longfin smelt, as measured by the FMWT index, is also inversely related to the number of fish salvaged at the SWP and CVP pumping facilities. (TBI/NRDC 4, pp. 19-20.) High pumping rates at the two facilities cause net OMR reverse flows which passively move all age groups of longfin smelt toward entrainment at the pumps. A subset of the juvenile and adult populations are counted at the pumping facilities. Larval longfin smelt (<20 mm) pass through the louvers and are not counted. Peak adult and juvenile longfin smelt salvage occurs in January and April to May, respectively. (Baxter *et al.* 2009.) Entrainment of larval smelt, although not counted, are likely greatest between March and April. (TBI/NRDC 4, p.16.) Adult and juvenile longfin smelt salvage is an inverse logarithmic function of net OMR flows. (Grimaldo *et al.* 2009.) Increasing OMR reverse flows results in an exponential increase in salvage loss. Juvenile longfin smelt salvage is a negative function of Delta outflow between March and May. (TBI/NRDC 4, p.17.) Higher outflow in these three months results in lower entrainment loss. This may result from the fact that during low outflow years spawning occurs higher in the system, placing adults and subsequent larvae and juveniles closer to the pumps. Also, negative net OMR flows can either passively draw fish to the pumps or at high levels mis-cue them as to the direction of higher salinity. A consequence is that juvenile longfin smelt are most in danger of entrainment at the CVP and SWP pumping facilities during low outflow years with high net negative OMR flows.

The OMR flow results discussed above are consistent with the findings of Baxter *et al* (2009). The authors used the Delta Simulation Model (DSM2, PTM subroutine) to predict the fate of larval longfin smelt. The PTM predicted that larval entrainment at the SWP might be substantial (2 to10%), particularly during the relatively low outflow conditions modeled. Baxter *et al.* (2009) also identified a significant negative relationship between spring (April to June) net negative OMR flows and the sum of combined SWP and CVP juvenile longfin smelt salvage. Juvenile longfin smelt salvage increased rapidly as OMR became more negative than -2,000 cfs. However, as winter-spring or just spring outflows increased, shifting the position of X2 downstream, the salvage of juvenile longfin smelt decreased significantly. Also, particle entrapment decreased, even with a high negative net OMR, when the flow of the Sacramento River at Rio Vista increased above 40,000 cfs. Entrainment of particles almost ceased at flows of 55,000 cfs.

TBI/NRDC (TBI/NRDC 2, pp. 15-19) conducted a generation to generation population abundance analysis for longfin smelt versus Delta outflow. The authors found that the probability of an increase in the FMWT longfin smelt index was greater than 50% in years when Delta outflow averaged 51,000 and 35,000-cfs between January to March and March to May, respectively. The analysis is important because it suggests a potential outflow trigger for growing the population.

There is also evidence that longfin smelt is food limited. (SFWC 1, p.59.) The FMWT index for longfin smelt is positively correlated in a multiple linear regression with the previous spring's *Eurytemora affinis* abundance (an important prey organism) after weighting the data by the proportion of smelt at each *Eurytemora* sampling station and normalizing by the previous years FMWT index. The spring population abundance of *Eurytemora* has itself been positively correlated with outflow between March and May since the introduction of *Corbula.* (Kimmerer, 2002a.) The positive correlation between *Eurytemora* abundance and spring outflow provides further support for a spring outflow criterion.

Longfin smelt populations are at an all time low. The average FMWT index for years 2001-2009 are only 3 percent of the average value for 1967 to 1987, a time period when pelagic fish did better in the estuary. The FMWT index for two of the last three years is the lowest on record.

Delta outflow recommendations to protect longfin smelt received from participants are summarized in Table 6. The DFG (DFG closing comments, p.7) recommended a Delta outflow between 12,400 and 28,000 cfs from January to June of all water year types to help transport larval/juvenile longfin smelt seaward in the estuary. TBI/NRDC (TBI/NRDC 2, pp. 19-26; TBI/NRDC Closing Comments, pp. 6-7) also made spring Delta outflow recommendations based on five sets of hydrologic conditions for the Central Valley. The TBI/NRDC recommendations range between 14,000 and 140,000 cfs for January through March and 10,000 to 110,000 cfs between April and May. The TBI/NRDC recommendations are based on their longfin smelt population abundance analysis which demonstrated positive growth in years with high spring outflow.

The four sets of OMR recommendations to protect longfin smelt received from participants are summarized in Table 7. TBI/NRDC (TBI/NRDC 4, pp. 21 and 30; TBI/NRDC closing comments, p. 11) recommended reducing entrainment losses of longfin smelt in dry years (March to May when outflow is less than 18,000 cfs) and population abundance is low (FMWT index less than 500) by maintaining positive net OMR flows in April and May. Alternatively, if the index is greater than 500 and Delta outflow is low, then net OMR flows should not be more negative than -1,500 cfs. The DOI (DOI 1, p.53) made a non-species specific recommendation that OMR

flows should be positive in all months between January and June. CSPA/CWIN made a non-species specific recommendations that combined export rates equal zero from mid-March through June. (CSPA 1, p.8; CWIN 2, p. 26.) Finally, the DFG has issued an Incidental Take Permit for longfin smelt (2081-2009-001-03) that restricts net OMR flows in some years based on the recommendations of the Delta Smelt Workgroup. (Baxter *et al.* 2009.)

Table 6. Participant Recommendations for Delta Outflow to Protect Longfin Smelt

Organization	Water Year	Jan	Feb	Mar	April	May	Jun
TBI/NRDC	81-100% (driest years)	14,000 – 21,000			10,000 – 17,500		3000 – 4200
	61-80%	21,000 – 35,200			17,500 – 29,000		4200 – 5000
	41-60%	35,200 – 55,000			29,000 – 42,000		5000 – 8500
	21-40%	55,000 – 87,500			42,000 – 62,500		8500 – 25000
	0-20% (wettest years)	87,500 – 140,000			62,500 – 110,000		25000 – 50000
DFG	all	12,400 to 28,000					

Population Goal

The immediate goal is to stabilize the longfin smelt population, as measured by the FMWT index, and to begin to grow the population. The long-term goal is to achieve the objective of the Recovery Plan for the Sacramento/San Joaquin Delta Native Fishes (USFWS 1996). The plan states that longfin smelt will be considered recovered when its abundance is similar to the 1967 to 1984 period.

Species- Specific Recommendations

Table 8 contains the species-specific flow criteria to protect longfin smelt. The purpose of the Delta outflow criteria is to stabilize and begin to grow the longfin smelt population; positive population growth is expected in half of all years with these flows. The net OMR flow criteria are intended to protect the longfin smelt population from entrainment in the CVP and SWP pumping facilities during years with limited Delta outflow (dry and critically dry years). As noted above, longfin smelt spawn in the Delta on both the Sacramento and San Joaquin rivers. Longfin smelt optimally need positive flow on both river systems to move buoyant larvae downstream and away from the influence of the pumps.

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Table 7. Participant Recommendations for Net OMR Reverse Flows to Protect Longfin Smelt

Organization	Water Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
2006 Bay-Delta Plan	all	Some restrictions, given in terms of E/I ratios											
DFG Take Permit	all	-1,250 to -5,000[1]											
TBI/NRDC	C/D				>0[2] or -1,500[3]								
DOI	all	>0											
CSPA/CWIN	all				Combined export rates = 0								

[1] This condition is not likely to occur in many years and is based on requirements in the DFG Incidental Take Permit 2081-2009-001-03 and the advice of the Smelt Working Team. The condition is most likely to occur in dry or critical years when longfin smelt spawn higher in the Delta and hydrology does not rapidly transport hatched larvae from the central and south Delta.

[2] If FMWT index is less than 500

[3] If FMWT index is greater than 500

Table 8. Delta Outflows to Protect Longfin Smelt

Flow Type	Water Year Type	Jan	Feb	Mar	April	May	Jun
Net Delta Outflow	C	14,000 – 21,000			10,000 – 17,500		3,000 – 4,200
	D	21,000 – 35,200			17,500 – 29,000		4,200 – 5,000
	BN	35,200 – >50,000			29,000 – 42,000		5,000 – 8,500
	AN	>50,000			>42,000		8,500 – 25,000
	W	>50,000			>42,000		25,000 – 50,000
OMR	C/D				>0[1] or -1,500[2]		

[1] If FMWT index is less than 500

[2] If FMWT index is greater than 500

Delta Smelt (*Hypomesus transpacificus*)

Status
Delta smelt is listed as endangered under the CESA and threatened under the ESA. (DFG 2010.)

Life History
Delta smelt are endemic to the Delta. Delta smelt have an annual, one-year life cycle although some females may live and reproduce in their second year. (Bennett 2005.) Delta smelt complete their entire life cycle in the Delta and upper estuary. Delta smelt feed primarily on planktonic copepods, cladocerans, and amphipods. (Baxter *et al*. 2008.) In September or October delta smelt begin a slow upstream migration toward their freshwater spawning areas in the upper Delta, a process that may take several months. (Moyle 2002.) The upstream migration may be triggered by Sacramento River flows in excess of 25,000 cfs. (DSWG 2006.) Spawning can occur from late February to July, although most reproduction appears to take place between early April and mid-May. (Moyle 2002.) Spawning areas include the lower Sacramento, Mokelumne, and San Joaquin rivers, the west and south Delta, Suisun Bay, Suisun Marsh, and occasionally in wet years, the Napa River. (Wang 2007.) Eggs are negatively buoyant and adhesive with larvae hatching in about 13 days. (Wang, 1986; Mager 1996.) Upon hatching, the larvae are semi-buoyant staying near the bottom. Within a few weeks, larvae develop an air bladder and become pelagic, utilizing vertical water column movement to maintain their longitudinal position in the estuary. (Moyle 2002.)

Freshwater outflow during spring (March to June) affects the distribution of larvae by transporting them seaward toward the low salinity zone. (Dege and Brown 2004.) High Delta outflow during spring can carry some smelt downstream of their traditional rearing areas in the west Delta and Suisun Bay and into San Pablo Bay where long-term growth and survival may not be optimal. Conversely, periods of low outflow increase residence time in the Delta. Increasing residence time in the Delta probably prolongs the exposure of delta smelt to higher water temperatures and increased risk of entrainment at the State and Federal pumping facilities. (Moyle 2002.) Ideal rearing habitat conditions are believed to be shallow water areas most commonly found in Suisun Bay. (Bennett 2005.) When the mixing zone was located in Suisun Bay, it may in the past have provided optimal conditions for algal and zooplankton growth, an important food source for delta smelt. (Moyle 2002.) However, the quality of habitat in Suisun Bay appears to have deteriorated with the introduction of the clam *Corbula* which now consumes much of the phytoplankton that previously supported large populations of zooplankton. Since 2005, approximately 40% of the delta smelt population now remains in the Cache Slough complex north of the Delta. This may represent an alternative life history strategy in which the fish stay upstream of the low salinity zone (LSZ) through maturity. (Sommer et al., 2009.)

Population Abundance and Relationship to Flow
Delta smelt population abundance is measured in the summer tow net survey, the FMWT survey and the 20-mm spring-summer survey of juvenile fish. (Kimmerer et al. 2009.) All three indices indicate that delta smelt populations are at an all time low and may be in danger of extinction. The average FMWT index for 2001-2009 is only 20% of the value measured between 1967 and 1987, a time period when pelagic fish did better in the estuary. FMWT indices for the last six years (2004 to 2009) include all of the lowest values on record. The cause of the decline is unclear but likely includes some combination of flow, export pumping, food limitation, and introduced species.

Three types of flow have been hypothesized to affect delta smelt abundance. These are spring and fall Delta outflow and net OMR reverse flow. Testimony was received at the public proceeding recommending management changes to all three types of flow (Table 9 and Table 10). In the past, there has been a weak negative relationship between spring Delta outflow and delta smelt abundance as measured by the FMWT, however, the relationship has now disappeared. (Kimmerer *et al.* 2009.) The cause for the disappearance of the spring outflow-abundance relationship is not known but may result from the deterioration of rearing habitat in Suisun Bay because of colonization by the clam *Corbula.*

Several organizations recommend fall Delta outflow criteria for protection of delta smelt (Table 9). The primary purpose of a fall Delta outflow criterion is to increase the quality and quantity of rearing habitat for Delta smelt. (Nobriga et al. 2008; Feyrer et al. 2007; Feyrer et al., in review.) Rearing habitat is hypothesized to increase when the fall LSZ is downstream of the confluence of the Sacramento and San Joaquin rivers. This corresponds to Delta outflows greater than about 7,500 cfs between September and November, which would have to be achieved by release of water from upstream reservoirs in most years. Grimaldo et al. (2009) found that X2 was a predictor for salvage of adult delta smelt at the intra-annual scale when net OMR flows were negative. Moving X2 westward in the fall serves to increase the geographic and hydrologic distance of delta smelt from the influence of the export facilities and therefore likely reduces the risk of entrainment. (DOI 1, p. 34.) The USFWS (2008) recommended in their Opinion that the LSZ be maintained in the fall of above normal and wet water year types in Suisun Bay (Action 4). The action was restricted to above average water years to insure that sufficient cold water pool resources remained for steelhead and salmon and because these are the years in which SWP and CVP operations have most significantly affected fall conditions. (USFWS 2008.) The National Academy of Sciences (NAS) (2010) commented on this action in their review:

> "The statistical relationship is complex. When the area of highly suitable habitat …is low, either high or low FMWT indices can occur. In other words, delta smelt can be successful even when habitat is restricted. More important, however, is that the lowest abundances all occurred when the habitat-area index was less than 6,000 ha. This could mean that reduced habitat area is a necessary condition for the worst population collapses, but it is not the only cause of the collapse… The … action is conceptually sound … to the degree that the amount of habitat available for smelt limits their abundance… however…the weak statistical relationship between the location of X2 and the size of smelt populations makes the justification for this action difficult to understand." The National Academy of Sciences noted approvingly that the U.S. Fish and Wildlife Service (2008) required "additional studies addressing elements of the habitat conceptual model to be formulated … and … implemented promptly."

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Table 9. Participant Recommendations for Delta Outflows to Protect Delta Smelt

	Water Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
2006 Bay-Delta Plan [1]	C	4500 [2]		7100 – 29200 [3]				4000	3000	3000	3000	3500	
	D	4500		7100 - 29200				5000	3500	3000	4000	4500	
	BN	4500		7100 - 29200				6500	4000	3000	4000	4500	
	AN	4500		7100 - 29200				8000	4000	3000	4000	4500	
	W	4500		7100 - 29200				8000	4000	3000	4000	4500	
USFWS Opinion [1]	AN									7000 [4]			
	W									12400			
EDF/Stillwater Sciences	C			26800	17500	17500	7500	4800	4800	4800	4800	4800	
	D			26800	17500	17500	7500	4800	4800	4800	4800	4800	
	BN			26800	26800	26800	11500	7500	7500	7500	7500	7500	
	AN			26800	26800	26800	11500	11500	11500	11500	11500	11500	
	W			26800	26800	26800	17500	17500	17500	17500	17500	17500	
TBI/NRDC	81-100%									5750 - 7500			
	61-80%									7500 - 9000			
	41-60%									9700 - 12400			
	21-40%									12400 - 16100			
	0-20%									16100 - 19000			

[1] 2006 Bay-Delta Plan and USFWS Opinion flows shown for comparative purposes.

[2] All water year types - Increase to 6000 if the December Eight River Index is > than 800 thousand acre-feet (TAF).

[3] Minimum Delta outflow calculated from a series of rules that are described in Tables 3 and 4 of the 2006 Bay-Delta Plan.

[4] USFWS Opinion (RPA concerning Fall X2 requirements [pp282-283] - improve fall habitat [quality and quantity] for delta smelt) (references USFWS 2008, Feyrer *et al* 2007, Feyrer *et al* in revision) - September-October in years when the preceding precipitation and runoff period was wet or above normal, as defined by the Sacramento Basin 40-30-30 Index, USBR and DWR shall provide sufficient Delta outflow to maintain monthly average X2 no greater than 74 km and 81 km in Wet and Above Normal years, respectively. During any November when the preceding water year was wet or above normal, as defined by Sacramento Basin 40-30-30 index, all inflow into the CVP/SWP reservoirs in the Sacramento Basin shall be added to reservoir releases in November to provide additional increment of outflow from Delta to augment Delta outflow up to the fall X2 of 74 km and 81 km for wet and above normal water years, respectively. In the event there is an increase in storage during any November this action applies, the increase in reservoir storage shall be released in December to augment the December outflow requirements in the 2006 Bay-Delta Plan.

Table 10. Participant Recommendations for Net OMR Flows to Protect Delta Smelt

	Water Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
2006 Bay-Delta Plan	all	Some restrictions, given in terms of exports to inflow ratios											
USFWS -Opinion	all	Action 1: -2000 cfs for 14 days once turbidity or salvage trigger has been met; Action 2: range btw -1250 and -5000 cfs [1]			Range between -1,250 and -5,000 [2]								See Jan-Mar
USFWS	all	>0 [3]											
CSPA/ CWIN					Combined Export Rates = 0[3]								
TBI/ NRDC	all	>-1,500 cfs											>-1500 cfs

[1] USFWS Opinion - RPA re: net OMR flows. Component 1 - Adults (December - March) - Action 1 (protect upmigrating delta smelt) - once turbidity or salvage trigger has been met, -2000 cfs OMR flow for 14 days to reduce flows towards the pumps. Action 2 (protect delta smelt after migration prior to spawning) – Net OMR flow range between -1250 and -5000 cfs determined using adaptive process until spawning detected. (pp.280-282.)

[2] USFWS Opinion - RPA re: net OMR flows. Component 2 - Larvae/juveniles - action starts once temperatures hit 12° C at three Delta monitoring stations or when spent female is caught. Net OMR flow range between -1250 and -5000 cfs determined using adaptive process. OMR flow restrictions continue until June 30 or when Delta water temperatures reach 25° C, whichever comes first. (pp. 280-282.)

[3] Recommendations by the USFWS and CSPA/CWIN were not species specific.

It should be reiterated that this measure should be implemented within an adaptive framework, including completing studies designed to clarify the mechanism(s) underlying the effects of fall habitat on the delta smelt population, and a comprehensive review of the outcomes of the action and its effectiveness. Until additional studies are conducted demonstrating the importance of fall X2 to the survival of delta smelt, additional fall flows, beyond those stipulated in the fall X2criteria, for the protection of delta smelt are not recommended if it will compete with preservation of cold water pool resources needed for the protection of salmonids.

Net negative OMR flows can affect delta smelt by pulling them into the central Delta where they are at risk of entrainment in the SWP and CVP pumps. Recent studies have shown that entrainment of delta smelt and other pelagic species increases as net OMR flows become more negative. (Grimaldo et al. 2009; Kimmerer 2008.) Delta smelt are at risk as juveniles in the spring during downstream migration to their rearing area, and as adults between the fall and early spring as they move upstream to spawn. Salvage of age-0 delta smelt at the SWP /CVP fish collection facilities at the intra-annual scale has been found to be related to the abundance of these fish in the Delta, while net OMR flows and turbidity were also strong predictors. (Grimaldo et al. 2009.) This suggests that within a given year, the mechanism influencing entrainment is probably a measure of the degree to which their habitat overlaps with the hydrodynamic "footprint" of net negative OMR flows. (Grimaldo et al. 2009.) PTM results suggest that entrainment is a function of both net OMR flows and river outflows. (Kimmerer and Nobriga 2008.) PTM results may be more applicable to neutrally buoyant larvae and poorly swimming juveniles than adult delta smelt. Particle entrainment increased as a logarithmic function of increasing net negative OMR flows and decreases in river outflows. The highest entrainment was observed at high net negative OMR flows and low outflows. PTM results suggest that entrainment losses might be as high as 40% of the total delta smelt population in some years. (Kimmerer 2008.) Similar results were obtained by Baxter et al. (2009) when evaluating entrainment of longfin smelt using PTM. Juvenile longfin smelt salvage increased rapidly as net OMR flows became more negative than -2,000 cfs. Also, particle entrapment decreased, even with high net negative OMR flows, when the flow of the Sacramento River at Rio Vista increased above 40,000 cfs. Entrainment of particles almost ceased at flows of 55,000 cfs.

Field population investigations support some of the spring PTM results. Gravid females and larvae are present in the Delta as early as March and April. (Bennett 2005.) However, analysis of otolith data on individuals collected later in the year by Bennett *et al.* (unpublished data) show that few of the early progeny survived if spawned prior to the VAMP time period (typically April 15 to May 15). The hydrodynamic data showed high net negative OMR flows in the months preceding and after the VAMP, leading the researchers to conclude that high winter and early spring net negative OMR flows were selectively entraining the early spawning and/or early hatching cohort of the delta smelt population. However, Baxter *et al.* (2008) stated that "under this hypothesis, the most important result of the loss of early spawning females would manifest itself in the year following the loss, and would therefore not necessarily be detected by analyses relating fall abundance indices to same-year predictors." No statistical relationships have been found between either OMR flows or CVP and SWP pumping rates and Delta smelt population abundance. (Bennett 2005.)

Entrainment of adult delta smelt occurs following the first substantial precipitation event ("first flush"), characterized by sudden increases in river inflows and turbidity, in the

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estuary as they begin their migration into the tidal freshwater areas of the Delta. (Grimaldo *et al.* 2009.) Patterns of adult entrainment are distinctly unimodal, suggesting that migration is a large population-level event, as opposed to being intermittent or random. (DOI 1, p. 36.) Grimaldo *et al.* (2009) provided evidence suggesting that entrainment during these "first flush" periods could be reduced if export reductions were made at the onset of such periods.

The USFWS Opinion identifies turbidity criteria for which to trigger first flush export reductions, but total Delta outflow greater than 25,000 cfs could serve as an alternate or additional trigger since such flows are highly correlated with turbidity. (Grimaldo *et al.* 2009, DOI 1, p. 36.) Managing OMR flows to thresholds at which entrainment or populations losses increase rapidly, represents a strategy for providing additional protection for adult delta smelt in the winter period (Dec-Mar). (DOI 1, p.36.). The USFWS Opinion identified the lower net OMR flow threshold as - 5000 cfs based on observed OMR flow versus salvage relationships from a longer data period (USFWS 2008) and additional data summarized over a more recent period. (Grimaldo et al. 2009.) The -5000 cfs OMR flow threshold is appropriate because it is the level where population losses consistently exceed 10%. (USFWS 2008, DOI 1, p. 36.) Adult delta smelt entrainment varies according to their distribution in the Delta following their upstream migration. The population is at higher entrainment risk if the majority of the population migrates into the south Delta, which may require net OMR flows to be more positive than -5000 cfs to reduce high entrainment. Conversely, if the majority of the population migrates up the lower Sacramento River or north Delta, a smaller entrainment risk is presumed, which would allow for OMR flows to be more negative than -5000 cfs for an extended period of time, or until conditions warrant a more protective OMR flow. (DOI 1, p.36.)

The USFWS Opinion for delta smelt includes net negative OMR flow restrictions to protect both spawning adult and out-migrating young. Component 1 of the USFWS Opinion has two action items; both are to protect adult delta smelt. Action 1 restricts OMR flow in fall to -2,000 cfs for 14 days when a turbidity or salvage trigger has been met. Both triggers have previously been correlated with the upstream movement of spawning adult smelt. Action 2 commences immediately after Action 1. Action 2 is to protect adult delta smelt after migration, but prior to spawning, by restricting net OMR flows to between -1250 and -5,000 cfs based on the recommendations of the Delta Smelt Workgroup. Component 2 of the USFWS Opinion is to protect larval and juvenile fish. Component 2 actions start once water temperatures hit 12°C at three monitoring stations in the Delta or when a spent female is caught. OMR flows during this phase are to be maintained more positive than -1,250 to -5000 cfs based on a 14-day running average. Component 2 actions are to continue until June 30 or when the 3-day-mean water temperature at Clifton Court Forebay is 25°C. The Delta Smelt Working Group is to make recommendations on the specific OMR flow restrictions between -1250 and -5000 cfs.

The NAS (2010) reviewed the USFWS Opinion OMR flow restrictions and concluded:

> "…it is scientifically reasonable to conclude that high negative OMR flows in winter probably adversely affect smelt populations. Thus, the concept of reducing OMR negative flows to reduce mortality of smelt at the SWP and CVP facilities is scientifically justified … but the data do not permit a confident identification of the threshold values to use … and … do not

permit a confident assessment of the benefits to the population…As a result, the implementation of this action needs to be accompanied by careful monitoring, adaptive management and additional analyses that permit regular review and adjustment of strategies as knowledge improves."

The negative impact of negative OMR flows on delta smelt, like on longfin smelt, is likely to be greatest during time periods with high negative OMR flows and low Sacramento River outflow. (Baxter *et al.* 2009; Kimmerer and Nobriga 2008.) The work of Grimaldo *et al*, (2009) suggests that impacts associated with the export facilities can be mitigated on a larger scale by altering the timing and magnitude of exports based on the biology of the fishes and changes in key physical and biological variables.

For the protection of longfin smelt, Delta outflow criteria between January and March range from 35,000 cfs in below normal water years to greater than 50,000 cfs in wet water years (Table 8). For the protection of longfin smelt, flow criteria between April and May range from 29,000 cfs to more than 42,000 cfs. These flows should also afford protection for larval delta smelt from excessive negative OMR flows and entrainment at the CVP and SWP pumping facilities. Under this criterion, lower outflows will still likely occur during critically dry and dry water year types (Table 6). These outflows may not be sufficient to prevent longfin and delta smelt entrainment at the pumping facilities. Therefore, the recommended criterion for longfin smelt specifies that net OMR flows should not be more negative than -1500 cfs in April and May of dry and critically dry water years to protect longfin smelt. The State Water Board determines that this criterion should be extended to include March and June of dry and critically dry water years to protect early and late spawning delta smelt (Table 11).

Minimizing net negative OMR flows during periods when adult delta smelt are migrating into the Delta could also substantially reduce mortality of the critical life stage. For example, one potential strategy is to reduce exports during the period immediately following the "first flush", based on a turbidity or flow trigger. (Grimaldo et al. 2009.) This supports a recommendation that net OMR flows be more positive than -5000 cfs during the period between December and March. Additional OMR flow restrictions may be warranted during periods when a significant portion of the adult delta smelt population migrates into the south or central Delta. In such instances, the determination of specific thresholds should be made through an adaptive approach that takes into account a variety of factors including relative risk (e.g., biology, distribution and abundance of fishes), hydrodynamics, water quality, and key physical and biological variables. The State Water Board agrees with the NAS (2010) that the data, as currently available, do not permit a confident assessment of the threshold OMR flow values nor of the overall benefit to the delta smelt population. Development of a comprehensive life-cycle model for delta smelt would be valuable in that it would allow for an assessment of population level impacts associated with entrainment. Such life-cycle models for delta smelt are currently under development. Therefore, net OMR flow criteria need to be accompanied by a strong monitoring program and adaptive management to adjust OMR flow criteria as more knowledge becomes available.

Delta smelt are food limited. Delta smelt survival is positively correlated with zooplankton abundance. (Feyrer et al., 2007; Kimmerer 2008; Grimaldo et al., 2009.) A new analysis by the SFWC (SFWC 1, p.60) also demonstrates a positive relationship between FMWT delta smelt indices and the previous spring and summer abundance of

Eurytemora and *Psuedodiaptomus.* There are several hypotheses for the cause of the decline in zooplankton abundance. First, zooplankton abundance in Suisun and Grizzly bays, prime habitat for delta smelt, declined after the introduction of the invasive clam *Corbula. Corbula* is thought to compete directly with zooplankton for phytoplankton food and lower phytoplankton levels may limit zooplankton abundance. A second hypothesis is that changes in nutrient loading and nutrient form in the Delta that result from the SRWTP discharge can have major impacts on food webs, from primary producers through secondary producers to fish. (Glibert, 2010.) Changes in nutrient concentrations and their ratios may have caused the documented shift in phytoplankton species composition from large diatoms to smaller, less nutritious algal forms for filter feeding organisms like zooplankton. If true, both of the above hypotheses could indirectly result in lower densities of delta smelt. Therefore, all recommended flow modifications should be accompanied by a strong monitoring and adaptive management process to determine whether changes in OMR flows result in an improvement in delta smelt population levels.

Population Abundance Goal

The immediate goal is to stabilize delta smelt populations, as measured by the FMWT index, and begin to grow the population. The long term goal should be to achieve the objective of the Recovery Plan for the Sacramento/San Joaquin Delta Native Fishes (USFWS 1996.)

Species-Specific Recommendations

Although a positive correlation between Delta outflows and delta smelt is lacking, Delta outflows do have significant positive effects on several measures of delta smelt habitat. (Kimmerer *et al.* 2009), and spring outflow is positively correlated with spring abundance of *Eurytemora affinis* (Kimmerer 2002a), an important delta smelt prey item. No specific spring Delta outflow criteria are therefore recommended for delta smelt. Flow criteria to protect longfin smelt in the spring of wetter years (Table 8) may, however, afford some additional protection for the Delta smelt population.

The State Water Board advances the OMR flow criteria in Table 11 for dry and critically dry years to protect the delta smelt population from entrainment in the CVP and SWP pumping facilities during years with limited Delta outflow. The OMR flow restrictions are an extension of the criteria for longfin smelt. In addition, the State Water Board includes criteria for OMR flows to be more positive than -5,000 cfs between December and February of all water year types to protect upstream migrating adult delta smelt. The -5,000 cfs criteria may need to be made more protective in years when delta smelt move into the central Delta to spawn. The more restrictive OMR flows would be recommended after consultation with the USFWS's Delta Smelt Working Group. In the absence of any other specific information, the State Water Board determines that the existing 2006 Bay-Delta Plan Delta outflow objectives for July through December are needed to protect delta smelt.

Table 11. Net OMR Flows for the Protection of Delta Smelt

Flow Type	Water Year Type	Dec	Jan	Feb	Mar - June
Net OMR flows	C/D				> -1,500 cfs
Net OMR flows	All	> - 5000 cfs (thresholds determined through adaptive management)			

Sacramento Splittail (*Pogonichthys macrolepidotus*)

Status

Sacramento splittail is currently recognized by the DFG as a species of special concern. Splittail was listed as a threatened species pursuant to the ESA in 1999; however, its status was remanded in 2003 on the premise of recent increases in abundance and population stability. This decision was subsequently challenged and the USFWS is revisiting the status of splittail and will make a new 12-month finding on whether listing is warranted by September 30, 2010.

Life History

Sacramento splittail (*Pogonichthys macrolepidotus*) is a cyprinid native to California that can live seven to nine years and has a high tolerance to a wide variety of water quality parameters including moderate salinity levels. (Moyle 2002, Moyle et al. 2004.)

Adult splittail are found predominantly in Suisun Marsh, Suisun Bay, and the western Delta, but are also found in other brackish water marshes in the San Francisco Estuary as well as the fresher Delta. Splittail feed on detritus and a wide variety of invertebrates; non-detrital food starts with cladocerans and aquatic fly larvae on the floodplains, progresses to insects and copepods in the rivers, and to mysid shrimps, amphipods and clams for older juveniles and adults. (Daniels and Moyle 1983, Feyrer et al. 2003, Feyrer et al. 2007a, as cited in DFG 1, p. 13.) In winter and spring when California's Central Valley experiences increased runoff from rainfall and snowmelt, adult splittail move onto inundated floodplains to forage and spawn. (Meng and Moyle 1995; Sommer et al. 1997, Moyle et al. 2004, as cited in DFG 1, p. 13.) Spawning takes place primarily between late February and early July, and most frequently during March and April (Wang 1986, Moyle 2002) and occasionally as early as January. (Feyrer et al. 2006a.) Splittail eggs, laid on submerged vegetation, begin to hatch in a few days and the larval fish grow fast in the warm and food rich environment. (e.g., Moyle et al. 2004, Ribeiro et al. 2004.) After spawning, the adult fish move back downstream.

Once they have grown a few centimeters, the juvenile splittail begin moving off of the floodplain and downstream into similar habitats as the adults. These juveniles become mature in two to three years. In the Yolo Bypass, two flow components appear necessary for substantial splittail production (Feyrer et al. 2006a): (1) inundating flows in winter (January to February) to stimulate and attract migrating adults; and (2) sustained floodplain inundation for 30 or more days from March through May or June to allow successful incubation through hatching (3 to 7 days, see Moyle 2002), and extended rearing until larvae are competent swimmers (10 to 14 days; Sommer et al. 1997) and beyond to maximize recruitment. (DFG 1, p. 13.)

Large-scale spawning and juvenile recruitment occurs only in years with significant protracted (greater than or equal to 30 days) floodplain inundation, particularly in the

Sutter and Yolo bypasses. (Meng and Moyle 1995, Sommer et al. 1997, Feyrer et al. 2006a, as cited in DFG 1, p. 13.) Some spawning also occurs in perennial marshes and along the vegetated edges of the Sacramento and San Joaquin rivers. (Moyle et al. 2004.) During periods of low outflow, splittail appear to migrate farther upstream to find suitable spawning and rearing habitats. (Feyrer et al. 2005.) Moyle et al. (2004) noted that though modeling shows splittail to be resilient, managing floodplains to promote frequent successful spawning is needed to keep them abundant.

Population Abundance and its Relationship to Flow

Age-0 splittail abundance has been significantly correlated to mean February through May Delta outflow and days of Yolo Bypass floodplain inundation, representing flow/inundation during the incubation and early rearing periods. (Meng and Moyle 1995, Sommer et al. 1997.) The flow-abundance relationship is characterized by increased abundance (measured by the FMWT) as mean February–May X2 decreases, indicating a significant positive relationship between FMWT abundance and flow entering the estuary during February–May. (Kimmerer 2002a.)

Feyrer et al. (2006a) proposed the following lines of evidence to suggest the mechanism supporting this relationship for splittail lies within the covarying relationship between X2 and flow patterns upstream entering the estuary: the vast majority of splittail spawning occurs upstream of the estuary in freshwater rivers and floodplains (Moyle et al. 2004); the averaging time frame (February–May) for X2 coincides with the primary spawning and upstream rearing period for splittail; the availability of floodplain habitat, as indexed by Yolo Bypass stage, is directly related to X2 during February–May ($y = 4.38 - 2.21x$; $p<0.001$; $r^2 = 0.97$); the center of age-0 splittail distribution does not reach the estuary until summer (Feyrer et al. 2005); and the splittail X2-abundance relationship has not been affected by dramatic food web changes (Kimmerer 2002a) that have significantly altered the diet of young splittail in the estuary. (Feyrer et al. 2003.)

Population Abundance Goal
The immediate goal is to stabilize the Sacramento Splittail population, as measured by the FMWT index, and to begin to grow the population. The long-term goal is to maintain population abundance index as measured by FMWT in half of all years above the long term population index value.

Species- Specific Recommendations
Delta Outflow - Upstream covariates of X2, such as the availability of suitable floodplain and off-channel spawning and nursery habitat, appear to be the attributes supporting the flow-abundance relationship for splittail. Therefore, the flow needs of this species, with respect to spawning and rearing habitat, are most effectively dealt with through establishment of flow criteria that address the timing, duration, and magnitude of floodplain inundation from a river inflow standpoint.

Delta Inflow - Information in the record on conditions conducive to successful spawning and recruitment of splittail shows that the species depends on inundation of off-channel areas. Sufficient flows are therefore needed to maintain continuous inundation for at least 30 consecutive days in the Yolo Bypass, once floodplain inundation has been achieved based on runoff and discharge for ten days between late-February and May, during above normal and wet years (Table 12). (DFG closing comments, p. 7.)

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Opportunities to provide floodplain inundation in other locations (e.g., the San Joaquin River) warrant further examination.

Feyrer *et al* (2006a) noted that manipulating flows entering Yolo Bypass such that floodplain inundation is maximized during January through June will likely provide the greatest overall benefit for splittail, especially in relatively dry years when overall production is lowest. Within the Yolo Bypass, floodplain inundation of at least a month appears to be necessary for a strong year class of splittail (Sommer *et al.* 1997); however, abundance was highest when the period of inundation extended 50 days or more. (Meng and Moyle 1995.) Floodplain inundation during the months of March, April, and May appears to be most important. (Wang 1986, Moyle 2002.) Managing the frequency and duration of floodplain inundation during the winter and spring, followed by complete drainage by the end of the flooding season, could favor splittail and other native fish over non-natives. (Moyle et al. 2007, Grimaldo et al. 2004.) Duration and timing of inundation are important factors that influence ecological benefits of floodplains.

Yolo Bypass Inundation – The Fremont Weir is a passive facility that begins to spill into the Yolo Bypass when the Sacramento River flow at Verona exceeds 55,000 to 56,000 cfs. (AR/NHI 1, p. 21; EDF 1, p. 50; TBI/NRDC 3, p. 35; Sommer et al. 2001b.) Water also enters the bypass at the Sacramento Weir and from the west via high flow events in small west-side tributaries. (Feyrer et al. 2006b.) Each of these sources joins the Toe Drain, a perennial channel along the east side of the Yolo Bypass floodplain, and water spills onto the floodplain when the Toe Drain flow exceeds approximately 3,500 cfs. (Feyrer et al. 2006b.) The Yolo Bypass typically floods in winter and spring in about 60% of years (DOI 1, p. 54; Sommer et al. 2001a; Feyrer et al. 2006a), with inundation occurring as early as October and as late as June, with typical peak period of inundation during January-March. (Sommer et al. 2001b.) In addition, studies suggest phytoplankton, zooplankton, and other organic material transported from the Yolo Bypass enhances the food web of the San Francisco Estuary. (Jassby and Cloern 2000; Mueller-Solger et al. 2002; Sommer et al. 2004.) Much of the water diverted into the bypass drains back into the north Delta near Rio Vista. Besides the Yolo Bypass, the only other Delta region with substantial connectivity to portions of the historical floodplain is the Cosumnes River, a small undammed watershed. (Sommer et al. 2001b.)

Multiple participants provided recommendations concerning the magnitude and duration of floodplain inundation along the Sacramento River, lower San Joaquin River, and within the Yolo and Sutter bypasses. (AR/NHI 1, p. 32; DFG closing comments; DOI 1, p. 54, EDF 1, pp. 50-52, 53-55; SFWC closing comments; TBI/NRDC 3, p. 36.) In addition, the draft recovery plan for the Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, and Central Valley Steelhead (NMFS 2009) calls for the creation of annual spring inundation of at least 8,000 cfs to fully activate the Yolo Bypass floodplain. (NMFS 5, p.157.)

Overtopping the existing weirs and flooding the bypasses (e.g., Yolo and Sutter) to achieve prolonged periods (30 to 60 days) of floodplain inundation in below normal and dry water years would require excessive amounts flows given the typical runoff patterns during those year types. (AR/NHI 1, p. 29.) From a practical standpoint, it is probably only realistic to achieve prolonged inundation during drier water year types by notching the upstream weirs and possibly implementing other modifications to the existing system. (AR/NHI 1, p. 29.)

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The BDCP is currently evaluating structural modifications to the Fremont Weir (e.g., notch the weir and install operable "inundation gates"), as a means of increasing the interannual frequency and duration of floodplain inundation in the Yolo Bypass. (BDCP 2009.) TBI/NRDC (TBI/NRDC 3, p. 36) and AR/NHI (AR/NHI 1, p. 32) provided floodplain inundation recommendations for the Yolo Bypass assuming structural modifications to the Fremont Weir were implemented. A potential negative impact of notching the Fremont Weir is that it will affect stage height and Sutter Bypass flooding, and the resulting spawning and rearing of splittail and spring-run Chinook salmon. (personal communication R. Baxter.)

The NMFS Opinion stipulates that USBR and DWR, in cooperation with DFG, USFWS, NMFS, and USACE, shall, to the maximum extent of their authorities (excluding condemnation authority), provide significantly increased acreage of seasonal floodplain rearing habitat, with biologically appropriate durations and magnitudes, from December through April, in the lower Sacramento River basin, on a return rate of approximately one to three years, depending on water year type. (NMFS 3, p.608.) USBR and DWR are to submit a plan to implement this action to NMFS by December 31, 2011. (NMFS 3, p. 608.) This plan is to include an evaluation of options to, among other things, increase inundation of publicly and privately owned suitable acreage within the Yolo Bypass and modify operations of the Sacramento Weir or Fremont Weir to increase rearing habitat. (NMFS 3, p. 608.) The NMFS Opinion specifies that in the event that this action conflicts with Shasta Operations Actions I.2.1 to I.2.3 (e.g., carryover storage requirements), the Shasta Operations Actions shall prevail. (NMFS 3, p. 608.)

OMR Flows - Entrainment of splittail at the SWP and CVP export facilities is highest during adult spawning migrations and periods of peak juvenile abundance in the Delta. (Meng and Moyle 1995, Sommer et al. 1997.) The incidence of age-0 splittail entrainment increased during wet years when abundance was also high (Sommer et al. 1997.) However, analyses conducted by Sommer et al. (1997) suggested that entrainment at the export facilities did not have an important population-level effect. However, Sommer et al. (1997) noted that their evidence does not demonstrate that entrainment never affects the species. For example, if the core of the population's distribution were to shift toward the south Delta export facilities during a dry year, there could be substantial entrainment effects to a year-class. (Sommer et al. 1997.) Criteria for net OMR flows intended to protect salmon, delta smelt, and longfin smelt populations, as well as restrictions stipulated in the Opinions (NMFS 3, pp. 648-653; USFWS 2008) are likely to reduce the number of splittail entrained at the export facilities.

Table 12. Floodplain Inundation Criteria for Sacramento Splittail

Mechanism	Water Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Spawning and Rearing Habitat	AN / W	--	≥ 30 day floodplain inundation			--	--	--	--	--	--	--

Starry Flounder (*Platichthys stellatus*)

Status

Starry flounder is not listed pursuant to either the ESA or CESA.

Life History

Starry flounder is a native to the Bay-Delta Estuary. The geographic distribution of flounder is from Santa Barbara, California, to Alaska and in the western Pacific as far south as the Sea of Japan. (Miller and Lea 1972.) Starry flounder are important in both the recreational and commercial catch in both central and northern California. (Haugen 1992; Karpov et al. 1995.)

Starry flounder is an estuarine dependent species. (Emmett et al. 1991.) Spawning occurs in the Pacific Ocean near the entrance to estuaries and other freshwater sources between November and February. (Orcutt 1950.) Juveniles migrate from marine to fresh water between March and June and remain through at least their second year of life before returning to the ocean. (Baxter 1999.) Young individuals are found in Suisun Bay and Marsh and in the Delta. Older individuals range from Suisun to San Pablo bays. Maturity is reached by males at the end of their second year and by females in their third or fourth years. (Orcott 1950.)

Population abundance of young of the year and one year old starry flounder have been measured by the San Francisco Otter Trawl Study since 1980 and reported as an annual index. (Kimmerer et al. 2009.) The index declined between 2000 and 2002 but has since recovered to values in the 300 to 500 range. The median index value for the 29 years of record is 293.

Population Abundance Relationship to Flow

Starry flounder age-1 abundance in the San Francisco Bay otter trawl study is positively correlated with the March through June outflow of the previous year. (Kimmerer et al. 2009.) The mechanism underlying the abundance outflow relationship is not known but may be increased passive transport of juvenile flounder by strong bottom currents during high outflow years. (Moyle 2002.) There has been a decline in the abundance of flounder for any given outflow volume since 1987, presumably because of the invasion by the clam Corbula, however, the overall abundance-flow relationship is still statistically significant. (Kimmerer 2002a.)

Population Abundance Goal

The goal is to maintain the starry flounder population abundance index, as measured by the San Francisco Otter Trawl Study, in half of all years above the long term population median index value of 293.

Species-Specific Recommendations

Outflow recommendations were only received from the DFG. (DFG 1, p. 16.) DFG recommends maintaining X2 between 65 and 74 km between February and June. This corresponds to an average outflow of 11,400 to 26,815 cfs. Table 13 contains the criteria needed for protection of starry flounder. The purpose of this outflow criteria is to

maintain population abundance near the long term median index value of 293. This net Delta outflow criteria is similar to those proposed for the protection of longfin smelt, delta smelt, and *Crangon sp.* The State Water Board's criteria for Delta outflow for the protection of both longfin and delta smelt and *Crangon* will also protect starry flounder. The proposed outflow is consistent with DFG's recommendation for starry flounder. There is no information in the record to support criteria for inflows or hydrodynamics to protect starry flounder.

Table 13. Criteria for Delta Outflow to Protect Starry Flounder

Flow Type	Water Year Type	Jan	Feb	Mar	April	May	Jun
Net Delta Outflow	C	14,000 – 21,000			10,000 – 17,500		
	D	21,000 – 35,200			17,500 – 29,000		
	BN	35,200 – >50,000			29,000 – 42,000		
	AN	>50,000			>42,000		
	W	>50,000			>42,000		

California Bay Shrimp (*Crangon franciscorum*)

Status

The California bay shrimp is not listed pursuant to either ESA or CESA.

Life History

There are three native species of Crangon, collectively known as bay shrimp or grass shrimp, common to the San Francisco Estuary: *Crangon franciscorum, C. nigricauda*, and *C. nigromaculata.* (Hieb 1999.) Bay shrimp are fished commercially in the lower estuary and sold as bait. (Reilly et al. 2001.) *C. franciscorum* species is targeted by the commercial fishery because of its larger size. Bay shrimp are also important prey organisms for many fish in the estuary. (Hatfield, 1995.)

The California bay shrimp (*Crangon franciscorum*) is an estuary dependent species that is distributed along the west coast of North America from Alaska to San Diego. Larvae hatch from eggs carried by females in winter in the lower estuary or offshore in the Pacific Ocean. Most late-stage larvae and juvenile *C. franciscorum* migrate into the estuary and upstream to nursery areas between April and June. Juvenile shrimp are common in San Pablo and Suisun bays in high outflow years. Their center of distribution moves upstream to Honker Bay and the lower Sacramento and San Joaquin rivers during low flow years. (Hieb 1999.) Mature shrimp migrate back down to higher salinity waters after a four to six month residence in the upper estuary. (Hatfield 1985.) *C. franciscornum* mature at one year and may live up to two years. Some females hatch more than one brood of eggs during a breeding season.

Population abundance of juvenile *C. franiscorum* is measured by DFG's San Francisco Bay Study and is reported as an annual index. (Jassby et al. 1995, Hieb 1999.) Indices over the 29 years of record have varied from 31 to 588 with a median value of about 103.

Population Abundance and Relationship to Flow

There is a positive correlation between the abundance of *C. franciscorum* and net Delta outflow from March to May of the same year. (Jassby et al. 1995; Kimmerer et al. 2009.) The statistical relationship has remained constant since the early years of the San Francisco Bay Study, which began in 1980. The mechanism underlying the abundance relationship is not known but may be an increase in the passive transport of juvenile shrimp up-estuary by strong bottom currents during high outflows years. (Kimmerer et al. 2009, Moyle 2002, DFG 1992.) Other potential mechanisms include the effects of freshwater outflow on the amount and location of habitat, the abundance of food organisms and predators, and the timing of the downstream movement of mature shrimp. (DFG 1, p. 23.)

Delta outflow recommendations (Table 14) were received from both the DFG (DFG 1, p. 23) and TBI/NRDC. (TBI/NRDC 2, p. 17). TBI/NRDC analyzed the productivity of *C. franciscorum* as a function of net Delta outflow between March and May. The analysis suggests that estuary populations increased in about half of all years when flows between March and May were approximately 5 million acre-feet (MAF), or about 28,000 cfs per month. TBI/NRDC recommended that flow be maintained in most years above 28,000 cfs during these three months to insure population growth about half the time. The DFG recommended a net Delta outflow criterion of 11,400 to 26,800 cfs between February and June of all water years to aid immigration of late stage larvae and small juveniles.

Table 14. Participant Recommendations for Delta Outflows to Protect Bay Shrimp

	Water Year	Feb	Mar	Apr	May	Jun
TBI/NRDC Exhibit 2	Most years		28,000			
Fish and Game Exhibit 1	all	11,400 to 26,815				

Population Abundance Goal

The goal is to maintain the juvenile C. *franciscorum* population abundance index, as measured by the San Francisco Bay Study otter trawl, in half of all years above a target value of 103. An index of 103 is the median longterm index value for this species in the San Francisco Estuary.

Species-Specific Recommendations

The State Water Board determines the Delta outflow criteria in Table 15 are needed to protect C*rangon franciscorum*. The purpose of the outflow criteria is to maintain population abundance at a long term median index value of 103. Positive population growth is expected in half of all years under these flow conditions. The Delta outflow criteria are similar to those proposed for protection of both longfin smelt and delta smelt. The nursery area for C. *franciscorum* is usually downstream of the influence of the pumps, therefore no OMR flow recommendations were received and no review was conducted.

Table 15. Criteria for Delta Outflows to Protect Bay Shrimp

Flow Type	Water Year Type	Jan	Feb	Mar	April	May
Net Delta Outflow	C	14,000 – 21,000			10,000 – 17,500	
	D	21,000 – 35,200			17,500 – 29,000	
	BN	35,200 – >50,000			29,000 – 42,000	
	AN	>50,000			>42,000	
	W	>50,000			>42,000	

Zooplankton (*E. affinis* and *N. mercedis*)

Status

Eurytemora affinis is a non-native species that is not listed pursuant to either the ESA or CESA. *Neomysis mercedis* is a native species that is not listed pursuant to either the ESA or CESA.

Life History[14]

Zooplankton is a general term for small aquatic animals that constitute an essential food source for fish, especially young fish and all stages of pelagic fishes that mature at a small size, such as longfin smelt and delta smelt (DFG 1987b). Although DFG follows trends of numerous zooplankton taxa (e.g., Hennessy 2009), two upper estuary zooplankton taxa of particular importance to pelagic fishes have exhibited abundance relationships to Delta outflow. The first is the mysid shrimp *Neomysis mercedis*, which before its decline, beginning in the late 1980s, was an important food of most small fishes in the upper estuary (see Feyrer et al. 2003). Prior to 1988, *N. mercedis* mean summer abundance (June through October) increased significantly as X2 moved downstream (mean March through November location, Kimmerer 2002a. Table 1). After 1987, *N. mercedis* abundance declined rapidly and is currently barely detectable (Kimmerer 2002a, Hennessy 2009). The second is a calanoid copepod, *Eurytemora affinis*, which also declined sharply after 1987, but more so in summer than in spring (Kimmerer 2002a). Before 1987, *E. affinis* was abundant in the low salinity habitat (0.8-6.3 ‰) throughout the estuary (Orsi and Mecum 1986). *E. affinis* is an important food for most small fishes, particularly those with winter and early spring larvae, such as longfin smelt, delta smelt and striped bass (Lott 1998, Nobriga 2002, Bryant and Arnold 2007, DFG unpublished).

Population Abundance and Relationship to Flow

E. affinis was historically abundant throughout the year, particularly in spring and summer, but after 1987 abundance declined in all seasons, most notably in summer and fall. (Hennessy 2009, as cited in DFG 1, p. 26.) After 1987, *E. affinis* spring abundance (March through May) has significantly increased as spring X2 has moved downstream. (Kimmerer 2002a. Table 1, as cited in DFG 1, p. 26.) Relative abundance in recent years is highest in spring and persistence of abundance is related to spring outflow. As flows decrease in late spring, abundance decreases to extremely low levels throughout the estuary. (Hennessey 2009, as cited in DFG 1, p. 26.)

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[14] This section was largely extracted from DFG Exhibit 1, page 25.

The only outflow recommendation identified in the record specifically for *E. affinis* and *N. mercedis* was submitted by DFG, in their closing comments (Table 16). According to DFG, their current science-based conceptual model is that placement of X2 in Suisun Bay represents the best interaction of water quality and landscape for fisheries production given the current estuary geometry. (DFG 2, p. 6.) Maintaining X2 at 75 km and 64 km corresponds to net Delta outflows of approximately 11,400 cfs and 29,200 cfs, respectively. The Bay Institute provided flow recommendations for a suite of species, including *E. affinis (*Table 17*).*

Table 16. DFG's Delta Outflow Recommendation to Protect *E. affinis* and *N. mercedis* (DFG Closing Comments)

Species	Parameter	Effect or Mechanism	Timing	Minimum	Maximum	Reference
Zooplankton	Flows	Habitat	February - June	X2 at 75 km	X2 at 64 km	DFG Exhibit 1, p.25-26; Exhibit 2, p.6

Table 17. The Bay Institute's Delta Outflow Recommendations to Protect Zooplankton Species Including *E. affinis*

Species	Mechanism	Water Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Eurytemora affinis	Habitat	81-100% (driest years)	14000-21000 cfs		10000-17500 cfs			3000-4200 cfs						
		61-80%	21000-35000 cfs		17500-29000 cfs			4200-5000 cfs						
		41-60%	35200-55000 cfs		29000-42500 cfs			5000-8500 cfs						
		21-40%	55000-87500 cfs		42500-62500 cfs			8500-25000 cfs						
		0-20% (wettest years)	87500-140000 cfs		62500-110000 cfs			25000-50000 cfs						

Species-Specific Recommendations
Table 18 shows the State Water Board's determination for Delta outflows needed to protect zooplankton. These recommendations are consistent with those submitted by DFG. (closing comments, p. 7.) The State Water Board concurs with DFG's current science-based conceptual model which concludes that placement of X2 in Suisun Bay represents the best interaction of water quality and landscape for fisheries production given the current estuary geometry. (DFG 2, p. 6.) Maintaining X2 at 75 km and 64 km corresponds to net Delta outflows of approximately 11,400 cfs and 29,200 cfs,

respectively. No explicit recommendations concerning zooplankton and inflow or hydrodynamic requirements were identified in the record.

Table 18. Criteria for Delta Outflows to Protect Zooplankton

Effect or Mechanism	Water Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Habitat	All	--		X2[1] – 75 to 64 km (~11400 – 29200 cfs)				--	--	--	--	--	--

4.3   Other Measures

Information in the record for this proceeding broadly supports the five key points submitted by the DEFG of experts (DEFG 1):

1) Environmental flows are more than just volumes of inflows and outflows
2) Recent flow regimes both harm native species and encourage non-native species
3) Flow is a major determinant of habitat and transport
4) Recent Delta environmental flows are insufficient to support native Delta fishes for today's habitats
5) A strong science program and a flexible management regime are essential to improving flow criteria

These key points recognize that although adequate environmental flows are a necessary element to protect public trust resources in the Delta ecosystem, flows alone are not sufficient to provide this protection. These key points and other information in the record warrant a brief summary discussion of other information in the record that should be considered in the development of flow criteria, consistent with the charge of SB1 that "the flow criteria include the volume, quality, and timing of water necessary for the Delta ecosystem. " Based on review of the information in the record this charge is expanded to include specific consideration of:

- Variability, flow paths, and the hydrograph
- Floodplain activation and other habitat improvements
- Water quality and contaminants
- Cold water pool management
- Adaptive management

4.3.1 Variability, Flow Paths, and the Hydrograph

The first of the five key points submitted by the DEFG of experts stated, in part: "There is no one correct flow number. Seasonal, interannual, and spatial variability, to which our native species are adapted, are as important as quantity." Species and biological systems respond to combinations of quantity, timing, duration, frequency and how these inputs vary spatially. (DEFG 1.) Based on their review of the literature in *Habitat Variability and Complexity in the Upper San Francisco Estuary*, Moyle *et al* (2010) find:

"… unmodified estuaries are highly variable and complex systems, renowned for their high production of fish and other organisms (McClusky and Elliott 2004). The San Francisco Estuary, however, is one of the most highly modified and controlled estuaries in the world (Nichols et al. 1986). As a consequence, the

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estuarine ecosystem has lost much of its former variability and complexity and has recently suffered major declines of many of its fish resources (Sommer et al. 2007).

…the concept of the "natural flow regime" (Poff et al. 1997) is increasingly regarded as an important strategy for establishing flow regimes to benefit native species in regulated rivers (Postel and Richter 2003; Poff et al. 2007; Moyle and Mount 2007). For estuaries worldwide, the degree of environmental variability is regarded as fundamental in regulating biotic assemblages (McLusky and Elliott 2004). Many studies have shown that estuarine biotic assemblages are generally regulated by a combination of somewhat predictable changes (e.g., tidal cycles, seasonal freshwater inflows) and stochastic factors, such as recruitment variability and large-scale episodes of flood or drought (e.g., Thiel and Potter 2001). The persistence and resilience of estuarine assemblages is further decreased by various human alterations, ranging from diking of wetlands, to regulation of inflows, to invasions of alien species (McLusky and Elliott 2004, Peterson 2003).

…a key to returning the estuary to a state that supports more of the desirable organisms (e.g., Chinook salmon, striped bass, delta smelt) is increasing variability in physical habitat, tidal and riverine flows, and water chemistry, especially salinity, over multiple scales of time and space. It is also important that the stationary physical habitat be associated with the right physical-chemical conditions in the water at times when the fish can use the habitat most effectively (Peterson 2003)."

An example of a major change in the natural flow regime of the Delta is demonstrated by the increase in net OMR reverse flows just north of the SWP and CVP pumping facilities. Reverse flows are now a regular occurrence in the Delta channels because Sacramento River water enters on the northern side of the Delta while the two major pumping facilities, the SWP and CVP, are located in the south. This results in a net water movement across the Delta in a north-south direction along a web of channels including OMR instead of the more natural pattern from east to west or from land to sea. Positive net flows, connected flow paths, and salinity gradients are important features of an estuary. Natural net channel flows move water and some biota toward Suisun Bay and maintain downstream directed salinity gradients. Today, Delta gates and diversions can substantially redirect tidal flows creating net flow patterns and salinity and turbidity distributions that did not occur historically. These changes may influence migratory cues for some fishes. These cues are further scrambled by a reverse salinity gradient in the south Delta caused by higher salinity in agricultural runoff. (DEFG 1.)

Per the DEFG's paper, *Habitat Variability and Complexity in the Upper San Francisco Estuary* (Moyle et al., 2010), a more variable Delta has multiple benefits:

"Achieving a variable, more complex estuary requires establishing seaward gradients in salinity and other water quality variables, diverse habitats throughout the estuary, more floodplain habitat along inflowing rivers, and improved water quality. These goals in turn encourage policies which: (1) establish internal Delta flows that create a tidally-mixed, upstream-downstream gradient (without cross-Delta flows) in water quality; (2) create slough networks with more natural channel

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geometry and less diked rip-rapped channel habitat; (3) improve flows from the Sacramento and San Joaquin rivers; (4) increase tidal marsh habitat, including shallow (1-2 m) subtidal areas, in both fresh and brackish zones of the estuary; (5) create/allow large expanses of low salinity (1-4 ppt) open water habitat in the Delta; (6) create a hydrodynamic regime where salinities in parts of the Delta and Suisun Bay and Marsh range from near-fresh to 8-10 ppt periodically (does not have to be annual) to discourage alien species and favor desirable species; (7) take species-specific actions that reduce abundance of non-native species and increase abundance of desirable species; (8) establish abundant annual floodplain habitat, with additional large areas that flood in less frequent wet years; (9) reduce inflow of agricultural and urban pollutants; and (10) improve the temperature regime in large areas of the estuary so temperatures rarely exceed 20°C during summer and fall months."

Similarly, reliance upon water year classification as a trigger for flow volumes has contributed to reduced flow variability in the estuary. The information received during this proceeding supports the notion that reliance upon water year classification as a trigger for flow volumes is an imperfect means of varying flows. Any individual month or season might have a dramatically different hydrology than the overall hydrology for the year. A critically dry year, for example, can have one or two very wet months, just as a wet year may have several disproportionately dry months. Figure 10 demonstrates how this actually occurs. Unimpaired Delta outflow for the month of June from 1922 through 2003 has historically been highly variable. Many June months that occur in years classified as wet have had much lower flows than June flows in years classified as below normal. The opposite is also true; several June flows in years classified as critically dry are higher than some years classified as above normal. Depending on the direction of this divergence of monthly flows (higher or lower) relative to the water year, reliance upon water year classification can provide less than optimal protection of the ecosystem or more than needed water supply impacts. The figure also shows the actual June flows for various periods of years, demonstrating how much lower actual flows have been than unimpaired flows. The primary reason for the lower historical flows is consumption of water in the watershed. The three periods shown, however, are not directly comparable to the unimpaired flow record because the shorter time frame may have been wetter or drier than the full historical record.

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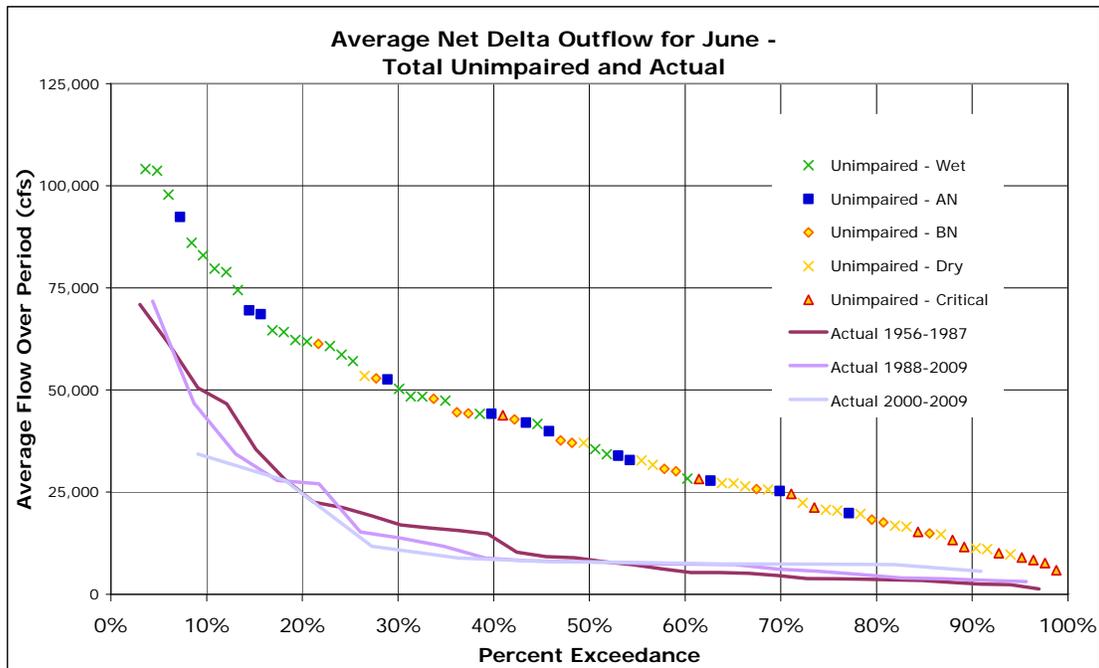
Figure 10. Actual and Unimpaired June Delta Outflow

Proportionality is one of the key attributes of restoring ecosystem functions by mimicking the natural hydrograph in tributaries to the Delta and providing for connectivity. Currently, inflows to the Delta are largely controlled by upstream water withdrawals and releases for water supply, power production, and flood control. As a result, inflows from tributaries frequently do not contribute flow to the Delta in the same proportions as they would have naturally, and to which native fish adapted. There is consensus in contemporary science that improving ecosystem function in the watershed, mainstem rivers, and the Delta is a means to improving productivity of migratory species. (e.g.,Williams 2005; NRC 1996, 2004a, 2004b as cited in NAS 2010, p. 42.) NAS found that, "Watershed actions would be pointless if mainstem passage conditions connecting the tributaries to, and through, the Delta were not made satisfactory." (NAS 2010, p. 42.) "Propst and Gido (2004) support this hypothesis and suggest that manipulating spring discharge to mimic a natural flow regime enhances native fish recruitment (Propst and Gido, 2004 and Marchetti and Moyle, 2001)." (DOI, 1 p. 25.) Specifically, providing pulse flows to mimic the natural hydrograph could diversify ocean entry size and timing for anadromous fishes so that in many years at least some portion of the fish arrive in saltwater during periods favoring rapid growth and survival. (DOI 1, p. 30.) Food production may also be improved by maintaining the attributes of a natural hydrograph (EFG 1, p. 8.) Connectivity between natal streams and the Delta is critical for anadromous species that require sufficient flows to emigrate out of natal streams to the Delta and ocean, and sufficient flows upon returning, including flows necessary to achieve homing fidelity. Specifically, it is necessary for the scent of the river to enter the Bay in order for adult salmonids to find their way back to their natal river. (NMFS 2009, p.407 as cited in EDF 1, p. 48.) Further, insuring adequate flows from all of the tributaries that support native fish is important to maintain genetic diversity and species resilience in the face of catastrophic events.

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4.3.2 Floodplain Activation and Other Habitat Improvements

Most floodplains in the Central Valley have been isolated from their rivers by levees. Due to the effects of levees and dams, side channel and floodplain inundating flows have been substantially reduced. At present, besides the Yolo Bypass, the only other Delta region with substantial connectivity to portions of the historical floodplain is the Cosumnes River, a small undammed watershed. (Sommer et al. 2001b.) Floodplains are capable of providing substantial benefits to numerous aquatic, terrestrial, and wetland species. (Sommer et al. 2001b.) Inundation of floodplains facilitates an exchange of organisms, nutrients, sediment, and organic material between the river and floodplain, and provides a medium in which biogeochemical processes and biotic activity (e.g., phytoplankton blooms, zooplankton and invertebrate growth and reproduction) can occur. (AR/NHI 1, p. 22.) This exchange of material can benefit downstream areas. For example, studies suggest phytoplankton, zooplankton, and other organic material transported from the Yolo Bypass enhances the food web of the San Francisco Estuary. (Jassby and Cloern 2000; Mueller-Solger et al. 2002; Sommer et al. 2004.)

Many fishes rear opportunistically on floodplains. (Moyle et al. 2007, as cited in Moyle et al. 2010), and juvenile salmon grow faster and become larger on floodplains than in the main-stem river channels. (Sommer et al. 2001a; Jeffres et al. 2008; DOI 1, p. 27; AR/NHI 1, p. 24.) Splittail require floodplains for spawning (Moyle et al. 2007), with large-scale juvenile recruitment occurring only in years with significant protracted (greater than or equal to 30 days) floodplain inundation, particularly in the Sutter and Yolo bypasses. (Meng and Moyle 1995, Sommer et al. 1997, Feyrer et al. 2006a.) Managing the frequency and duration of floodplain inundation during the winter and spring, followed by complete drainage by the end of the flooding season, could favor splittail and other native fish over non-natives. (Moyle et al. 2007, Grimaldo et al. 2004.) In addition, modeling conducted by Moyle et al. (2004) shows that while splittail are resilient, managing floodplains to promote frequent successful spawning is needed to keep them abundant. Improving management of the Yolo Bypass for fish, increasing floodplain areas along other rivers (e.g., Cosumnes and Mokelumne rivers), and developing floodplain habitat along the lower San Joaquin River, including a bypass in the Delta, represent opportunities to increase the frequency and extent of floodplain inundation. (Moyle et al. 2010.) The BDCP is currently evaluating structural modifications to the Fremont Weir (e.g., notch weir and install operable "inundation gates"), as a means of increasing the interannual frequency and duration of floodplain inundation in the Yolo Bypass. (BDCP 2009.)

The NMFS Opinion stipulates that USBR and DWR, in cooperation with DFG, USFWS, NMFS, and USACE, shall, to the maximum extent of their authorities (excluding condemnation authority), provide significantly increased acreage of seasonal floodplain rearing habitat, with biologically appropriate durations and magnitudes, from December through April, in the lower Sacramento River basin, on a return rate of approximately one to three years, depending on water year type. (NMFS 3, p. 608.) Per this NMFS Opinion, USBR and DWR are to submit a plan to implement this action to NMFS by December 31, 2011. (Id.) This plan is to include an evaluation of options to, among other things, increase inundation of publicly and privately owned suitable acreage within the Yolo Bypass, and modify operations of the Sacramento Weir or Fremont Weir to increase rearing habitat. (Id.)

Moyle et al. (2010) discuss the value of creating more slough networks with natural geometry and less diked, rip-rapped channel habitat, the value of tidal marsh habitat, and low salinity, open water habitat in the Delta:

> "Re-establishing the historical extensive dendritic sloughs and marshes is essential for re-establishing diverse habitats and gradients in salinity, depth and other environmental characteristics important to desirable fish and other organisms (e.g., Brown and May 2008). These shallow drainages are likely to increase overall estuarine productivity if they are near extensive areas of open water, because they can deliver nutrients and organic matter to the more open areas. Dendritic slough networks will develop naturally in Suisun Marsh after large areas become inundated following dike failures and they can be recreated fairly readily in the Cache Slough region by reconnecting existing networks. In the Delta, the present simplified habitat in the channels between islands needs to be made more suitable as habitat for desirable species. Many levees are maintained in a nearly vegetation-free state, providing little opportunity for complex habitat (e.g., marshes and fallen trees) to develop. Much of the low-value channel habitat in the western and central Delta will disappear as islands flood, but remaining levees in submerged areas should be managed to increase habitat complexity (e.g., through planting vegetation), especially in the cooler northern and eastern parts of the Delta.
>
> [Subtidal] habitat has been greatly depleted because marshes in the Delta and throughout the estuary have been diked and drained, mostly for farming and hunting (Figure 3). Unfortunately, most such habitat in shallow water today is dominated by alien fishes, including highly abundant species such as Mississippi silverside which are competitors with and predators on native fishes (Moyle and Bennett 1996; Brown 2003). Such habitat could become more favorable for native fishes with increased variability in water quality, especially salinity. In particular, increasing the amount of tidal and subtidal habitat in Suisun Marsh should favor native fishes, given the natural variability in salinity and temperature that occurs there. The few areas of the marsh with natural tidal channels tend to support the highest diversity of native fishes, as well as more striped bass (Matern et al. 2002; Moyle, unpublished data). With sea level rise, many diked areas of Suisun Marsh currently managed for waterfowl (mainly dabbling ducks and geese) will return to tidal marsh and will likely favor native fishes such as splittail and tule perch (Hysterocarpus traski), as well as (perhaps) migratory fishes such as juvenile Chinook salmon. Experimental (planned) conversions of some of these areas would be desirable for learning how to manage these inevitable changes to optimize habitat for desired fishes.
>
> Open water habitat is most likely to be created by the flooding of subsided islands in the Delta, as well as diked marshland 'islands' in Suisun Marsh (Lund et al. 2007, 2010; Moyle 2008). The depth and hydrodynamics of many of these islands when flooded should prevent establishment of alien aquatic plants while variable salinities in the western Delta should prevent establishment of dense populations of alien clams (Lund et al. 2007).

Although it is hard to predict the exact nature of these habitats, they are most likely to be better habitat for pelagic fishes than the rock-lined, steep-sided and often submerged vegetation-choked channels that run between islands today (Nobriga et al. 2005). Experiments with controlled flooding of islands should provide information to help to ensure that these changes will favor desired species. Controlled flooding also has the potential to allow for better management of hydrodynamics and other characteristics of flooded islands (through breach location and size) than would be possible with unplanned flooding."

4.3.3 Water Quality and Contaminants

Toxic effects are one of three general factors identified by scientists with the IEP in 2005 as contributing to the decline in pelagic productivity. The life history requirements and water quality sections above identify specific species sensitivities to water quality issues.

Though the information received in this proceeding supports the recommendation that modification to flow through the Delta is a necessary first step in improving the health of the ecosystem, it also supports the recommendation that flow alone is insufficient. The Delta and San Francisco Bay are listed under section 303(d) of the Federal Clean Water Act as impaired for a variety of toxic contaminants that may contribute to reduced population abundance of important fish and invertebrates. The contaminants include organophosphate and pyrethrin pesticides, mercury, selenium and unknown toxicity. In addition, low DO levels periodically develop in the San Joaquin River at the DWSC and in OMR. The low oxygen levels in the DWSC inhibit the upstream migration of adult fall-run Chinook salmon and adversely impact other resident aquatic organisms.

There is concern that a number of non-303(d) listed contaminants, such as ammonia, pharmaceuticals, endocrine disrupting compounds, and blue-green algal blooms could also limit biological productivity and impair beneficial uses. Sources of these contaminants include agricultural, municipal and industrial wastewater, urban storm water discharges, discharges from wetlands, and channel dredging activities. More work is needed to determine their impact on the aquatic community.

Ammonia has emerged as a contaminant of special concern in the Delta. Recent hypotheses are that ammonia is causing toxicity to delta smelt, other local fish, and zooplankton and is reducing primary production rates in the Sacramento River below the SRWTP and in Suisun Bay. A newer hypothesis is that ammonia and nitrogen to phosphorus ratios have altered phytoplankton species composition and these changes have had a detrimental effect on zooplankton and fish population abundance. (Glibert 2010.) More experiments are needed to evaluate the effect of nutrients, including ammonia, on primary production and species composition in the Sacramento River and Delta.

4.3.4 Cold Water Pool Management

As mentioned in the specific flow criteria, the criteria contained in this report should be tempered by the additional need to maintain cold water resources in reservoirs on tributaries to the Delta until improved passage and other measures are taken that would reduce the need for maintaining cold water reserves in reservoirs. As discussed in the Chinook salmon section, salmon have specific temperature tolerances during various portions of their life-cycle. Historically salmonids were able to take advantage of cooler

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upstream temperatures for parts of their life-cycle to avoid adverse temperature effects. Since construction of the various dams in the Central Valley, access to much of the cooler historic spawning and rearing habitat has been blocked. To mitigate for these impacts, reservoirs must be managed to preserve cold water resources for release during salmonid spawning and rearing periods. As reservoir levels drop, availability of cold water resources also diminishes. Accordingly, it may not be possible to attain all of the identified flow criteria in all years and meet the thermal needs of the various runs of Chinook salmon and other sensitive species. Thorough temperature and water supply modeling analyses should be conducted to adaptively manage any application of these flow criteria to suit real world conditions and to best manage the competing demands for water needed for the protection of public trust resources, especially in the face of future climate change.

Specifically, these criteria should not be construed as contradicting existing and future cold water management requirements that may be needed for the protection of public trust resources, including those for the Sacramento River needed to protect the only remaining population of winter-run Chinook salmon. (see NMFS 3, p. 590-603.)

4.3.5 Adaptive Management

Any environmental flow prescription for native species in the Delta will be imperfect. The problem is too complex, uncertainties are too large, and the situation in the Delta is changing too rapidly in too many ways for any single flow prescription to be correct, or correct for long. (Fleenor et al. 2010.) Some degree of certainty regarding future conditions in the Delta is needed before long term flow criteria can be developed. Since it is unlikely that certainty will be achieved before actions or responses are required by geologic, biological, and legal processes, it might be valuable to provide substantial financial and water reserve resources, along with responsible institutional wherewithal to respond to changes and undertake necessary experiments for more successfully transitioning into the largely unexplored new Delta. (Fleenor et al. 2010.) This confounding need for certainty of operations and water supply at the same time there is uncertainty underlying ecosystem needs, provides good rationale to rely upon adaptive management to address this uncertainty.

The Delta is continually changing. Flow criteria developed for the present Delta ecosystem will become less reflective of ecosystem needs with the passage of time. Accordingly, it is important that flow criteria be adaptive to future changes. Flows, habitat restoration, and measures to address other stressors should be managed adaptively. (AR/NHI Closing Comments.)

Adaptive management is "an iterative process, based on a scientific paradigm that treats management actions as experiments subject to modification, rather than as fixed and final rulings, and uses them to develop an enhanced scientific understanding about whether or not and how the ecosystem responds to specific management actions." (NRC 1999 as cited in DOI Ex.1.) This notion of treating actions as experiments is key, because information received in this proceeding indicates that the mechanisms underlying the relationship between flows and the health of the Delta ecosystem are, at times, unclear. Adaptive management is the most suitable approach for managing with uncertainty. (DEFG 1.)

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Murray and Marmorek (2004) describe an adaptive management approach as:

- exploring alternative ways to meet management objectives
- predicting the outcomes of alternatives based on the current state of knowledge
- implementing one or more of these alternatives
- monitoring to learn about the impacts of management actions
- using the results to update knowledge and adjust management actions

An adaptive approach provides a framework for making good decisions in the face of critical uncertainties, and a formal process for reducing uncertainties so that management performance can be improved over time. (Williams et al. 2007.)

Adaptive management does not postpone action until "enough" is known but acknowledges that time and resources are too short to defer *some* action, particularly actions to address urgent problems. (Lee 1999.) Adaptive management provides a means of informing planning and management decisions in spite of uncertainty. Key point number 5 of the DEFG states: "a strong science program and a flexible management regime are essential to improving flow criteria. (DEFG 1.)

Adaptive management can be used to manage uncertainty in two ways, over two time frames. Over the short-term, adaptive management could allow for a specific response to real time conditions so long as the response is otherwise consistent with the constraints of some overarching regulatory framework. Over the longer term, adaptive management could allow for the more nimble modification of regulatory constraints, so long as these modifications fell within the clearly defined parameters of the overarching regulatory framework.

Short-term Adaptive Management
Per the DEFG's assessment regarding the role of uncertainty…

> "…despite [our] extensive scientific understanding substantial knowledge gaps remain about the ecosystem's likely response to flows. First, ecosystem processes in a turbid estuary are mostly invisible, and can be inferred only through sampling. Second, monitoring programs only scratch the surface of ecosystem function by estimating numbers of fish and other organisms, whereas the system's dynamics depend on birth, growth, movement, and death rates which can rarely be monitored. Third, this system is highly variable in space (vertical, cross-channel, along-channel, and larger-scale), time (tidal, seasonal, and interannual), flow, salinity, temperature, physical habitat type, and species composition. Each of the hundreds of species has a different role in the system, and these differences can be subtle but important. As a result, we have little ability to predict how the ecosystem will respond to the numerous anticipated deliberate and uncontrolled changes." (DEFG 1.)

Flexible management can be designed into a regulatory framework so that any requirements rely upon real time information and real time decisions to guide specific real-time action. A current example of this is the Delta Smelt Working Group that provides information and analyses used to guide real time operation of export facilities so that these facilities can be operated in a manner that conforms with the current NMFS

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and USFWS opinions. Any such flexible management will need to consider the processes and governance structures required to make sound sciencfically-based real-time decisions. The Delta Smelt Working Group is a good example of how scientific assessment of real-time data, including the presence of fish, can better inform the real-time operation of export facilities.

Long-term Adaptive Management
Over the longer term, adaptive management can be used to more nimbly modify regulatory constraints so that fishery and water resource agencies are not locked into prescriptive constraints well past the time that current scientific understanding can support. This longer term adaptive management has bearing on a number of the flow criteria being considered in this report because many of these criteria lack sufficiently robust information to support a specific numeric criterion. Although the functional basis for a beneficial flow may be understood, the basis for a specific numeric criteria may not. Some regulatory flows may therefore need to take the form of an informed experimental manipulation. Such flows would need to be implemented… "as if they were experiments, with explicit conceptual and simulation models, predicting outcomes, and feedback loops so that the course of management and investigation can change as the system develops and knowledge is gained. A talented group of people tasked to integrate, synthesize, and recommend actions based on the data being gathered are essential for making such a system work. Failure to implement an effective adaptive management program will likely lead to a continued failure to learn from the actions, and a lack of responsiveness to changing conditions and increased understanding." (DEFG 1.)

The Delta Science Program, IEP, and other institutions could be relied upon to evaluate experimental flows and make recommendations to be considered for modifications of such flows.

4.4   Expression of Criteria as a Percentage of Unimpaired Flow

In some cases, participants' recommendations were expressed as specific flows in specific months, to be applied during specific water year types or with specified probabilities of exceedance. Review of unimpaired hydrology shows there is great variability in the quantity of unimpaired flow during these specified months when categorized by water year type. Reliance upon monthly or seasonal flow prescriptions based on water year type would therefore result in widely ranging relative amounts of unimpaired flow depending upon the specific hydrology of the month or season. Also, the rather coarse division of the hydrograph into five water year types can lead to abrupt step-wise changes in flow requirements. In an attempt to more closely reflect the variation of the natural hydrograph, the State Water Board recommends that, when possible, the flow criteria be expressed as a percentage of unimpaired flow.

To develop criteria in this way, the unimpaired flow rate for a specified time period (e.g. average monthly flow over a range of months) was plotted on an exceedance probability graph (using the Weibull plotting position formula) along with the flow recommendations and desired return frequencies. The unimpaired flow rates were also plotted such that the associated water year type can be identified and their percent exceedance estimated. A percentage of unimpaired flow was selected by trial and error so that the desired flow rate and exceedance frequency was achieved. A separate exceedance plot was produced for each time period being evaluated.

The unimpaired flow estimates used in the development of these flow criteria are based on those developed in the DWR May 2007 document: *"California Central Valley Unimpaired Flow Data" Fourth Edition Draft.* (DWR 2007.) This report contains estimates of the monthly flow for 24 sub-basins in the Central Valley. Each sub-basin uses a separate calculation dependant on conditions specific to that sub-basin, available gauge data, and relationships to other sub-basins. In many cases the methods change over the period of record to incorporate changes to infrastructure within the sub-basins that need to be accounted for. Estimates are provided for 83 water years from 1922 through 2003. A water year begins in October of the previous calendar year through September of the named water year. The following describes the unimpaired flow estimates that are the basis for flow criteria for the Sacramento River at Rio Vista, the San Joaquin River at Vernalis, and Net Delta Outflow.

Sacramento Valley Unimpaired Total Outflow

Estimates of the unimpaired Sacramento Valley outflow were computed as the sum of estimates from 11 sub-basins in the watershed and are understood to represent the flow that would occur on the Sacramento River at approximately Freeport. These 11 sub-basins include the Sacramento Valley Floor, Putah Creek near Winters, Cache Creek above Rumsey, Stony Creek at Black Butte, Sacramento Valley West Side Minor Streams, Sacramento River near Red Bluff, Sacramento Valley East Side Minor Streams, Feather River near Oroville, Yuba River at Smartville, Bear River near Wheatland, and the American River at Fair Oaks.

The unimpaired Sacramento Valley outflow from DWR 2007 is used as the basis for flow criteria on the Sacramento River at Rio Vista, even though it is understood they are more representative of unimpaired flows expected at Freeport. This is a necessary simplification as such estimates do not exist at Rio Vista, but should be adequate for the purpose of these criteria. If future flow requirements are to be established at Rio Vista based on a percentage of unimpaired flow, it is recommended that new estimates of unimpaired flow be developed specific for this location.

San Joaquin Valley Unimpaired Total Outflow

Estimates of the unimpaired San Joaquin Valley outflow were computed as the sum of estimates from nine sub-basins in the watershed and are understood to represent the flow that would occur on the San Joaquin River at Vernalis. These nine sub-basins include the Stanislaus River at Melones Reservoir, San Joaquin Valley Floor, Tuolumne River at Don Pedro Reservoir, Merced River at Exchequer Reservoir, Chowchilla River at Buchanan Reservoir, Fresno River near Daulton, San Joaquin River at Millerton Reservoir, Tulare Lake Basin Outflow, San Joaquin Valley West Side Minor Streams.

Delta Unimpaired Total Outflow

Estimates of unimpaired Net Delta Outflow in DWR 2007 were computed generally as Delta Unimpaired Total Inflow minus unimpaired net use in the Delta, including both lowlands and uplands. Delta Unimpaired Total Inflows was calculated as the sum of the Sacramento Valley and San Joaquin Valley Unimpaired Total Outflows as described above and the East Side Streams Unimpaired Total Outflow. The later consists of four sub-basins including San Joaquin Valley East Side Minor Streams, Cosumnes River at Michigan Bar, Mokelumne River at Pardee Reservoir, and Calaveras River at Jenny Lind. Generally the unimpaired net use in the Delta is an estimate of the consumptive

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use from riparian and native vegetation (replacing historical irrigated agriculture and urban areas), plus evaporation from water surfaces, minus precipitation, and assumes that existing Delta levees and island remain intact. Unimpaired flow graphs in this report use the unimpaired flow record from 1922 to 2003.

5. Flow Criteria

Two types of criteria are provided in this report: numeric flow criteria, and other, non-numeric, measures that should be considered to complement the numeric criteria. Numeric criteria are subdivided into two categories: category "A" criteria have more and better scientific information, with less uncertainty, to support specific numeric criteria than do Category "B" criteria. Summary numeric criteria are provided for Delta outflow, as well as Sacramento River and San Joaquin River inflows, and Hydrodynamics (Old and Middle River, Inflow-Export Ratios, and Jersey Point flows) in Tables 19 through 22.

In addition to new criteria for Delta outflows, inflows, and hydrodynamics, some of the objectives for the protection of fish and wildlife from the 2006 Bay-Delta Plan are advanced as criteria in this report. While the State Water Board did not specifically reevaluate the methodology and basis for the Bay-Delta Plan objectives, the State Water Board recognizes that these flows provide some level of existing protection for fish and wildlife and, in the absence of more specific information, merit inclusion in these criteria. At the time the Bay-Delta Plan objectives were adopted, they were supported by substantial evidence, including scientific information. While the purpose of this report is to develop flow criteria using best available scientific information, water quality objectives are established taking into account scientific and other factors pursuant to Water Code section 1241.

5.1   Delta Outflows

Following are Delta outflow criteria based on analysis of the species-specific flow criteria and other measures:

1) Net Delta Outflow: 75% of 14-day average unimpaired flow for January through June
2) Fall X2 for September through November
    - Wet years X2 less than 74 km (greater than approximately 12,400 cfs)
    - Above normal years X2 less than 81 km (greater than approximately 7,000 cfs)
3) 2006 Bay-Delta Plan Delta Outflow Objectives for July through December

Delta outflow criteria 1 is a Category A criterion because it is supported by more robust scientific information. Delta outflow criteria 2 and 3 are Category B criteria because there is less scientific information to support specific numeric criteria, but there is enough information to support the conceptual need for flows. Category A and B criteria are both equally important for protection of the public trust resource, but there is more uncertainty about the appropriate volume of flow required to implement Category B criteria. Following is discussion and rationale for these criteria.

The narrative objective of the flow criteria is to halt the population decline and increase populations of native species as well as species of commercial and recreational importance. The need to estimate the magnitude, duration, timing, and quality of Delta outflows necessary to support viable populations of these species is inherent to this

objective. McElhany et al. (2000) proposed that four parameters are critical for evaluating population viability: abundance, population growth rate, population spatial structure, and diversity. Delta outflow may affect one, all, or some combination of these parameters for a number of resident and anadromous species. A species-specific analysis of flow needs for a suite of upper estuary species is included in section 4.2.4.

An analysis of generation to generation population abundance versus Delta outflows indicates that the "likelihood" of an increase in the longfin smelt FMWT abundance index in 50% of years corresponded with flow volumes of approximately 9.1 MAF (51,000 cfs) and 6.3 MAF (35,000 cfs) during January through March and March through May, respectively. (TBI/NRDC 2, pp. 17-19.) The provision of sufficient flows to achieve these flow volumes during January through March and March through May in approximately 45% and 47% of years, respectively, is intended to promote increased abundance and improved productivity for longfin smelt and other desirable estuarine species. Based on a comparison of the flows needs identified in section 4.2.4, it appears that winter-spring outflows designed to be protective of longfin smelt would benefit the other upper estuary species evaluated. The DFG recommended that spring outflows extend through June to fully protect a number of estuarine species. (DFG 1, pp. 2-5.) During June, sufficient outflow should be provided to maintain X2 in Suisun Bay (between 75 km and 64 km). (DFG closing comments, p. 7; DFG 2, p. 6.)

The State Water Board recognizes that the target flow volumes of 9.1 MAF (Jan-Mar, 51,000 cfs) and 6.3 MAF (Mar-May, 35,000 cfs) in greater than or equal to approximately 45% and 47% of years, respectively, and the positioning of X2 in Suisun Bay during the month of June are necessary in order to promote increased abundance and improved productivity for longfin smelt and other desirable estuarine species. An approach based on a percentage of unimpaired flows is intended as a means of distributing flows to meet the above-mentioned criteria in a manner that more closely resembles the natural hydrograph. Such an approach also recognizes the importance of preserving the general attributes of the flow regimes to which the native estuarine species are adapted.

Analyses of historic conditions (1921 to 2003), indicates that at 75% of unimpaired flows, average flows of 51,000 cfs occurred between January and March in approximately 35% of years, while average flows of 35,000 cfs happened between March and May in 70% of years. At 75% of unimpaired flow, X2 would be maintained west of Chipps Island more than 90% of the time between January and June (analyses not shown). Rather than advance multiple static flow criteria for the January through March, March through May, and June time periods, the State Water Board determines, as a Category A criterion, that 75% of 14-day average unimpaired flow is needed during the January through June time period to promote increased abundance and improved productivity for longfin smelt and other desirable estuarine species. It is important to note that this criterion is not a precise number; rather it reflects the general timing and magnitude of flows needed to protect public trust resources in the Delta ecosystem. However, this criterion could serve as the basis from which future analysis and adaptive management could proceed.

Given the extensive modifications to the system there may be a need to diverge from the natural hydrograph at certain times of the year to provide more flow than might have actually occurred to compensate for such changes. Fall outflow criteria, intended to improve conditions for Delta smelt by enhancing the quantity and quality of habitat in wet and above normal water years, represent such an instance. As a Category B criterion, the State Water Board determines that sufficient outflow is needed from September

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through November of wet and above normal water year types to position X2 at less than or equal to 74 km and 81 km, respectively (Fall X2 action). In addition, the Delta Outflow Objectives contained within the Bay-Delta Plan for July through December are advanced as a Category B criterion. The State Water Board does not recommend increasing fall flows beyond those stipulated in the Bay-Delta Plan and Fall X2 action at this time. The quantity and timing of fall outflows necessary to protect public trust resources warrants further evaluation.

Category A: Winter – Spring Net Delta Outflows
The flow regime is important in determining physical habitat in aquatic ecosystems, which is in turn a major factor in determining biotic composition. (DEFG 1.) Bunn and Arthington (2002) highlight four principles by which the natural flow regime influences aquatic biodiversity: 1) developing channel form, habitat complexity, and patch disturbance, 2) influencing life-history patterns such as fish spawning, recruitment, and migration, 3) maintaining floodplain and longitudinal connectivity, and 4) discouraging non-native species. Altering flow regimes affects aquatic biodiversity and the structure and function of aquatic ecosystems. The risk of ecological change increases with greater flow regime alteration. (Poff and Zimmerman 2010.)

A suite of native, and recreationally or commercially important species were evaluated in an effort to assess the timing, volume, and quality of water necessary to protect public trust resources. Flow criteria were developed for each of the species identified by DFG as those that are priority concern and will benefit the most as a result of improved flow conditions. (DFG closing comments, p. 3.) For Delta outflow, this included longfin smelt, delta smelt, starry flounder, American shad, bay shrimp (*Crangon* sp.), mysid shrimp, and *Eurytemora affinis*. Through this process, data or information pertaining to life history attributes (e.g., timing of migration, spawning, rearing), relationships of species abundance or habitat to Delta outflow, season or time period when flow characteristics are most important, factors influencing and/or limiting populations, and other characteristics were assessed and summarized in the individual species write-ups.

Statistically significant relationships between annual abundance and X2 (or outflow) have been demonstrated for a diverse assemblage of species within the estuary. (Stevens and Miller 1983; Jassby et al. 1995; Kimmerer 2002a; Rosenfield and Baxter 2007; Kimmerer *et al.* 2009.) The causal mechanisms underlying the variation in annual abundance indices of pelagic species in the estuary are poorly understood, but likely vary across species and life stages.

Longfin smelt have the strongest X2-abundance relationship of those species for which such a relationship has been demonstrated. (Kimmerer et al. 2009.) Abundance indices for this species are inversely related to X2 during its winter-spring spawning and early rearing periods. (Stevens and Miller 1983; Jassby et al. 1995; Kimmerer 2002a; Rosenfield and Baxter 2007; Kimmerer et al. 2009.) However, a four-fold decline in the relationship, with no significant change in slope, occurred after 1987, coincident with the introduction and spread of the introduced clam *Corbula amurensis.* (Kimmerer 2002a.) Reduced prey availability due to clam grazing has been identified as a likely mechanism for the decline in the X2-abundance relationship. (Kimmerer 2002a.)

One of the key biological goals of the informational proceeding was to identify the flows needed to increase abundance of native and other desirable species. Logit regression (StatSoft 2010, as cited in TBI/NRDC 2, p.17) was used to address the question: What

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outflow corresponded to positive longfin smelt population growth 50% of the time in the past? Logit regression is used to find a regression solution when the response variable is binary. For the purpose of this analysis, the generation-over-generation changes in abundance indices were converted to a binary variable (increase = 1 or decrease = 0). The analysis was conducted using FMWT abundance indices for the period extending from 1988 to 2007 (post-*Corbula*). Two periods of the winter-spring seasons (January to March and March to May) were evaluated, as different life stages of longfin smelt are present in the Delta during those periods (spawning adults and larvae/juveniles, respectively) and the mechanisms underlying the flow-abundance relationship may occur and/or vary in some or all of the months during these periods. (TBI/NRDC 2, p. 13.) The results were statistically significant ($p < 0.015$) and revealed that the "likelihood" of an increase in FMWT abundance index in 50% of years corresponded with flows of approximately 9.1 MAF and 6.3 MAF during January through March and March through May, respectively. (Figure 11, TBI/NRDC 2, pp. 17-19.)
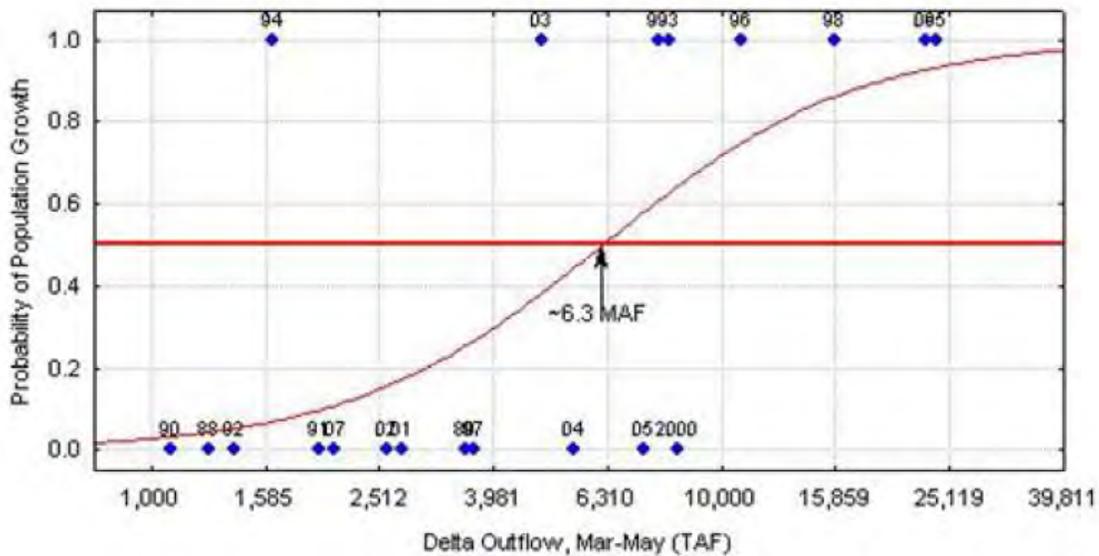
Logit regression showing relationship between March through May Delta outflow and generation-over-generation change in abundance of longfin smelt (measured as the difference between annual FMWT abundance indices). Positive changes in the abundance index were scored at "1" and declines were scored as "0". Arrow indicates flows above which growth occurred in more than 50% of years. Point labels indicate year of the FMWT index. (Source: TBI 2, Figure 15.)

Figure 11. Logit Regression Showing Relationship Between March through May Delta Outflow and Generation-Over-Generation Change in Longfin Smelt Abundance

A similar analysis was conducted for bay shrimp (*Crangon* sp.), a species whose flow-abundance relationship did not experience a "step decline" following the invasion of *Corbula*. (Kimmerer 2002a.) Results of the logit analysis indicate that abundance indices for this species increased in about 50% of years when flows during March through May were approximately 5 MAF. (TBI/NRDC 1, p. 17.) Therefore, flows

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associated with positive changes in the longfin smelt abundance index are anticipated to improve the likelihood of increases in bay shrimp abundance as well.

An analysis of historical longfin smelt flow-abundance relationships that corresponded to recovery targets in the Recovery Plan for the Sacramento/San Joaquin Delta Native Fishes (USFWS 1996) was also conducted. During the periods of January through March and March through May, cumulative Delta outflows of greater than 9.5 MAF and greater than 6.3 MAF, respectively, historically corresponded to abundance indices equal to or exceeding the recovery targets. (TBI/NRDC 2, p. 14.) These results are based on the intersection of the 1967 to1987 flow-abundance relationship and the recovery target. Use of the 1988 to 2007 flow-abundance relationship predicts lower abundance indices per any given flow, as compared to the historical relationship. Use of the pre-*Corbula* flow-abundance relationship underscores the need to address other stressors that may be affecting longfin smelt abundance concurrently with improved flow conditions. (TBI/NRDC 2, p. 14.) Applying this method and the logit regression produces very similar results.

As noted above, the results of the logit analysis indicate that the "likelihood" of an increase in the longfin smelt FMWT abundance index in 50% of years corresponded with flows of approximately 9.1 MAF and 6.3 MAF during January through March and March through May, respectively. (TBI/NRDC 2, pp. 17-19.) Hereafter, these two flow volumes are reported in cubic feet per second, as 51,000 cfs and 35,000 cfs, respectively. Analyses indicate that under historic unimpaired conditions (1921 to 2003) average flows of 51,000 cfs occurred between January and March in approximately 50% of years (Figure 12a), while average flows of 35,000 cfs happened between March and May approximately 85% of the time (Figure 13a). The review of the historic record suggests that it is unrealistic to expect a 100% return frequency for the two magnitudes. A point of reference for determining a more realistic return frequency might be the actual (impaired) flows that occurred from 1956 to 1987. This was a time period when native fish were more abundant than today. Actual average flows between 1957 and 1987 of 51,000 cfs occurred between January and March in approximately 45% of years (Figure 12b). Similarly average flows of 35,000 cfs occurred between March and May 47% of the time (Figure 13b). However, since 2000, average flows of this magnitude only occurred about 27% and 33% of the time, respectively (Figures 12b and 13b). At 75% of unimpaired flow, average flows of 51,000 and 35,000 cfs would happen 35% and 70% of the time, respectively (Figure 12a and Figure 13a). Finally, the DFG has indicated that spring outflows should continue through June to fully protect a number of estuarine species (DFG 1, pp.2-5.)

A fixed 75% of unimpaired flow would extend the flow criteria to other years and distribute flows in a manner that more closely resembles the natural hydrograph. Expression of this criterion as a 14-day running average would better reflect the timing of actual flows (compared with a 30-day running average) while still allowing for a time-step to which reservoirs could be operated. The appropriateness of the 14 day averaging period warrants further evaluation. The unimpaired flows from which the 75% criterion is calculated are monthly values. Estimates of 14-day average unimpaired flows have not been published, but a cursory analysis indicates that they are likely to generate an exceedance curve similar to one generated with monthly values.

The State Water Board therefore determines that the Net Delta Outflow criterion be 75% of the 14-day average unimpaired flow between January and June (Figure 14a, Table

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20). Consistent with the DFG recommendation (closing comments, p. 7) that X2 be maintained between 65 and 74 km (Chipps Island and Port Chicago) from January through June, a criterion of 75% of unimpaired flow, would maintain X2 west of Chipps Island more than 90% of the time, between January and June, based on monthly averages (analyses not shown). The return frequency for all months combined is about 98% of the time (Figure 14a). This compares with about a 90% percent return frequency between 2000 and 2009 (Figure 14b).
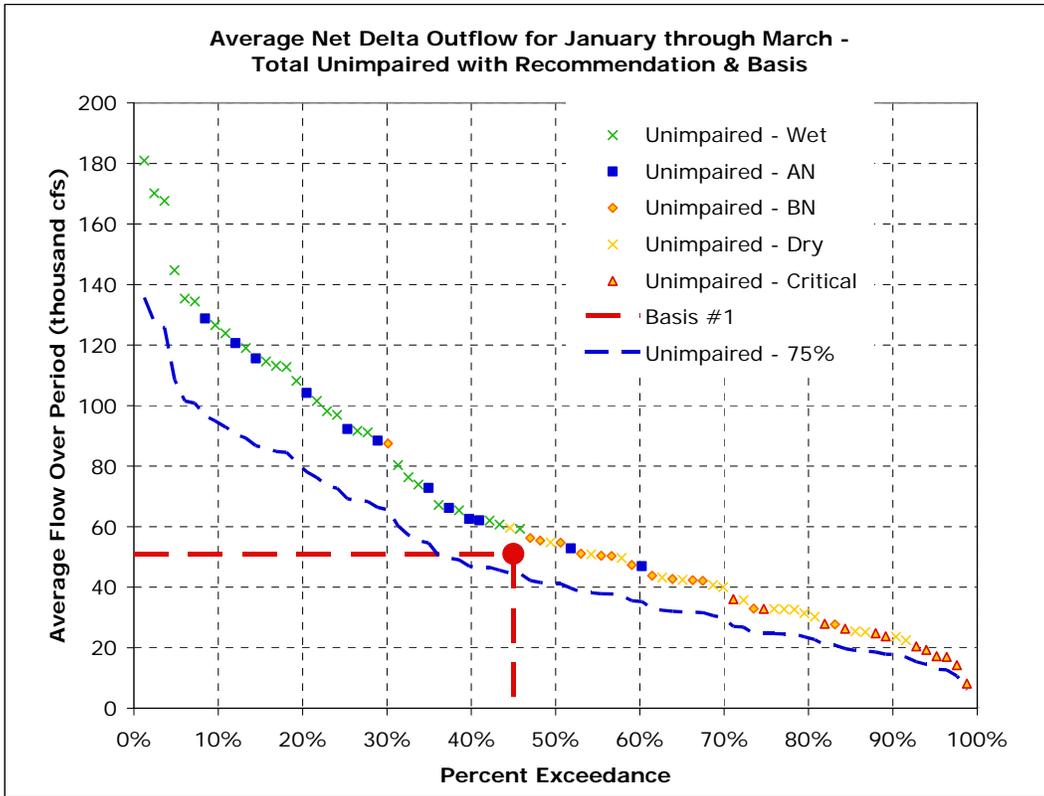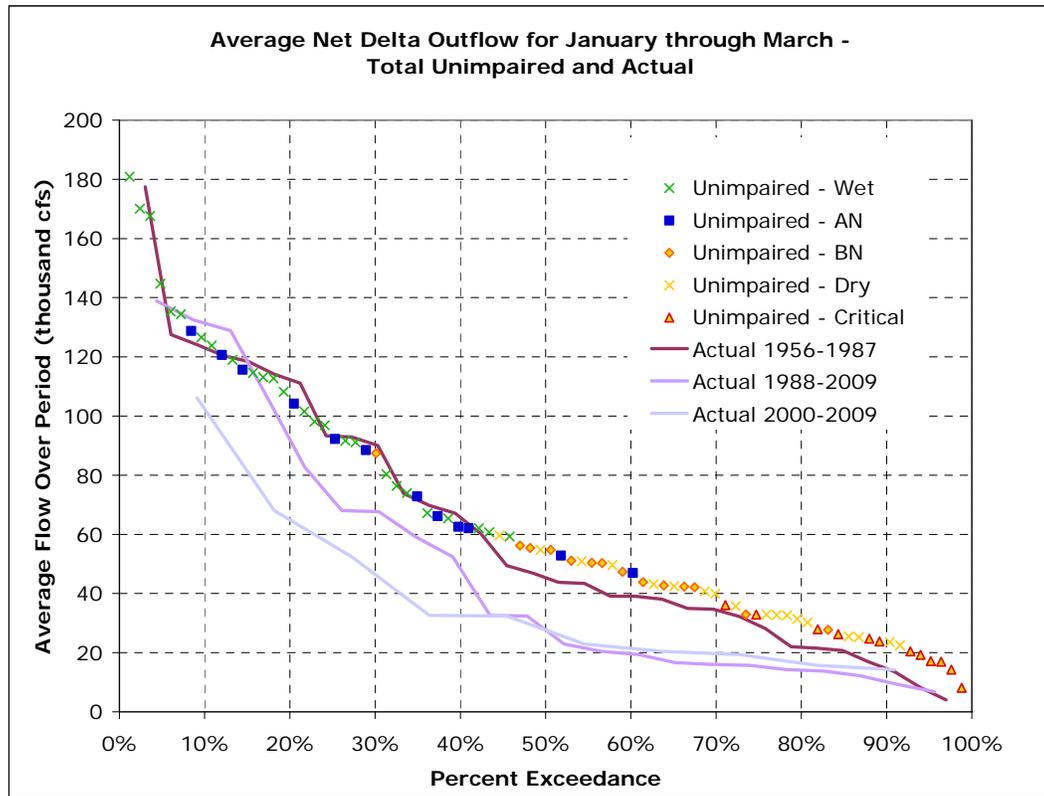
Figure 12. Net Delta Outflow Flow Exceedance Plot - January through March

a) Average Net Delta Outflow for March through May -
Total Unimpaired with Recommendation & Basis

b) Average Net Delta Outflow for March through May -
Total Unimpaired and Actual
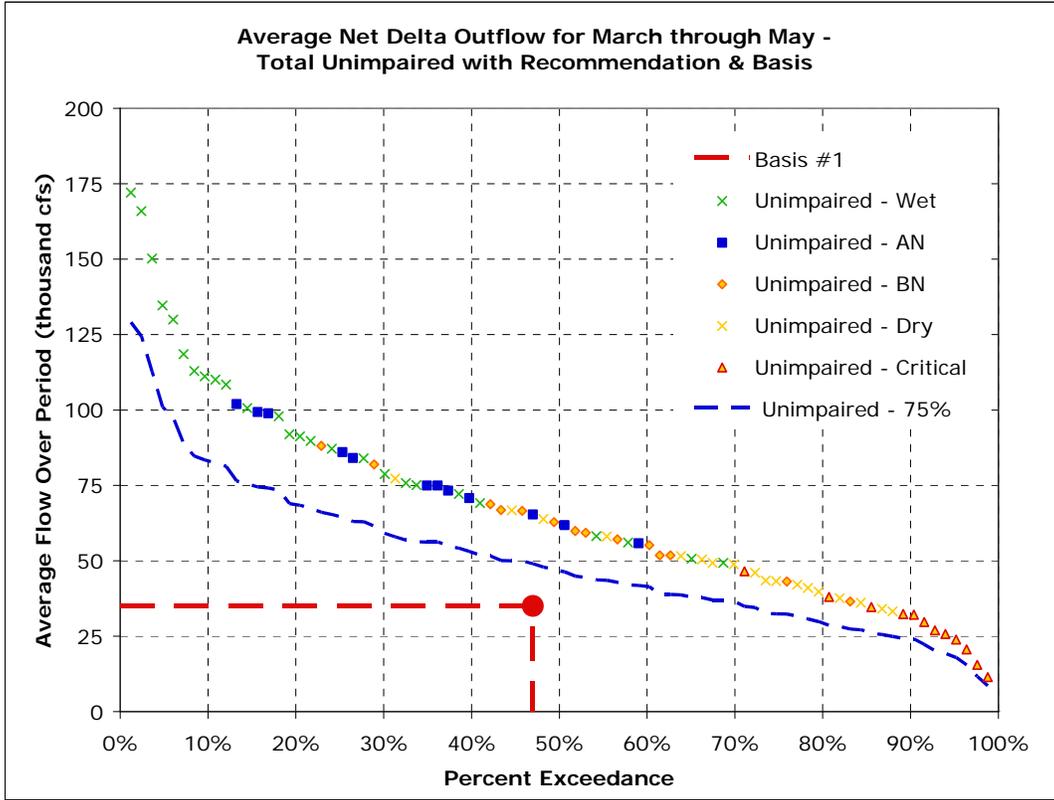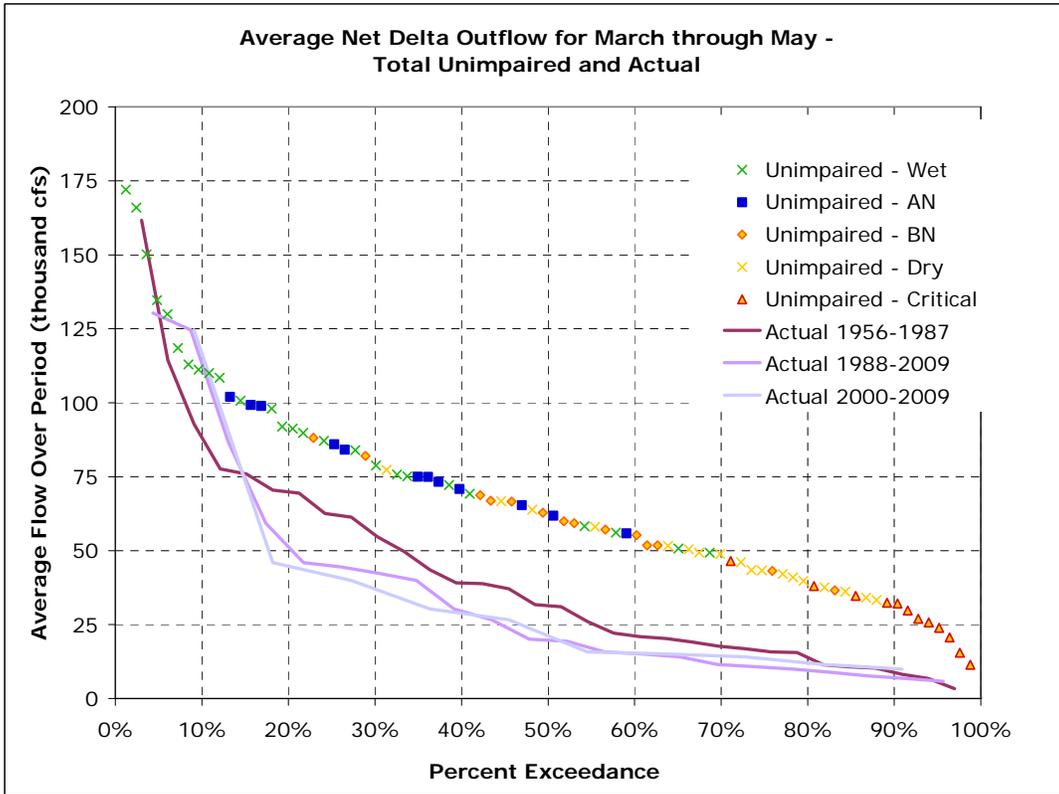
Figure 13. Net Delta Outflow Flow Exceedance Plot - March through May

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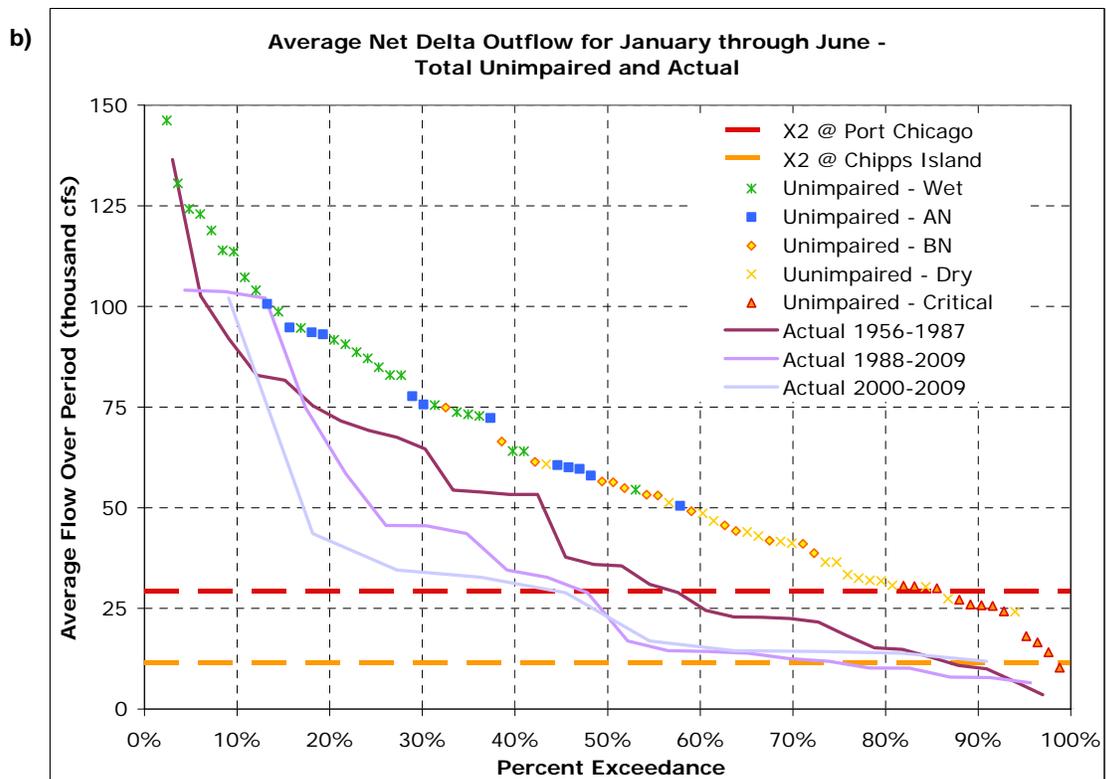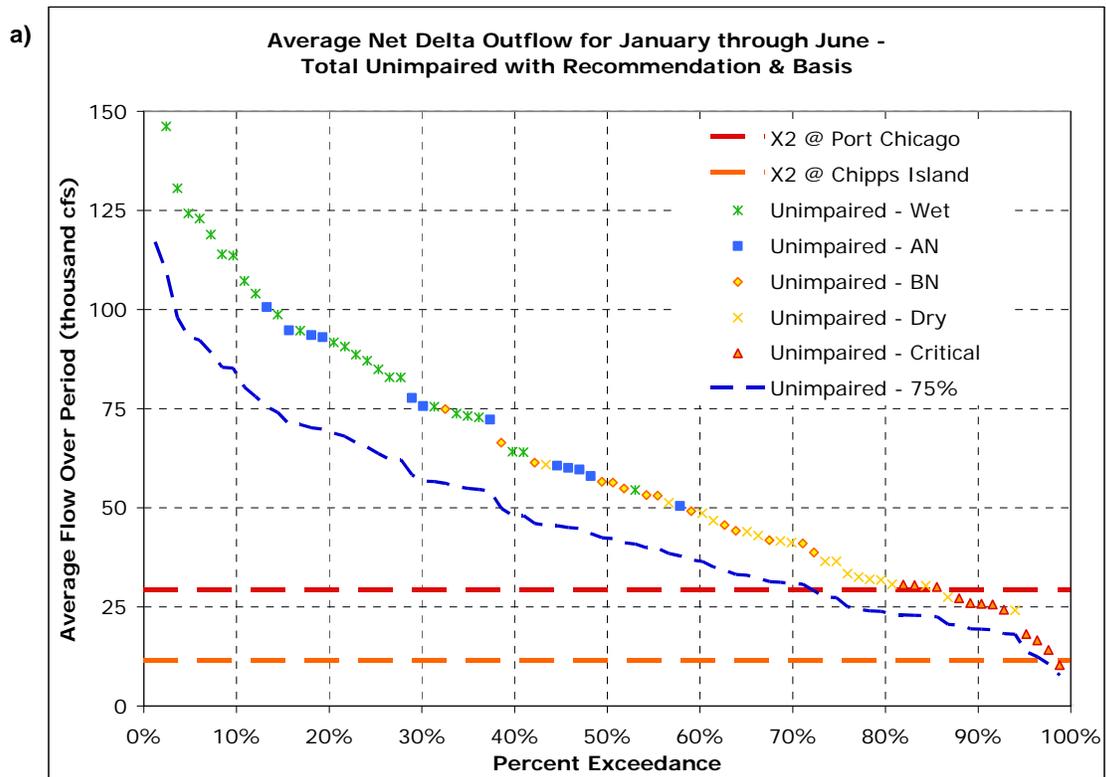
Figure 14. Net Delta Outflow Flow Exceedance Plot - January through June

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The net Delta outflow criterion of 75% of unimpaired flows from January through June is anticipated to increase the likelihood of positive population growth for a number of other public trust species, notably those for which abundance-X2 relationships have been demonstrated, including American shad, striped bass, starry flounder, bay shrimp (*Crangon franciscorum*), and *Eurytemora affinis* (spring abundance). For example, the spring (March through May) abundance of *Eurytemora affinis* has been positively related to flow, following the invasion of *Corbula.* (Kimmerer 2002a.) This species represents an important prey item for most small fishes, particularly those with winter and early spring larvae, such as longfin smelt, delta smelt and striped bass. (Lott 1998, Nobriga 2002, Bryant and Arnold 2007, DFG unpublished.) Increases in the abundance of prey species, such as *E. affinis* and bay shrimp, has the potential to improve productivity of the estuarine food web and benefit a number of fishes, especially given that food limitation has been identified as a potential contributing factor in the POD. (Baxter *et al.* 2008.) Additional information concerning the relationship of population abundance to flow for these species is provided in the species life history section of this report.

Delta smelt abundance does not respond to freshwater outflow in a predictable manner similar to that of other numerous estuarine species. (Stevens and Miller 1983; Jassby et al. 1995; Kimmerer 2002a.) However, freshwater outflow during spring (March to June) does affect the distribution of delta smelt larvae by transporting them seaward toward the low salinity zone. (Dege and Brown 2004.) Ideal rearing habitat conditions for this species are believed to be shallow water areas most commonly found in Suisun Bay. (Bennett 2005.) Outflows that locate X2 in Suisun Bay (mean April through July location) produce the highest delta smelt abundance levels; however, low abundances have also been observed under the same conditions, which indicates several mechanisms must be operating. (Jassby et al. 1995; DFG 1, p. 15.) A criterion of 75% of unimpaired flow is expected to place X2 in Suisun Bay from March through June in nearly all years.

The DFG's current science-based conceptual model is that placement of X2 in Suisun Bay represents the best interaction of water quality and landscape for fisheries production given the current estuary geometry. (DFG 2, p. 6.) The DFG (closing comments, p. 7) provided recommended flow criteria for the Delta based on the placement of X2, for January through June (exact period varied by species), for longfin smelt, starry flounder, bay shrimp, zooplankton, and American shad. For each of these species, the DFG (*Id.*) recommends that sufficient outflow be provided to position X2 between 75 km and 64 km. These criteria are generally consistent with spring X2 requirements in the 2006 Bay-Delta Plan, which requires salinity at one compliance point (81 km) not to exceed 2 psu continuously, and at two other compliance points (64 km [Port Chicago] and 75 km [Chipps Island]) not to exceed 2 psu for a set number of days during February through June. Positioning X2 at 75 km and 64 km is equivalent to a 3-day running average Net Delta Outflow Index of 11,400 cfs and 29,200 cfs, respectively. Implementation of the 75% of unimpaired flow criteria would be largely consistent with the intent of the DFG's recommendations by placing X2 between Chipps Island and Port Chicago, or further to the west, in nearly all years during the January through June period.

The step-decline in the abundance-X2 relationship that occurred after 1987 for many of these species in combination with the lack of understanding concerning the causal mechanisms underlying those relationships leads to uncertainty regarding the future response of these species to elevated flows. In addition, a number of major changes to

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the Delta landscape, including levee failure and island flooding, are likely to occur over the next several decades. (Lund et al. 2007, 2008.) Flow regimes needed to maintain desired environmental conditions will change through time, in response to changes in the geometry of waterways, climate, and other factors. A number of "stressors" are currently being evaluated as potential contributors to the POD, including attributes of physical and chemical fish habitat. (Sommer et al. 2007; Baxter et al. 2008.) Increasing flows, without concurrent improvements to habitat and water quality, would decrease the extent of expected improvements in native species abundances and habitats. (DOI 1, p. 40.) However, the scientific information received during this proceeding supports the conclusion that flow, though not sufficient in and of itself, is necessary to protect public trust resources and that the current flow regime has harmed native species and benefited non-native species. Each of these issues adds further support to the need for a strong adaptive management program.

The specific flow criteria may need to be tempered by the need to maintain water in reservoirs to provide adequate cold water resources to support egg incubation, juvenile rearing, and holding in the Sacramento River, San Joaquin River, and associated tributary basins. It may not be possible to attain the outflow criteria and meet the thermal needs of the various runs of Chinook salmon and other sensitive species in certain years. Water supply modeling and temperature analyses should be conducted to identify conflicting requirements to achieve both outflow and cold water temperature goals.

Category B: Fall X2
Abiotic habitat parameters for delta smelt have been described for both the summer and fall seasons as combinations of salinity, temperature, and turbidity. (Nobriga et al. 2008; Feyrer et al. 2007; Feyrer et al. in review.) During fall, delta smelt typically occur in low salinity rearing habitats located around the confluence of the Sacramento and San Joaquin Rivers. Suitable abiotic habitat for delta smelt during fall has been defined as relatively turbid water (Secchi depths < 1.0 m) with a salinity of approximately 0.6-3.0 psu. (Feyrer et al. 2007.) Long-term trend analysis has shown that environmental quality, as defined by salinity and turbidity, has declined across a broad geographical range, most notably within the south-eastern and western regions of the Delta, leaving a relatively restricted area in the lower Sacramento River and around the confluence of the Sacramento and San Joaquin rivers with the least habitat alteration, compared to the rest of the upper estuary. (Feyrer et al. 2007, DOI 1, p.34.)

The amount of habitat available to delta smelt is controlled by freshwater flow and how that flow affects the position of X2, geographically, in the estuary (Figure 15). (Feyrer et al. in review.) Through the use of a 3D hydrodynamic model, Kimmerer et al. (2009) showed that the extent of delta smelt habitat, as defined by salinity, increases as X2 moves seaward. When X2 is located downstream of the confluence of the Sacramento and San Joaquin rivers, suitable abiotic habitat extends into Suisun and Grizzly bays, resulting in a large increase in the total area of suitable abiotic habitat. (Feyrer et al. in review.) The average position of X2 during fall has moved upstream, resulting in a corresponding reduction in the amount and location of suitable abiotic habitat. (Feyrer et al. 2007; Feyrer et al. in review.)

Average Net Delta Outflow for September, October, and November are presented in Figure 16, Figure 17, and Figure 18. Historically, unimpaired flows in fall were independent of water year type. Interestingly, actual outflow was greater than

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unimpaired flow between 1956 and 1987. However, fall outflows have fallen since then and since 2000 are almost always less than unimpaired flow. This is consistent with the observations of Feyrer et al. (2007) that fall X2 has moved upstream and this has reduced the amount of available habitat for smelt in fall.

Fall conditions may be very important for delta smelt, since this period of time coincides with the pre-spawning period for adult delta smelt. (Feyrer et al. 2007.) In general, reductions in habitat constrict the range of these fishes, which combined with an altered food web, may affect their health and survival. (Feyrer et al. 2007.) There is a statistically significant stock-recruitment relationship for delta smelt in which pre-adult abundance measured by the FMWT positively affects the abundance of juveniles the following year in the Summer Townet survey. (Bennett 2005; Feyrer et al. 2007, as cited in USFWS 2008.) Incorporating the combined effects of specific conductance and Secchi depth improved the stock-recruitment relationship. (Feyrer et al. 2007.)

Feyrer et al. (In Review) demonstrated that delta smelt are more abundant when a large amount of habitat is available. However, the relationship between habitat area and FMWT abundance is complex and not strong. (NAS 2010.) When the area of highly suitable habitat is low, either high or low FMWT indices can occur (Figure 15). Therefore, delta smelt can be successful in instances where habitat is limited. More important, however, is that the lowest abundances all occurred when the habitat-area index was less than 6,000 ha. (Feyrer et al. in review; NAS 2010.) This potentially suggests that while reduced habitat area may be an important factor associated with the worst population collapses, it is not likely the only cause of the collapse. (NAS 2010.)

The fall X2 action described in the USFWS Opinion is focused on wet and above normal years because these are the years in which project operations have most significantly affected fall outflows. Actions in these years are more likely to benefit delta smelt. (USFWS 2008.) The action calls for maintaining X2 in the fall of wet years and above-normal years at 74 km and 81 km, respectively. (Figures 14, 15, and 16; USFWS 2008.) In addition to increasing the quality and quantity of habitat for delta smelt, moving X2 westward in the fall may also reduce the risk of entrainment by increasing the geographic and hydrologic distance of delta smelt from the influence of the Project export facilities. (DOI 1, p. 34.)

The NAS (2010) commented on this action in their review of the USFWS Opinion and concluded:

> "The X2 action is conceptually sound in that to the degree that habitat for
> smelt limits their abundance, the provision of more or better habitat would
> be helpful. However, the examination of uncertainty in the derivation of
> the details of this action lacks rigor. The action is based on a series of
> linked statistical analyses (e.g., the relationship of presence/absence data
> to environmental variables, the relationship of environmental variables to
> habitat, the relationship of habitat to X2, the relationship of X2 to smelt
> abundance), with each step being uncertain. The relationships are
> correlative with substantial variance being left unexplained at each step.
> The action also may have high water requirements and may adversely
> affect salmon and steelhead under some conditions (memorandum from
> USFWS and NMFS, January 15, 2010). As a result, how specific X2

targets were chosen and their likely beneficial effects need further clarification."

The State Water Board determines that inclusion of the delta smelt fall X2 action as a Category B flow criterion, consistent with requirements stipulated in the USFWS Opinion will likely improve habitat conditions for delta smelt. However, in light of the uncertainty about specific X2 targets and the overall effectiveness of the fall X2 action, the State Water Board recommends this action be implemented within the context of an adaptive management program. The program should include studies designed to clarify the mechanisms underlying the effects of fall habitat on the delta smelt populations, the establishment and peer review of performance measures and performance evaluation related to the action, and a comprehensive review of the outcomes of the action and effectiveness of the adaptive management program. (USFWS 2008.) Absent study results demonstrating the importance of fall X2 to the survival of delta smelt, fall flows beyond those stipulated in the fall X2 action for the protection of delta smelt are not recommended at this time.

Relationship between X2 and habitat area for delta smelt during fall, with standard shown for wet and above normal years. (Source: USFWS 2008, Figure B17).
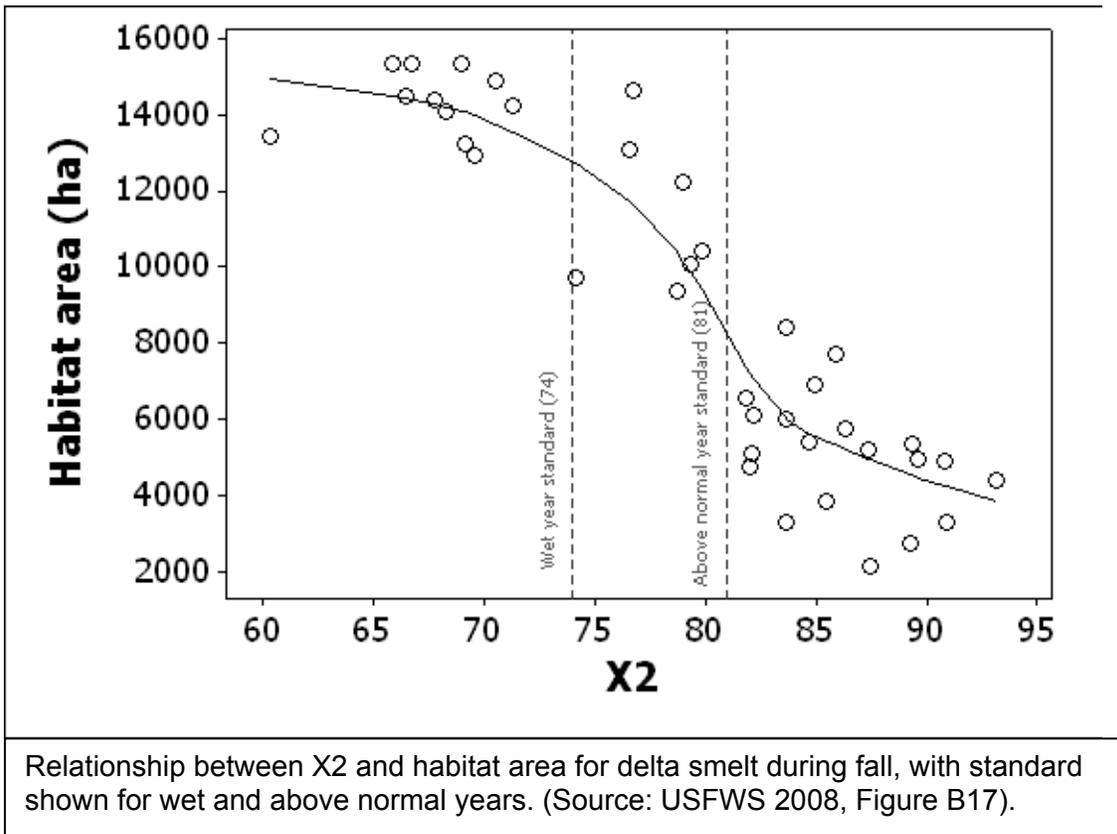
Figure 15. X2 Versus Habitat Area for Delta Smelt During Fall
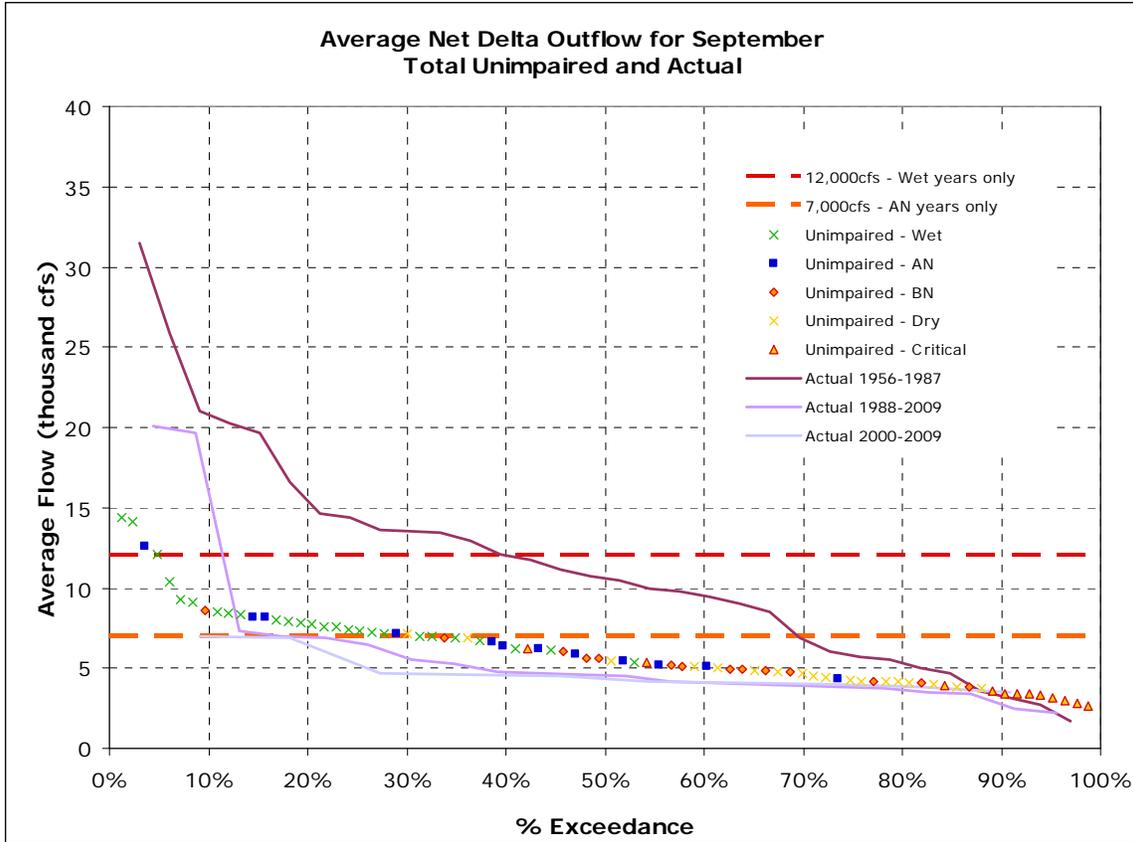
Figure 16. Net Delta Outflow Flow Exceedance Plot - September
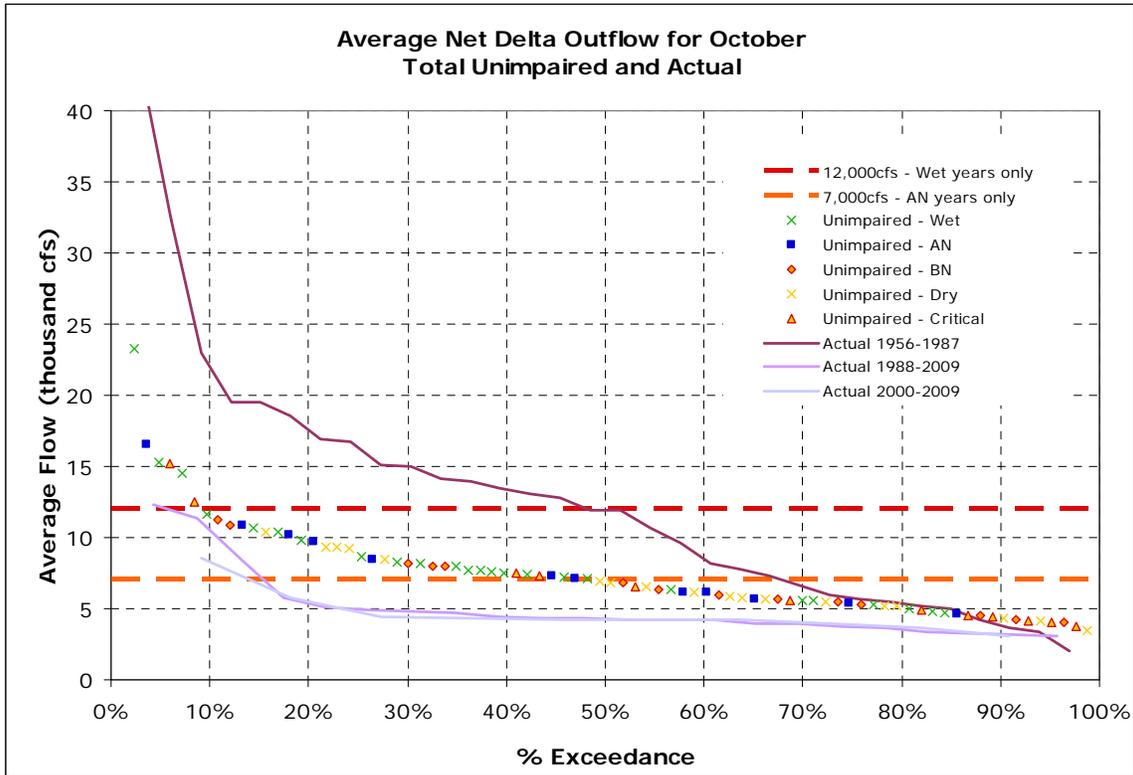
Figure 17. Net Delta Outflow Flow Exceedance Plot - October

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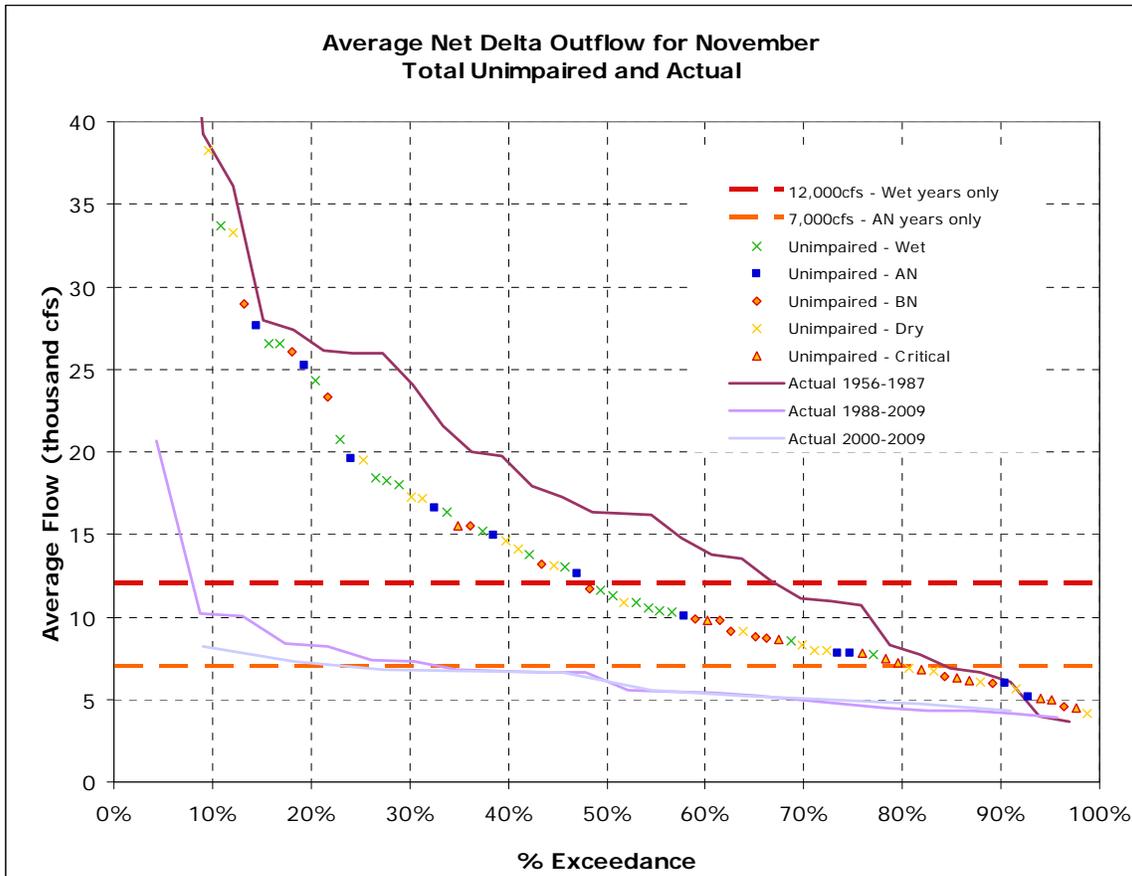
Figure 18. Net Delta Outflow Flow Exceedance Plot - November

The specific Delta outflow criteria may need to be tempered by the need to maintain water in reservoirs to provide adequate cold water and tributary specific flows on tributaries to the Delta. It may not be possible to attain both the flow criteria and meet the thermal and tributary specific flow needs of all of the sensitive species in the Delta Watershed. Water supply modeling and temperature analyses should be conducted to identify conflicting requirements to achieve both flow and cold water temperature goals.

Category B: 2006 Bay-Delta Plan Summer – Fall Delta Outflow
Resident estuarine species, such as delta smelt, require flows sufficient to provide adequate habitat throughout the year. Delta outflow criteria for January through June are discussed above. In addition to providing flows to support resident species, sufficient flows must also be provided in the fall to provide attraction cues and a homing mechanism for returning adult salmon. Criteria for fall salmon attraction flows on the Sacramento and San Joaquin rivers are discussed in Sections 5.2 and 5.3. The 2006 Bay-Delta Plan contains summer – fall Delta outflow water quality objectives for fish and wildlife beneficial uses, which are summarized below in Table 19.

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Table 19. 2006 Bay-Delta Plan Delta Outflow Objectives for July through December

Water Year	July	Aug	Sept	Oct	Nov	Dec
Critical	4000	3000	3000	3000	3500	3500
Dry	5000	3500	3000	4000	4500	4500
Below Normal	6500	4000	3000	4000	4500	4500
Above Normal	8000	4000	3000	4000	4500	4500
Wet	8000	4000	3000	4000	4500	4500

Multiple participants submitted testimony concerning the need for additional flows in the fall to benefit delta smelt, striped bass, and other resident species (CSPA 1, p. 7; CWIN 2, p. 29; DOI 1, pp. 46-48; EDF 1, pp. 49-50; TBI/NRDC 2, pp. 27-37), and as a means to potentially control the spread of harmful invasive species (e.g., *Corbula* and toxic algae). (TBI/NRDC 2, pp. 27-37.) The recommendations were based largely on recent research conducted by Feyrer *et al.* (2007 and In Review) and the fall X2 action in the USFWS's Opinion. The Fall X2 action in the USFWS Opinion requires that sufficient outflow be provided in September through November of Above Normal and Wet water year types to position X2 at 81 km and 74 km, respectively. This action was restricted to Above Normal and Wet years because these are the years in which project operations have most significantly affected fall outflows and to limit potential conflicts with cold water pool storage. (USFWS 2008.)

Following its review of the USFWS Opinion, the NAS (2010) noted that:

> "[a]lthough there is evidence that the position of X2 affects the distribution of smelt, the weak statistical relationship between the location of X2 and the size of smelt populations makes the justification for this action difficult to understand… The X2 action is conceptually sound in that to the degree that the amount of habitat available for smelt limits their abundance, the provision of more or better habitat would be helpful… the committee concludes that how specific X2 targets were chosen and their likely beneficial effects need further clarification."

The USFWS Opinion also recognized uncertainty concerning the position of fall X2 and subsequent abundance of delta smelt and requires that the action be implemented with an adaptive management program to provide for learning and improvement of the action over time.

However, some participants provided flow recommendations that called for increased fall outflows during all water year types, as compared to the objectives in the 2006 Bay-Delta Plan, and in certain instances in excess of those required by the USFWS Opinion. Given the need for improved understanding concerning the fall X2 criterion, including the mechanisms underlying the effects of fall habitat on delta smelt populations, determination of specific X2 targets, potential conflicts with cold water pool storage, and the likely effectiveness of the action, the State Water Board is not advancing criteria for increased fall flows in Critical, Dry, and Below Normal water year types beyond those required in the 2006 Bay-Delta Plan and in Above Normal and Wet water year types beyond those stipulated in the fall X2 action (Category B). The quantity and timing of fall outflows necessary to protect public trust resources warrants further evaluation and underscores the need for a well-designed adaptive management program. The potential

to use variability in flows during summer and fall months as a means of controlling the distribution and abundance of invasive species should also be evaluated.

5.2 Sacramento River

Following are the Sacramento River inflow criteria based on analysis of the species-specific flow criteria and other measures:

1) Sacramento River Flow at Rio Vista: 75 percent of 14-day average unimpaired flow from April through June to increases juvenile salmon outmigration survival for fall-run Chinook salmon
2) Sacramento River Flow at Rio Vista: 75 percent of 14-day average unimpaired flow from November through March to increases juvenile salmon outmigration survival for other runs of Chinook salmon
3) Sacramento River at Wilkins Slough: Provide pulse flows of 20,000 cfs for 7 days starting in November coincident with fall/early winter storm events; the timing, magnitude, duration, and number of pulses should be determined on an adaptive management basis informed by unimpaired flow conditions and monitoring of juvenile salmon migration to promote juvenile salmon emigration
4) Sacramento River Flow at Freeport: Provide flows of 13,000 to 17,000 cfs in the Sacramento River downstream of confluence with Georgiana Slough when salmon are migrating through the Delta from November through June to increase juvenile salmon outmigration survival by reducing straying into Georgiana Slough and the central Delta
5) Sacramento River at Rio Vista: 2006 Bay-Delta Plan flow objectives for September and October to provide Fall adult Chinook salmon attraction flows

The magnitude, duration, timing, and source of Sacramento River inflows are important to all runs of Chinook salmon migrating through the Bay-Delta and several different aspects of their life history. Inflows are needed to provide appropriate conditions to cue upstream adult migration to the Sacramento River and its tributaries, adult holding, egg incubation, juvenile rearing, emigration from the Sacramento River and its tributaries, and other functions. Sacramento River inflows are important throughout the year to support various life stages of the different Chinook salmon runs inhabiting the Sacramento River. However, given the focus of this proceeding on inflows to the Delta and the importance of the juvenile salmon emigration period, the Sacramento River inflow criteria included in this report focus primarily on flows needed to support emigrating juvenile Chinook salmon from natal streams through the Delta. Following is a brief summary of the Sacramento River inflow criteria that were developed based on the species-specific flow needs analyses for salmon included in section 4.2.3 followed by a detailed discussion.

Available scientific information indicates that average April through June flows of 20,000 to 30,000 cfs on the Sacramento River at Rio Vista represent a flow threshold at which survival of juveniles and subsequent adult abundance is substantially improved for fall-run Chinook salmon. Less information is available for the other runs of Chinook salmon on the Sacramento River. However, outmigration flows needed to protect other races are assumed to be generally the same since factors that affect fall-run survival are generally applicable to other runs with some exceptions. In addition, analyses indicate that providing pulse flows of 20,000 cfs at Wilkins Slough on the Sacramento River beginning in November and extending through the first of the year provides for earlier

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migration timing and increased survival of juvenile winter, spring, and late-fall run Chinook salmon. In addition, information indicates that flows of 13,000 cfs to 17,000 cfs may be needed on the Sacramento River at Freeport to prevent salmon from migrating through Georgiana Slough and the interior Delta where survival is substantially lower.

Continuity of flows from natal stream through the Delta and flow variability are also important so rather than static April through June threshold flows of 20,000 to 30,000 cfs, the State Water Board determines, as a Category A criterion, that 75% of unimpaired flow is needed to achieve a threshold flow of 25,000 cfs (average of 20,000 and 30,000 cfs) approximately 50% of the time. The same percentage of unimpaired flow for the November through March period is also advanced as a Category B criterion due to the lack of information upon which this criterion was based. In addition, as Category B criteria, the State Water Board determines that shorter pulse flows of 20,000 cfs for 7 days at Wilkins Slough are needed starting in November and extending through the first of the year and flows of 13,000 cfs to 17,000 cfs at Freeport are needed from November through June to provide additional protection for Sacramento River Chinook salmon. The State Water Board also advances the Sacramento River flow objectives from the Bay-Delta Plan during September and October to provide a minimal level of protection during these months pending development of additional information concerning flow needs during this period. All of the Sacramento River flow criteria are not precise; rather they reflect the general timing and magnitude of flows needed to protect public trust resources, but could serve as a reasonable basis from which future analysis and adaptive management could proceed. The criteria also do not consider other Sacramento River flow needs.

Sacramento River Inflow as a Percentage of Unimpaired Flows
It appears to be important to preserve the general attributes of the natural hydrograph to which the various salmon runs adapted over time. Information indicates that Chinook salmon respond to variations in flows and need some continuity of flow between natal streams and the Delta for transport and homing fidelity. As such, the historic practice of developing monthly flow criteria to be met from limited sources may be less than optimal for protecting Chinook salmon runs. At the same time, given the impediments to fish passage into historic spawning and rearing areas, there may also be a need to diverge from the natural hydrograph at certain times of year to provide more flow than might have naturally occurred or less flow such that those flows are available at other times of year to mitigate for passage and habitat issues (e.g. cold water pool management).

Based on the above, the State Water Board developed Sacramento River inflow criteria, intended to mimic the natural hydrograph during the peak emigration period, to protect emigrating juvenile Chinook salmon. While emigration of some runs may occur outside of this period, peak emigration is generally believed to occur between November through June. As such, the criteria are recommended to apply to this time period. To achieve the attributes of a natural hydrograph, the criteria are recommended as a percentage of unimpaired flow on a 14-day average, to be provided generally on a proportional basis from the tributaries to the Sacramento River. The 14-day average is intended to better capture the peaks of actual flows compared to a 30-day average time-step, while still allowing for a time-step at which facilities can be operated. The appropriateness of this time-step for protecting public trust resources should be further evaluated.

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Spring Sacramento River Inflows at Rio Vista
The species-specific flow needs analyses for salmon in section 4.2.3 indicates that average April through June flows of 20,000 to 30,000 cfs on the Sacramento River at Rio Vista provide for improved survival and abundance of juvenile fall-run Chinook salmon on the Sacramento River.

Flow exceedance graphs were used to determine the percentage of flow needed to achieve various flows needed to protect Chinook salmon. Analysis of unimpaired flows at Freeport (Figure 19) shows that under historic unimpaired conditions, average April through June flows of 30,000 cfs or more would occur in approximately 60% of years. Flows of 25,000 cfs or more would occur is approximately 72% of years, and flows of 20,000 cfs or more would occur in roughly 85% of years. At 75% of unimpaired flows, average flows of 30,000 cfs would be achieved between April and June in roughly 37% of years, flows of 25,000 cfs would be achieved in roughly 50% of years, and flows of 20,000 cfs would be achieved in approximately 70% of years. At 50% of unimpaired flows, flows of 30,000 cfs would be achieved in approximately 15% of years, flows of 25,000 cfs in roughly 25% of years, and flows of 20,000 cfs in roughly 35% of years. Actual flows of 30,000, 25,000, and 20,000 cfs were met in 26, 32, and 39% of years, respectively between 1986 and 2005. It is important to note, however, that unimpaired flows between 1986 through 2005 are not necessarily representative of the longer term unimpaired flow record. Flow criteria equal to 75% of unimpaired flows during the April through June period, on average, would therefore provide favorable conditions for fall-run juvenile Chinook salmon in at least 50% of years (assuming 25,000 cfs flows). As a result, the State Water Board advances 75% of unimpaired flows on a 14-day average from April through June as a potential means to achieve the 20,000 to 30,000 cfs Sacramento River flow threshold discussed above while maintaining variability and the attributes of the natural hydrograph. This criterion is included as criterion 1) for Sacramento River flows and is a Category A criterion.

The unimpaired estimates from which the 75% criterion is calculated are monthly estimates. Estimates of 14-day unimpaired flow have not been published, but are expected to generate an exceedance curve similar to one generated with monthly estimates. This specific percent of unimpaired flow and the averaging period should be adaptively managed. More information and analyses should be conducted to determine if there are maximum flows above which no, or significantly diminishing, additional biological or geomorphological benefits are obtained. This criterion would allow for flows to vary over time coincident with precipitation events reflecting the natural hydrograph. Climate change, however, and its associated effect on flow patterns will likely change how effective such flows are in protecting Chinook salmon. As such, these flow criteria would need to be adaptively managed in the future to ensure the protection of Chinook salmon.
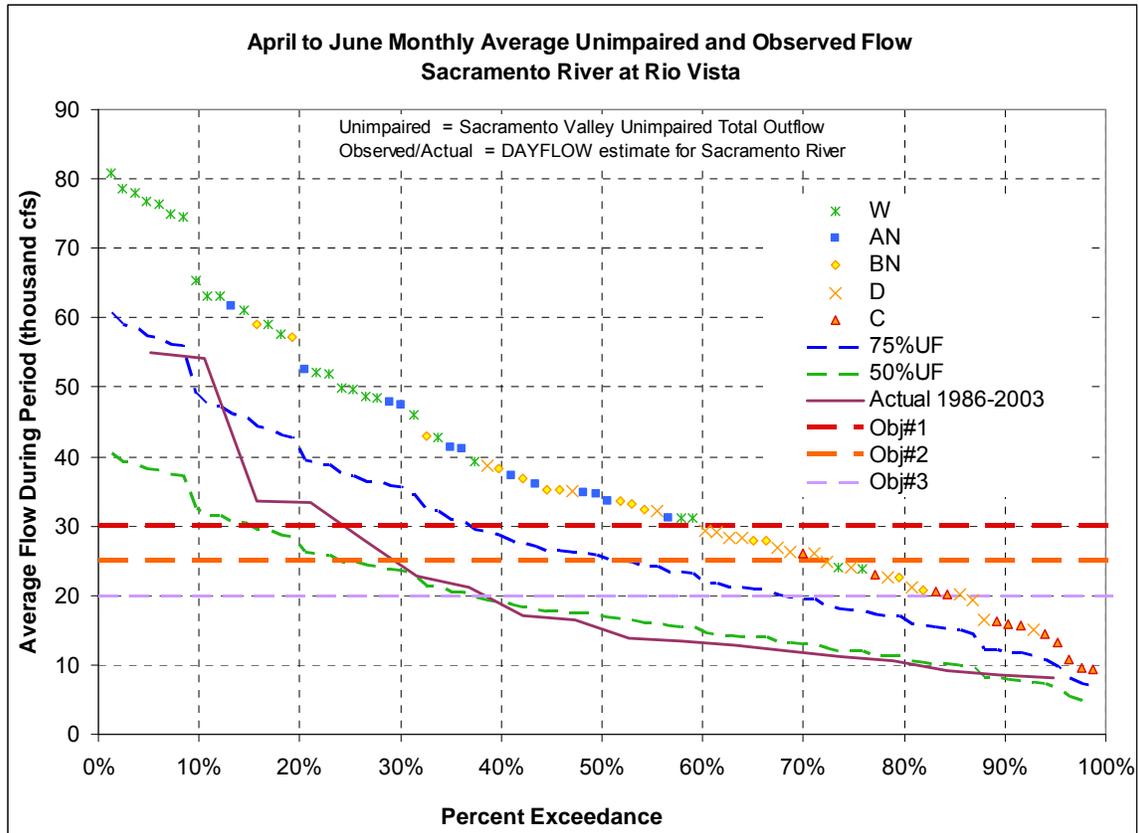
Figure 19. Sacramento River Flow Exceedance Plot - April through June

Fall and Winter Sacramento River Inflows at Rio Vista
Available data and analysis focus primarily on juvenile fall-run Chinook salmon outmigration. Outmigration flows to protect other races and life stages are assumed to be generally the same since factors that affect fall-run survival are generally applicable to other runs, with some exceptions including temperature, which may not be a concern in the winter months. (USFWS 1992, p. 8.) In the absence of sufficient data and analyses regarding flows needed for other Chinook salmon runs, however, the State Water Board advances 75% of unimpaired flows between November and March as an initial criterion from which future analysis and adaptive management could proceed. There is, however, no specific information that indicates that 75% is the correct percent of unimpaired flow. Additional quantitative analyses should be conducted to determine the specific flow needs of winter, spring, and late-fall run Chinook salmon.

Sacramento River Flow at Freeport
Analyses show that Chinook salmon survival is significantly lower for fish migrating through Georgiana Slough. Reverse flows in the vicinity of Georgiana Slough increase the occurrence of salmon migrating through Georgiana Slough. The available data show that flows of 13,000 to 17,000 cfs on the Sacramento River at Freeport provide adequate flow conditions to prevent reverse flows in Georgiana Slough. Flow criteria of 13,000 to 17,000 cfs on the Sacramento River at Freeport when salmon are migrating through the Delta during the November through June period is advanced as a Category B criterion. Additional analyses should be conducted to verify that flows of this magnitude are

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needed to achieve the desired outcome of significantly reducing straying of outmigrating juvenile Chinook salmon. These flows are also expected to benefit adult Chinook salmon returning to the Sacramento River basin to spawn during this period. However, additional analyses regarding the relationship of adult Chinook salmon and reverse flows in Georgiana Slough should also be conducted.

Sacramento River Flow at Wilkins Slough
Information discussed in the species-specific flow needs analyses for salmon in section 4.2.3 indicates that significant precipitation in the Sacramento River in the fall facilitates emigration of juvenile Chinook salmon. When this flow is delayed, emigration of salmon is also delayed resulting in reduced survival to the Delta. The available data show that juvenile salmon require flows of 15,000 cfs to 20,000 cfs at Wilkins Slough by November continuing through the first of the year to facilitate emigration. These flows are needed to provide ecological continuity from natal streams to the Delta. Information supports a range of pulse flows of 15,000 cfs to 20,000 cfs at Wilkins Slough to be provided coincident with fall and early winter storm events. This range should be adaptively managed and further evaluated. Absent additional information, flows of 20,000 cfs for seven days are advanced. Such an approach will retain the attributes of the natural hydrograph and provide for ecological continuity. The timing, magnitude, duration, and number of pulses should be determined through adaptive management, informed by unimpaired flow conditions and monitoring of juvenile salmon migration. Additional analyses should be conducted regarding this flow relationship to refine these criteria and inform adaptive management.

Sacramento River at Rio Vista: 2006 Bay-Delta Plan Objectives
The above criteria cover flows on the Sacramento River from the November through June time period. In addition, the Bay-Delta Plan provides minimum flows from September through December. Aside from what is discussed above, there was no new information submitted in the record for this proceeding on fall flows and the Sacramento River fall flow objectives were not specifically reviewed. In the absence of any new information, the State Water Board advances the 2006 Bay Delta Plan Sacramento River inflow objectives for September and October as a Category B criterion. Given that Chinook salmon may also be present in the Sacramento River during July and August, it is likely warranted that some minimal flows be provided during those months as well. However, adequate information on which to base such flows was not readily available for this proceeding. Further, adequate minimal flows during this time period may be provided by temperature and other requirements and reservoir releases for power production and export operations.

The specific Sacramento River flow criteria may need to be tempered by the need to maintain water in reservoirs to provide adequate cold water and tributary specific flows in the Sacramento River basin. It may not be possible to attain both the flow criteria and meet the thermal and tributary specific flow needs of the various runs of Chinook salmon and other sensitive species in the Sacramento River basin. Water supply modeling and temperature analyses should be conducted to identify conflicting requirements to achieve both flow and cold water temperature goals.

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5.3   San Joaquin River

Following are the San Joaquin River inflow criteria based on analysis of the species-specific flow criteria and other measures:

1) San Joaquin River at Vernalis: 60%of 14-day average unimpaired flow from February through June
2) San Joaquin River at Vernalis: 10 day minimum pulse of 3,600 cfs in late October
3) San Joaquin River at Vernalis: 2006 Bay-Delta Plan flow objective for October

San Joaquin River inflow criterion 1 and 2 are Category A criteria because they are supported by sufficiently robust scientific information. The 2006 Bay-Delta Plan San Joaquin River inflow objective for October is included as a Category B criterion because it is not clear that eliminating this criterion in lieu of criteria 2 would provide adequate protection to migrating adult Chinook salmon. Following is discussion and rationale for these criteria. Category A and B criteria are both equally important for protection of the public trust resource, but there is more uncertainty about the appropriate volume of flow required to achieve the goals of the Category B criterion. Following is discussion and rationale for these criteria.

As discussed in the Sacramento River inflow section, the magnitude, duration, timing, and source of San Joaquin River inflows are important to Chinook salmon migrating through the Bay-Delta and several different aspects of their life history. Inflows are needed to provide appropriate conditions to cue upstream adult migration to the San Joaquin River and its tributaries, adult holding, egg incubation, juvenile rearing, emigration from the San Joaquin River and its tributaries, and other functions. San Joaquin River inflows are important for much of the year to support various life stages of San Joaquin basin fall-run Chinook salmon (and spring-run when they are reintroduced). However, given the focus of this proceeding on inflows to the Delta and the lack of information received concerning spring-run flow needs on the San Joaquin River, the San Joaquin River inflow criteria included in this report focus on flows needed to support migrating fall-run Chinook salmon from and to natal streams through the Delta. Following is a brief summary of the San Joaquin River inflow criteria that were developed based on the species-specific flow needs analyses for salmon included in section 4.2.3 followed by a detailed discussion.

Available scientific information indicates that average March through June flows of 5,000 cfs on the San Joaquin River at Vernalis represent a flow threshold at which survival of juveniles and subsequent adult abundance is substantially improved for fall-run Chinook salmon and that average flows of 10,000 cfs during this period may provide conditions necessary to achieve doubling of San Joaquin basin fall-run. Both the AFRP and DFG flow recommendations to achieve doubling also seem to support these general levels of flow, though the time periods are somewhat different (AFRP is for February through May and DFG is for March 15 through June 15). Available information also indicates that flows of 3,000 to 3,600 cfs for 10 to 14 days are needed during mid to late October to reduce straying, improve olfactory homing fidelity, and improve gamete viability for San Joaquin basin returning adult Chinook salmon.

Continuity of flows from natal stream through the Delta and flow variability are also important, so rather than advancing static flow criteria for the spring period to support emigration of juvenile San Joaquin basin fall-run Chinook salmon, the State Water Board

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determines, as a Category A criterion, that 60% of unimpaired flow from February through June is needed in order to achieve a threshold flow of 5,000 cfs or more in most years (over 85% of years) and flows of 10,000 cfs slightly less than half of the time (45% of years). Given that the focus of this proceeding is on protection of public trust resources, the State Water Board determines that the time period for these flows should be extended to cover all three periods supported by the DFG, AFRP, and TBI/NRDC analyses concerning flow needs. In addition, the State Water Board determines, as a Category A criterion, that flows of 3,600 cfs are needed for 10 days in late October. These flows could also be provided in a manner that better reflects the natural hydrograph to coincide with natural storm events. Until additional information is developed, maintaining the October pulse flow called for in the 2006 Bay-Delta Plan is also determined to be a Category B criterion to assure that the existing protection provided during this period is not diminished. All of the San Joaquin River flow criteria are not precise; rather they reflect the general timing and magnitude of flows needed to protect public trust resources, but could serve as a reasonable basis from which future analysis and adaptive management could proceed. The criteria also do not consider other San Joaquin River flow needs.

San Joaquin River Inflows as a Percentage of Unimpaired Flow During the Spring
As discussed in the Sacramento River inflow section, it is important to preserve the general attributes of the natural hydrograph to which the various salmon runs adapted to over time, including variations in flows and continuity of flows. Accordingly, as with the Sacramento River flow criteria, the State Water Board developed flow criteria for San Joaquin River inflows to protect emigrating juvenile Chinook salmon intended to mimic the natural hydrograph during the peak emigration period of February through June. This period may also cover a portion of the rearing period for juveniles as well. As with the Sacramento River flow criteria, to achieve the attributes of a natural hydrograph, the criteria are advanced as a percentage of unimpaired flow on a 14-day average, to be achieved on a proportional basis from the tributaries to the San Joaquin River. The unimpaired estimates from which the 60% criterion is calculated are monthly estimates. Estimates of 14-day unimpaired flow have not been published, but the exceedance curve is likely similar to one generated with monthly estimates. The appropriateness of this time-step and the percentage of unimpaired flows should be further evaluated.

To determine the percentage of unimpaired flow needed to protect Chinook salmon, the State Water Board reviewed flow exceedance information to determine what percentage of flow would be needed to achieve various flows. The analysis in section 4.2.3 indicates that increasing spring flows on the San Joaquin River and its tributaries is needed to protect Chinook salmon in the San Joaquin River basin. The TBI/NRDC analyses of temperatures and population growth indicate that there is a threshold response for fall-run Chinook salmon survival to flows above 5,000 cfs during the spring period and that average flows of 10,000 cfs during this same period may provide adequate flows to achieve doubling. Both the AFRP and DFG modeling analyses also seem to support these flows. However, the time periods for the AFRP recommended flows is from February through May and the time period for the DFG recommended flows is from March 15 through June 15. AFRP, DFG, and TBI/NRDC provide different recommendations for how to distribute flows during the spring period in different years, with increasing flows in increasingly wet years. All are generally consistent with an approach that mimics the natural flow regime to which these fish were adapted. Other analyses speak to the validity of this approach. (Propst and Gido, 2004 and Marchetti and Moyle, 2001, as cited in DOI 1, p. 25.) San Joaquin River flow criteria for the

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February through June period are determined to be 60% of unimpaired flows. Figure 20b shows that if 60% of unimpaired San Joaquin River flow at Vernalis were provided, average March through June flows would meet or exceed 5,000 cfs in over 85% of years (shown by red circle). An unimpaired flow of 60% during this period would also meet or exceed 10,000 cfs during the March through June time period in approximately 45% of years. The exceedance rates are not significantly different if applied to the February through June period as shown in Figure 20a. Additional information should be developed to determine whether these flows could be lower or higher and still meet the Chinook salmon doubling goal in the long term.

San Joaquin River Fall Flows
In addition to spring flows, fall pulse flows on the San Joaquin River are needed to provide adequate temperature and DO conditions for adult salmon upstream migration, to reduce straying, improve gamete viability, and improve olfactory homing fidelity for San Joaquin basin salmon. Analyses support a range of flows from 3,000 to 3,600 cfs for 10 to 14 days during mid to late October. Absent additional information, the State Water Board determines flow criteria for late fall to be 3,600 cfs for a minimum of 10 days in mid to late October. Providing these flows from the tributaries to the San Joaquin River that support fall-run Chinook salmon appears to be a critical factor to achieve homing fidelity and continuity of flows from the tributaries to the mainstem and Delta. Until additional information is developed regarding the need to maintain the 2006 Bay-Delta Plan October flow objective, these flows supplement and do not replace the 2006 Bay-Delta Plan October flow requirements such that flows do not drop below historic conditions during the remainder of October when the pulse flow criteria would not apply. Additional analyses should be conducted to determine the need to expand the pulse flow time period and modify the criteria to better mimic the natural hydrograph by coinciding pulse flows with natural storm events in order to potentially improve protection by mimicking the natural hydrograph.

Given that salmon and steelhead may be present in the San Joaquin River and its tributaries for all or most of the year (including spring-run in the future) and that the Bay-Delta plan does not currently include any flow requirements from July through September and November through January, additional flow criteria for the remainder of the year may be needed to protect Chinook salmon and their habitat. Specifically, additional criteria for spawning, egg incubation, rearing and riparian vegetation recruitment may be needed. However, adequate information is not available in the record for this proceeding upon which to base such criteria at this time. Additional information, building on the AFRP and other analyses, should be developed to determine needed flows for the remainder of the year.

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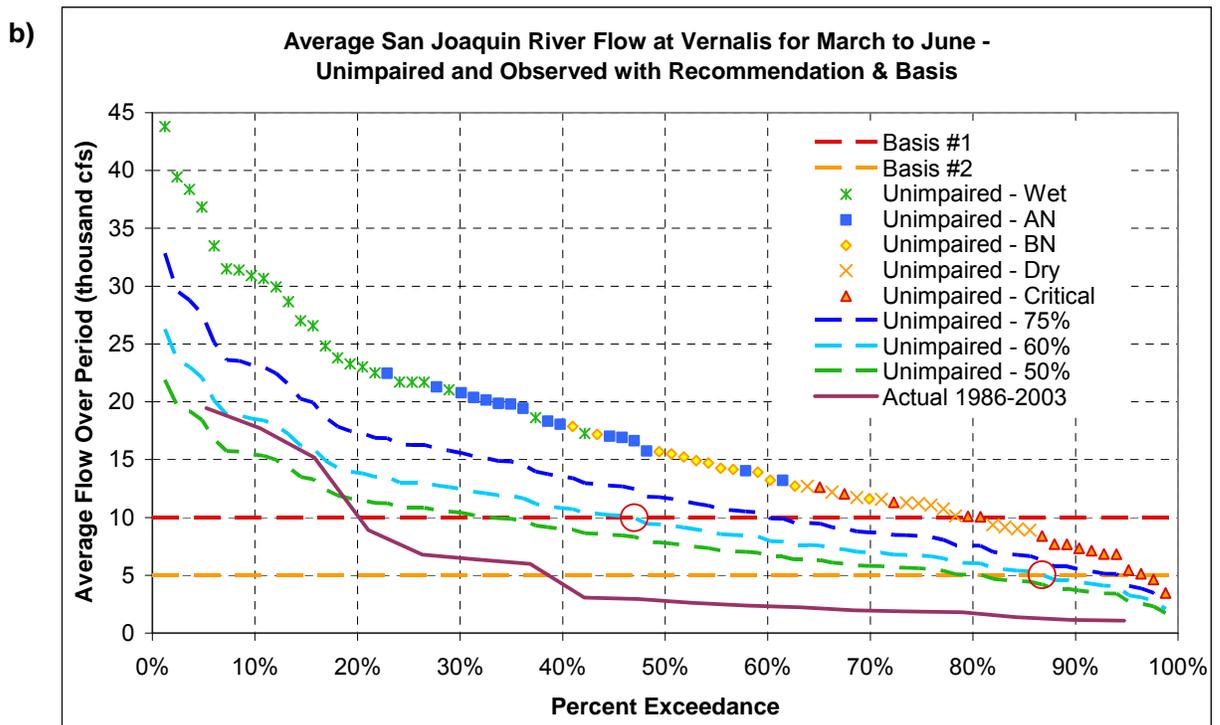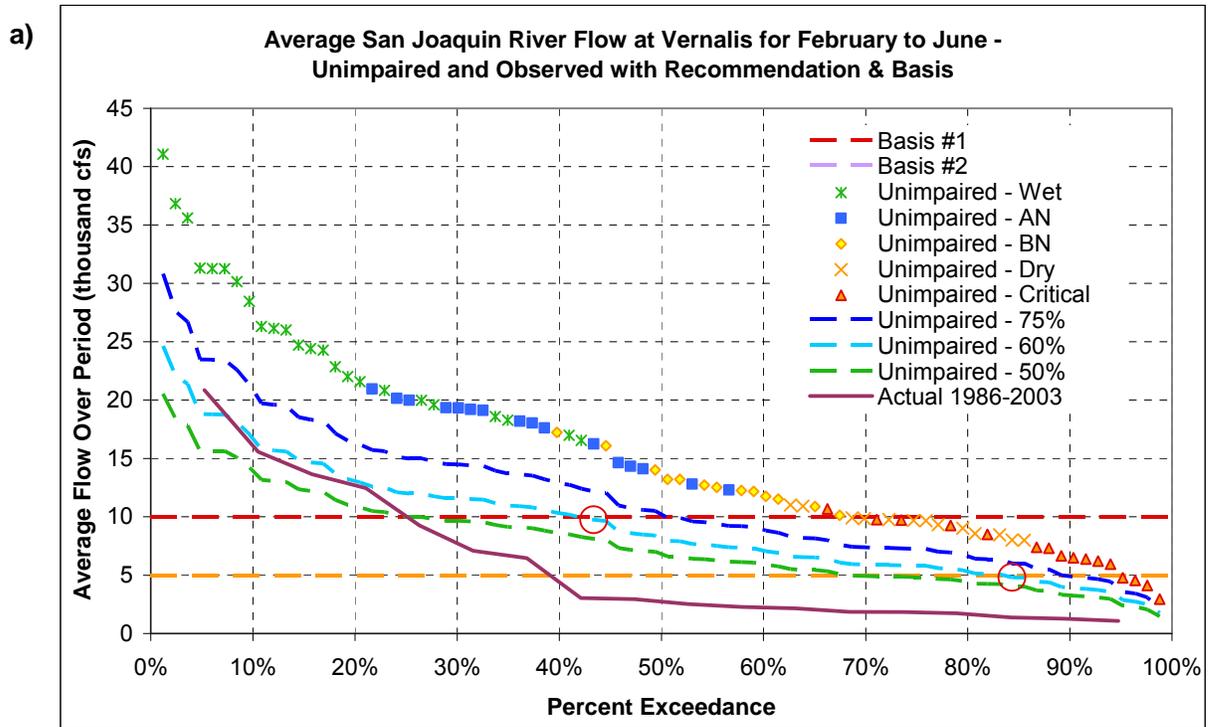
Figure 20. San Joaquin River Flow Exceedance Plot - February through June

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The specific San Joaquin River flow criteria may need to be tempered by the need to maintain water in reservoirs to provide adequate cold water and tributary specific flows in the San Joaquin River basin. It may not be possible to attain both the flow criteria and meet the thermal and tributary specific flow needs of steelhead, fall-run Chinook salmon, and other sensitive species in the San Joaquin River basin. Water supply modeling and temperature analyses should be conducted to identify conflicting requirements to achieve both flow and cold water temperature goals.

5.4   Hydrodynamics

The following hydrodynamic related criteria have been developed based on analysis of the species-specific flow criteria and other measures discussed above:

1) San Joaquin River Flow to Export Ratio: Vernalis flows to exports great than .33 during the 10 day San Joaquin River pulse flow in October
2) Old and Middle River Flows: greater than -1,500 cfs in March and June of Critical and Dry water years
3) Old and Middle River Flows: greater than 0 or -1,500 cfs in April and May of Critical and Dry water years, when FMWT index for longfin smelt is less than 500, or greater than 500, respectively
4) Old and Middle River Flows: greater than -5,000 cfs from December through February in all water year types
5) Old and Middle River Flows: greater than -2,500 when salmon smolts are determined to be present in the Delta from November through June
6) San Joaquin River Flow to export Ratio: Vernalis flow to exports greater than 4.0 when juvenile San Joaquin River salmon are migrating in the mainstem San Joaquin River from March through June
7) San Joaquin River at Jersey Point Flows: Positive flows when salmon are present in the Delta from November through June
8) 2006 Bay-Delta Plan Exports to Delta Inflow Limits for the Entire Year

Hydrodynamic criteria 1 is a Category A criterion because it is supported by more robust scientific information. Hydrodynamic criteria 2-7 are Category B criteria because there is less scientific information, with more uncertainty, to support the specific numeric criteria. The 2006 Bay-Delta Plan exports to Delta inflow objective (criteria 8) is offered as a Category B criterion as a minimal level of protection when the other criteria above do not apply. However, the validity of the specific export restrictions included in the 2006 Bay-Delta Plan were not specifically reevaluated. Category A and B criteria are both equally important for protection of the public trust resource, but there is more uncertainty about the appropriate volume of flow required to achieve the goals of the Category B criteria. Following is discussion and rationale for these criteria.

Pelagic Species Criteria
Net OMR reverse flows have increased in both magnitude and frequency with the development of the California water projects (Figure 8) and are having a detrimental effect on biotic resources in the Delta. (Brown et al. 1996.) It is also clear that the negative impact of net OMR reverse flows increases as Sacramento River inflows and net Delta outflow decreases. (Grimaldo et al. 2009; Kimmerer 2008; USFWS 2008; NMFS, 2009.) Net OMR flow restrictions for the protection of longfin and Delta smelt are only recommended for dry and critically dry water years when less Delta outflow may be available (Table 23, criteria 2 and 3). No spring restrictions for the protection of longfin

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and delta smelt are proposed for other water year types if the higher net Delta outflow criteria are met. If higher outflows are not provided in wetter years, then restrictions on OMR may be needed in these years as well. The State Water Board determines that net OMR flow criteria of greater than -5,000 cfs, from December through February in all water year types, to protect upstream migrating adult smelt are needed. The -5,000 cfs criterion may need to be made more protective if a large portion of the smelt population moves into the central Delta. The additional restrictions would be recommended after consultation with the USFWS (2008) Smelt Working Group. Spring and winter net OMR flow criteria for the protection of longfin and Delta smelt are classified as Category B because, as noted by the NAS (2010),

> "… the data do not permit a confident identification of the threshold [OMR] values to use … and … do not permit a confident assessment of the benefits to the population… As a result, the implementation of this action needs to be accompanied by careful monitoring, adaptive management and additional analyses that permit regular review and adjustment of strategies as knowledge improves…"

Chinook Salmon Criteria

Salmon must migrate through the Delta past the effects of the south Delta export facilities and the associated inhospitable conditions in the central Delta, first as juveniles on their way to the ocean, and later as adults returning to spawn. Exports change the hydrodynamic patterns in the Delta, drawing water across the Delta rather than allowing water to flow out of the Delta in a natural pattern. Over the years, different criteria have been developed to attempt to protect migrating salmon from the adverse hydrodynamic conditions caused by the south Delta export facilities in order to preserve the functional flows needed for migration that could be used to protect public trust resources. Net OMR flows, Jersey Point flows, and Vernalis flow to export ratios are all criteria that can be used to protect migrating salmon. The State Water Board advances a combination of these criteria to protect migrating salmon from export effects.

Increasingly negative net OMR flows have been shown to increase particle entrainment, particularly beginning at flows between -2,500 and -3,500 cfs. While juvenile salmon do not necessarily behave like particles, the particle entrainment estimates are a useful guide until additional information can be developed using evolving acoustic tracking methods and other appropriate techniques. Reduced negative net OMR flows should also provide some level of protection from the indirect reverse flow effects related to fish entering the central Delta where predation and other sources of mortality are higher. Based on the above, the State Water Board determines criteria for net OMR flows should be for greater than -2,500 cfs when salmon are present in the Delta during the peak juvenile outmigration period of November through June, for the protection of Chinook salmon. This is a Category B criterion because there is limited information upon which to base a specific numeric criteria at this time. Such information should be developed to better understand the relationship between salmon survival and net OMR flows to determine more specific criteria that would protect against entrainment and other factors leading to indirect mortality.

Increased reverse flows at Jersey Point have also been shown to decrease survival of salmon smolts migrating through the lower San Joaquin River. However, the precise Jersey Point flow that is necessary to protect migrating salmon is unclear. In addition, it is unclear whether the same functions of such a flow could be better met using different

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criteria such as net OMR flows or San Joaquin River flow to export ratios. The State Water Board therefore advances positive Jersey Point flows when salmon are present in the Delta during the peak juvenile salmon outmigration period of November through June. Again, this is a Category B criterion because there is limited information upon which to base a specific numeric criteria at this time.

Increased San Joaquin River flow to export ratios appear to improve survival for San Joaquin River salmon, though the exact ratio that is needed to protect public trust resources is not well understood. A San Joaquin River flow to export ratio of greater than 4.0 is recommended as a Category B criterion when San Joaquin River juvenile salmon are outmigrating from the San Joaquin River from March through June. There is, however, sufficient information in the record to support a Category A criterion for exports to be kept to less than 300% of San Joaquin River flows (equal to a San Joaquin River flow to export ratio of more than 0.33) at the same time that the recommended San Joaquin River pulse flows are provided. Additional analyses should be conducted to determine if this time frame should be extended to capture more of the San Joaquin River adult Chinook salmon return period between October and January.

The NAS review concerning OMR restrictions for salmon concluded that:

> "…the strategy of limiting net tidal flows toward the pump facilities is sound, but the support for the specific flows targets is less certain. In the near-term telemetry-based smolt migration and survival studies (e.g, Perry and Skalski, 2009) should be used to improve our understanding of smolt responses to OMR flow levels." (NAS 2010, p. 44.)

Much additional work is needed to better understand the magnitude and timing of the recommended criteria and how net OMR flow criteria should be integrated with other criteria for San Joaquin River flows, San Joaquin River flows to export ratios, Sacramento River flows, and net OMR flow restrictions for the protection of pelagic species. For all of the OMR, Jersey Point, and Vernalis flows to export ratiocriteria, further analysis and consideration is needed to determine: 1) how salmon presence should be measured and the information used to temper the criteria; 2) an appropriate averaging period; and 3) how to adaptively manage to assure that flows are sufficiently, but not overly, protective.

The October San Joaquin River flow to export ratio criteria is a Category A criterion since the basis for this minimum criterion is sufficiently understood to develop a quantitative criteria. Additional analyses should still, however, be conducted to determine if this criteria could be refined to provide better protection for migrating adult San Joaquin River Chinook salmon. All of the other hydrodynamic criteria for the protection of Chinook salmon are Category B criteria.

The San Joaquin River flow to export criterion during the spring is also a Category B criterion due to a lack of certainty regarding the needed protection level. Regarding this issue, the NAS concluded that:

> "…the rationale for increasing San Joaquin River flows has a stronger foundation than the prescribed action of concurrently managing inflows and exports. We further conclude that the implementation of the 6-year steelhead smolt survival study (action IV.2.2) could provide useful insight

as to the actual effectiveness of the proposed flow management actions
as a long-term solution." (NAS 2010, p. 45.)

In addition, based on similar uncertainty regarding needed protection levels and interaction between net OMR flows and San Joaquin River flows to export ratios, the San Joaquin River at Jersey Point criterion is also a Category B criterion. More work is needed to develop a suite of operational tools and an operational strategy for applying those tools to protect public trust resources in the Delta from the adverse hydrodynamic effects of water diversions, channel configurations, reduced flows, and other effects.

<u>2006 Bay-Delta Plan</u> <u>Export Objectives</u>
The 2006 Bay-Delta Plan includes export limitations for the entire year. From February through June exports are limited to 35-45% of Delta inflow. (State Water Board 2006a, pp. 184-187.) From July through January, exports are limited to 65% of Delta inflow. (*Id.*) The export to Delta inflow restrictions are intended to protect the habitat of estuarine-dependent species. (State Water Board 2006b, pp. 46-47.) These export restrictions provide a minimum level of protection for public trust uses and should be maintained to the extent that the other recommended criteria do not override them.

For all of the hydrodynamic criteria, biologically appropriate averaging periods need to be developed. Averaging periods may need to include a two-step approach whereby a shorter averaging period is included that allows for some divergence from the criteria and a longer averaging period is included that does not.

5.5   Other Inflows - Eastside Rivers and Streams

The Cosumnes and Mokelumne rivers, and smaller streams such as the Calaveras River, Bear Creek, Dry Creek, Stockton Diversion Channel, French Camp Slough, Marsh Creek, and Morrison Creek are all tributary to the Delta. Flows should generally be provided from tributaries in proportion to their contribution to unimpaired flow.

5.6   Other Measures

5.6.1 Variability, Flow Paths, and the Hydrograph

Criteria should reflect the frequency, duration, timing, and rate of change of flows, and not just volumes or magnitudes. Accordingly, whenever possible, the criteria specified herein are expressed as a percentage of the unimpaired flow rather than as a single number or range of numbers that vary by water year type. Additional efforts should focus on restoring habitat complexity. Inflows should generally be provided from tributaries to the Delta watershed in proportion to their contribution to unimpaired flow in order to assure connection between Delta flows and upstream tributaries, to the extent that such connections are beneficial to protecting public trust resources. Flows should be at levels that maintain flow paths and positive salinity gradients through the Delta. This concept is reflected in the specific determinations made above. More study is needed to determine to which tributaries such criteria should apply. For example, since the percent of unimpaired flow criteria determined to protect public trust uses for San Joaquin River inflows is at times lower than the criteria determined for Delta outflow, more study is needed to determine the appropriate source of such flows to protect public trust resources. All determined flow criteria must also be tempered by the need to protect health and safety. No flow criteria, for example, should be in excess of flows that would lead to flooding. For all of the flow criteria, there may be a need to reshape the

specified flows to better protect public trust resources based on real-time considerations. All of the criteria should be implemented adaptively to allow for such appropriate reshaping to improve biological and geomorphological processes.

Moyle *et al* (2010) concluded, however, that there is a fundamental conflict between restoring variability and maintaining the current Delta:

> "restoring environmental variability in the Delta is fundamentally inconsistent with continuing to move large volumes of water through the Delta for export. The drinking and agricultural water quality requirements of through-Delta exports, and perhaps even some current in-Delta uses, are at odds with the water quality and variability needs of desirable Delta species."

5.6.2 Floodplain Activation and Other Habitat Improvements

Activated floodplains stimulate food web activity and provide spawning and rearing habitat for floodplain adapted fish. The frequency of low-magnitude floods that occurred historically has been reduced, primarily by low water control levees. The record supports the conclusion that topography changes associated with future floodplain restoration will provide improved ecosystem function with less water. Studies and demonstration projects for, and implementation of, floodplain restoration projects should therefore proceed to allow for the possible reduction of flows required to protect public trust resources in the Delta.

Floodplain Flow Determinations for Protection of Salmon and Splittail:
Floodplain and off-channel inundation are required for splittail spawning and appear to be important in protecting Chinook salmon. At the same time, it is also important how and when such inundation occurs. Due to the effects of levees and dams, natural side channel and floodplain inundating flows have been substantially reduced. As a result, modification to weirs and other changes may be needed to substantially improve floodplain inundation conditions on the Sacramento and San Joaquin rivers. Based on the above, the State Water Board determines that an effort be made to provide appropriate additional seasonal floodplain habitat for salmon, splittail, and other species in the Central Valley. The various recommendations the State Water Board received for floodplain inundation are included in Appendix A.1. The State Water Board has no specific flow determinations for floodplain inundation. The State Water Board recommends that BDCP, the Council, and others continue to explore the various issues concerning flood protection, weir modifications, and property rights related to floodplain inundation.

Other future habitat improvements will likely change the response of native fishes to flow and allow flow criteria to be modified. Habitat restoration should proceed to allow for the possible reduction of flows required to protect public trust resources in the Delta. Other future habitat restoration that should be reviewed and implemented include:

- Development of slough networks with natural channel geometry and less diked and rip-rapped channel habitat
- Increased tidal marsh habitat, including shallow (one to two meters) subtidal areas in both fresh and brackish zones of the estuary (in Suisun Marsh, for example)

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- Create large expanses of low salinity open water habitat in the Delta

5.6.3 Water Quality and Contaminants

Any set of flow criteria should include the capacity to readily adjust the flows to adapt to changing future conditions and improved understanding. (DEFG 1.) As our understanding of the effect of contaminants on primary production and species composition in the Sacramento River and Delta improves, flow criteria may need to be revisited.

The Central Valley and San Francisco Regional Water Boards should continue developing Total Maximum Daily Loads (TMDLs) for all listed pollutants and adopting programs to implement control actions. Specifically, the Central Valley Regional Board should require additional studies and incorporate discharge limits and other controls into permits, as appropriate, for the control of nutrients, including ammonia.

5.6.4 Coldwater Pool Resources and Instream Flow Needs on Tributaries

The flow criteria contained in this report should be tempered by the need to maintain cold water resources and meet tributary specific flow needs in the Delta watershed. It may not be possible to attain all of the identified flow criteria in all years and meet the tributary flow needs and thermal needs of the various runs of Chinook salmon, steelhead, and other sensitive species. Temperature and water supply modeling analyses should be conducted to identify conflicting requirements to achieve both flow and cold water temperature goals. In addition, these flow determinations do not consider the needs of other non-fish species and terrestrial species which should be considered before any implementation of these criteria.

5.6.5 Adaptive Management

The numeric criteria are all short term criteria that are only appropriate for the current physical system and climate. There is uncertainty in these criteria even for the current physical system and climate, and therefore for the short term. Long term numeric criteria, beyond five years, for example, and assuming a modified physical system, are highly speculative. Only the underlying principles for the proposed numeric criteria and the other measures are advanced as long term determinations.

The information received in this proceeding suggests that the relationships between hydrology, hydrodynamics, water quality, and the abundance of desirable species are often unclear. In preparing for the long term, resources should be directed toward better understanding these relationships. In particular, there is significant uncertainty associated with Category B numeric criteria advcanced in this report. Category B criteria should therefore be high priority candidates for grant funded research.

A strong science program and a flexible management regime are critical to improving flow criteria. The relationship between flow, habitat, and abundance is not well enough understood to recommend flows in the Delta ecosystem without some reliance on adaptive management to better manage these flows. The State Water Board intends to work with the Council, the Delta Science Program, IEP, and others to develop the framework for adaptive management that could be relied upon for the management and regulation of flows in the Delta. The State Water Board will consider supporting and incorporating into its regulations greater reliance upon adaptive management in its flow regulations.

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5.7 Summary Determinations

Table 20 through Table 23 provide summary determinations for Delta outflows, Sacramento inflows, San Joaquin River inflows, and hydrodynamics, respectively. Each table shows various numbered criteria, applicable to the shaded range of months. Criteria fall into two categories. Category "A" criteria have more robust scientific information to support specific numeric criteria than do Category "B" criteria. Both categories of criteria are considered equally important for protection of public trust resources in the Delta ecosystem, and are supported by scientific information on function-based species or ecosystem needs. The basis and explanation for each criterion is provided. Each table is appended with the following notes to explain the limitations and constraints of how the criteria should be considered:

- All flows are subject to appropriate ramping rates to avoid ramping impacts to public trust resources
- These flow criteria should be tempered by tributary specific flow needs and the need to manage cold-water resources for the protection of public trust resources
- Criteria for percentages of unimpaired flows apply only up to a specified maximum cap; appropriate maximum flow caps still need to be determined based on public trust needs and to avoid flooding.
- Additional flows may be needed for the protection of public trust resources for periods of time for which no flow criteria have been determined or where Bay-Delta Plan flow objectives are advanced, but adequate information is not available at this time to determine such flows

These criteria are made specifically to achieve the stated goal of halting the population decline and increase populations of native species as well as species of commercial and recreational importance. Additionally, positive changes in the Delta ecosystem resulting from improved flow or flow patterns will benefit humans as well as fish and wildlife, especially when accompanied by large-scale habitat restoration and pollution reduction. (Moyle *et al*, 2010.)

In addition, Table 24 contains a summary of other issues and concepts that should be considered in conjunction with the numeric criteria. These other measures are also based on a synthesis of the best scientific information submitted by participants in the State Water Board's Informational Proceeding. These criteria and other measures, however, must be further qualified as to their limitations. The limitations of this and any other flow prescription are described at the end of the Fleenor *et al.* (2010) "flow prescriptions" report as a "further note of caution":

> "How much water do fish need?" has been a common refrain in Delta water management for many years… it is highly unlikely that any fixed or predetermined prescription will be a "silver bullet". The performance of native and desirable fish populations in the Delta requires much more than fresh water flows. Fish need enough water of appropriate quality over the temporal and spatial extent of habitats to which they adapted their life history strategies. Typically, this requires habitat having a particular range of physical characteristics, appropriate variability, adequate food supply and a diminished set of invasive species. While folks ask "How much water do fish need?" they might well also ask, "How much habitat of different types and locations, suitable water quality,

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improved food supply and fewer invasive species that is maintained by better governance institutions, competent implementation and directed research do fish need?" The answers to these questions are interdependent. We cannot know all of this now, perhaps ever, but we do know things that should help us move in a better direction, especially the urgency for being proactive. We do know that current policies have been disastrous for desirable fish. It took over a century to change the Delta's ecosystem to a less desirable state; it will take many decades to put it back together again with a different physical, biological, economic, and institutional environment."

The State Water Board concurs with this cautionary note and recommends the flow criteria and other conclusions advanced in this report be used to inform the planning efforts for the Delta Plan and BDCP and as a report that can be used to guide needed research by the Delta Science Program and other research institutions.

Table 20. Delta Outflow Summary Criteria

Delta Outflows												
Category A												
Water Year												**Criteria**
O	N	D	J	F	M	A	M	J	J	A	S	
												1) Net Delta Outflows: 75% of 14-day average unimpaired flow
Category B												
Water Year												**Criteria**
O	N	D	J	F	M	A	M	J	J	A	S	
												2) Fall X2 a. Wet years: X2 less than 74 km (greater than approximately 12,400 cfs) b. Above normal years: X2 less than 81 km (greater than approximately 7,100 cfs)
												3) Net Delta Outflows: 2006 Bay-Delta Plan Delta Outflow Objectives - applies during critical, dry, and below normal years
Basis for Criteria and Explanation												

1) Promote increased abundance and improved productivity (positive population growth) for longfin smelt and other desirable estuarine species
2) Increase quantity and quality of habitat for delta smelt; fall X2 requirement limited to above normal and wet years to reduce potential conflicts with cold water pool storage, while promoting variability with respect to fall flows and habitat conditions in above normal and wet water year types; expected to result in improved conditions for delta smelt, however, the statistical relationship between fall X2 and abundance is not strong; note 2) above regarding need for improved understanding concerning the fall X2 action also applies
3) Fish and wildlife beneficial use protection

Notes:
- These flow criteria do not consider any balancing of public trust resource protection with public interest needs for water.
- All flows are subject to appropriate ramping rates to avoid ramping impacts to public trust resources.
- These flow criteria should be tempered by tributary specific flow needs and the need to manage cold-water resources for the protection of public trust resources.
- Criteria for percentages of unimpaired flows apply only up to a specified maximum cap; appropriate maximum flow caps still need to be determined based on public trust needs and to avoid flooding.
- Additional flows may be needed for the protection of public trust resources for periods of time for which no flow criteria are recommended or where 2006 Bay-Delta Plan flow objectives are recommended, but adequate information is not available at this time to recommend such flows.

Table 21. Sacramento River Inflow Summary Criteria

Sacramento River Inflows													
Category A													
Water Year													**Criteria**
O	N	D	J	F	M	A	M	J	J	A	S		
						▓	▓	▓					1) Rio Vista: 75% of 14-day average unimpaired flow[1]
Category B													
Water Year													**Criteria**
O	N	D	J	F	M	A	M	J	J	A	S		
▓	▓	▓	▓	▓									2) Rio Vista: 75% of 14-day average unimpaired flow to support same functions as #1 for other runs of Chinook salmon
▓	▓	▓											3) Wilkins Slough: Provide pulse flows of 20,000 cfs for 7 days starting in November coinciding with storm events producing unimpaired flows at Wilkins Slough above 20,000 cfs until monitoring indicates that majority of smolts have moved downstream[2]
▓	▓	▓	▓	▓	▓	▓							4) Freeport: Positive flows in Sacramento River downstream of confluence with Georgiana Slough while juvenile salmon are present (approximately 13,000 to 17,000 cfs)
▓											▓		5) Rio Vista: 2006 Bay-Delta Plan flow objectives

Basis for Criteria and Explanation, and Notes

1) Increase juvenile salmon outmigration survival and abundance for fall-run Chinook salmon
2) Promote juvenile salmon emigration for other runs of Chinook salmon
3) Increase juvenile salmon outmigration survival by reducing diversion into Georgiana Slough and the central Delta
4) Increases juvenile salmon outmigration survival
5) Fall adult Chinook salmon attraction flows

Notes:
- These flow criteria do not consider any balancing of public trust resource protection with public interest needs for water.
- All flows are subject to appropriate ramping rates to avoid ramping impacts to public trust resources.
- These flow critiera should be tempered by tributary specific flow needs and the need to manage cold-water resources for the protection of public trust resources.
- Criteria for percentages of unimpaired flows apply only up to a specified maximum cap; appropriate maximum flow caps still need to be determined based on public trust needs and to avoid flooding.
- Additional flows may be needed for the protection of public trust resources for periods of time for which no flow criteria are recommended or where 2006 Bay-Delta Plan flow objectives are recommended, but adequate information is not available at this time to recommend such flows.

[1] 75% of unimpaired flow at Freeport applied to Rio Vista
[2] Definition of storm, number of storms, and how to determine when the majority of juveniles have outmigrated needs to be determined.

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Table 22. San Joaquin River Inflow Summary Criteria

San Joaquin River Inflows												

Category A

Water Year												Criteria
O	N	D	J	F	M	A	M	J	J	A	S	
					▨	▨	▨	▨				1) Vernalis: 60% of 14-day average unimpaired flow
▨												2) Vernalis: 10 day minimum pulse flow of 3,600 cfs in late October (e.g., October 15 to 26)

Category B

Water Year												Criteria
O	N	D	J	F	M	A	M	J	J	A	S	
▨												3) Vernaisl: 2006 Bay-Delta Plan October flows

Basis for Criteria and Explanation, and Notes

1) Increase juvenile Chinook salmon outmigration survival and abundance and provide conditions that will generally produce positive population growth in most years and achieve the doubling goal in more than half of years
2) Minimum adult Chinook salmon attraction flows to decrease straying, increase DO, reduce temperatures, and improve olfactory homing fidelity
3) Adult Chinook salmon attraction flows

Notes:
- These flow criteria do not consider any balancing of public trust resource protection with public interest needs for water.
- All flows are subject to appropriate ramping rates to avoid ramping impacts to public trust resources.
- These flow criteria should be tempered by tributary specific flow needs and the need to manage cold-water resources for the protection of public trust resources.
- Criteria for percentages of unimpaired flows apply only up to a specified maximum cap; appropriate maximum flow caps still need to be determined based on public trust needs and to avoid flooding.
- Additional flows may be needed for the protection of public trust resources for periods of time for which no flow criteria are recommended or where 2006 Bay-Delta Plan flow objectives are recommended, but adequate information is not available at this time to recommend such flows.

Table 23. Hydrodynamics Summary Criteria

Hydrodynamics: Net OMR, Inflow-Export Ratios, and Jersey Point													
Category A													
Water Year												**Criteria**	
O	N	D	J	F	M	A	M	J	J	A	S		
▓												1) San Joaquin River Flow to Export Ratio: Vernalis flows to exports greater than 0.33 during fall pulse flow (e.g., October 15 – 26); complementary action to San Joaquin River inflow critieria #2	
Category B													
Water Year												**Criteria**	
O	N	D	J	F	M	A	M	J	J	A	S		
					▓	▓	▓					2) Net OMR Flows: greater than -1,500 cfs in Critical and Dry water years	
					▓							3) Net OMR Flows: greater than 0 or -1,500 cfs in Critical and Dry water years, when FMWT index for longfin smelt is less than 500, or greater than 500, respectively	
	▓	▓	▓									4) Net OMR Flows: greater than -5,000 cfs in all water year types	
	▓	▓	▓	▓	▓	▓	▓					5) Net OMR Flows: greater than -2,500 cfs when salmon smolts are determined to be present in the Delta	
				▓	▓	▓	▓					6) San Joaquin River Flow to Export Ratio: Vernalis flows to exports greater than 4.0 when juvenile San Joaquin River salmon are migrating in mainstem San Joaquin River	
	▓	▓	▓	▓	▓	▓	▓					7) Jersey Point: Positive flows when salmon present in the Delta	
▓	▓	▓	▓	▓	▓	▓	▓					8) Exports to Delta Inflows: 2006 Bay-Delta Plan exports to inflows restrictions	
Basis for Criteria and Explanation													

1) Reduce straying and improve homing fidelity for San Joaquin basin adult salmon
2) Reduce entrainment of larval / juvenile delta smelt, longfin smelt, and provide benefits to other desirable species
3) Same as number 2), but if the previous FMWT index for longfin smelt is less than 500, then OMR must be greater than 0 (to reduce entrainment losses when abundance is low), or greater than -1,500 if the previous FMWT index for longfin smelt is greater than 500
4) Reduce entrainment of adult delta smelt, longfin smelt, and other species; less negative flows may be warranted during periods when significant portions of the adult smelt population migrate into the south or central Delta; thresholds for such flows need to be determined
5) Reduce risk of juvenile salmon entrainment and straying to central Delta at times when juveniles are present in the Delta; will also provide associated benefits for adult migration
6) Improve survival of San Joaquin River juvenile salmon emigrating down the San Joaquin River and improve subsequent escapement 2.5 years later
7) Increase survival of outmigrating smolts, decrease diversion of smolts into central Delta where survival is low, and provide attraction flows for adult returns
8) Protection of estuarine dependent species

(cont.)

Notes:
- These flow criteria do not consider any balancing of public trust resource protection with public interest needs for water.
- All flows are subject to appropriate ramping rates to avoid ramping impacts to public trust resources.
- These flow critieria should be tempered by tributary specific flow needs and the need to manage cold-water resources for the protection of public trust resources.
- Criteria for percentages of unimpaired flows apply only up to a specified maximum cap; appropriate maximum flow caps still need to be determined based on public trust needs and to avoid flooding.
- Additional flows may be needed for the protection of public trust resources for periods of time for which no flow criteria are recommended or where 2006 Bay-Delta Plan flow objectives are recommended, but adequate information is not available at this time to recommend such flows.

Table 24. Other Summary Determinations

Variability and the Natural Hydrograph:
- Criteria should reflect the frequency, duration, timing, and rate of change of flows, and not just volumes or magnitudes. Accordingly, whenever possible, the criteria specified above are expressed as a percentage of the unimpaired hydrograph.
- Inflows should generally be provided from tributaries to the Delta watershed in proportion to their contribution to unimpaired flow unless otherwise indicated. This concept is reflected in the specific criteria above.

Floodplain Activation and Other Habitat Improvements:
- Studies and demonstration projects for, and implementation of, floodplain restoration, improved connectivity and passage, and other habitat improvements should proceed to provide additional protection of public trust uses and potentially allow for the reduction of flows otherwise needed to protect public trust resources in the Delta.

Water Quality and Contaminants:
- The Central Valley and San Francisco Regional Water Boards should continue developing TMDLs for all listed pollutants and adopting programs to implement control actions.
- The Central Valley Regional Board should require additional studies and incorporate discharge limits and other controls into permits, as appropriate, for the control of nutrients and ammonia.

Coldwater Pool Resources and Instream Flow Needs on Tributaries:
- Temperature and water supply modeling and analyses should be conducted to identify conflicting requirements to achieve both flow and cold water temperature goals.

Adaptive Management:
- A strong science program and a flexible management regime are critical to improving flow criteria. The State Water Board should work with the Council, the Delta Science Program, IEP, and others to develop the framework for adaptive management that could be relied upon for the management and regulation of Delta flows.
- The numeric criteria in this report are all short term criteria that are only appropriate for the current physical system and climate; actual flows should be informed by adaptive management
- Only the underlying principles for the numeric criteria and these other measures are advanced as long termcriteria.

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7. Appendices

Appendix A: Summary of Participant Recommendations

Appendix A, Table 1. Delta outflow recommendations summary table (cfs unless otherwise noted).

	Water Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Source / Note
Unimpaired Flow 1956-2003	C	16092	23292	31045	29103	27552	15301	5974	3880	4096	8167	8372	12531	
	D	24670	37460	52907	45810	39512	18994	6801	4759	5180	7221	16635	19339	
	BN	32402	63985	52056	53471	49644	25325	9091	5683	6004	7027	12842	16911	
	AN	88051	99722	86990	69589	78076	50019	18214	7932	7862	8162	13980	26763	
	W	113261	114512	103250	92975	96911	68197	27987	11354	8717	11804	30357	77204	
Historical Flow 1956-2003	C / D	14117	17916	17597	9193	7367	4504	3952	3334	4285	6896	9663	12734	87
	BN	27274	48832	32673	14991	10100	4336	3952	5025	7798	12116	15192	18996	
	AN	61801	70133	70404	32283	27876	13444	7172	5985	7865	6766	10940	17093	
	W	94930	111565	87497	67642	46530	29897	14279	10588	15545	13385	23024	60061	
D1641	C	4500 [1]		7100 - 29200 [2]				4000	3000	3000	3000	3500		1, 2
	D	4500		7100 - 29200				5000	3500	3000	4000	4500		
	BN	4500		7100 - 29200				6500	4000	3000	4000	4500		
	AN	4500		7100 - 29200				8000	4000	3000	4000	4500		
	W	4500		7100 - 29200				8000	4000	3000	4000	4500		
Draft D1630	All			6700										3
	C					3300	3100	2900						4
	D					4300	3600	3200						
	BN					11400	9500	6500						
	AN					14000	10700	7700						
	W					14000	14000	10000						
	W			10000										5
	BN & AN			12000										6
	All			6600 (if > flow not required by other standards)										7
TBI / NRDC / AR / NHI / EDF	81-100% (driest years)		14000 - 21000		10000 - 17500		3000 - 4200			5750 - 7500				8
	61-80%		21000 - 35000		17500 - 29000		4200 - 5000			7500 - 9000				
	41-60%		35200 - 55000		29000 - 42500		5000 - 8500			9700 - 12400				
	21-40%		55000 - 87500		42500 - 62500		8500 - 25000			12400 - 16100				
	0-20% (wettest years)		87500 - 140000		62500 - 110000		25000 - 50000			16100 - 19000				
CSPA / C-WIN	C	4100	9100		6700					4100				9
	D	9200	23500		10800					9200				
	BN	12100	41000		14400					12100				
	AN	14600	90800		23000					14600				
	W	29000	91800		43000					29000				
EDF / Stillwater (monthly average)	C	11500	26800	26800	17500	17500	7500	4800	4800	4800	6500	5300	7500	10, 11, 12
	D	11500	26800	26800	17500	17500	7500	4800	4800	4800	6500	5300	7500	
	BN	26800	26800	26800	26800	26800	11500	7500	7500	7500	7500	7500	11500	
	AN	26800	26800	26800	26800	26800	11500	11500	11500	11500	11500	11500	17500	
	W	26800	26800	26800	26800	26800	17500	17500	17500	17500	17500	17500	26800	
EDF / Stillwater (peak flows)	C	11500	26800	26800	17500	17500	7500	4800	4800	4800	6500	5300	7500	13
	D	11500	26800	26800	17500	17500	7500	4800	4800	4800	6500	5300	7500	
	BN	26800	90800 [14]	90800 [15]	26800	26800	11500	7500	7500	7500	7500	7500	11500	14, 15
	AN	26800	105600 [16]	105600 [17]	26800	26800	11500	11500	11500	11500	11500	11500	17500	16, 17
	W	26800	105600 [18]	105600 [19]	26800	26800	17500	17500	17500	17500	17500	17500	26800	18, 19
USFWS - OCAP Bio Op	AN									X2 $\le$ 81 km (approx. 7000)	X2 $\le$ 81 km			20
	W									X2 $\le$ 74 km (approx. 12400)	X2 $\le$ 74 km			

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Appendix A, Table 1. Delta outflow recommendations summary table - con't. (p. 2 of 2)

	Water Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Source / Note
CDFG	All	Recommendation in X2 format: 64 - 75 km (approx. 29200 - 11400 cfs)												21
DWR / SFWC	All	Recommendation to maintain requirements stipulated in D-1641												22
The following is from Fleenor et al. 2010 (Preliminary Draft) - Functional flow approach with exports occurring via a peripheral canal, tunnel, or other alternative form of conveyance.														
Delta Solutions Group	5 of 10 yrs				48000									23

Appendix A, Table 2. Sacramento River inflow recommendations (cfs unless noted otherwise).

	Water Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Source / Note
D1641	C										3000		3500	
	D									3000	4000		4500	
	BN									3000	4000		4500	
	AN									3000	4000		4500	
	W									3000	4000		4500	
Draft D1630	All				≥18000									24
	All				≥13000 (14-day running average) and ≥9000 (min mean daily flow)									25
	C	1500	2500		2000			1000	1000			1500		26
	D	1500	2500		2500			1000	1000			1500		
	BN	2500	2500		3000			2000	1000			2500		
	AN	2500	2500		3000			2000	1000			2500		
	W	2500	3000		5000			3000	1000			5000		
CDFG	All				6000 (base flows)									27
	All				20000 - 30000 (pulse flows @ Rio Vista)									
C-WIN / CSPA	All				6000 (minimum base flows, measured @ Rio Vista)									28
	All				30000 (Freeport to Chipps Island)									29
PCFFA	All				25000 (Hood to Chipps Island)									30
USFWS					The catch of juvenile salmon at Chipps Island between April and June is correlated to flow at Rio Vista. The highest abundance leaving the Delta has been observed when flows at Rio Vista between April and June averaged above 20000 cfs..."									31
AR / NHI	All	Sac Riv at Bend Bridge - Pulse flows continuously exceed 8000, periodically exceed 12000, for a duration exceeding 2 weeks										See Jan - May		32
	All	Sac Riv at Wilkins Slough and Freeport - Pulse flows of 15000 at Wilkins Slough, and up to 20000 at Freeport, should occur for a duration of 7 days or longer. There should be at least 5 such events in dry years and more in wet years											See Jan - May	33
TBI / NRDC / AR / NHI	C (0-20 percentile)	27500 for 15 cont days												34
	D (20-40 percentile)	27500 for 30 cont days												
	BN	30000 for 60 cont days												
	AN	32500 for 90 continuous days												
	W	35000 for 120 continuous days												
NMFS	AN & W	≥ 17700 (at Grimes RM125)												35
	AN & W	≥ 31100 (at Verona RM80)												
	All	Provide pulse flows ≥ 20000 cfs, measured at Freeport periodically during winter-run emigration season to facilitate outmigration past Chipps Island (ie, Dec-Apr)											See Jan-Apr	36

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Appendix A, Table 2. Sacramento River inflow recommendations - con't. (p. 2 of 2)

	Water Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Source / Note
EDF / Stillwater	C	3500		10000		Determined based on Delta outflows ([38])					3000 - 3500 ([39])		3500	37, 38, 39
	D	4500		10000							3000 - 4500		4500	
	BN	4500		10000							3000 - 4500		4500	
		64000 (pulse flow, 21 consecutive days)												
	AN	4500		10000							3000 - 4500		4500	
		64000 (pulse flow, 35 consecutive days)												
	W	4500		10000							3000 - 4500		4500	
		64000 (pulse flow, 49 consecutive days)												
DWR / SFWC	All	Recommendation to maintain requirements stipulated in D-1641												22

The following is from Fleenor et al. 2010 (Preliminary Draft) - Functional flow approach with exports occurring via a peripheral canal, tunnel, or other alternative form of conveyance.

	Water Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Source / Note
Delta Solutions Group	6 of 10 yrs			10000								10000		40
	6 of 10 yrs					25000								41
	1 of 10 yrs			70000										41
	8 of 10 yrs		Yolo Bypass 2500 (Sac Riv ~45750)											42
	6 of 10 yrs		Yolo Bypass 4000 (pulse) (Sac Riv ~ 50150)											

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Appendix A, Table 3. San Joaquin River inflow recommendations summary table (cfs unless noted otherwise).

	Water Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Source / Note
D1641	C		710 or 1140 ([43])		3110 or 3540 ([44])		710 or 1140 ([43])				1000 ([45])			43, 44, 45
	D		1420 or 2280		4020 or 4880		1420 or 2280				1000			
	BN		1420 or 2280		4620 or 5480		1420 or 2280				1000			
	AN		2130 or 3420		5730 or 7020		2130 or 3420				1000			
	W		2130 or 3420		7330 or 8620		2130 or 3420				1000			
Draft D1630	C				2000 ([46])						>2000 ([47])			46, 47
	D				4000						>2000			
	BN				6000						>2000			
	AN				8000						>2000			
	W				10000						>2000			
CDFG	C			1500 (Base) 5500 (Pulse) (4/15-5/15) (Total 7000)										48
	D			2125 (Base) 4875 (Pulse) (4/11-5/20) (Total 7000)										
	BN			2258 (Base) 6242 (Pulse) (4/6-5/25) (Total 8500)										
	AN			4339 (Base) 5661 (Pulse) (4/1-5/30) (Total 10000)										
	W			6315 (Base) 8685 (Pulse) (3/27-6/4) (Total 15000)										
C-WIN / CSPA	C			13400	4500	6700	8900	1200				5400			49
	D			13400 (2 days)	4500	6700	8900	1200				5400			
	BN			13400 (16 days), 26800 (2 days)	4500	6700	8900	11200	1200			5400			
	AN			13400 (13 days), 26800 (5 days)	4500	6700	8900	11200	1200			5400			
	W			13400 (17 days), 26800 (5 days)		13400		14900				5400			
TBI / NRDC	100% of years (all yrs)		2000			5000				2000				50
	80% (D yrs)		2000		5000	10000	7000	5000			2000			
	60% (BN yrs)		2000		20000	10000	7000	5000			2000			
	40% (AN yrs)		2000	5000	20000		7000				2000			
	20% (W yrs)		2000	5000	20000		7000				2000			

	Water Year	Jan	Feb	Mar		Apr	May		Jun	Jul	Aug	Sept	Oct	Nov	Dec	Source / Note
AR / NHI	100% of years (all yrs)			3000	4000	5000			2000							51
	80% (D yrs)			3000	4000	5000	10000	7000	5000	2000							
	60% (BN yrs)			3000	5000	20000	10000	7000	5000	2000							
	40% (AN yrs)			3000	5000	20000		7000		2000							
	20% (W yrs)			3000	5000	20000		7000		2000							
	All			Flows of approx. 10000 cfs should occur at Vernalis for ≥5 days. There should be at least 2 such events in dry years, and more in wetter years.												
EDF / Stillwater	All												> 1800 in DWSC			52
	All			Discuss USFWS (1995) and D-1641, no clear recommendation ([55])					Determined based on Delta outflows ([38])				3500 (10-14 days) ([54])	FERC ([53])		38, 53, 54, 55
	C & D	1000 (positive flows at Jersey Pt)													See Jan-Feb		56
	BN & AN	2000 (positive flows at Jersey Pt)													See Jan-Feb		
	W	3000 (positive flows at Jersey Pt)													See Jan-Feb		
	AN	14800 (pulse flow, ≥ 21 consecutive days)															57
	W	14800 (pulse flow, ≥ 35 consecutive days)															
USFWS				"...the Board should consider the Vernalis flows contained in USFWS (2005) [AFRP] and DFG's San Joaquin Escapement Model as a starting point for establishing flow for the protection of salmon and steelhead migrating from the San Joaquin basin"												58
AFRP (salmon doubling)	C		1744	2832		4912	5665									59
	D		1784	3146		5883	7787									
	BN		1809	3481		6721	9912									
	AN		2581	5162		8151	13732									
	W		4433	8866		10487	17369									
AFRP (53% Increase in Salmon Production)	C		1250	1665		2888	3331									60
	D		1350	1850		3459	4579									
	BN		1450	1933		3733	5505									
	AN		1638	2703		4266	7194									
	W		2333	4667		5520	9142									
NMFS OCAP Bio Op						Interim Operations in 2010-2011, min flows at Vernalis ranging from 1500 - 6000 based on New Melones Index										61
		In addition, USBR/DWR shall seek supplemental agreement with SJRGA as soon as possible to achieve the min flows listed below at Vernalis															
	C					1500										
	D					3000										
	BN					4500										
	AN					6000										
	W					6000										

	Water Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Source / Note
NMFS	AN & W AN & W		≥ 14000 (at Vernalis) ≥ 7000 (at Newman)												62
DWR / SFWC	All	Recommendation to maintain requirements stipulated in D-1641													22
The following is from Fleenor et al. 2010 (Preliminary Draft) - Functional flow approach with exports occurring via a peripheral canal, tunnel, or other alternative form of conveyance.														
Delta Solutions Group	C D BN AN W		2000 2000 2000 2000 2000		5000 7000 10000 15000 20000					2000 2000 2000 2000 2000					63

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Appendix A, Table 4. Old and Middle River flow, export restriction, San Joaquin River flows at Jersey Point (e.g., QWEST) recommendations summary table (cfs unless noted otherwise).

	Water Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Source / Note
D1641	All	See Jul-Dec	Export/Inflow Ratio: 35% of Delta Inflow ([64])					Export/Inflow Ratio: 65% of Delta Inflow						64
	All				Export Limit: > of 1500 or 100% of 3-day avg. Vernalis flow									65
Draft D1630	All	QWEST > -2000	No reverse flow for all year types on a 14-day running average in the Western Delta (QWEST > 0 cfs, as calculated in Dayflow)					QWEST > -1000	QWEST > -2000					66
	C & D				14-day running average combined export rate for Tracy, Banks, and Contra Costa pumping plants shall be ≤ 4000 cfs									
	BN, AN, W				14-day running average combined export rate for Tracy, Banks, and Contra Costa pumping plants shall be ≤ 6000 cfs									
CSPA / C-WIN	All				Combined Export Rates = 0									67
	All			2000 cfs daily flow in Old and Middle Rivers										68
	C	1000 (positive 14-day mean flows at SJ Riv at Jersey Pt)										See Jan-June		69
	D	1500 (positive 14-day mean flows at SJ Riv at Jersey Pt)										See Jan-June		
	BN	2000 (positive 14-day mean flows at SJ Riv at Jersey Pt)										See Jan-June		
	AN	2500 (positive 14-day mean flows at SJ Riv at Jersey Pt)										See Jan-June		
	W	3000 (positive 14-day mean flows at SJ Riv at Jersey Pt)										See Jan-June		
TBI / NRDC		Sac Salmonids, Delta Smelt, Longfin Smelt*		Sac & SJR Salmonids, D. Smelt, L. Smelt*	Sac & SJR Salmonids, D. Smelt, L. Smelt (C & D yrs)		Sac & SJR Salmonids, D. Smelt				Sac Basin Salmon		Sac Salmon, D. Smelt	70
	C	-1500 or >0*	-1500 or >0*	-1500 or >0*	>0	>0	-1500				-2000	-2000	-1500	
	D	-1500 or >0*	>0	>0	>0	>0	-1500				-2000	-2000	-1500	
	BN	-1500 or >0*	-1500 or >0*	>0	>0	>0	-1500				-2000	-2000	-1500	
	AN	-1500 or >0*	-1500 or >0*	>0	>0	>0	-1500				-2000	-2000	-1500	
	W	-1500 or >0*	-1500 or >0*	>0	>0	>0	-1500				-2000	-2000	-1500	
AFRP	C / D	1000 (net seaward flows at Jersey Pt)									See Jan-June			71
	BN / AN	2000 (net seaward flows at Jersey Pt)									See Jan-June			
	W	3000 (net seaward flows at Jersey Pt)									See Jan-June			
NMFS - OCAP Bio Op	All	Limit negative flows to -2000 to -5000 cfs in Old and Middle Rivers, depending on the presence of salmonids (see decision tree upon which the negative flow objective w/in the range shall be determined)												72
	All				Export restrictions based on Vernalis flow: <6000 cfs = 1500 cfs export limit 6000-21750 cfs = 4:1 (Vernalis flow:export ratio) >21750 = Unrestricted									

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	Water Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Source / Note
USFWS	All	Board should develop reverse flow criteria that would maintain Old and Middle River flow positive during key months (Jan - Jun)												73
	All	"...the AFRP Working Paper (USFWS, 1995) Restoration Action #3 calls for maintaining positive QWEST flows, or an equivalent measure of net seaward flows at Jersey Point... Higher flow at Jersey Point has been provided during the VAMP period (mid-April to mid-May) with the adoption of VAMP flows and exports. We encourage the Board to retain or expand this type of action to assure the contribution of downstream flow from the San Joaquin Basin to Delta outflow..."										See Jan - June		74
USFWS - OCAP Bio Op	All	Action 1: -2000 cfs for 14 days once turbidity or salvage trigger has been met. Action 2: range btw -1250 and -5000 cfs ([75])			Range between -1250 and -5000 ([76])								See Jan-Mar	75, 76
CDFG Longfin Smelt Incidental Take Permit	All	Condition 5.1 (Dec - Feb): >-5000 ([77]) Condition 5.2 (Jan - June): OMR flow between -1250 and -5000 cfs ([78])											Condition 5.1 (Dec-Feb)	77, 78
DWR / SFWC	All	Recommendation to maintain requirements stipulated in D-1641												22

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Appendix A, Table 5. Floodplain inundation flow recommendations summary table.

	Water Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Source / Note
CDFG	AN & W	≥ 30 day floodplain inundation												79
EDF / Stillwater	BN AN W	64000 (pulse flow, 21 consecutive days) 64000 (pulse flow, 35 consecutive days) 64000 (pulse flow, 49 consecutive days)												37 Sacr Riv - Yolo Byp
TBI / NRDC / AR / NHI	C (0-20 percentile) D (20-40 percentile) BN AN W	27500 for 15 cont days 27500 for 30 cont days 30000 for 60 cont days 32500 for 90 continous days 35000 for 120 continuous days												34 Sac Riv - Yolo Byp
AR / NHI	All	Sac Riv at Bend Bridge - Pulse flows continuously exceed 8000, periodically exceed 12000, for a duration exceeding 2 weeks										See Jan - May		32
USFWS	6 of 10 yrs	"The Board should consider the importance of more frequent floodplain inundation (especially Yolo Bypass flows) when determining the Delta outflows…"												80
NMFS - OCAP Bio Op	All	"…Reclamation and DWR shall, to the maximum extent of their authorities, provide significantly increased acreage of seasonal floodplain rearing habitat, with biologically appropriate durations and magnitudes, from December through April, in the lower Sacramento River basin, on a return rate of approximately one to three years, depending on water year type."										See Jan-Apr		81
NMFS - Recovery Plan	All	"Enhance the Yolo Bypass by re-configuring Fremont and Sacramento weirs to: … and (6) create annual spring inundation of at least 8000 cfs to fully activate the Yolo Bypass floodplain."												82
Delta Solutions Group	8 of 10 yrs 6 of 10 yrs	Yolo Bypass 2500 (Sac Riv ~ 45750) Yolo Bypass 4000 (pulse) (Sac Riv ~ 50150)												42

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	Water Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Source / Note
EDF / Stillwater	AN W	14800 (pulse flow, ≥ 21 consecutive days) 14800 (pulse flow, ≥ 35 consecutive days)												57

See TBI / NRDC and AR / NHI SJ River Inflow recommendations, flows >20000 cfs to trigger floodplain inundation

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Appendix A, Table 6. Delta Cross Channel closures summary table.

	Water Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Source / Notes
D-1641		see Nov	Gates Closed			Close for 14 days ([83])						Nov-Jan - gates may be closed for up to total of 45 days		83
Draft D-1630	All	Closed if daily DOI >12000	Operated based on results of real-time monitoring											84
CSPA / C-WIN	All / All		Gates Closed / Acoustic Barrier at head of Georgiana Slough at Sacramento River											85
NMFS - OCAP Bio Op	All	Dec 15 - Jan 31 Gates closed	Gates Closed per D1641			Gates closed up to 14 days per D1641					Gates closed if fish are present	Gates closed except for experiments/water quality	Dec 15 Jan 31 Gates closed	86

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Appendix A, Table 7. Notes for Tables 1 through 6.

No.	Entity	Type	Notes (excerpts from source documents)
1	D1641	Outflow	All water year types - Increase to 6000 if the Dec 8RI is > than 800 TAF
2	D1641	Outflow	Habitat Protection Flows, minimum Delta outflow calculated from a series of rules that are described in Tables 3 and 4 of D1641
3	Draft D1630	Outflow	Striped Bass, Antioch spawning - Delta outflow index, Sac Riv at Chipps Island, average for the period not less than value shown (cfs).
4	Draft D1630	Outflow	Striped Bass, general - Delta outflow index, Sac River at Chipps Island - average for period not less than value shown (cfs), May period = May 6-31
5	Draft D1630	Outflow	Suisun Marsh - Delta outflow index at Sac River at Chipps Island - average of daily DOI for each month, not less than value shown (cfs)
6	Draft D1630	Outflow	Suisun Marsh - Delta outlflow index, Sac River at Chipps Island - minimum daily DOI for 60 consecutive days in the period
7	Draft D1630	Outflow	Suisun Marsh - Delta outflow index, Sac River at Chipps Island - average of daily DOI for each month, not less than value shown, in cfs: applies whenever storage is at or above minimum level in flood control reservation envelope at two of the following - Shasta Reservoir, Oroville Reservoir, and CVP storage on the American River
8	TBI et al	Outflow	Water year categories represent exceedance frequencies for the 8-river index, they are not equivalent to the DWR "water year types" (which account for storage and other conditions). TBI_Exhibit 2 (Outlfow). References for correlation btw winter-spring outlfow and abundance of numerous species on p.3. Winter-spring Delta outflow criteria approximate the frequence distribution of outflow levels, i.e., the relationship btw outflow and the 8 River Index, for the 1956-1987 period. Winter and spring outlfow recommendations to benefit public trust uses of pelagic species (as represented by abundance and productivity of longfin smelt, Crangon shrimp, and starry flounder and spatial distribution of longfin smelt) (see TBI Exhibit 2, pp 21-25). Two methods were used to develop outflow criteria: an analysis of historical flow-abundance relationships that corresponded to recovery targets for longfin smelt abundance (Native Fishes Recovery Plan, USFWS 1995), and an analysis of population growth response to outflows in order to identify outflows that produced population growth more than 50% of the time. Applying these
8 cont	TBI et al	Outflow	two methods produces very similar results regarding desirable outflow levels. Break in summary table at mid-Mar is artificial, original table included Mar under both Winter and Spring, so for simplicity, it was split at 15 Mar. Fall outflows (TBI Exhibit 2, p. 35, Table 1 and Fig 27) - analyzed emerging statistical evidence of relationship btw outlfow and abundance and distribution of delta smelt and striped bass (Feyrer et al 2007; Feyrer et al In Review; DSWG notes, Aug 21, 2006), in order to develop recommendations. Recommendations occassionaly exceed unimpaired outflow in limited cases (would require reservoir releases in fall independent of antecedent conditions).

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Appendix A, Table 7. Notes for Tables 1 through 6.

No.	Entity	Type	Notes (excerpts from source documents)
9	CSPA / C-WIN	Outflow	Net Delta Outflow, as a 14-day running average - Source WRINT-DFG Exh 8 (1992). Feb-Mar - flows correspond to Table 8 (p.23), Alternative C (Estuarine species - target mean monthly flows based on data from DWR's 1995 Level of Development + 50% increase). Orig. recommendations by month, C-WIN/CSPA took average of Feb and Mar, and reported as such. Apr-July - flows correspond to Table 2 (p16), Alternative C (mean Delta outflows required to maintain populations of 1.7 million adult striped bass). Aug-Jan - based on Alt C (discussed above), in combination with flow recommendations developed by C-WIN for Jan. DFG identified flows for all months except Jan, C-WIN developed a method for Jan flows from DayFlow information (C-WIN extracted monthly average Delta outflows from DayFlow, sorted them, and then allocated them to water years based on unimpaired runoff data from the California Data Exchange Center. The medians of the water year types were then used as January flows in developing our optimal conditions recommendations for mean Delta outflows in the August 1 through January 31 period).
10	EDF / Stillwater	Outflow	Stillwater Focal Species Approach - Source - EDF closing comments (Table 1), Supporting Info - EDF Exhibit 1 (Winter [Dec-Feb] outflows - p.52-53). A primary objective was to provide enough Delta outflow to maintain X2 westward of 65 km, w/ variations to allow eastward excursion of X2 as far as 80 km in drier water year types. Proximate function is to increasethe westward extent of fresh water into Suisun and San Francisco bays to more closely approximate historical conditions. "This will serve to increase the availability of food resources to larval fish species in late winter as well as improve access to low salinity habitat in the shallows of Grizzly and Honker bays (Feyrer et al 2009)." Flows also designed to limit the eastward distribution and density of overbite clam. "...low salinity may inhibit spawning and subsequent adult recruitment, thereby reducing grazing pressures on phytoplankton and the pelagic food web. Improvements in food resources to the western Delta will serve to increase populations of Delta smelt, striped bass, and other pelagic species that are currently in decline."
11	EDF / Stillwater	Outflow	Stillwater Focal Species Approach - Source - EDF closing comments (Table 1), Supporting Info - EDF Exhibit 1 (Spring [Mar-May] Outlfows - p.55-56). Spring flows primarily based on delta outflows needed to maintain X2 in locations that are beneficial to delta pelagic fish populations as well as the provision of floodplain inundation in the Yolo Bypass during March Primary objective was to provide enough Delta outflow to maintain X2 westward of 65 km, w/ variations to allow eastward excursion of X2 as far as 70 km in drier water year types. References in justification: Feyrer et al. In Revision, Bennett et al 2005. Herbold 1994, Hobbs et al 2004, Bennett et al. 2008, and others). Secondary goal is to provide sufficient flows to maintain inundated season floodplain habitat in Yolo Bypass and lower SJ Riv for varying periods in March based on water year type. These floodplain inundation flows should be coordinated with flows in late winter to provide prolonged periods of inundation.
12	EDF / Stillwater	Outflow	Stillwater Focal Species Approach - Source - EDF closing comments (Table 1), Supporting Info - EDF Exhibit 1 (Fall [Sept-Nov] - pp.49-50; Summer - pp.57-58) Summer (Jun-Aug) and Fall flows based primarily on Delta outflows needed to maintain X2 in the shallow-water habitats of Suisun Bay. Secondary objective for Fall outflows from the Delta were to provide attraction flows for upstream-migrating salmonids and to maintain adequate DO concentrations for fall-run chinook salmon within the lower SJ River system. Summer and Fall - in some months and water year types, depending on water year type and month, the projected monthly outflows are higher than the unimpaired and/or current flow ranges. Thus some modification of upstream reservoir release schedules may be required to meet these flows. Fall - references in justification - Feyrer et al 2007; Feyrer et al In revision; Bennet et al 2002; Jassby et al 1995; and others

Appendix A, Table 7. Notes for Tables 1 through 6.

No.	Entity	Type	Notes (excerpts from source documents)
13	EDF / Stillwater	Outflow	EDF_Closing Comments (Table 1) - Peak flows required to provide floodplain inundation are assumed to be concurrent between the Sac and SJ River basins as well as the east side tributaries. However, the duration of the peak flows varies by water year (see notes 69-74)
14	EDF / Stillwater	Outflow	EDF_Closing Comments (Table 1) - Includes 14 days of floodplain inundation flow of 64000 cfs in the Sac River
15	EDF / Stillwater	Outflow	EDF_Closing Comments (Table 1) - Includes 7 days of floodplain inundation flow of 64000 cfs in the Sac River
16	EDF / Stillwater	Outflow	EDF_Closing Comments (Table 1) - Includes 21 days of floodplain inundation flow of 64000 cfs in the Sac River and 14 days of floodplain inundation flow of 14800 cfs in the SJ River
17	EDF / Stillwater	Outflow	EDF_Closing Comments (Table 1) - Includes 14 days of floodplain inundation flow of 64000 cfs in the Sac River and 7 days of floodplain inundation flow of 14800 cfs in the SJ River.
18	EDF / Stillwater	Outflow	EDF_Closing Comments (Table 1) - Includes 28 days of floodplain inundation flow of 64000 cfs in the Sac River and 21 days of floodplain inundation flow if 14800 cfs in the SJ River
19	EDF / Stillwater	Outflow	EDF_Closing Comments (Table 1) - Includes 21 days of floodplain inundation flow of 64000 cfs in the Sac River and 14 days of floodplain inundation flow of 14800 cfs in the SJ River
20	USFWS	Outflow	Delta smelt biological opinion (RPA concerning Fall X2 requirements [pp. 282-283] - improve fall habitat [quality and quantity] for DS) (references USFWS 2008, Feyrer et al 2007, Feyrer et al in revision) - Sept-Oct in years when the preceeding precipitation and runoff period was wet or above normal, as defined by the Sacramento Basin 40-30-30 Index, USBR and DWR shall provide sufficient Delta outflow to maintain monthly average X2 no greater than 74 km and 81 km in Wet and Above Normal yrs, respectively. During any November when the preceding water yr was W or AN, as defined by Sac Basin 40-30-30 index, all inflow into the CVP/SWP reservoirs in the Sac Basin shall be added to reservoir releases in Nov to provide additional increment of outflow from Delta to augment Delta outflow up to the fall X2 of 74 km and 81 km for W and AN water yrs, respectively. In the event there is an increase in storage during any Nov this action applies, the increase in reservoir storage shall be released in December to augment the Dec outflow requirements in SWRCB D-1641.
21	CDFG	Outflow	Outflow recommendations from closing comments. Originally provided as X2 recommendations - Source - DFG Exhibit 1 and Exhibit 2 - Consolidates recommendations for American Shad, Longfin Smelt, Starry Flounder, Bay Shrimp, Zooplankton (consistent with D1641 requirements to maintain X2 at one of two compliance points in Suisun Bay [64 km or 75 km] from Feb-June). Longfin smelt = Jan - June; Starry flounder, Bay shrimp, zooplankton = Feb - Jun; and American Shad = April - June.
22	DWR / SFWC	Outflow, SJ Riv Inflow, Sac Riv Inflow, OMR	DWR_closing comments, in response to request for a table identifing recommended flows, DWR submitted summary of D-1641 objectives.

Appendix A, Table 7. Notes for Tables 1 through 6.

No.	Entity	Type	Notes (excerpts from source documents)
23	UCDavis - Delta Solutions Group	Outflow	Functional Flow 5a - Delta Smelt flows, 48000 cfs, from March through May (5 out of 10 years, every other year). Maintain freshwater to low salinity habitat in the northeastern Delta to Napa River, facilitating a broad spatial and temporal range in spawning and rearing habitat (Bennett 2005, Hobbs et al 2005). Flow recommendation not based on water year type, but rather number of years out of 10. Based on exports through an alternative form of conveyance (e.g., peripheral canal or tunnel).
24	Draft D1630	Sac River Inflow	Function = Chinook salmon. Sac River at Freeport. Average flow at Freeport >18000 cfs for a 14-day continuous period corresponding to release of salmon smolts from Coleman Nat Fish Hatchery. Anticipate to occur in late April or early May. If no fish are released from the hatchery, the Executive Director shall determine the appropriate timing of this pulse flow with advice from CDFG.
25	Draft D1630	Sac River Inflow	Function = striped bass, general; Sac River at Freeport - 14-day running average at Freeport >13000 cfs for a 42-day continuous period, with minimum mean daily flow >9000 cfs. Requirement initiated when real-time monitoring indicates the presence of striped bass eggs and larvae in Sac River below Colusa. This period should begin in late April or early May in most years.
26	Draft D1630	Sac River Inflow	Function = chinook salmon. Sac River at Rio Vista - 14-day running average of minimum daily flow.
27	CDFG	Sac River Inflow	Chinook salmon, smolt outmigration. (1) Feb - Oct base flows. Source - DFG Exhibit 14 (WRINT-DFG-8, p.11). (2) Apr - Jun pulse flows. Source - DFG Exhibit 1, page 1, 6, and USFWS Exhibit 31 (Kjelson).
28	CSPA	Sac River Inflow	CSPA Closing Comments. Source - CDFG_1992_WRINT-DFG-Exhibit #8, p.11. Minimum base flow, measured at Rio Vista. 14-day average flow.
29	CSPA / C-WIN	Sac River Inflow	Sacramento River from Freeport to Chipps Island - Pulse flows - flows needed to sustain viable migration corridor for optimal smolt passage and survival. Source - USFWS Exhibit 31 (Kjelson)
30	PCFFA	Sac River Inflow	Function = salmonid juvenile outmigration. PCFFA closing comments, Source - USFWS Exhibit 31 (Kjelson). Kjelson and Brandes research - found that flows of 20000 to 30000 cfs yield the greatest survival of juvenile salmon during out-migration from Sac River to San Francisco Bay (PCFFA recommends splitting the difference and setting standard at 25000 cfs). Set from Hood to Chipps Island.
31	USFWS	Sac River Inflow	USFWS testimony concerning scientific information used to determine flow criteria. Source: U.S. Department Of the Interior - Comments Regarding the California State Water Resources Control Board's Notice of Public Informational Proceeding to Develop Delta Flow Criteria for the Delta Ecosystem Necessary to Protect Public Trust Resources, Sections II and III, pages 25, 54, and 57. "The catch of juvenile salmon at Chipps Island between April and June is correlated to flow at Rio Vista (USFWS, 1987; Brandes and McLain, 2001; Brandes et al., 2006). The highest abundance leaving the Delta has been observed when flows at Rio Vista between April and June averaged above 20,000 cfs which is also the level where we have observed maximum survival in the past (USFWS, 1987)" (p.25).

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No.	Entity	Type	Notes (excerpts from source documents)
32	AR / NHI	Sac River Inflow	AR_NHI_Exh1 (testimony of Cain, Opperman, and Tompkins) and AR_NHI_closing comments. Purpose - interconnect side channels with main channel, contribute to foodweb productivity and rearing habitat for salmon. Inundated off-channel habitat such as high flow channels can also provide rearing habitat for salmon (Peterson and Reid 1984), but regulated spring flows are generally insufficient to inundate these habitats for prolonged periods (30-60 days), A recent study of these habitats in the Sac River determined that a large proportion of secondary channels between Red Bluff and Colusa become fully connected to the river at flows above 12000 cfs (Kondolf 2007). (from AR_NHI_Exh1 p.28)
33	AR / NHI	Sac River Inflow	AR_NHI_Exh1 (Testimony of Cain, Opperman, and Tompkins) and AR_NHI_closing comments - aid migration of winter-run chinook, in later months aid migration of spring and fall-run. Recent analyses indicate that the onset of emigration of winter-run fish to the Delta at Knights Landing is triggered by flow pulses of 15000 cfs at Wilkins Slough, and emigration from the Sac River to Chipps Island follows pulse flows of 20000 cfs at Freeport (del Rosario 2009). Previous studies found that smolt survival increased with increasing Sac River flow at Rio Vista, with maximum survival observed at or above about 20000 and 30000 cfs (USFWS 1987, Exhibit 31). Despite uncertainty about the exact magnitude of flow necessary to initiate substantial bank erosion, there is growing evidence that flows between 20000 and 25000 cfs will erode some banks while flows above 50000 to 60000 cfs are likely to cause widespread bank erosion (Stillwater 2007).
34	TBI / NRDC / AR / NHI	Sac River Inflow	TBI_Exh3 (Inflows - Table 3), TBI_closing comments (Table 3), AR/NHI_Exh1 (Testimony of Cain, Opperman, and Tompkins), AR/NHI closing comments - Table 3. Flows recommended for floodplain inundation (Sutter and Yolo Bypasses) - salmonid rearing, splittail spawning and early rearing. Flows measured at Verona. Flow magnitudes assume structural modifications to the weir to allow inundation at lower flow rates than is currently possible. Reservoir releases should be timed to coincide with and extend duration of high flows that occur naturally on less regulated rivers and creeks. The duration target is fixed for each year type, but actual timing of inundation should vary across the optimal window depending on hydrology and to maintain life history diversity.
35	NMFS	Sac River Inflow	NMFS_Exh9 (from ARFP 1995), Sturgeon (Grn and Wht) - adult migration to spawning and downstream larval transport
36	NMFS	Sac River Inflow	Public Draft Recovery Plan for Central Valley Salmon and Steelhead (October 2009). NMFS_Exhibit_5. Section 6.1.1 Recovery Action Narrative, Action 1.5.9, p.158.
37	EDF / Stillwater	Sac River Inflow	Source: EDF_Exh1 (Stillwater Sciences - Focal Species Approach). Spring flows - Establishing base flows of at least 10000 cfs in the Sac Riv in spring would improve transport of eggs and larval striped bass and other young anadromous fish and to reduce egg settling and mortality at low flows (USFWS 2001, EDF_Exh1, p.53). Proximate function of Delta inflows is to maintain net transport of passively swimming fishes (juv salmonids, larval delta smelt, and striped bass) and nutrients towards Suisun and San Francisco bays (USFWS 2008). Goal of winter and spring floodplain activation flows (managed pulse flows of approx 64000 cfs at Verona) is to maintain inundated seasonal floodplain habitat conditions in much of Yolo Bypass during January and April for a minimum of 21, 35, and 49 days in Below Normal, Above Normal, and Wet water year types, respectively. The NMFS (2009) draft recovery plan for Sac winter-run chinook, CV spring-run chinook, and CV steelhead ESUs calls for an annual spring flow of 8000 cfs (approx 64000 cfs at Verona) above the initial spill level "to fully activate the Yolo Bypass floodplain." For the

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No.	Entity	Type	Notes (excerpts from source documents)
37 cont	EDF / Stillwater	Sac River Inflow	purposes of this assessment, Stillwater allocated the Delta inflows for floodplain inundation to February and March. Summer Delta inflows to be determined by Delta outflows. Fall Inflows - Maintenance of D1641 flow standards in necessary to provide attraction flows for Chinook salmon, although these levels would potentially need to be increased to provide adequate Delta outflows. Winter Inflows - Winter flows primarily designed to provide upstream migration passage for salmonids and striped bass during Dec and Jan, as well as to inundate floodplains such as Yolo Bypass for benefit of rearing juv salmonids and other floodplain associated species (p.50-51). See Spring for discussion of goal of combined winter-spring floodplain activation flows.
38	EDF / Stillwater	Sac Riv Inflow / SJ Riv Inflow	Inflows determined based on Delta outflows (EDF_Exh1 - Stillwater Focal Species)
39	EDF / Stillwater	Sac River Inflow	These levels may need to be increased to provide adequate Delta outflows (EDF_Exh1 - Stillwater Focal Species)
40	UCDavis - Delta Solutions Group	Sac River Inflow	Functional Flow 2a - Sac River adult salmon - 10000 cfs to to occur from Oct - June during 6 out of 10 years (references Newman and Rice 2002, Williams 2006, Harrell et al. 2009, USFWS Exhibit 31 1987, Kjelson and Brandes 1989). Functional Flow 2b - Sac River juvenile salmon migration - 25000 cfs from Mar - June during 6 out of 10 years (references Newman and Rice 2002, Williams 2006, Harrell et al. 2009, USFWS Exhibit 31 1987, Kjelson and Brandes 1989). Flows not based on water year type, but rather number of years out of ten.
41	UCDavis - Delta Solutions Group	Sac River Inflow	Functional Flow 2c - Sacr River adult sturgeon flows - 70000 cfs to occur between Jan and May during 1 out of 10 years (flows for salmon -2a, 2b, and 1a,1b) (Kohlhorst et al 1991 [flow rate], Harrell and Sommer 2003 [passage problems at Fremont Weir]). Flows not based on water year type, but rather number of years out of ten.
42	UCDavis - Delta Solutions Group	Sac River Inflow	Functional Flow 1a - yolo bypass inundation - salmon and splittail (area inundated based on recommended flows BDCP draft rpt 2008) (other references related to flow and corresponding extent of habitat in Yolo Bypass Moyle et al. 2004, Sommer et al. 2004, Harrell and Sommer 2003, Harrell et al. 2009). Functional Flow 1b - yolo bypass pulse - salmon and splittail (area inundated based on recommended flows BDCP draft rpt 2008) (other references related to flow and corresponding extent of habitat in Yolo Bypass Moyle et al. 2004, Sommer et al. 2004, Harrell and Sommer 2003, Harrell et al. 2009). Functional Flows 1a and 1b require flows at Freeport of approx. 45750 and 50150 cfs, respectively, based on regressions of historical data.
43	D1641	SJ River Inflow	Base Vernalis minimum monthly average flow rate in cfs (the 7-day running average shall not be less than 20% below the objective). Take the higher objective if X2 is required to be west of Chipps Island
44	D1641	SJ River Inflow	Pulse Vernalis minimum monthly average flow rate in cfs. Take the higher objective if X2 is required to be west of Chipps Island
45	D1641	SJ River Inflow	Pulse - up to an additional 28 TAF pulse/attraction flow to bring flows up to a monthly average of 2000 cfs except for a critical year following a critical year. Time period based on real-time monitoring and determined by CalFed Op's group

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No.	Entity	Type	Notes (excerpts from source documents)
46	Draft D1630	SJ River Inflow	SJ River at Vernalis. Function = chinook salmon. Minimum daily flow, in cfs, for 21-day continuous period. Start date depends on beginning of chinook salmon smolt out-migration from SJ basin. During this time, water right holders on Mokelumne and Calaveras rivers shall bypass all inflows for 5 consecutive days. Daily mean combined pumping at Tracy, Banks, and Contra Costa pumping plants shall be $\leq$1500 cfs. All pumping restrictions are to be split equally between CVP and SWP. Total annual maximum of 150 TAF for the two salmon flows (these and fall attraction flows) from the SJ Basin reservoirs
47	Draft D1630	SJ River Inflow	SJ River at Vernalis. Function = chinook salmon. Minimum daily flow, for 14-day continuous period. Start date depends upon beginning of chinook salmon adult spawning migration. Attraction flow shall be provided only if water is avaiable from the 150 TAF alloted for the two salmon flows. During this time, water right holders on Mokelumne and Calaveras rivers shall bypass all inflows for 5 consecutive days.
48	CDFG	SJ River Inflow	Source: SJR Salmon Model V.1.6 (CDFG 2009), DFG Exhibit 3 (Flows needed in the Delta to restore anadromous salmonid passage from the SJ River at Vernalis to Chipps Island) - Table 10 - South Delta (Vernalis) flows needed to double smolt production at Chipps Island (by water year type), and CDFG closing comments. Flows to support smolt outmigration.
49	CSPA / C-WIN	SJ River Inflow	CSPA and C-WIN Closing Comments - CSPA Table 2. Based on WRINT-DFG Exhibit 8 (1992) and C. Mesick 2010 (C-Win Exh 19). Pulse flows in all years to attract adult spawning salmonids, Oct 20-29, SJR at Vernalis. To the tributary flows (each measured at their confluence with SJ Riv mainstem (see Mesick 2010), C-WIN / CSPA added in a flow of the SJ Riv below Millerton Lake reflecting that river's fair share unimpaired flow, as well as accretions and other inflows. Combined valley flows at Vernalis assumes tributaries (Mer, Stan, Tuol) are 67.06% of total SJ River flow at Vernalis. Spring - pulse flows for temperature regulation, migration cues, habitat inundation. Oct - pulse flows to attract adult salmonids.
50	TBI / NRDC	SJ River Inflow	TBI Exhibit 3 - Delta Inflows (Table 1, p.28), TBI / NRDC closing comments (Table 3b). Flows >5000 cfs to maintain minimum temperature ($\leq$ 65F) for migrating salmonids in April and May. Flows >20000 to trigger floodplain inundation. Year-round flows should exceed 2000 cfs to alleviate potential for DO problems in DWSC.
51	AR / NHI	SJ River Inflow	AR_NHI_Exh1 (testimony of Cain, Opperman, and Tompkins) and AR_NHI_closing comments (Table 2). SJ River flows to benefit salmon rearing habitat and smolt out-migration (increase flow velocities and turbidity), with focus on temperature (maintain temp at or below 65F) and floodplain inundation. Criteria recommended to be in addition to those stipulated in D1641.
52	EDF / Stillwater	SJ River Inflow	EDF / Stillwater Exh 1 (focal species approach, pp.47-49). Based upon investigations for the SJ River DO TMDL, minimum instream flows at the Stockton DWSC should be maintained in excess of 1,800 cfs during Sept and Oct of each year. Low DO in the lower SJ River has been found to impede upstream salmon migration (NMFS 2009, p.74). Studies by Hallock (1970) indicate that low DO at Stockton delay upmigration and straying rates.
53	EDF / Stillwater	SJ River Inflow	EDF / Stillwater Exh 1 (focal species approach, pp.47-49). Flows during November should correspond to current minimum Federal Energy Regulatory Commission (FERC) spawning flow requirements from the Stanislaus, Tuolumne, Merced, and upper San Joaquin rivers.

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No.	Entity	Type	Notes (excerpts from source documents)
54	EDF / Stillwater	SJ River Inflow	EDF / Stillwater Exh 1 (focal species approach, pp.47-49). Salmonid spawning attraction flows in excess if 3500 cfs at Vernalis should be provided for 10-14 days during October, using coordinated releases from the SJ River and tributaries. For remainder of fall, Delta inflows would be determined by the minimum instream flow requirements of the SJ River basin and east side tributaries. Upstream flow levels would likely be increased to meet the Delta outflow recommendations.
55	EDF / Stillwater	SJ River Inflow	EDF / Stillwater Exh 1 (focal species approach, pp.54). "Although USFWS (1995) previously recommended spring Delta inflows ranging from 4,050 cfs to 15,750 cfs at Vernalis based upon of regression models of Chinook salmon smolt survival. The current D-1641 flow minimums range from 3,110 cfs to 8,620 cfs (Table 1-5), depending upon water year type, have never been fully implemented. In addition to baseline flows, for the benefit of rearing Chinook salmon and other native fishes, floodplain activation flows should be provided..."
56	EDF / Stillwater	SJ River Inflow	EDF / Stillwater Exh 1 (focal species approach, pp.51-52). Winter Inflows - Minimum flows at Vernalis and the eastside tributaries should be coordinated to maintain net seaward flows at Jersey Point of 1000 cfs in Critical and Dry years, 2000 cfs in Below and Above Normal years, and 3000 cfs in Wet years (USFWS 1995 3-Xe-19). Net seaward flows for benefit of outmigrating juvenile salmon.
57	EDF / Stillwater	SJ River Inflow	EDF / Stillwater Exh 1 (focal species approach, pp.54-55). For the benefit of rearing chinook salmon and other native fishes, floodplain activation flows should be provided of 14800 cfs in the lower SJ River in Above Normal and Wet water year types. A series of pulse flows instead of a single extended high flow event might also be used to achieve the desired target of continuous days of inundated floodplain. Goal for combined winter and spring floodplain activation flows is to maintain inundated seasonal floodplain habitat conditions (or the potential for such conditions in sites where floodplain restoration actions may be undertaken in the future) in the lower SJ River during Jan through Apr for a minimum of 21 and 35 consecutive days in Above Normal and Wet water year types, respectively. For the purposes of this assessment, Stillwater allocated the Delta inflows for floodplain inundation to February and March. Also discusses inundation of Cosumnes River floodplain.
58	USFWS	SJ River Inflow	USFWS testimony concerning scientific information used to determine flow criteria. Source: U.S. Department Of the Interior - Comments Regarding the California State Water Resources Control Board's Notice of Public Informational Proceeding to Develop Delta Flow Criteria for the Delta Ecosystem Necessary to Protect Public Trust Resources, Sections II and III, pages 56-57 and 25. Quote in table from p.56-57. "The Anadromous Fish Restoration Program has developed estimates of flow levels needed at Vernalis to achieve a 53% increase (page 9) and a doubling (page 10) in predicted Chinook salmon production for the basin (USFWS, 2005). These Vernalis flow criteria vary by water year type and by month between February and May. We recommend these flows as starting point for establishing minimum and maximum volume of flow for increasing juvenile salmon and steelhead survival in the San Joaquin basin." (p.25).
59	AFRP	SJ River Inflow	Anadromous Fish Restoration Program (ARFP). Recommended streamflow schedules to meet the AFRP Doubling Goal in the San Joaquin River Basin (USFWS, 27 Sept 2005). Salmon doubling - total average flow (Stanislaus, Tuolumne, Merced) that would be expected to double the total predicted Chinook salmon production for the basin.

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No.	Entity	Type	Notes (excerpts from source documents)
60	AFRP	SJ River Inflow	Anadromous Fish Restoration Program (ARFP) - Recommended streamflow schedules to meet the AFRP Doubling Goal in the San Joaquin River Basin (USFWS, 27 Sept 2005). Total average flow (Stanislaus, Tuolumne, Merced) that would be expected to achieve a 53% increase in total predicted Chinook salmon production for the basin.
61	NMFS	SJ River Inflow	NMFS OCAP Bio Opinion, Action IV.2.1 (pp.641-644) San Joaquin River Inflow to Export Ratio - both interim (2010-2011) and long-term (beginning in 2012) requirements are stipulated. Interim flows are based on maintaining a minimum status quo for SJ River basin salmonid populations. Long term flow schedules for the SJ River are expected to result from SWRCB proceedings on SJ River flows. Export limitations and flows are also described on pp. 642-644
62	NMFS	SJ River Inflow	NMFS_Exh9 (from AFRP 1995) - Sturgeon (Green and White), mean monthly flows - ensure suitable conditions for sturgeon to migrate and spawn and for progeny to survive.
63	UCDavis - Delta Solutions Group	SJ River Inflow	Functional Flows 3a - transport juvenile salmon (references USFWS Exhibit 31, 1987; Newman and Rice 2002; Williams 2006) - wet years - 20000 cfs, Apr-Jun (2 out of 10 years); AN years - 15000 cfs, April - Jun 15 (4 out of 10 years); BN years - 10000 cfs, Apr-May (6 out of 10 years); Dry years - 7000 cfs, Apr-May 15 (8 out of 10 years); and Critical years - 5000 cfs, Apr (10 out of 10 years). Functional Flows 3c - adult salmon recruitment (reference USFWS Exhibit 31, 1987) - 2000 cfs year round (10 out of 10 years) (flows were not experienced in unimpaired conditions, but likely result from the disturbed conditions). Functional Flows 3b - Improve DO conditions in DWSC (2000 cfs, July-Oct, all years) (Lehman et al 2004, Jassby and VanNieuwenhuyse 2005).
64	D1641	OMR	Export/Inflow ratio - the maximum percent Delta inflow diverted for Feb may vary depending on the Jan 8RI (see D1641)
65	D1641	OMR	SWP/CVP Export Limit - All water year types, Apr 15 - May 15, the greater of 1500 cfs or 100% of 3-day avg. Vernalis flow. Maximum 3-day average of combined export rate (cfs), which includes Tracy Pumping Plant and Clifton Court Forebay Inflow less Byron-Bethany pumping. The time period may need to be adjusted to coincide with fish migration. Maximum export rate may be varied by CalFed Ops Group.
66	Draft D1630	OMR	Reverse flow restrictions for all year types are relaxed when combined CVP and SWP exports are < 2000 cfs. Export pumping restriction is relaxed for all year types when Delta outflow > 50000 cfs, except for the export pumping restriction during the SJ River pulse period. July 1 - Jan 31 - 14-day running average flow (as calculated in DAYFLOW), these restrictions do not apply whenever the EC at the Mallard Slough monitoring station is < 3 mmhos/cm. QWEST standards in 1630 discussed in DOI submittal, p.53, section concerning reverse flows.
67	CSPA / C-WIN	OMR	CSPA closing comments, C-WIN closing comments, CSPA_Exh1_Jennings. Combined export rates would be 0 cfs in all years from March 16 through June 30. Prevent entrainment and keep migration corridors open to maximize salmon juvenile and smolt survival. Facilitate SJ River salmonid migration down Old River.
68	CSPA / C-WIN	OMR	CSPA and C-WIN closing comments - flow direction, entrainment protection and provision of migration corridors

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No.	Entity	Type	Notes (excerpts from source documents)
69	CSPA / C-WIN	OMR	SJ River at Jersey Point flow recommendations (positive 14-day mean flows). Source: CSPA_exh1_Jennings_test; CDFG_1992_WRINT-DFG-Exhibit #8, Alt C (p.11, flows at Jersey Pt from Apr 1 through June 30, salmon); AFRP Working Paper, 1995, p. 3-Xe-19 (salmon). Function maintain positive flow for salmonid smolt outmigration and protect Delta smelt, originally two separate recommendations. DS - Feb 1 - Jun 30, Salmon - Oct 1 - Jun 30, only difference between flow recommendations where overlap occurred was DS in AN years = 2500 cfs, salmon in AN years = 2000. For this table, recommendations merged and 2500 cfs used for AN years (+DFG Exh 8 recommends 2500 cfs in AN years)
70	TBI / NRDC	OMR	TBI/NRDC closing comments (Table 4). The hydrodynamic recommendations expressed as Vernalis flow and/or export to inflow ratios in TBI/NRDC Exh4 (Delta Hydrodynamics, p.30) were converted to OMR flows, using the San Joaquin flow recommendations as described in TBI/NRDC Exh 3 (Delta Inflows), for inclusion in Table 4. Note: recommended OMR flows assume SJ River flows recommended in TBI Exhibit 3 are also implemented. (*) - when the previous longin smelt FMWT index <500, OMR flows in Jan-Mar are >0. This corrects a typographical error in the table on p.30 of TBI Exhibit 4
71	AFRP	OMR	Anadromous Fish Restoration Program (ARFP) (Working Paper on Restoration Needs, Habitat Restoration Actions to Double Natural Production of Anadromous Fish in the Central Valley of California, Volume 3, 1995, p. 3-Xe-19). Action 3 - Maintain positive QWEST flows, or an equivalent measure of net seaward flows at Jersey Point, of 1000 cfs in Critical and Dry years, 2000 cfs in below- and above normal years, and 3000 cfs in wet years from Oct 1 through June 30. Objective - Increase survival of smolts migrating down the mainstem rivers, decrease the number of smolts diverted into the central Delta, increase the survival of smolts diverted into the central Delta, and provide attraction flows for San Joaquin Basin adults (Oct - Dec).
72	NMFS	OMR	NMFS OCAP Bio Opinion, Action IV.2.3 - Old and Middle River Flow Management (pp. 648-652). See action triggers on pp. 648-650. Actions will be taken in coordination with USFWS RPA for Delta Smelt and State-listed longfin smelt 2081 incidental take permit. During the Jan 1 - Jun 15 period, the most restrictive export reduction shall be implemented.
73	USFWS	OMR	USFWS testimony concerning scientific information used to determine flow criteria. Source: U.S. Department Of the Interior - Comments Regarding the California State Water Resources Control Board's Notice of Public Informational Proceeding to Develop Delta Flow Criteria for the Delta Ecosystem Necessary to Protect Public Trust Resources, Sections II and III, pages 50, 53, and 24-25 (references USFWS 1992; AFRP Working Paper p.3-Xe-19, USFWS 2005, Restoration Action #3; D-1630, pp44-47). "Based on the scientific information we reviewed, the Board should develop reverse flow criteria that would maintain the Old and Middle river flow positive during key months (January through June) of the year to protect important public trust resources in the Delta" (p.53).

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No.	Entity	Type	Notes (excerpts from source documents)
74	USFWS	OMR	USFWS testimony concerning scientific information used to determine flow criteria. Source: U.S. Department Of the Interior - Comments Regarding the California State Water Resources Control Board's Notice of Public Informational Proceeding to Develop Delta Flow Criteria for the Delta Ecosystem Necessary to Protect Public Trust Resources, Sections II and III, pages 24,25, and 53. "In a previous Board exhibit (USFWS, 1992), we showed a positive relationship between temperature corrected juvenile survival indices and flow at Jersey Point for marked fish released at Jersey Point (QWEST) (USFWS, 1992, p.21). In addition, the AFRP Working Paper (USFWS, 1995) Restoration Action #3 calls for maintaining positive QWEST flows, or an equivalent measure of net seaward flows at Jersey Point, of 1000 cfs in critical and dry years, 2000 cfs in below- and above-normal years, and 3000 cfs in wet years from Oct 1 through June 30. Higher flow at Jersey Point has been provided during the VAMP period (mid-April to mid-May) with the adoption of VAMP flows and exports. We encourage the Board to retain or expand this
74 cont	USFWS	OMR	type of action to assure the contribution of downstream flow from the San Joaquin Basin to Delta outflow for the protection of juvenile and adult salmonids migrating from the San Joaquin basin."
75	USFWS	OMR	USFWS OCAP Bio Opinion - RPA re: OMR flows. Component 1 - Adults (Dec - Mar) - Action 1 (protect upmigrating delta smelt) - once turbidity or salvage trigger has been met, -2000 cfs OMR for 14 days to reduce flows towards the pumps. Action 2 (protect delta smelt after migration prior to spawning) - OMR range between -1250 and -5000 cfs determined using adaptive process until spawning detected. pp.280-282
76	USFWS	OMR	USFWS OCAP Bio Opinion - RPA re: OMR flows. Component 2 - Larvae/Juveniles - action starts once temperatures hit 12 degrees C at three delta monitoring stations or when spent female is caught. OMR range between -1250 and -5000 cfs determined using adaptive process. OMR flows continue until June 30 or when Delta water temperatures reach 25 degrees C, whichever comes first. pp. 280-282
77	CDFG	OMR	Longfin Smelt Incidental Take Permit (2009), p. 9-10, Condition 5.1. This Condition is not likely to occur in many years. To protect adult longfin smelt migration and spawning during December through February period, the Smelt Working Group (SWG) or DFG SWG personnel staff shall provide OMR flow advice to the Water Operations Management Team (WOMT) and to Director of DFG weekly. The SWG will provide the advice when either: 1) the cumulative salvage index (defined as the total longfin smelt salvage at the CVP and SWP in the December through February period divided by the immediately previous FMWT longfin smelt annual abundance index) exceeds five (5); or 2) when a review of all abundance and distribution survey data and other pertinent biological factors that influence the entrainment risk of adult longfin smelt indicate OMR flow advise is warranted. Permittee shall ensure the OMR flow requirement is met by maintaining the OMR flow 14-day running average is no more negative than -5000 cfs and the initial 5-day running average is not more negative than -6250 cfs. During any time OMR flow restrictions for
77 cont	CDFG	OMR	the FWS's 2008 Biological Opinion for delta smelt are being implemented, this condition (5.1) shall not result in additional OMR flow requirements for protection of adult longfin smelt. Once spawning has been detected in the system, this Condition terminates and 5.2 begins. Condition 5.1 is not required or would cease if previously required when river flows are 1) > 55000 cfs in the Sac River at Rio Vista; or 2) > 8000 cfs in the SJ River at Vernalis. If flows go below 40000 cfs in the Sac River at Rio Vista or 5000 cfs in the SJ River at Vernalis, the OMR flow in Condition 5.1 shall resume if triggered previously. Review of survey data and other pertinent biological factors that influence the entrainment risk of adult longfin smelt may result in a recommendation to relax or cease an OMR flow requirement.

Appendix A, Table 7. Notes for Tables 1 through 6.

No.	Entity	Type	Notes (excerpts from source documents)
78	CDFG	OMR	Longfin Smelt Incidental Take Permit (2009), p. 10-11, Condition 5.2. To protect larval and juvenile longfin smelt during Jan-June period, the SWG or DFG SWG personnel shall provide OMR flow advice to the WOMT and the DFG Director weekly. The OMR flow advice shall be an OMR flow between -1250 and -5000 cfs and be based on review of survey data, including all of the distributional and abundance data, and other pertinent biological factors that influence the entrainment risk of larval and juvenile longfin smelt. When a single Smelt Larval Survey (SLS) or 20 mm Survey sampling period results in: 1) longfin smelt larvae or juveniles found in 8 or more of the 12 SLS or 20mm stations in the central and south Delta (Stations 809, 812, 901, 910, 912, 918, 919) or, 2) catch per tow exceeds 15 longfin smelt larvae or juveniles in 4 or more of the 12 survey stations listed above, OMR flow advice shall be warranted. Permittee shall ensure the OMR flow requirement is met by maintaining the OMR flow 14-day running average no more negative than the required OMR flow and the 5-day running average is within 25% of the
78 cont	CDFG	OMR	required OMR. This Conditions OMR flow requirement is likely to vary throughout Jan through June. Based on prior analysis, DFG has identified three likely scenarios that illustrate the typical entrainment risk level and protective measures for larval smelt over the period: High Entrainment Risk Period: Jan - Mar OMR range from -1250 to -5000 cfs; Medium Entrainment Risk Period: April and May OMR range from -2000 to -5000 cfs, and Low Entrainment Risk Period: June OMR -5000 cfs. When river flows are: 1) greater than 55000 cfs in the Sac River at Rio Vista; or 2) greater than 8000 cfs in the SJ River at Vernalis, the Condition would not trigger or would be relaxed if triggered previously. Should flows go below 40000 cfs in Sac River at Rio Vista or 5000 cfs in the SJ River at Vernalis, the Condition shall resume if triggered previously. In addition to river flows, the SWG or DFG SWG personnel review of all abundance and distribution survey data and other pertinent biological factors that influence the entrainment risk of longfin smelt may result in a recommendation by DFG to WOMT to relax or cease an OMR flow requirement.
79	CDFG	Floodplain	DFG_Closing: DFG Exhibit 1, Page 13. Sacramento Splittail - floodplain inundation (habitat) - incubation, early rearing, egg and larval habitat and survival
80	USFWS	Floodplain	USFWS testimony concerning scientific information used to determine flow criteria. Source: U.S. Department Of the Interior - Comments Regarding the California State Water Resources Control Board's Notice of Public Informational Proceeding to Develop Delta Flow Criteria for the Delta Ecosystem Necessary to Protect Public Trust Resources, Sections II and III, pages 28 and 54. "The Board should consider the importance of more frequent floodplain inundation (especially Yolo Bypass flows) when determining the Delta outflows needed to restore the Delta ecosystem pursuant to the Board's public trust responsibilities" (p.28). "The Yolo Bypass floods via the Fremont Weir when flows on the Sacramento River exceed approximately 70,000 cfs, which it currently does in about 60% of years (Feyrer, et al. 2006). Flows on the Sacramento River should therefore exceed 70,000 cfs in at least six out of ten years. Recent historical floodplain inundation events are shown in Figure 4 (Sommer et al., 2001)" (p.54).

Appendix A, Table 7. Notes for Tables 1 through 6.

No.	Entity	Type	Notes (excerpts from source documents)
81	NMFS	Floodplain	NMFS OCAP Bio Opinion, Action I.6.1 - Restoration of Floodplain Rearing Habitat. p.608. " <u>Objective:</u> To restore floodplain rearing habitat for juvenile winter-run, spring-run, and CV steelhead in the lower Sacramento River basin. This objective may be achieved at the Yolo Bypass, and/or through actions in other suitable areas of the lower Sacramento River. <u>Action:</u> In cooperation with CDFG, USFWS, NMFS, and Corps, Reclamation and DWR shall, to the maximum extent of their authorities, provide significantly increased acreage of seasonal floodplain rearing habitat, with biologically appropriate durations and magnitudes, from December through April, in the lower Sacramento River basin, on a return rate of approximately one to three years, depending on water year type. In the event this action conflicts with Shasta Operations Actions I.2.1 to I.2.3., the Shasta Operations Actions shall prevail." By December 31, 2011, Reclamation and DWR shall submit to NMFS a plan to implement this action.
82	NMFS	Floodplain	NMFS - Public Draft Recovery Plan for the ESUs of Sacramento River Winter-run Chinook Salmon and Central Valley Spring-run Chinook Salmon and the DPS of Central Valley Steelhead (October 2009), Section 1.5.5, p.157. "Enhance the Yolo Bypass by re-configuring Fremont and Sacramento weirs to: (1) all for fish passage through Fremont Weir for multiple species; (2) enhance lower Putah Creek floodplain habitat; (3) improve fish passage along the toe drain/Lisbon weir; (4) enhance floodplain habitat along the toe drain; and (5) eliminate stranding events;and (6) create annual spring inundation of at least 8000 cfs to fully activate the Yolo Bypass floodplain."
83	D1641	DCC	For the May 21 - June 15 period, close the Delta Cross Channel gates for a total of 14 days per CALFED Ops Group. During the period the DCC gates may close 4 consecutive days each week, excluding weekends
84	Draft D1630	DCC	When monitoring indicates that significant numbers of salmon smolts or striped bass eggs and larvae are present or suspected to be present, the Executive Director (ED) or his designee shall order USBR to close the gates. The ED, with advice from other agencies, will develop specific monitoring and density criteria for closing and opening the gates.
85	CSPA / C-WIN	DCC	CSPA_Exh1_Jennings, C-WIN closing comments. Source CDFG_1992_WRINT-DFG-Exhibit #8, Alt C (p10). Function: reduce entrainment of Sacramento salmon smolts into the interior Delta
86	NMFS	DCC	NMFS OCAP Bio Opinion, Action Suite IV.1 (pp. 631-640)
87	EDF / Stillwater	Ouflow	EDF_Closing Comments (Table 1) - Mean Historical Delta Outflow Volumes (TAF) for 1956-2003 by month and water year type. Historical and unimpaired flow values are based on Water Years 1956-2003 using California Central Valley Unimpaired Flow Data, 4th ed. (CDWR 2007). In instances where there was a difference between Dry and Critically Dry years, the value for Critically Dry years was selected. Originally reported as volume (TAF). Conversion calculated as follows: (TAF/month)(1000 AF/TAF)(43560 ft3/AF)(month/X days)(day/86400 sec)

Appendix B: Enacting Legislation

California Water Code, Division 35 (Sacramento-San Joaquin Delta Reform Act of 2009), Part 2 (Early Actions), Section 85086

(a) The board shall establish an effective system of Delta watershed diversion data collection and public reporting by December 31, 2010.

(b) It is the intent of the Legislature to establish an accelerated process to determine instream flow needs of the Delta for the purposes of facilitating the planning decisions that are required to achieve the objectives of the Delta Plan.

(c)

    (1) For the purpose of informing planning decisions for the Delta Plan and the Bay Delta Conservation Plan, the board shall, pursuant to its public trust obligations, develop new flow criteria for the Delta ecosystem necessary to protect public trust resources. In carrying out this section, the board shall review existing water quality objectives and use the best available scientific information. The flow criteria for the Delta ecosystem shall include the volume, quality, and timing of water necessary for the Delta ecosystem under different conditions. The flow criteria shall be developed in a public process by the board within nine months of the enactment of this division. The public process shall be in the form of an informational proceeding conducted pursuant to Article 3 (commencing with Section 649) of Chapter 1.5 of Division 3 of Title 23 of the California Code of Regulations, and shall provide an opportunity for all interested persons to participate. The flow criteria shall not be considered predecisional with regard to any subsequent board consideration of a permit, including any permit in connection with a final BDCP.

    (2) Any order approving a change in the point of diversion of the State Water Project or the federal Central Valley Project from the southern Delta to a point on the Sacramento River shall include appropriate Delta flow criteria and shall be informed by the analysis conducted pursuant to this section. The flow criteria shall be subject to modification over time based on a science-based adaptive management program that integrates scientific and monitoring results, including the contribution of habitat and other conservation measures, into ongoing Delta water management.

    (3) Nothing in this section amends or otherwise affects the application of the board's authority under Part 2 (commencing with Section 1200) of Division 2 to include terms and conditions in permits that in its judgment will best develop, conserve, and utilize in the public interest the water sought to be appropriated.

(d) The board shall enter into an agreement with the State Water Project contractors and the federal Central Valley Project contractors, who rely on water exported from the Sacramento River watershed, or a joint powers authority comprised of those contractors, for reimbursement of the costs of the analysis conducted pursuant to this section.

(e) The board shall submit its flow criteria determinations pursuant to this section to the council for its information within 30 days of completing the determinations.

ATTACHMENT 10

The Delta Plan

ABOUT THIS CHAPTER

This chapter discusses the purpose and role of the Delta Stewardship Council (Council) in the context of Sacramento-San Joaquin Delta (Delta) governance. It also describes the Council's approach to developing, implementing, and updating the Delta Plan, all within the framework of adaptive management. It describes why best available science and adaptive management are particularly important tools in the Delta, and proposes the development of a new Delta Science Plan to aid in the coordination and focus of science efforts across agencies. For State of California (State) or local agencies that propose a plan, program, or project occurring in whole or in part in the Delta, this chapter contains a description of the regulatory application of the Delta Plan. For instance:

- What is a covered action?

- Certifications of consistency

- Covered action consistency appeals

The chapter includes one policy and one recommendation.

RELEVANT LEGISLATION

The Sacramento-San Joaquin Delta Reform Act of 2009 established the Delta Stewardship Council to achieve more effective governance while providing for the sustainable management of the Delta ecosystem and a more reliable water supply, using an adaptive management framework, as reflected in the Water Code sections below.

85001 (c) By enacting this division, it is the intent of the Legislature to provide for the sustainable management of the Sacramento-San Joaquin Delta ecosystem, to provide for a more reliable water supply for the state, to protect and enhance the quality of water supply from the Delta, and to establish a governance structure that will direct efforts across state agencies to develop a legally enforceable Delta Plan.

85020 (h) Establish a new governance structure with the authority, responsibility, accountability, scientific support, and adequate and secure funding to achieve these objectives.

85022 (a) It is the intent of the Legislature that state and local land use actions identified as "covered actions" pursuant to Section 85057.5 be consistent with the Delta Plan. This section's findings, policies, and goals apply to Delta land use planning and development.

85052 "Adaptive management" means a framework and flexible decision making process for ongoing knowledge acquisition, monitoring, and evaluation leading to continuous improvement in management planning and implementation of a project to achieve specified objectives.

85204 The council shall establish and oversee a committee of agencies responsible for implementing the Delta Plan. Each agency shall coordinate its actions pursuant to the Delta Plan with the council and the other relevant agencies.

85211 The Delta Plan shall include performance measurements that will enable the council to track progress in meeting the objectives of the Delta Plan. The performance measurements shall include, but need not be limited to, quantitative or otherwise measurable

assessments of the status and trends in all of the following:

(a) The health of the Delta's estuary and wetland ecosystem for supporting viable populations of aquatic and terrestrial species, habitats, and processes, including viable populations of Delta fisheries and other aquatic organisms.

(b) The reliability of California water supply imported from the Sacramento River or the San Joaquin River watershed.

85225.5 To assist state and local public agencies in preparing the required certification, the council shall develop procedures for early consultation with the council on the proposed covered action.

85225.10 (a) Any person who claims that a proposed covered action is inconsistent with the Delta Plan and, as a result of that inconsistency, the action will have a significant adverse impact on the achievement of one or both of the coequal goals or implementation of government-sponsored flood control programs to reduce risks to people and property in the Delta, may file an appeal with regard to a certification of consistency submitted to the council.

(b) The appeal shall clearly and specifically set forth the basis for the claim, including specific factual allegations, that the covered action is inconsistent with the Delta Plan. The council may request from the appellant additional information necessary to clarify, amplify, correct, or otherwise supplement the information submitted with the appeal, within a reasonable period.

(c) The council, or by delegation the executive officer, may dismiss the appeal for failure of the appellant to provide information requested by the council within the period provided, if the information requested is in the possession or under the control of the appellant.

85300(c) The council shall review the Delta Plan at least once every five years and may revise it as the council deems appropriate. The council may request any state agency with responsibilities in the Delta to make

recommendations with respect to revision of the Delta Plan.

(d) (1) The council shall develop the Delta Plan consistent with all of the following:

(A) The federal Coastal Zone Management Act of 1972 (16 U.S.C. Sec.1451 et seq.), or an equivalent compliance mechanism.

(B) Section 8 of the federal Reclamation Act of 1902.

(C) The federal Clean Water Act (33 U.S.C. Sec. 1251 et seq.).

(2) If the council adopts a Delta Plan pursuant to the federal Coastal Zone Management Act of 1972 (16 U.S.C. Sec. 1451 et seq.), the council shall submit the Delta Plan for approval to the United States Secretary of Commerce pursuant to that act, or to any other federal official assigned responsibility for the Delta pursuant to a federal statute enacted after January 1, 2010.

85300(a) The Delta Plan shall include subgoals and strategies to assist in guiding state and local agency actions related to the Delta.

85302(e) The following subgoals and strategies for restoring a healthy ecosystem shall be included in the Delta Plan:

(1) Restore large areas of interconnected habitats within the Delta and its watershed by 2100.

(2) Establish migratory corridors for fish, birds, and other animals along selected Delta river channels.

(3) Promote self-sustaining, diverse populations of native and valued species by reducing the risk of take and harm from invasive species.

(4) Restore Delta flows and channels to support a healthy estuary and other ecosystems.

(5) Improve water quality to meet drinking water, agriculture, and ecosystem long-term goals.

(6) Restore habitat necessary to avoid a net loss of migratory bird habitat and, where feasible, increase migratory bird habitat to promote viable populations of migratory birds.

85300(a) The Delta Plan may also identify specific actions that state or local agencies may take to implement the subgoals and strategies.

85302(a) Implementation of the Delta Plan shall further the restoration of the Delta ecosystem and a reliable water supply.

85302(b) The Delta Plan may include recommended ecosystem projects outside the Delta that will contribute to achievement of the coequal goals.

85302(c) The Delta Plan shall include measures that promote all of the following characteristics of a healthy Delta ecosystem:

(1) Viable populations of native resident and migratory species.

(2) Functional corridors for migratory species.

(3) Diverse and biologically appropriate habitats and ecosystem processes.

(4) Reduced threats and stresses on the Delta ecosystem.

(5) Conditions conducive to meeting or exceeding the goals in existing species recovery plans and state and federal goals with respect to doubling salmon populations.

85302(d) The Delta Plan shall include measures to promote a more reliable water supply that address all of the following:

(1) Meeting the needs for reasonable and beneficial uses of water.

(2) Sustaining the economic vitality of the state.

(3) Improving water quality to protect human health and the environment.

85302(h) The Delta Plan shall include recommendations regarding state agency management of lands in the Delta.

85303 The Delta Plan shall promote statewide water conservation, water use efficiency, and sustainable use of water.

85304 The Delta Plan shall promote options for new and improved infrastructure relating to the water conveyance in the Delta, storage systems, and for the operation of both to achieve the coequal goals.

85305(a) The Delta Plan shall attempt to reduce risks to people, property, and state interests in the Delta by promoting effective emergency preparedness, appropriate land uses, and strategic levee investments.

85305(b) The council may incorporate into the Delta Plan the emergency preparedness and response strategies for the Delta developed by the California Emergency Management Agency pursuant to Section 12994.5.

85306 The council, in consultation with the Central Valley Flood Protection Board, shall recommend in the Delta Plan priorities for state investments in levee operation, maintenance, and improvements in the Delta, including both levees that are a part of the State Plan of Flood Control and nonproject levees.

85307(a) The Delta Plan may identify actions to be taken outside of the Delta, if those actions are determined to significantly reduce flood risks in the Delta.

85307(b) The Delta Plan may include local plans of flood protection.

85307(c) The council, in consultation with the Department of Transportation, may address in the Delta Plan the effects of climate change and sea level rise on the three state highways that cross the Delta.

85307(d) The council, in consultation with the State Energy Resources Conservation and Development Commission and the Public Utilities Commission, may incorporate into the Delta Plan additional actions to address the needs of Delta energy development, energy storage, and energy distribution.

85308 The Delta Plan shall meet all of the following requirements:

(a) Be based on the best available scientific information and the independent science advice provided by the Delta Independent Science Board.

(b) Include quantified or otherwise measurable targets associated with achieving the objectives of the Delta Plan.

(c) Where appropriate, utilize monitoring, data collection, and analysis of actions sufficient to determine progress toward meeting the quantified targets.

(d) Describe the methods by which the council shall measure progress toward achieving the coequal goals.

(e) Where appropriate, recommend integration of scientific and monitoring results into ongoing Delta water management.

(f) Include a science-based, transparent, and formal adaptive management strategy for ongoing ecosystem restoration and water management decisions.

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The Delta Plan

No single entity in California has the sole responsibility or authority for managing water supply and the Delta ecosystem. Instead, authority, expertise, and resources are spread out among a cadre of federal, State, and local agencies, with no single government agency empowered to provide leadership or a long-term vision. This is why governance reform enacted by the Delta Reform Act is fundamentally different from past approaches to managing the Delta. The milestone legislation created the Council, and gave it the direction and authority to serve two primary governance roles: (1) set a comprehensive, legally enforceable direction for how the State manages important water and environmental resources in the Delta through the adoption of a Delta Plan, and (2) ensure coherent and integrated implementation of that direction through coordination and oversight of State and local agencies proposing to fund, carry out, and approve Delta-related activities.

Recommended in significant part by the Delta Vision Task Force effort in 2008, this new approach is different from governance attempts over the past several decades that have tried, but largely failed, to provide effective and stable leadership. The *Delta Vision Strategic Plan* referred to some 200 agencies that play some role in managing the Delta's varied resources (Delta Vision 2008). One of the major goals articulated in that strategic plan was the establishment of a new governance structure with sufficient authority, responsibility, accountability, science support, and secure funding to achieve the coequal goals of providing a more reliable water supply for California and protecting, restoring, and enhancing the Delta ecosystem. The creation of the independent Council was a significant step toward implementing this goal. The Council is made up of seven members who provide a broad, statewide perspective and diverse expertise, and is advised by a 10-member board of nationally and internationally renowned scientists, the Delta Independent Science Board (ISB). The Delta Reform Act instructs the Council to "direct efforts across state agencies," but considerable challenges lie ahead in coordinating and supporting the multitude of agencies to achieve the goals of the Delta Plan.

The first major task for the newly created Council is the development of this Delta Plan. The Delta Reform Act requires the Council to develop and adopt a legally enforceable, long-term management plan for the Delta that uses best available science and is built upon the principles of adaptive management. The Delta Reform Act also established the Delta Science Program within the Council to provide the best possible unbiased scientific information to inform water and environmental decision making in the Delta. Because California's Delta is linked to so many statewide issues, described in Chapter 1, the Delta Plan's scope and purview encompasses statewide water use, flood management, and the Delta watershed, but with a specific focus on the legal Delta and Suisun Marsh. The Delta Plan contains a set of regulatory policies that will be enforced by the Council's

appellate authority and oversight, described in this chapter. These regulatory policies and supporting documents are contained in Appendix B. The Delta Plan also contains priority recommendations, which are nonregulatory but call out actions essential to achieving the coequal goals. The Council has chosen to apply its regulatory authority in a targeted manner, and does so in an effort to ensure that all significant activities occurring in whole or in part in the Delta become better aligned over time with State policy priorities, including—and especially—the achievement of the coequal goals. The process for demonstrating compliance with Delta Plan policies is described in detail in this chapter.

In developing the first Delta Plan, the Council sought extensive public, stakeholder, and government agency input and, based on that input, developed the foundational set of policies and recommendations detailed in the following chapters to guide actions over the first few years of Plan implementation. Every stage of implementing the Delta Plan will necessitate leadership by the Council and ongoing coordination across a broad range of agencies, nongovernmental entities, and stakeholders.

The Delta Stewardship Council

As described in Chapter 1, the Delta of today is the result of centuries of natural and human-made actions and reactions. Government historically has worked to treat individual problems rather than adopt a systemwide approach. Dozens of agencies, task forces, and working groups have struggled to find the right combination of policy, science, and structure to address what are now California's fundamental goals for managing the Delta, the coequal goals.

The mission of the Council is to further the achievement of the coequal goals. To do so, the Council was charged with the development of a legally enforceable, long-term

management plan for the Delta. To accomplish this, the Council will apply a common-sense approach based on a strong scientific foundation in an adaptive management framework to protect and restore the Delta ecosystem; improve the quality and reliability of California's water supplies; reduce risk to people, property, and State interests; and protect and enhance the Delta as an evolving place.

The Council's most important and challenging role is the facilitation, coordination, and integration of a range of actions and policies in support of the coequal goals. Implementation will occur through the Council's leadership of a formal Interagency Implementation Committee, ongoing informal staff-to-staff agency coordination, development of science to support the Delta Plan, and use of the Council's various authorities to ensure progress and accountability in how the Delta is managed. See Table 2-1 for a reference list of agencies with responsibilities in the Delta or related to the management of the Delta.

In addition to its role in setting State policy for the Delta in the Delta Plan, and in facilitating and coordinating agencies to achieve policy objectives, the Council was granted specific regulatory and appellate authority over certain actions that take place in whole or in part in the Delta. To do this, the Delta Plan contains a set of regulatory policies with which State and local agencies are required to comply. The Delta Reform Act specifically established a certification process for compliance with the Delta Plan. This means that State and local agencies that propose to carry out, approve, or fund a qualifying action in whole or in part in the Delta, called a "covered action," must certify that this covered action is consistent with the Delta Plan and must file a certificate of consistency with the Council that includes detailed findings. This process is described in the section "Covered Actions and Delta Plan Consistency" later in this chapter.

Agencies with Responsibilities in the Delta

TABLE 2-1

State	
Delta Stewardship Council	Established in 2009 by the Delta Reform Act to further the achievement of the coequal goals through the development and implementation of a legally enforceable Delta Plan.
California Department of Fish and Wildlife	Provides fish and wildlife protection and management, including management of wildlife areas and ecological reserves, public access, conservation planning, permitting, and implementation of the Ecosystem Restoration Program.
California Department of Water Resources	Owns and operates the State Water Project (which stores water upstream and conveys water through the Delta), has emergency response and flood planning responsibilities, holds water quality/supply contracts with Delta water agencies, and coordinates overall statewide water planning.
Delta Protection Commission	Prepares a comprehensive long-term resource management plan for land uses within the approximate 500,000-acre Primary Zone. Local government plans must be consistent.
Sacramento-San Joaquin Delta Conservancy	A primary State agency to implement ecosystem restoration in the Delta and also to assist/protect the region's agricultural, cultural, economic, and historical value.
State Water Resources Control Board	Required to develop in 2010 nonregulatory flow criteria for the Delta ecosystem necessary to protect public trust uses to inform planning proceedings for the Delta Plan and Bay Delta Conservation Plan (BDCP). Responsible for developing and implementing the Bay-Delta Water Quality Control Plan to establish water quality objectives, including flow objectives, to ensure reasonable protection of beneficial uses in the Bay-Delta. Responsible for establishing, implementing, and enforcing water right requirements to ensure the proper allocation and efficient use of water in and out of the Delta, including the role of the Delta Watermaster and implementation of the Bay-Delta Water Quality Control Plan. With regional boards, responsible for developing and implementing other water quality standards and control plans consistent with State and federal laws to reasonably protect aquatic beneficial uses.
California Emergency Management Agency	Plans, prepares emergency response, and coordinates the activities of all State agencies in connection to an emergency in the Delta; provides resources if local agencies are overwhelmed.
Central Valley Flood Protection Board	Plans flood control along the Sacramento and San Joaquin rivers and their tributaries in cooperation with the U.S. Army Corps of Engineers.
Office of the Delta Watermaster	Created in 2009 to oversee day-to-day administration of water rights, enforcement activities, and reports on water right activities regarding diversions in the Delta.
California Natural Resources Agency	Coordinates with a group of local water agencies, environmental and conservation organizations, State and federal agencies, and other interest groups developing the BDCP, a conservation strategy to be compliant with the Endangered Species Act (ESA) and Natural Community Conservation Planning Act, to be implemented over the next 50 years.
Other State agencies	Have various roles or responsibilities in the Delta relevant to the agency's concern (for example, California Department of Food and Agriculture, California Department of Transportation, California State Parks, California Department of Boating and Waterways, State Lands Commission, California Environmental Management Agency, and others).

Agencies with Responsibilities in the Delta

TABLE 2-1

Federal	
Bureau of Reclamation	Owns and operates the Central Valley Project, which, among other activities, pumps water through and out of the Delta.
U.S. Fish and Wildlife Service	Develops plans for the conservation and recovery of fish and wildlife resources, and addresses the variable needs of fish and wildlife pursuant to the ESA.
U.S. Army Corps of Engineers	Involved with both federal and nonfederal partners in assessing channel navigation, ecosystem, and flood risk management projects in the Delta. Works cooperatively with its nonfederal partners regarding the regulation, maintenance, and improvement of project levees in the Delta.
National Marine Fisheries Service	Develops plans for the conservation and recovery of salmonids in the Delta pursuant to the ESA.
U.S. Environmental Protection Agency	Responsible for protection and restoration of water quality in the Delta, pursuant to the Clean Water Act, which regulates the discharge of pollutants into waterways and sets standards for water quality. Oversees implementation of Clean Water Act programs and policies delegated to the State.
Other federal agencies	Various roles or responsibilities in the Delta relevant to the agency's concern (for example, U.S. Department of Agriculture, Natural Resources Conservation Service, and others).
Local	
Hundreds of local reclamation districts, resource conservation districts, water districts, city and county governments, and other special districts.	

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To be effective, governance to support science and implement adaptive management for a changing Delta must be flexible and have the capacity to change policies and practices in response to what is learned over time. An adaptive management approach as detailed in this chapter will ensure that the Delta Plan is updated as often as necessary to incorporate new information or modify policies and recommendations to ensure achievement of the coequal goals. The following section discusses the particular importance of science and adaptive management as they relate to the Delta.

Science and Adaptive Management in the Delta

The Delta Reform Act requires that the Delta Plan be based on and implemented using the best available science, and requires the use of science-based, transparent, and formal adaptive management strategies for ongoing ecosystem restoration and water management decisions. This section describes the importance of science, especially as it relates to the Delta, describes how the Delta Plan itself uses an adaptive management plan, and proposes the development of a Delta Science Plan as a companion to the Delta Plan.

The State of Bay-Delta Science report concluded that most of the decision making in the Delta was occurring on the basis of a false understanding that the Delta was a static system, and that "the Delta of the future would be much the same as the Delta of today" (Healey et al. 2008). Science indicates that significant changes are expected in the Delta over the coming decades, including climate change and the potential for earthquakes and flooding, as described in Chapter 1. In addition, current planning processes for habitat restoration, changes to water conveyance in the Delta, urban expansion, and other human drivers could reshape the Delta as we know it today.

The State of Bay-Delta Science urged a new perspective for decision making in the Delta (Healey et al. 2008). Decision making should be based on best available science, should account for risk and uncertainty, should acknowledge the dynamic nature of ecosystems, and should be responsive and adaptive to future change. The Delta Reform Act, enacted 1 year after that report, requires a strong science foundation for Council decisions. This includes the ongoing provision of scientific expertise to support the Council and other agencies through the Delta Science Program and Delta ISB. The Delta Science Program's mission is to provide the best possible scientific information for water and environmental decisions in the Bay-Delta system. The Delta ISB provides oversight of the scientific research, monitoring, and assessment programs that support adaptive management of the Delta to ensure that the application of the best science is used in Delta programs. The Delta ISB reviewed early drafts of this Delta Plan to ensure that the best science was used in the Delta Plan.

Why is it important that the Delta Plan emphasize science? First, science provides the basis of nearly all current understanding of the Delta's status (Healey et al. 2008, Lund et al. 2010). Second, new perspectives on science and policy in the Delta instill urgency for addressing the health of Delta ecosystems and the need for a more reliable water supply. Third, the interaction of multiple stressors to the ecosystem must be understood if they are to inform effective policy decisions.

Science and adaptive management are not simply academic exercises; they are tools that provide managers and decision makers an approach for using public funds more effectively, and increase the likelihood of success for a given project. Science by itself does not make or prioritize management decisions; it only informs actions and proposals. "Using the best science is only part of what is needed to resolve the competing interests…" that clamor over the Delta (NRC 2012).

The next sections describe what the Council means when it comes to best available science and adaptive management in the context of the coequal goals.

Best Available Science

Not all science is created equal nor deserves equal weight in decision making. Best available science provides the knowledge base for making sound decisions and is foundational for adaptive management. Best available science provides understanding for defining problems, developing conceptual models, identifying potential management actions, monitoring ecological and physical responses, and analyzing responses relative to the actions taken. Adaptive management both uses best available science and contributes to the creation of the best available science.

Best available science is specific to the decision being made and the time frame available for making that decision. There is no expectation of delaying decisions to wait for improved scientific understanding. Action may be taken on the basis of incomplete science if the information used is the best available at the time.

Best available science is developed through a process that meets the criteria of (1) relevance, (2) inclusiveness, (3) objectivity, (4) transparency and openness, (5) timeliness, and (6) peer review (NRC 2004). Best available science is consistent with the scientific process (Sullivan et al. 2006). Ultimately, best available science requires scientists using the best information and data to assist management and policy decisions. The processes and information used should be clearly documented and effectively communicated to foster improved understanding and decision making.

Under the Delta Plan, covered actions are required to demonstrate the use of best available science in their decision making (see policy G P1 in this chapter). Guidelines and criteria for identifying or developing best available science are provided in Appendix C.

SCIENCE IN THE DELTA – ADVANCES IN UNDERSTANDING

The following is a partial list of scientific advances that have changed understanding of the Delta and California's water supply over the last decade.

Effects of Climate Change on People and the Environment

- Increased frequency of (1) extreme water heights that cause floods, (2) water temperatures lethal to salmon and delta smelt, and (3) flooding in the Yolo Bypass, which will be much more common by the latter half of this century (Cloern et al. 2011).

- Trends in snowfall versus rainfall precipitation in the western United States show that temperatures have warmed during winter and early spring storms; and, consequently, the fraction of precipitation that falls as snow has declined while the fraction that falls as rain has increased. This shift from snowfall to rainfall will reduce natural water storage and is likely to increase risks of winter and spring flooding (Knowles et al. 2006).

- By mid-century, the Colorado River Reservoir System will not be able to meet all of the demands placed on it, including water supply for Southern California and the inland southwest, because reservoir levels will be reduced by over one-third and releases reduced by as much as 17 percent. Reductions in precipitation for the Colorado River Basin will threaten the ability to meet mandated water allocations (Barnett et al. 2004).

Water Supply Reliability

- The rate of groundwater depletion in the Central Valley was quantified using satellite imaging; approximately 2.5 million acre-feet per year of groundwater was lost during the period from October 2003 to March 2010 (Famiglietti et al. 2011).

- Precipitation and streamflow are proportionally more variable from year to year in California than in any other part of the United States (Dettinger et al. 2011).

Ecosystem Restoration

- Several open-water (pelagic) fish species have undergone steep declines known as the Pelagic Organism Decline (POD) (Sommer et al. 2007). The Interagency Ecological Program investigation of these declines led to new insights about the effects of multiple stressors on these species and the Delta ecosystem (summarized in Baxter et al. 2010). Improved knowledge about the POD also led to regulatory changes for water exports and pollutant discharges.

- In 86 percent of approximately 3,000 assessed streams across the United States, streamflow magnitudes (especially flow maxima and minima) were altered. In comparison to other evaluated stressors, streamflow alterations were found to have the greatest significance for explaining ecological impairment (Carlisle et al. 2011).

- Altered flow regimes by human activities influence the ecological impact of drought anomalies and increase the susceptibility of ecosystems to biological invasion. Extreme climatic events act together with environmental disturbances to enable the establishment of invasive species (Winder et al. 2011).

- Ratios of nutrients in Delta waters have been hypothesized to be a primary driver in the composition of aquatic food webs in the Bay-Delta (Glibert et al. 2011).

Water Quality

- Ammonium concentrations may be having a significant impact on phytoplankton composition and open-water food webs because of suppression of diatom blooms in the Bay-Delta (Dugdale et al. 2007).

- Pyrethroid pesticides largely derived from urban and suburban runoff are regularly found at levels that are toxic to aquatic invertebrates (Weston et al. 2005, Weston and Lydy 2010).

Risk Reduction

- With permanently flooded conditions and managed water depths, short-term sediment accretion rates as high as 7 to 9 centimeters per year can be obtained to help reverse subsidence on Delta islands (Miller et al. 2008).

- Atmospheric rivers (narrow corridors of concentrated moisture in the atmosphere) contribute 33 to 50 percent of the total average amount of rainfall for California and have been the source of many floods along the West Coast of the United States. California's water resources and floods come from the same storms to an extent, which makes integrated flood and water resources management all the more important (Dettinger et al. 2011).

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Adaptive Management

Adaptive management is defined in the Delta Reform Act as:

a framework and flexible decision making process for ongoing knowledge acquisition, monitoring, and evaluation leading to continuous improvements in management planning and implementation of a project to achieve specified objectives (Water Code section 85052).

Adaptive management is useful in that it provides flexibility and feedback to manage natural resources in the face of often considerable uncertainty. This approach requires careful science-based planning followed by measurement to determine whether a given action actually achieves intended goals.

If goals are not achieved, informed adjustments can be made. This is especially important in the context of the Delta because, in some instances, competing and uncertain explanations arise, and decision making cannot be delayed until causes are better understood (Healey et al. 2008). The Council has adopted a three-phase adaptive management framework for the purposes of developing, implementing, and updating the Delta Plan, described later in this chapter, and also for use by ecosystem restoration and water management covered actions, as set forth in G P1 with additional detail in Appendix C.

A Delta Science Plan

Multiple frameworks for science in the Delta have been proposed, but a comprehensive science plan that specifies how scientific research, monitoring, analysis, and data management will be coordinated among entities has yet to be developed. Currently, science efforts in the Delta are performed by multiple entities with varying missions and mandates, and without an overarching plan. The National Research Council (NRC) found that "only a synthetic, integrated, analytical approach to understanding the effects of suites of environmental factors (stressors) on the

ecosystem and its components is likely to provide important insights that can lead to enhancement of the Delta and its species" (NRC 2012). Therefore, a comprehensive science plan for the Delta is needed to organize and integrate ongoing scientific research, monitoring, and learning about the Delta as it changes over time.

A Delta Science Plan will guide efficient use of resources for balancing investments in addressing short-term science needs and those that build understanding over the long run. This plan will address effective governance for science in the Delta, strategies for addressing uncertainty and conflicting scientific information, the prioritization of research, near-term science needs, financial needs to support science, and more. Such a plan is essential to support the adaptive management of ecosystem restoration and water management decisions in the Delta.

Additional detail regarding the proposed Delta Science Plan is provided in recommendation G R1 in this chapter.

The Delta Plan

The Delta Reform Act established the Council and directed it to develop an overarching, long-term management plan for the Delta. Figure 2-1 shows the roles assigned to the Council under the Act. The Act specifically requires that this plan for the Delta include a science-based, formal adaptive management strategy for ongoing ecosystem restoration and water management decisions.

This section presents a three-phase adaptive management framework (Plan, Do, and Evaluate and Respond), describes specific considerations that went into the development of the Delta Plan, and provides the overarching framework for how the Council (in collaboration with others) will implement and continuously amend the Delta Plan to achieve the coequal goals.

Council Roles and the Delta Plan

Council Roles and the Delta Plan

COORDINATE	ENSURE CONSISTENCY	INFORM	COMMENT	ENSURE ACCOUNTABILITY	BDCP OVERSIGHT
• Develop, implement, and update Delta Plan • Establish and oversee Interagency Implementation Committee	• Determine consistency of covered actions upon appeal • Advise local and regional agencies on consistency with Delta Plan	Adaptive management of the Delta Plan: Develop and use best available science and information to inform decision making in the Delta	Review and comment on environmental impact reports and other Delta-related programs and projects	• Hold hearings • Request reports • Track performance measures	• Serve as responsible agency on EIR • Independent appellate role

Figure 2-1

The Council's Three-phase Adaptive Management Framework

Several existing frameworks for adaptive management provide the basis for the Delta Plan's own adaptive management approach.[1] Although there are differences among various frameworks, they generally consist of three broad phases: Plan, Do, and Evaluate and Respond. Throughout all three phases of the adaptive management process, decisions are made by managers, policy makers, and/or technical experts. In developing an adaptive management plan, the best available science should be used to inform all phases of the adaptive management process.

In addition to requiring adaptive management for certain proposed covered actions, the Council, in coordination with others, will use adaptive management to develop, implement, and update the Delta Plan. The Council will rely in large part on the Delta Science Program to determine the relevance, value, and reliability of the best available science and to organize that information for its use in the Council's decisions. The Council has the final responsibility for determining the best available science used in support of its actions, including

when a choice among competing interpretations of available science must be made.

The three phases of the Council's adaptive management framework (Plan, Do, and Evaluate and Respond) are shown on Figure 2-2, and are further broken down into nine steps, which are described in detail in Appendix C.

The Delta Stewardship Council's Three-phase Adaptive Management Framework
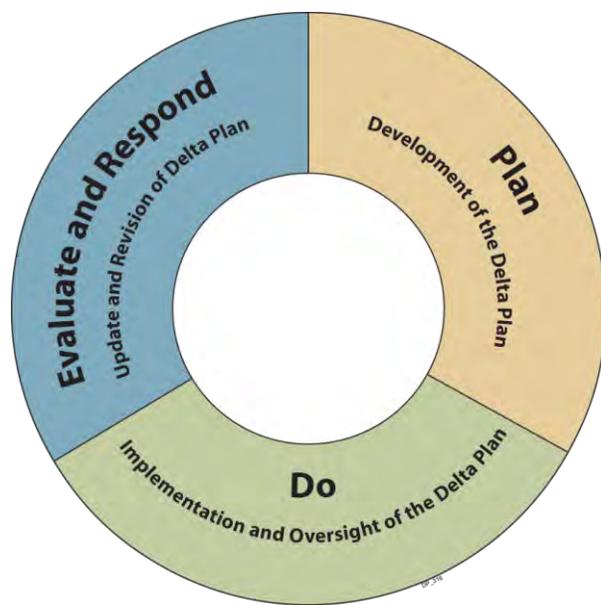
Figure 2-2

[1] Christensen et al. 1996, Stanford and Poole 1996, CALFED Bay-Delta Program 2000, Habron 2003, Abal et al. 2005, Healey et al. 2008, Kaplan and Norton 2008, Bay Delta Conservation Plan Independent Science Advisors on Adaptive Management 2009, Williams et al. 2009.

Plan: Development of the Delta Plan

The first phase of adaptive management is "Plan." The Plan phase requires clear definition of the problem, establishment of objectives, how to achieve those objectives, and actions for implementation. Performance measures are included to evaluate whether the actions are successfully meeting their intended objectives. As described in Chapter 1, the Council was established in response to an ongoing crisis in the Delta. Water supply reliability and the health of the Delta ecosystem are both at risk, and the status quo—including the patchwork governance of State, local, and federal agencies—is not making acceptable progress toward reversing disturbing trends in a balanced and sustainable manner.

The Delta Plan is intended to be foundational and adaptive. It is foundational in that the Council has built on previous efforts, including CALFED, the Delta Vision, the California Water Plan, planning efforts of the State Water Resources Control Board (SWRCB), the Delta Protection Commission (DPC), and others. The framework established in this Delta Plan is intended to advance the coequal goals of water supply reliability and ecosystem health, and to employ adaptive management to improve the Plan over time.

This Delta Plan officially supersedes and replaces the Interim Delta Plan adopted by the Council on August 27, 2010.

Structure of the Delta Plan

The Delta Plan contains five core policy chapters (Chapters 3 through 7) and a chapter on Funding Principles to Support the Coequal Goals (Chapter 8). The narrative sections of each policy chapter provide subject matter context and rationale for the selection and implementation of core strategies. These core strategies are then broken down into actions: the policies and recommendations. The policies in the Delta Plan are regulatory in nature, and compliance is required for those who propose covered actions. In each policy chapter, the Policies and Recommendations section is followed by a section identifying both science needs and key issues for future evaluation by the Council.

Finally, each policy chapter concludes with a set of performance measures. The Delta Reform Act requires that the Delta Plan include performance measures to evaluate whether it is achieving its objectives over time. Information learned from performance measures will be an important part of how the Council determines when and how to update the Delta Plan as part of the Evaluate and Respond phase of the adaptive management process. See the sidebar, Performance Measures in the Delta Plan, later in this chapter.

Considerations in the Development of the Delta Plan

The Delta Reform Act set forth certain requirements and guidance for the development of the Delta Plan. The Act required the development of several State agency plans to inform the Delta Plan planning process and set forth statutory guidelines for the consideration or inclusion of certain plans, some of which were not yet completed at the date of Delta Plan publication and will be considered in future plan updates.

- **Delta Reform Act objectives.** The Act lists numerous objectives and, in some sections, provides detailed guidance for what the Delta Plan shall include (see Table 2-2).

- **State agency proposals.** Specific agencies are named in the Delta Reform Act as being responsible for submitting reports or recommendations to the Council for consideration for inclusion in the Delta Plan. The DPC, California State Parks, and the California Department of Food and Agriculture (CDFA) all submitted proposals that were considered in the development of this Delta Plan.

- **Consistency with federal law.** The Delta Reform Act requires that the Delta Plan be developed consistent with the federal Clean Water Act, Section 8 of the federal Reclamation Act of 1902, and the federal Coastal Zone Management Act of 1972 (CZMA), or an equivalent compliance mechanism. See sidebar, Federal Participation in Implementing the Delta Plan, for more information.

Delta Plan Requirements by Water Code Section

TABLE 2-2

Water Code Section	Requirement
85211	The Delta Plan shall include performance measurements that will enable the council to track progress in meeting the objectives of the Delta Plan. The performance measurements shall include, but need not be limited to, quantitative or otherwise measurable assessments of the status and trends in all of the following:
85211(a)	– The health of the Delta's estuary and wetland ecosystem for supporting viable populations of aquatic and terrestrial species, habitats, and processes, including viable populations of Delta fisheries and other aquatic organisms.
85211(b)	– The reliability of California water supply imported from the Sacramento River or the San Joaquin River watershed.
85300(a)	The Delta Plan shall include subgoals and strategies to assist in guiding state and local agency actions related to the Delta.
85302(e)	The following subgoals and strategies for restoring a healthy ecosystem shall be included in the Delta Plan:
85302(e)(1)	– Restore large areas of interconnected habitats within the Delta and its watershed by 2100.
85302(e)(2)	– Establish migratory corridors for fish, birds, and other animals along selected Delta river channels.
85302(e)(3)	– Promote self-sustaining, diverse populations of native and valued species by reducing the risk of take and harm from invasive species.
85302(e)(4)	– Restore Delta flows and channels to support a healthy estuary and other ecosystems.
85302(e)(5)	– Improve water quality to meet drinking water, agriculture, and ecosystem long-term goals.
85302(e)(6)	– Restore habitat necessary to avoid a net loss of migratory bird habitat and, where feasible, increase migratory bird habitat to promote viable populations of migratory birds.
85300(a)	The Delta Plan may also identify specific actions that state or local agencies may take to implement the subgoals and strategies.
85302(a)	Implementation of the Delta Plan shall further the restoration of the Delta ecosystem and a reliable water supply.
85302(b)	The Delta Plan may include recommended ecosystem projects outside the Delta that will contribute to achievement of the coequal goals.
85302(c)	The Delta Plan shall include measures that promote all of the following characteristics of a healthy Delta ecosystem:
85302(c)(1)	– Viable populations of native resident and migratory species.
85302(c)(2)	– Functional corridors for migratory species.
85302(c)(3)	– Diverse and biologically appropriate habitats and ecosystem processes.
85302(c)(4)	– Reduced threats and stresses on the Delta ecosystem.
85302(c)(5)	– Conditions conducive to meeting or exceeding the goals in existing species recovery plans and state and federal goals with respect to doubling salmon populations.
85302(d)	The Delta Plan shall include measures to promote a more reliable water supply that address all of the following:
85302(d)(1)	– Meeting the needs for reasonable and beneficial uses of water.
85302(d)(2)	– Sustaining the economic vitality of the state.
85302(d)(3)	– Improving water quality to protect human health and the environment.
85302(h)	The Delta Plan shall include recommendations regarding state agency management of lands in the Delta.

Delta Plan Requirements by Water Code Section

TABLE 2-2

Water Code Section	Requirement
85303	The Delta Plan shall promote statewide water conservation, water use efficiency, and sustainable use of water.
85304	The Delta Plan shall promote options for new and improved infrastructure relating to the water conveyance in the Delta, storage systems, and for the operation of both to achieve the coequal goals.
85305(a)	The Delta Plan shall attempt to reduce risks to people, property, and state interests in the Delta by promoting effective emergency preparedness, appropriate land uses, and strategic levee investments.
85305(b)	The council may incorporate into the Delta Plan the emergency preparedness and response strategies for the Delta developed by the California Emergency Management Agency pursuant to Section 12994.5.
85306	The council, in consultation with the Central Valley Flood Protection Board, shall recommend in the Delta Plan priorities for state investments in levee operation, maintenance, and improvements in the Delta, including both levees that are a part of the State Plan of Flood Control and nonproject levees.
85307(a)	The Delta Plan may identify actions to be taken outside of the Delta, if those actions are determined to significantly reduce flood risks in the Delta.
85307(b)	The Delta Plan may include local plans of flood protection.
85307(c)	The council, in consultation with the Department of Transportation, may address in the Delta Plan the effects of climate change and sea level rise on the three state highways that cross the Delta.
85307(d)	The council, in consultation with the State Energy Resources Conservation and Development Commission and the Public Utilities Commission, may incorporate into the Delta Plan additional actions to address the needs of Delta energy development, energy storage, and energy distribution.
85308	The Delta Plan shall meet all of the following requirements:
85308(a)	– Be based on the best available scientific information and the independent science advice provided by the Delta Independent Science Board.
85308(b)	– Include quantified or otherwise measurable targets associated with achieving the objectives of the Delta Plan.
85308(c)	– Where appropriate, utilize monitoring, data collection, and analysis of actions sufficient to determine progress toward meeting the quantified targets.
85308(d)	– Describe the methods by which the council shall measure progress toward achieving the coequal goals.
85308(e)	– Where appropriate, recommend integration of scientific and monitoring results into ongoing Delta water management.
85308(f)	– Include a science-based, transparent, and formal adaptive management strategy for ongoing ecosystem restoration and water management decisions.

■ **Incorporation of the Bay Delta Conservation Plan into the Delta Plan.** The Bay Delta Conservation Plan (BDCP) is a major project considering large-scale improvements in water conveyance and large-scale ecosystem restoration in the Delta. When completed, it must be incorporated into the Delta Plan if it meets certain statutory requirements. Completion of the BDCP process and the number of projects now under consideration in that process would have large impacts on the Delta and would affect the coequal goals. (More detailed discussions of the BDCP are provided in Chapters 3 and 4.) The Delta Reform Act describes a separate, explicit process for incorporating the BDCP into the Delta Plan (Water Code section 85320), and the

Council has adopted administrative procedures governing appeals to the Council related to BDCP incorporation (see Appendix D). If the BDCP is incorporated into the Delta Plan, it becomes part of the Delta Plan and, therefore, part of the basis for future consistency determinations.

■ **Incorporation of other plans into the Delta Plan.** The Council may incorporate other plans or programs in whole or in part into the Delta Plan to the extent that they promote the coequal goals.

Do: Implementation and Oversight of the Delta Plan

The second phase of adaptive management is "Do." The "doing," or implementation, of the Delta Plan will occur over time (through 2100) through the coordinated efforts of many State, local, and federal agencies, in cooperation with nongovernmental organizations and private parties, and Council oversight and exercise of appellate authorities.

Federal participation in implementing the Delta Plan and the coequal goals is described in detail in the sidebar, Federal Participation in Implementing the Delta Plan.

The Council is responsible for overseeing the Delta Plan's implementation. Given the numerous government agencies that frequently have conflicting or overlapping jurisdictional and programmatic interest in Delta matters (see Table 2-1), there is a compelling need for the Council to fulfill the role as integrator of Delta policy and coordinator of actions. This integration and coordination will occur through convening a formal Interagency Implementation Committee, providing ongoing informal staff-to-staff agency coordination, providing comments and advice from the Council to other agencies on proposed or ongoing plans and programs, holding public hearings, developing science to support the Delta Plan, and using the Council's appellate authority over consistency of significant actions in the Delta with the Delta Plan.

Delta Plan Interagency Implementation Committee

Perhaps the most significant tool the Council will have for implementing the Delta Plan and ensuring accountability is a formal method for active agency coordination. The Delta Reform Act directs the Council to establish and oversee a committee of agencies responsible for implementing the Delta Plan. Notably, the law states that "each agency shall coordinate its actions pursuant to the Delta Plan with the Council and other relevant agencies" (Water Code section 85204). Governance challenges have long plagued management of the Delta and California's ability to achieve stated objectives for water supply and the Delta ecosystem. Ambiguous and sometimes conflicting authorities and responsibilities among agencies thwart real progress (NRC 2012).

The Council, therefore, will coordinate implementation of the Delta Plan through the establishment and leadership of an Interagency Implementation Committee to do the following:

■ Monitor progress of priority actions and agency activities to implement the Delta Plan;

■ Report regularly on implementation plans and actions;

■ Identify opportunities for integration and leveraging of funding;

■ Identify funding needs and support development of a finance plan to implement the Delta Plan;

■ Assist in the ongoing development and tracking of Delta Plan performance measures;

■ Coordinate regulatory actions on significant projects to implement the Delta Plan, as appropriate; and

■ Discuss common issues and resolve interagency conflicts.

The Interagency Implementation Committee, which shall convene at least twice each year and more often as needed, will be overseen by the Council and will be organized around the implementation of the Delta Plan. The Interagency Implementation Committee will include federal, local, and State agency representatives as dictated by the specific matter or subject area in the Delta Plan. At a minimum, the Interagency Implementation Committee will consist of the Council's Executive Officer, the Delta Science Program lead

FEDERAL PARTICIPATION IN IMPLEMENTING THE DELTA PLAN

The Delta Reform Act recognizes the federal government's critical role in achieving the coequal goals through the Delta Plan's comprehensive, Delta-wide planning and implementation effort. This effort goes beyond federal participation in the more narrowly focused BDCP. This recognition builds upon the history of federal-State cooperative governance efforts in the Delta made necessary by the multitude of federal and State agencies working on interconnected, cross-jurisdictional issues in and related to the Delta, including water project operations, water quality regulation, levee maintenance, habitat restoration, and endangered species regulation.

Federal Law Now Incorporates the Coequal Goals

The federal Energy and Water Development Appropriations Act of 2012 (Title II of the Consolidated Appropriations Act of 2012 (PL 112-074)) contains, in pertinent part, the following:

The Federal policy for addressing California's water supply and environmental issues related to the Bay-Delta shall be consistent with State law, including the coequal goals of providing a more reliable water supply for the State of California and protecting, restoring, and enhancing the Delta ecosystem…Nothing herein modifies existing requirements of Federal law. (Section 205)

The Council's staff will work with federal agency representatives to explore opportunities for federal participation in Delta Plan implementation efforts to help those agencies comply with this new Congressional policy directive.

The current regulatory provisions of the Delta Plan, including the consistency review and appeals process, apply to only covered actions of State and local agencies. However, once the Delta Plan is adopted, the Delta Reform Act requires the Council to pursue a compliance mechanism that requires consistency of federal actions. The Delta Reform Act identifies the CZMA, or "an equivalent compliance mechanism," as the preferred means to accomplish this objective. Under the CZMA, states are authorized to review certain activities of federal agencies, including activities directly conducted by federal agencies and activities permitted or licensed by these agencies, for consistency with a state's federally approved coastal management program. This review authority applies to any activity that affects any land or water use or natural resource of the state coastal zone.

In this regard, the Council staff has met, and will continue to meet, with federal agency representatives to identify the appropriate process to submit the Delta Plan to the Secretary of Commerce for approval under the CZMA (and with representatives of the California Coastal Commission and the San Francisco Bay Conservation and Development Commission, which administer California's coastal management program).

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scientist, and executive officers or directors from the California Department of Water Resources (DWR); California Department of Fish and Wildlife (DFW); SWRCB and regional water quality control boards; the San Francisco Bay Conservation and Development Commission; the California Water Commission; the Sacramento-San Joaquin Delta Conservancy; the DPC; the Delta Watermaster; the CDFA; the Natural Resources Agency; the Business, Transportation and Housing Agency; and the California Environmental Protection Agency. Federal agencies such as National Oceanic and Atmospheric Administration Fisheries, U.S. Fish and Wildlife Service, Bureau of Reclamation, Natural Resources Conservation Service, U.S. Geological Survey, U.S. Army Corps of Engineers, U.S. Environmental Protection Agency, and others, as appropriate, will be invited to participate and provide status reports on various projects and programs related to Delta Plan implementation.

The meetings of the Interagency Implementation Committee will be open to the public, and the agenda will be noticed in advance. The committee will create ad hoc workgroups as appropriate to facilitate focus on specific issues. Stakeholder representatives will be encouraged to participate in the various workgroups. The work of both the formal Interagency Implementation Committee and the workgroups may be supplemented with meetings or hearings conducted by the Council.

The Delta Protection Commission's Role in Delta Plan Implementation

The Delta Protection Act states that the DPC is the appropriate agency to identify and provide recommendations to the Council on methods of preserving the Delta as an evolving place. The DPC developed and submitted a set of recommendations to the Council, many of which were incorporated in this Delta Plan (DPC 2012). The Delta Protection Act outlines a process for the DPC to review and provide comments and recommendations to the Council on any significant project or proposed project within the scope

of the Delta Plan that may affect the unique values of the Delta (Public Resources Code section 29773(a)). The Council's adopted procedures include a process whereby the Council will notify the DPC of covered action appeals.

Other Delta Plan Implementation Actions

In addition to convening the Interagency Implementation Committee and carrying out the other responsibilities assigned to it by the Delta Reform Act, the Delta Plan assigns other tasks that will further refine the Delta Plan to the Council. These tasks are described in the following recommendations: G R1 (Chapter 2), WR R5 (Chapter 3), WR R15 (Chapter 3), DP R7 (Chapter 5), DP R19 (Chapter 5), RR R4 (Chapter 7), and FP R1 through R3 (Chapter 8).

Additional Council Authorities in Implementing the Delta Plan

The Delta Reform Act enumerated a range of specific authorities for the Council related to the implementation of the Delta Plan (as shown on Figure 2-1). A full list of authorities can be found in Water Code section 85210 and in various sections of the Delta Reform Act. In implementing the Delta Plan, the Council has the authority to:

- **Comment on environmental impact reports.** The Council has a role in commenting on any State agency environmental impact reports (EIRs) as appropriate to the mission of the Council.

- **Comment on policies related to the coequal goals and implementation of the Delta Plan.** As appropriate, the Council may comment formally on any proposed policies or regulations that will impact the achievement of the coequal goals and the implementation of the Delta Plan.

- **Advise local governments.** The Council has a role in advising local and regional planning agencies regarding the consistency of their planning documents with the Delta Plan. As described in Chapter 5, the Council will review sustainable community strategies and regional transportation plans to prevent conflicts with the Delta

Plan and to coordinate metropolitan development with actions in the Delta.

- **Request reports from State, federal, and local agencies.** The Council has the authority to request reports from agencies on issues related to the implementation of the Delta Plan.

- **Hold hearings.** The Council has the authority to hold hearings in all parts of the state and to subpoena witnesses.

- **Develop, coordinate, and promote the use of science through the Delta Science Program.** The Council has a role in providing the best available unbiased scientific information to inform water and environmental decision making in the Delta by funding research, synthesizing and communicating scientific information to policy makers and decision makers, promoting independent peer review, and coordinating with Delta agencies to promote science-based adaptive management.

- **Make consistency determinations upon appeal.** The Legislature intended that State and local actions that would have a significant impact on the coequal goals or a government-sponsored flood control program be consistent with the Delta Plan. The Council has the authority to implement the Delta Plan in part through the enforcement of consistency of covered actions with the Delta Plan upon appeal. The Delta Reform Act also gave the Council a specific appellate role with respect to the BDCP and its future incorporation into the Delta Plan. The Council's appellate roles, the definition of a covered action, and the consistency determination process and appeals process are described in detail in the Covered Actions and Delta Plan Consistency section later in this chapter.

Monitoring Progress toward Achieving the Coequal Goals

The Council will use existing monitoring efforts (such as the efforts of the Interagency Ecological Program, California Water Quality Monitoring Council, and California Statewide Groundwater Elevation Monitoring) and new monitoring

efforts to inform progress toward achieving the performance measures in the Delta Plan. The Council will monitor the progress of programs and projects toward achieving the administrative, output, and outcome performance measures in the current Delta Plan and those developed in the future. Working with others, in particular the Interagency Implementation Committee, the Council will use coordinated information about relevant status and trends and progress toward meeting the coequal goals to inform revisions to the Delta Plan. The Council's monitoring activities will be reported on the Council website.

Evaluate and Respond: Updating and Amending the Delta Plan

The third phase of Delta Plan adaptive management is "Evaluate and Respond." According to the Delta Reform Act, the Council must review the Delta Plan at least once every 5 years and can revise it as the Council deems appropriate. This authority is consistent with the Council's obligation to base the Delta Plan on the best available scientific information and to use an adaptive management approach in updating the Plan as new information becomes available.

When updating the Delta Plan, the Council will consider information from other adaptive management activities in the Delta; evaluation of Delta Plan policies and recommendations; performance measures; other completed plans related to the Delta; and coordination, hearings, and oversight. The Council will rely in large part on the Delta Science Program for determining the relevance, value, and reliability of the best available science, and organizing that information for its use in the Council's decisions. The Council has the final responsibility for determining the best available science used in support of its actions, including when a choice among competing interpretations of available science must be made.

Reporting on Delta Plan Performance Measures

This Delta Plan contains preliminary performance measures developed to monitor performance of Delta Plan policies and recommendations. (See sidebar, Performance Measures in the Delta Plan, for more detailed information.) Upon adoption of the Delta Plan, staff will take the lead, working with scientific, agency, and stakeholder experts to continue to refine the Delta Plan's performance measures. Delta Plan performance measures will be periodically reviewed by independent expert review panels and will be sent to the Delta ISB for further review and comment. The resulting updated performance measures will be developed no later than December 31, 2014, for consideration by the Council for incorporation into the Delta Plan. The Council will issue periodic public reports on the status of performance measures.

Data collection related to the Delta and water management in California is already occurring, although more is needed. The Council, through the Interagency Implementation Committee and working with stakeholders, will report regularly on Delta Plan performance measures and the Delta Plan's progress in advancing the coequal goals. These reports will be made available to the public.

PERFORMANCE MEASURES IN THE DELTA PLAN

The performance measures included in this Delta Plan are primarily administrative measures focused on implementation of near-term actions (generally, actions contained within policies and recommendations of the Delta Plan) that support the coequal goals. This initial set of performance measures will be expanded and refined after adoption of the Delta Plan and will be considered for inclusion in subsequent updates of the Delta Plan.

Delta Plan performance measures have been placed into three general classes:

- Administrative performance measures describe decisions made by policy makers and managers to finalize plans or approve resources (funds, personnel, projects) for implementation of a program or group of related programs.

- Output (also known as "driver") performance measures evaluate the factors that may be influencing outcomes and include on-the-ground implementation of management actions, such as acres of habitat restored or acre-feet of water released, as well as natural phenomena outside of management control (such as a flood, earthquake, or ocean conditions).

- Outcome performance measures evaluate responses to management actions or natural outputs.

Administrative performance measures are included in Appendix E. Output and outcome performance measures, where appropriate, are included at the end of individual chapters.

Development of informative and meaningful performance measures is a challenging task that will continue after the adoption of the Delta Plan. Performance measures need to be designed to capture important trends and to address whether specific actions are producing expected results. Efforts to develop performance measures in complex and large-scale systems like the Delta are commonly multiyear endeavors. The Council will improve all performance measures, but will focus on outcome measures through a multiyear effort, using successful approaches for developing performance measures employed by similar efforts elsewhere (such as the Kissimmee River Restoration, The State of San Francisco Bay, and Healthy Waterways Southeast Queensland, Australia) as positive examples (see Appendix C for more information).

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Communication and the Delta Plan

Keeping the public and decision makers informed as future Delta Plan changes are proposed and considered is a vital step. The Council is committed to open communication of current understanding gained through the evaluation of performance measures, monitoring, science, and adaptive management. This communication will be continuous as the Council receives and produces information that will be used to adapt its strategy toward meeting the coequal goals and updating the Delta Plan.

The Council's website and meetings will remain the central hub for communicating information about progress toward meeting the coequal goals and the objectives of the Delta Plan. Information learned from the analysis, synthesis, and evaluation of how well the policies and recommendations in the Delta Plan are meeting their intended goals will be gathered and communicated through a number of media and forums that may include:

- The Council's meetings and workshops, website, social media, and newsletter

- Staff reports on the status and trends of the Delta Plan performance measures

- Reports, presentations, and correspondence presented to the Council

- Interagency Implementation Committee meetings and products

- The Delta Science Program website, *Science News*; the online journal, *San Francisco Estuary & Watershed Science*; brown bag seminars; and Biennial Bay-Delta Science Conference

- Delta ISB meetings and products

Covered Actions and Delta Plan Consistency

The Delta Reform Act directs the Council to develop a legally enforceable long-term management plan for the Delta (this Delta Plan) and includes a mechanism for enforcement of Delta Plan policies over State and local actions identified

as covered actions (Water Code sections 85001(c) and 85022). The Council has taken a hybrid approach to developing the Delta Plan by including both regulatory policies and nonregulatory recommendations. This section presents a discussion of the process and general requirements for certifying consistency with the Delta Plan through compliance with its regulatory policies, and includes examples of covered actions and exemptions.

Delta Plan regulatory policies are not intended and shall not be construed as authorizing the Council or any entity acting pursuant to this section to exercise their power in a manner that will take or damage private property for public use without the payment of just compensation. These policies are not intended to affect the rights of any owner of property under the Constitution of the State of California or the United States. None of the Delta Plan policies increases the State's flood liability.

Covered Actions Must Comply with Delta Plan Policies

The Delta Reform Act requires State and local actions that fit the legal definition of a covered action to be consistent with the policies included in the Delta Plan. The mechanism for determining consistency is the filing of a certification of consistency. Not all actions that occur in whole or in part in the Delta are covered actions. Only certain activities qualify as covered actions, and the Delta Reform Act establishes specific criteria and exclusions, discussed in this chapter. Furthermore:

- The State or local agency that carries out, approves, or funds a proposed action determines whether that proposed plan, program, or project is a covered action (subject to judicial review of whether the determination was reasonable and consistent with the law).

- The State or local agency that carries out, approves, or funds a covered action ("proponents") needs to certify consistency with the policies included in the Delta Plan.

- In the case of all other actions (those that do not meet the criteria of being a covered action or are otherwise explicitly excluded), the Delta Plan's policies, where applicable, are recommendations.

What Is a Covered Action?

For a State or local agency to determine whether its proposed plans, programs, or projects are covered actions under the Delta Plan and, therefore, subject to the regulatory provisions in the plan, it must start with the Delta Reform Act, which defines a covered action as (Water Code section 85057.5(a)):

…a plan, program, or project as defined pursuant to Section 21065 of the Public Resources Code that meets all of the following conditions:

1. *Will occur, in whole or in part, within the boundaries of the Delta or Suisun Marsh;*

2. *Will be carried out, approved, or funded by the state or a local public agency;*

3. *Is covered by one or more provisions of the Delta Plan;*

4. *Will have a significant impact on the achievement of one or both of the coequal goals or the implementation of government-sponsored flood control programs to reduce risks to people, property, and state interests in the Delta.*

Figure 2-3 shows the steps to follow for identifying whether a proposed plan, project, or program is a covered action.

Screening Criteria for Covered Actions

As used in this Delta Plan, the statutory criteria for covered actions under the Delta Plan are collectively referred to as "screening criteria." Before using the screening criteria, a project proponent should first determine whether its proposed plan, program, or project is exempt from covered action status under either the Council's administrative

exemptions or the Delta Reform Act's statutory exemptions, discussed below. Early consultation with Council staff is encouraged and can assist in this determination.

1. **Is a "Project," as defined by section 21065 of the Public Resources Code.** A proponent's first step in determining whether a plan, program, or project is a covered action is to identify whether it meets the definition of a project as defined in Public Resources Code section 21065. That particular provision is the section of the California Environmental Quality Act (CEQA) that defines the term "project" for purposes of potential review under CEQA.[2] If the plan, program, or project does indeed meet the definition of a project under CEQA, the next step in determining a covered action is to review the four additional screening criteria in the definition of covered action, *all* of which must be met by a proposed plan, program, or project for it to qualify as a covered action (see sidebar, What Does CEQA Consider a "Project"?).

2. **Will occur in whole, or in part, within the boundaries of the Delta or Suisun Marsh.** To qualify as a covered action, a project must include one or more activities that take place at least partly within the Delta or Suisun Marsh. This means, for example, that the diversion and use of water in the Delta watershed that is entirely upstream of the statutory Delta or Suisun Marsh would not satisfy this criterion. By contrast, this criterion *would* be met if water intended for use upstream were transferred through the statutory Delta or Suisun Marsh (pursuant, for example, to a water transfer longer than 1 year in duration).

Decision Tree for State and Local Agencies on Possible Covered Actions

Figure 2-3

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[2] It is important to note that CEQA's various statutory and categorical exemptions—which are considered only after the threshold determination of a CEQA "project" is made—are not similarly incorporated by cross-reference in the definition of covered action. Therefore, the Delta Plan must expressly incorporate a CEQA exemption for it to apply to the Delta Plan.
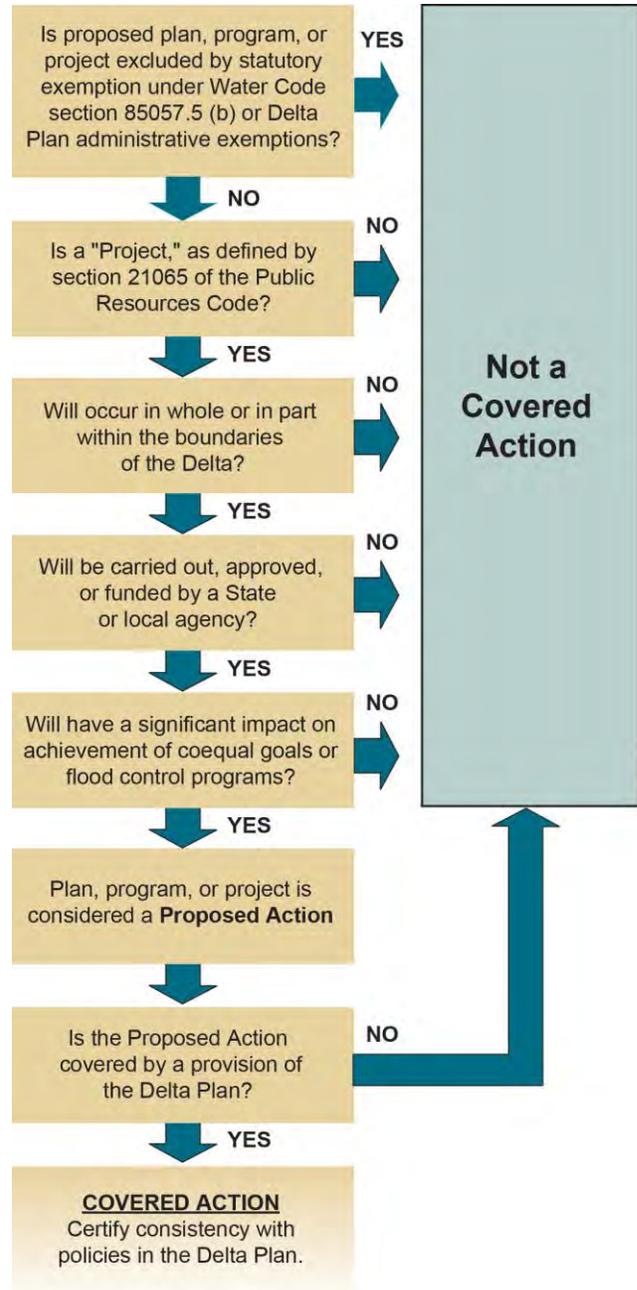
3. **Will be carried out, approved, or funded by the State or a local public agency.** If these screening criteria are met, it is recommended that the "significant impact" criteria be analyzed next.

4. **Will have a significant impact on the achievement of one or both of the coequal goals or the implementation of a government-sponsored flood control program to reduce risks to people, property, and State interests in the Delta.** In addition, a proposed project must have a "significant impact" as defined under Water Code section 85057.5(a)(4) to qualify as a covered action. For this purpose, significant impact means a substantial positive or negative impact on the achievement of one or both of the coequal goals or the implementation of a government-sponsored flood control program to reduce risks to people, property, and State interests in the Delta, that is directly or indirectly caused by a project on its own or when the project's incremental effect is considered together with the impacts of other closely related past, present, or reasonably foreseeable future projects. The coequal goals and government-sponsored flood control programs are further defined in Chapters 3, 4, and 7.

The following categories of projects will not have a significant impact for this purpose:

- "Ministerial" projects exempted from CEQA, pursuant to Public Resources Code section 21080(b)(1);

- "Emergency" projects exempted from CEQA, pursuant to Public Resources Code section 21080(b)(2) through (4);

- Temporary water transfers of up to 1 year in duration. This provision shall remain in effect only through December 31, 2016, and as of January 1, 2017, is repealed, unless the Council acts to extend the provision prior to that date. The Council

contemplates that any extension would be based upon DWR and the SWRCB's participation with stakeholders to identify and implement transfer measures, as recommended in WR R15;

- Other projects exempted from CEQA, unless there are unusual circumstances indicating a reasonable possibility that the project will have a significant impact under Water Code section 85057.5(a)(4). Examples of unusual circumstances could arise in connection with, among other things:

  - Local government general plan amendments for the purpose of achieving consistency with the DPC's Land Use and Resource Management Plan; and

  - Small-scale habitat restoration projects, as referred to in CEQA Guidelines, section 15333 of Title 14 of the California Administrative Code, proposed in important restoration areas, but which are inconsistent with the Delta Plan's policy related to appropriate habitat restoration for a given land elevation.

WHAT DOES CEQA CONSIDER A "PROJECT"?

Public Resources Code section 21065 (which is incorporated by reference in the Delta Reform Act) defines the term "project" in the following manner:

21065. "Project" means an activity which may cause either a direct physical change in the environment, or a reasonably foreseeable indirect physical change in the environment, and which is any of the following:

(a) An activity directly undertaken by any public agency.

(b) An activity undertaken by a person which is supported, in whole or in part, through contracts, grants, subsidies, loans, or other forms of assistance from one or more public agencies.

(c) An activity that involves the issuance to a person of a lease, permit, license, certificate, or other entitlement for use by one or more public agencies.

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The Council will consider, as part of its ongoing adaptive management of the Delta Plan, whether these exemptions remain appropriate and/or whether the Delta Plan should be amended to include other types of projects.

If the above four screening criteria are met, then for purposes of the Delta Plan, the plan, program, or project is referred to as a "proposed action." Although a proposed action meets the first four screening criteria, the action has not yet been reviewed by the State or local agency to determine whether it meets the fifth screening criterion: is the proposed action covered by one or more Delta Plan policies? If the proposed action is covered by at least one Delta Plan regulatory policy, then the proposed action is a "covered action." If the proposed action is not covered by any Delta Plan regulatory policy, it is not a covered action.

5. **Is covered by one or more provisions of the Delta Plan.** This means that the proposed action must be covered by one or more regulatory policies contained in Chapters 3 through 7 of the Delta Plan. Each of those regulatory policies specifies the types of proposed actions that they cover. If the proposed action is covered by one or more provisions of the Delta Plan—the final criteria—the proposed action is, therefore, a covered action.

Statutory Exemptions

Certain actions are statutorily excluded from the definition of covered action and are exempt from the Council's regulatory authority (Water Code section 85057.5(b)). A complete list is included in Appendix F. These exemptions include:

- A regulatory action of a State agency (such as the adoption of a water quality control plan by the SWRCB, or the issuance of a California Endangered Species Act take permit by DFW)

- Routine maintenance and operation of the State Water Project or the Central Valley Project

- Routine maintenance and operation of any facility located, in whole or in part, in the Delta, that is owned or operated by a local public agency (such as routine maintenance of levees by a reclamation district)

Although a regulatory action by another State agency is not a covered action, the underlying action regulated by that agency can be a covered action (provided it otherwise meets the definition). The Council has concurrent jurisdiction over covered actions when that action is also regulated by another State agency. For example, the issuance of a California Endangered Species Act take permit by DFW is a regulatory action of a State agency and, therefore, is not a covered action. However, the underlying action requiring the take permit could be a covered action, and, if it is, it must be consistent with the Delta Plan's policies. Therefore, even when a covered action is regulated by another agency (or agencies), the covered action still must be consistent with the Delta Plan. In the situation where a covered action is governed by multiple agencies and laws, the action must comply with all relevant legal requirements.

Who Determines Whether a Proposed Plan, Program, or Project Is a Covered Action?

A State or local agency that proposes to carry out, approve, or fund a plan, program, or project is the entity that must determine whether that plan, program, or project is a covered action. That determination must be reasonable, made in good faith, and consistent with the Delta Reform Act and relevant provisions of this Plan. If requested, Council staff will meet with an agency's staff during early consultation to review consistency with the Delta Plan and to offer advice as to whether the proposed plan, program, or project appears to be a covered action, provided that the ultimate determination in this regard must be made by the agency. If an agency determines that a proposed plan, program, or project is not a covered action, that determination is not subject to Council regulatory review, but is subject to judicial review as to whether it was reasonable, made in good faith, and is

consistent with the Delta Reform Act and relevant provisions of this Plan.

Mitigation of Significant Adverse Impacts on the Environment

Public Resources Code section 21081.6 requires a public agency to adopt a mitigation monitoring or reporting program (MMRP) to ensure compliance with the mitigation measures adopted by the agency at the time of project approval. The MMRP is a working implementation document to ensure that mitigation measures are implemented. The MMRP for the *Delta Plan Program Environmental Impact Report* (PEIR) ensures compliance with the Delta Plan mitigation measures. The Delta Plan MMRP lists the mitigation measures incorporated into the Delta Plan, when they need to be implemented, who is responsible for implementing them, and who reports on compliance. As specified in policy G P1 of the Delta Plan, any covered action that is not exempt must include either the mitigation measures identified in the Delta Plan's PEIR, if applicable and feasible; substitute mitigation measures that the proposing agency finds to be equally or more effective than those identified in the Delta Plan PEIR; or an explanation of why such mitigation is not feasible. Monitoring and/or reporting on implementation of the adopted Delta Plan mitigation measures will be accomplished through the certification of consistency process as part of the certification forms. The MMRP can be found on the DSC's website at http://deltacouncil.ca.gov/.

Certifications of Consistency

Once a State or local agency has determined that their plan, program, or project is a covered action under the Delta Plan, they are required to submit a written certification to the Council, with detailed findings, demonstrating that the covered action is consistent with the Delta Plan (Water Code section 85225 et seq.). Furthermore:

- The first policy in the Delta Plan, G P1, describes requirements to be included in the certification of consistency for all covered actions and is included in this chapter.

- The certification of consistency must be submitted to the Council prior to initiating implementation of the covered action.

- The certification of consistency should not be submitted to the Council until the covered action has been fully described and the impacts associated with the covered action have been identified; this coincides with the completion of the CEQA process.

- Should the covered action project change substantially, the agency will be required to submit a new certification of consistency to the Council.

The Council has developed a discretionary checklist that agencies may use to facilitate the process, as well as certification forms and related materials, available on the Council website.

Bay Delta Conservation Plan Covered Activity Consistency Certification

The Delta Reform Act describes a specific process for the potential incorporation of BDCP into the Delta Plan. If BDCP is incorporated, an agency proposing a qualifying "covered activity" under BDCP that also meets the statutory definition of a covered action must file a short form certification of consistency with findings indicating only that the covered action is consistent with the BDCP. Consistency for these purposes shall be presumed if the certification filed by the agency includes a statement to that effect from DFW.

Covered Action Consistency Appeals

In contrast to how many other governmental plans are implemented, the Council does *not* exercise direct review and approval authority over covered actions to determine their consistency with the regulatory policies in the Delta Plan. Instead, State or local agencies self-certify Delta Plan

consistency, and the Council serves as an appellate body for those determinations.

Any person, including any member of the Council or its Executive Officer, who claims that a covered action is inconsistent with the Delta Plan and, as a result of that inconsistency, will have a significant adverse impact on the achievement of one or both of the coequal goals or implementation of government-sponsored flood control program, may file an appeal with regard to a certification of consistency submitted to Council.

The Council has appellate authority to determine the consistency of covered actions with the Delta Plan if they are challenged. The Council is required to apply the standard of substantial evidence when reviewing covered action appeals. State or local agencies are required to submit detailed findings upon filing their consistency determination, described previously. These findings and the record will provide the basis for the Council's decision making.

Per statute, an appeal must be filed within 30 days; if a valid appeal is filed, the Council is responsible for subsequent

evaluation and determination—as provided in statute and the Council's Administrative Procedures Governing Appeals— of whether the covered action is consistent with the Delta Plan's policies. More than one policy in the Delta Plan may apply to a covered action. If no person appeals the certification of consistency, the State or local public agency may proceed to implement the covered action.

In the event of an appeal of a covered action, the Council may consult with the DPC consistent with Public Resources Code section 29773.

Upon receiving an appeal, the Council has 60 days to hear the appeal and an additional 60 days to make its decision and issue specific written findings. If the covered action is found to be inconsistent, the project may not proceed until it is revised so that it is consistent with the Delta Plan.

The appeals process is described in statute and further defined in the appeals procedures adopted by the Council; it is attached for reference purposes as Appendix D.

POLICIES AND RECOMMENDATIONS

State and local agencies approve many important plans, programs, and projects annually that are in or otherwise affect the Delta. Interagency coordination is often limited and, despite the Delta's special status, there are no overarching guidelines or coordinated best management practices to ensure that all significant actions use best available science or adaptive management in particular. The Delta Reform Act, in describing a process for coordinating actions under the Delta Plan, requires that State or local government actions are consistent with the Delta Plan and supported by detailed findings. Policy G P1 describes compliance requirements for covered actions that are to be included in the project proponent's written findings.

Problem Statement

Independent and disparate actions by individual agencies can lead to conflict and reduce successful achievement of the coequal goals. Lack of uniform use of best available science and adaptive management for water supply and ecosystem projects can lead to unintended consequences, reduced likelihood of project success, and increased likelihood of adverse environmental impacts. In addition, management actions can be delayed when uncertainty exists, while adaptive management allows for flexible decision making despite uncertainty.

In some cases, project proponents do not carefully plan for the resources and costs of monitoring and tracking, and full adaptive management does not occur. Failure of significant Delta-related actions to comply with existing law can thwart the successful achievement of the coequal goals.

Policies

The appendices referred to in the policy language below are included in Appendix B of the Delta Plan.

G P1. Detailed Findings to Establish Consistency with the Delta Plan

(a) *This policy specifies what must be addressed in a certification of consistency filed by a State or local public agency with regard to a covered action. This policy only applies after a "proposed action" has been determined by a State or local public agency to be a*
covered action because it is covered by one or more of the policies contained in Article 3. Inconsistency with this policy may be the basis for an appeal.

(b) *Certifications of consistency must include detailed findings that address each of the following requirements:*

(1) *Covered actions, in order to be consistent with the Delta Plan, must be consistent with this regulatory policy and with each of the regulatory policies contained in Article 3 implicated by the covered action. The Delta Stewardship Council acknowledges that in some cases, based upon the nature of the covered action, full consistency with all relevant regulatory policies may not be feasible. In those cases, the agency that files the certification of consistency may nevertheless determine that the covered action is consistent with the Delta Plan because, on whole, that action is consistent with the coequal goals. That determination must include a clear identification of areas where consistency with relevant regulatory policies is not feasible, an explanation of the reasons why it is not feasible, and an explanation of how the covered action nevertheless, on whole, is consistent with the coequal goals. That determination is subject to review by the Delta Stewardship Council on appeal;*

(2) *Covered actions not exempt from CEQA must include applicable feasible mitigation measures identified in the Delta Plan's Program EIR (unless the measure(s) are within the exclusive jurisdiction of an agency other than the agency that files the certification of consistency), or substitute mitigation measures that the agency that files the certification of consistency finds are equally or more effective;*

(3) *As relevant to the purpose and nature of the project, all covered actions must document use of best available science;*

(4) *Ecosystem restoration and water management covered actions must include adequate provisions, appropriate to the scope of the covered action, to assure continued implementation of adaptive management. This requirement shall be satisfied through both of the following:*

(A) *An adaptive management plan that describes the approach to be taken consistent with the adaptive management framework in Appendix 1B, and*

(B) *Documentation of access to adequate resources and delineated authority by the entity responsible for the implementation of the proposed adaptive management process.*

(c) *A conservation measure proposed to be implemented pursuant to a natural community conservation plan or a habitat conservation plan that was:*

(1) *Developed by a local government in the Delta; and*

(2) *Approved and permitted by the California Department of Fish and Wildlife prior to May 16, 2013*

is deemed to be consistent with sections 5005 through 5009 of this Chapter if the certification of consistency filed with regard to the conservation measure includes a statement confirming the nature of the conservation measure from the California Department of Fish and Wildlife.

23 CCR Section 5002
NOTE: Authority cited: Section 85210(i), Water Code.
Reference: Sections 85225, 85225.10, 85020, 85054, 85302(g), and 85308, Water Code.

Problem Statement

Currently, science efforts related to the Delta are performed by multiple entities with multiple agendas and without an overarching plan for coordinating data management and information sharing among entities. Increasingly, resource management decisions are made in the courtroom as conflicting science thwarts decision making and delays action. Multiple frameworks for science in the Delta have been proposed, but a comprehensive science plan that organizes and integrates ongoing scientific research, monitoring, analysis, and data management among entities has yet to be fully formulated.

Recommendations

G R1. Development of a Delta Science Plan

The Delta Stewardship Council's Delta Science Program should develop a Delta Science Plan by December 31, 2013. The Delta Science Program should work with the Interagency Ecological Program, Bay Delta Conservation Plan, California Department of Fish and Wildlife, and other agencies to develop the Delta Science Plan. To ensure that best science is used to develop the Delta Science Plan, the Delta Independent Science Board should review the draft Delta Science Plan.

The Delta Science Plan should address the following:

- *A collaborative institutional and organizational structure for conducting science in the Delta*

- *Data management, synthesis, scientific exchange, and communication strategies to support adaptive management and improve the accessibility of information*

- *Strategies for addressing uncertainty and conflicting scientific information*

- *Prioritization of research and balancing of the short-term immediate science needs with science that enhances comprehensive understanding of the Delta system over the long term*

- *Identification of existing and future needs for refining and developing numerical and simulation models along with enhancing existing Delta conceptual models (e.g., the Interagency Ecological Program (IEP) Pelagic Organism Decline (POD) and the Delta Regional Ecosystem Restoration Implementation Plan (DRERIP) models)*

- *An integrated approach for monitoring that incorporates existing and future monitoring efforts*

- *An assessment of financial needs and funding sources to support science*

Timeline for Implementing Policies and Recommendations

Figure 2-4 lays out a timeline for implementing the policies and recommendations described in the previous section. The timeline emphasizes near-term and intermediate-term actions.

Timeline for Implementing Policies and Recommendations

TIMELINE CHAPTER 2: The Delta Plan				
ACTION (REFERENCE #)	**LEAD AGENCY(IES)**		**NEAR TERM 2012–2017**	**INTERMEDIATE TERM 2017–2025**
POLICIES Detailed findings to establish consistency with the Delta Plan (G P1)	Varies		●	●
RECOMMENDATIONS Development of a Delta Science Plan (G R1)	Council		●	
COUNCIL ACTIONS Establish Delta Plan Interagency Implementation Committee	Council		●	●

Agency Key:

Council: Delta Stewardship Council

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Figure 2-4

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ATTACHMENT 11

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7

8

9   BEFORE THE CALIFORNIA STATE WATER RESOURCES CONTROL BOARD

10   IN THE MATTER OF

11 CALIFORNIA DEPARTMENT OF WATER   ) **TESTIMONY OF DOUG DEMKO**
    RESOURCES AND UNITED STATES   ) **(San Joaquin Tributaries Authority [SJTA]**
12 BUREAU OF RECLATION PETITION FOR   ) **SJTA REBUTTAL, EXHIBIT 402**)
    WATER RIGHT CHANGE RE: CALIFORNIA   )
13 WATERFIX.   )
)
14   )
)
15 _____)

16   I, Doug Demko, declare as follows:

17   **SUMMARY OF CREDENTIALS**

18   1.   I am a fisheries professional and the President of FISHBIO Inc., a U.S. based

19 company that specializes in fisheries research, monitoring, and conservation. I am the President of

20 FISHBIO Laos, Limited, a foreign company that specializes in fisheries research, monitoring, and

21 conservation in the Mekong River Basin in South East Asia. I am the President of La Cuesta Roja,

22 S.A., a Costa Rican company established to develop a research center for the purpose of conducting

23 fisheries research, monitoring, and conservation of freshwater and marine environments in Central

24 America. I am the President of Roja Adventures, S.A., a Costa Rican company established for the

25 purpose of promoting eco-tourism, education, and conservation practices in Costa Rica. I fund and

26 lead the development of the Mekong Fish Network (mekongfishnetwork.org), an international effort

27 to promote research data sharing and collaboration among diverse governments and interests in the

28 Mekong River Basin. I also fund FISHBIO's Three Rivers program, an effort to promote fisheries

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      TESTIMONY OF DOUG DEMKO – SJTA REBUTTAL, EXHIBIT SJTA-402

1   and environmental education for primary school children. Collectively, I employ, manage, and

2   oversee roughly 50 people (depending on year, season, project requirements) domestically and

3   internationally for the purposes of fisheries research, monitoring, conservation, and ecotourism.

4   　　　　2.　　　I have testified as a fisheries expert witness before the U.S. House of

5   Representatives. I have twice testified as a fisheries expert witness in front of the California State

6   Legislature on Central Valley fisheries management issues. I also testified before the State Water

7   Resources Control Board (SWRCB) a number of times relating to California Central Valley

8   fisheries management issues.

9   　　　　3.　　　I have 29 years of experience researching and monitoring fish populations in

10   California's Central Valley. I have been involved with research and monitoring projects in the

11   Stanislaus River in the San Joaquin basin since 1991, likely longer than any other Central Valley

12   researcher. I led the development of unique sampling strategies in the Stanislaus River (and other

13   tributaries), such as using upstream and downstream rotary screw traps to evaluate migration rate

14   and in-river salmon mortality rates; use of a portable resistance board weir and underwater camera

15   to evaluate upstream adult Chinook salmon abundance and factors, such as flow, that may influence

16   their migration; conducting annual summer *O. mykiss* abundance surveys to evaluate population

17   size, factors that influence the population, and factors that may influence anadromy or residency life

18   history strategies.

19   　　　　4.　　　Since 1991 I have led or been involved in numerous studies on the Stanislaus,

20   Tuolumne, Merced, Mokelumne, and Calaveras rivers. A partial list of these efforts includes:

21   establishing long term juvenile and adult salmon monitoring programs (rotary screw traps, seine,

22   weirs, remote cameras, snorkel); Chinook salmon redd surveys to assess spawn timing and habitat

23   preferences; radio tracking juvenile Chinook to evaluate migration rates and mortality; wire fyke

24   trapping to evaluate non-native predator species abundance; boat electrofishing to evaluate fry

25   habitat use; boat electrofishing to remove predators from Clifton Court Forebay; Vernalis Adaptive

26   Monitoring Plan study to evaluate relationships between salmon smolt survival and San Joaquin

27   River flows, exports, and operation of the Head of Old River Barrier; juvenile chinook and *O.*

28   *mykiss* floodplain use; floodplain habitat assessments; habitat mapping; habitat restoration; hatchery

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1 assessments; mark-recapture studies; development of a 5 year program to assess predator abundance

2 and influence on juvenile Chinook salmon mortality in the Stanislaus River with NOAA Fisheries

3 and CDFW; estimation of *O. mykiss* oversummering abundance; Habitat Conservation planning;

4 benthic macroinvertebrate assessments; migration barrier assessments; Chinook salmon stranding

5 surveys; Watershed Stewardship Group facilitation; and volunteer snorkel surveys.

6   5.   Internationally my fisheries research and monitoring experience includes projects in

7 the Mekong Basin, including projects in Laos PDR, Vietnam, Cambodia, and Thailand. A partial

8 list of these projects includes: establishing fisheries monitoring programs including programs driven

9 by large power companies and remote villages; establishing and studying Fish Conservation Zones;

10 Mekong Giant Catfish satellite telemetry; use of environmental DNA to identify species

11 distribution; establishing and training villagers in participatory fishery monitoring surveys;

12 developing community water quality and water resource management programs; seasonal wetlands

13 evaluation; state of the basin assessments; climate change and aquatic organisms assessment;

14 fisheries management plans; fish hatchery assessment; establishment of turtle conservation zones;

15 and macroinvertebrate assessments.

16   6.   Since starting FISHBIO in 2006 I have worked for or partnered with many private

17 companies, public agencies, Non-Government Organizations, non-profit groups, and universities for

18 the purposes of researching fish populations domestically and internationally. A partial list of

19 clients, partners, and grantors includes: U.S. State Department; World Wide Fund for Nature

20 (WWF); Mohamed bin Zayed Species Conservation Fund; International Union for Conservation of

21 Nature (IUCN), Laos, and Critical Ecosystem Partnership Fund (CEPF); The Asia Foundation;

22 Sustainable Mekong Research Network (SUMERNET); International Crane Foundation; Fauna &

23 Flora International, Myanmar; Theun Hinboun Power Company; Mekong River Commission; Nam

24 Ngiep Power Company; The Agro Biodiversity Institute; University of Nevada Reno; USAID;

25 Wildlife Conservation Society and Turtle Survival Alliance; Chiang Mai University and

26 International Development Research Centre; Earth Systems Mekong; United States Bureau of

27 Reclamation; California Department of Water Resources; San Joaquin Tributaries Authority;

28 Modesto and Turlock Irrigation Districts; Merced Irrigation District; Oakdale Irrigation District;

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1 South San Joaquin Irrigation District; West Stanislaus Irrigation District; Banta-Carbona Irrigation

2 District; Patterson Irrigation District; Stockton East Water District; South Valley Water

3 Association; River Partners; The Nature Conservancy; NOAA Fisheries; Monterey County Water

4 Resource Agency; ICF International.

5   7.   Attached as Exhibit 1 is a true and correct copy of my curriculum vitae.

6

7 <div align="center">**OVERVIEW OF TESTIMONY**</div>

8   8.   For this proceeding, my testimony will address deficiencies of the State Water

9 Resources Control Board's (SWRCB) 2010 report entitled Development of Flow Criteria for the

10 Sacramento-San Joaquin Delta Ecosystem that I will hereafter refer to as the Delta Flow Criteria

11 Report (DFCR). The specific basis for my rebuttal testimony, and specific case-in-chief evidence to

12 which it is responsive, is set forth in SJTA-Exhibit 404 (Declaration of Tim O'Laughlin).

13   9.   The DFCR is being used to inform analysis for a change in the point of diversion of

14 the State Water Project or the federal Central Valley Project from the southern Delta to a point on

15 the Sacramento River as required by the Delta Reform Act. The DFCR claims that 60% of

16 unimpaired flow (UIF) of the San Joaquin River during February- June is needed to transport fall-

17 run Chinook salmon (FRCS) smolts through the Delta during spring to contribute to the SWRCB's

18 2006 Bay-Delta Plan salmon protection water quality objective (doubling goal). However, there are

19 deficiencies in the DFCR analyses which, in addition to the limitations acknowledged by the

20 SWRCB in the DFCR, further restrict its utility. My testimony will discuss shortcomings of the

21 DFCR analysis, and reasons why substantial increases in San Joaquin River flows cannot be

22 expected to contribute substantially to the SWRCB's 2006 Bay-Delta Plan salmon protection water

23 quality objective. These issues are briefly summarized below, followed by more detailed discussion

24 in the following sections.

25   ●   The DFCR uses a nine-component 60% UIF to estimate the frequency at

26 which 5,000 cfs and 10,000 cfs would be met at Vernalis. However, the Phase I revisions to

27 the Bay-Delta Plan only address three of these components: the Stanislaus, Tuolumne &

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Merced Rivers. As a result, the DFCR grossly overstates the frequency at which these flows would occur.

● Purported threshold values cannot be met in most years under managed conditions, smolt survival to Chipps Island will not be substantially improved, and recovery of salmon populations, particularly as defined by the "doubling goal", cannot be achieved through implementation of the flow regime proposed by the Petitioners in this proceeding for the San Joaquin River (i.e., Water Rights Decision 1641), nor by the flow regime proposed in the SWRCB's Phase I Revisions to the Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary (Phase I Revisions to Bay-Delta Plan).

● The DFCR references results from Version 1.6 of CDFW's SalSim model as presented in CDFW Exhibit 3 as the primary basis for the San Joaquin River flow recommendations. During the peer review process of the updated version (2.0) of SalSim, the panel noted that "much additional work is needed for SalSim to be management-ready" (p.11). Further, the panel was not confident that the existing model has sufficiently realistic representations regarding the effects of flow and temperature in the freshwater life stages (p. 8). Therefore, it cannot be considered the best available science and does not provide a sound, scientific basis for the San Joaquin flow recommendations made by the SWRCB in the DFCR.

● The use of CDFW Exhibit 3 is not consistent with the Central Valley Project Improvement Act (CVPIA) Section 3406(b)(1) which specifically calls for doubling of numerous anadromous species in the Central Valley. Production is defined as the number of Chinook salmon captured in ocean and recreational fisheries, in addition to the number that returned to the spawning grounds (i.e., escapement). The CVPIA Doubling Goal is not doubling smolt production nor is it doubling of adult production in the San Joaquin Basin or any given tributary.

● Even if modeling results are treated as reliable (i.e., if there was a positive [and consistent] relationship between increased flow and smolt survival), gains in survival to

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Chipps Island would be insufficient to compensate for natural and fishing mortality at later

life stages.

● Given the now significantly improved understanding of Chinook salmon

populations in the San Joaquin River basin and, more broadly, in the Central Valley

(pertaining to *hatchery operations, survival- and population dynamics*), physical

characteristics of the basin *(hydrodynamics, water temperature coldwater pool management,*

floodplain habitat), and existing constraints (*i.e., predation pressures, excessive ocean*

harvest rates, limited in-river and Delta habitat), DFCR flows will not substantially

improve Chinook salmon survival through the Delta. As a direct consequence, the viability,

sustainability, production, and escapement of SJR Chinook populations will not be

substantially improved over the current conditions by the Petitioners' proposal for flows on

the San Joaquin River (i.e., D-1641), nor by the Phase I Revisions to the Bay-Delta Plan.

The DCFR and related exhibits failed to account for the underlying population dynamics of

the San Joaquin River population of fall-run Chinook salmon. This population is

characterized by a pronounced cyclic nature with boom and bust cycles that occur

approximately every 12 - 15 years with low periods of abundance corresponding to drier or

drought periods. However, the DFCR cannot substantially improve conditions during these

periods, which may limit long-term population abundance, and therefore has little chance of

improving the overall viability, abundance, or productivity of this population.

● Implementation of the DFCR would result in frequent depletion of reservoir

coldwater pools, leading to elevated in-stream water temperatures in late summer and fall.

Fisheries monitoring during the recent drought demonstrated the deleterious effects of

elevated temperatures on over-summering populations of threatened *O. mykiss* and fall-run

Chinook salmon reproduction.

TESTIMONY

10. Under the Delta Reform Act of 2009, the SWRCB was required to develop new flow

criteria for the Delta. The SWRCB's review of existing water quality objectives, analyses of

existing data, and recommendations for the volume, quality, and timing of water needed for the

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1   Delta were presented in the DFCR. As required by the Delta Reform Act, the DFCR is being used

2   to inform analysis for a change in the point of diversion of the State Water Project or the federal

3   Central Valley Project from the southern Delta to a point on the Sacramento River.

4   11.   One of the biological goals of the DFCR was to provide sufficient flow in the San

5   Joaquin River to transport smolts through the Delta during spring to contribute to the SWRCB's

6   2006 Bay-Delta Plan salmon protection water quality objective. As such, the DFCR considered flow

7   alone as the factor responsible for depressed production of fall-run Chinook salmon, and, by

8   extension, as the sole remedy to improve struggling salmon populations to achieve the doubling

9   goal. The DFCR does not consider additional limiting factors such as harvest allotments, predation,

10   or hatchery practices, nor does it discuss and accurately consider the limitations of physical or

11   biological responses that could be achieved by increasing flows (flow thresholds cannot be met as

12   frequently as portrayed; opportunity to inundate habitats with floodplain characteristics is extremely

13   limited within the range of managed flows). Lastly, the DFCR omits evaluation of competing

14   beneficial uses, particularly in light of the ambiguity, uncertainties, and shortcomings of portrayed

15   benefits to salmonid populations.

16   12.   The DFCR relies on Exhibits submitted by TBI, NRDC, CalSPA, and most notably

17   by CDFW (Exhibit 3), hypothesizing that increased spring flows increases salmon smolt survival,

18   and that subsequent adult abundance is substantially increased. I will discuss three major

19   deficiencies in the use of these exhibits in the DFCR.

20   13.   First, the DFCR concluded that (1) spring flows of 5,000 cfs represent a flow

21   threshold to substantially improve juvenile salmon survival and subsequent adult abundance, and

22   (2) average flows of 10,000 cfs during this period may provide conditions to achieve doubling of

23   San Joaquin Basin FRCS based on analyses of water temperatures and population growth submitted

24   by TBI/NRDC. However, the DFCR also noted on page 121 that "additional information should be

25   developed to determine whether these flows could be lower or higher and still meet the Chinook

26   salmon doubling goal in the long-term". In other words, there was an indication of these flows

27   potentially representing threshold values, but the issue needed further investigation. At any rate, it

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1   was estimated that 60% UIF would meet or exceed 5,000 cfs in more than 85% of years and would

2   meet or exceed 10,000 cfs in approximately 45% of years.

3   14.   However, as explained in the testimony of Daniel B. Steiner (SJTA Exhibit 401), the

4   DFCR analysis used a nine-component UIF for the San Joaquin Valley as the foundation for its

5   simulations. These include not only the unimpaired flow of the Stanislaus, Tuolumne, and Merced

6   rivers (at reservoir), but also include the San Joaquin River at Friant, overflows from the Kings

7   River, the Fresno and Chowchilla Rivers, and valley floor components. Limiting the requirement to

8   only the Stanislaus, Tuolumne, and Merced rivers excludes approximately 40% of the watershed

9   above Vernalis, resulting in much lower flows at Vernalis than the 60% UIF of the entire San

10   Joaquin Basin as analyzed by the DFCR. Specifically, the frequency of meeting 5,000 cfs and

11   10,000 cfs under 60% UIF decreases from 85% to 60% and from 45% to 10%, respectively

12   (compare Figure 1 with Figure 2; see Table 1). Under the 40% UIF proposed by Phase I of the

13   WQCP, 5,000 cfs is reached 41% of the time, but 10,000 cfs is never met (Figure 3; Table 1). For

14   comparison, actual historical flows during 1986-2003 reached 5,000 cfs 35% of the time and

15   reached 10,000 cfs approximately 25% of the time, which is more often than the 10% under a 60%

16   UIF (Figure 2; Table 1). As a consequence, the population growth inferred in the DFCR cannot be

17   expected to occur.

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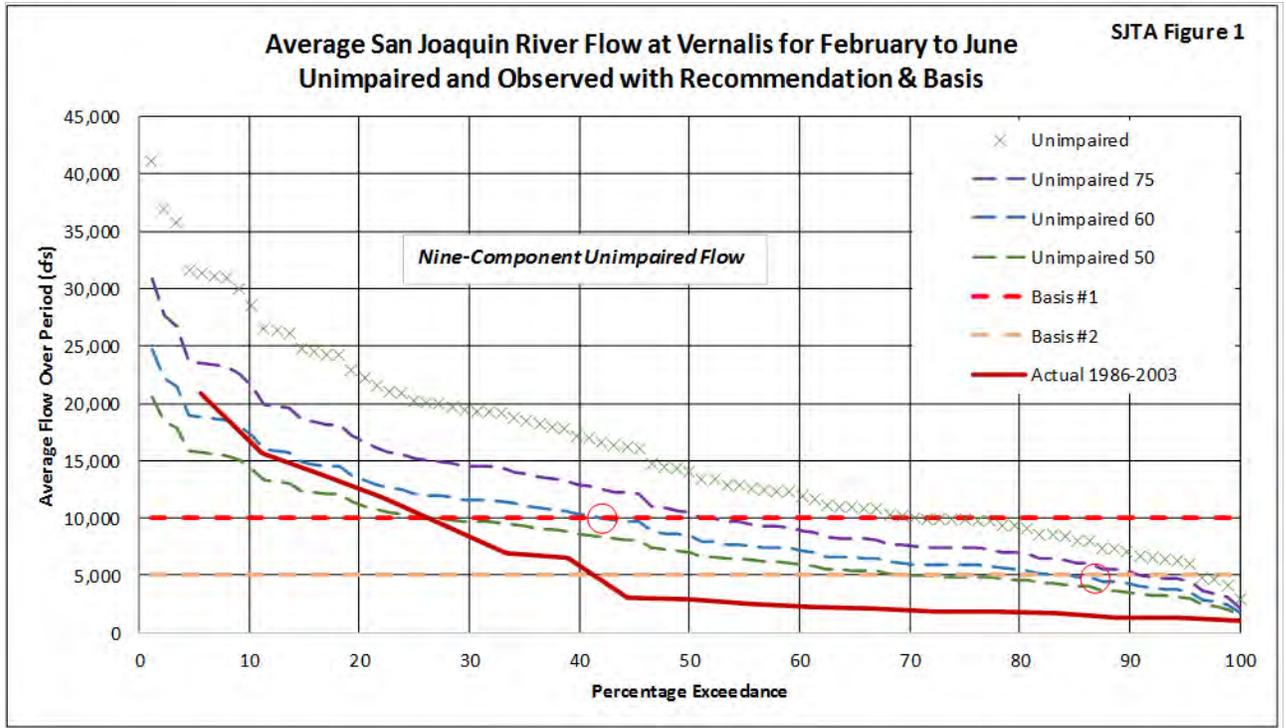
Figure 1. Frequency of occurrence of average February-June San Joaquin River flow at Vernalis. (Nine-Component Unimpaired Flow)
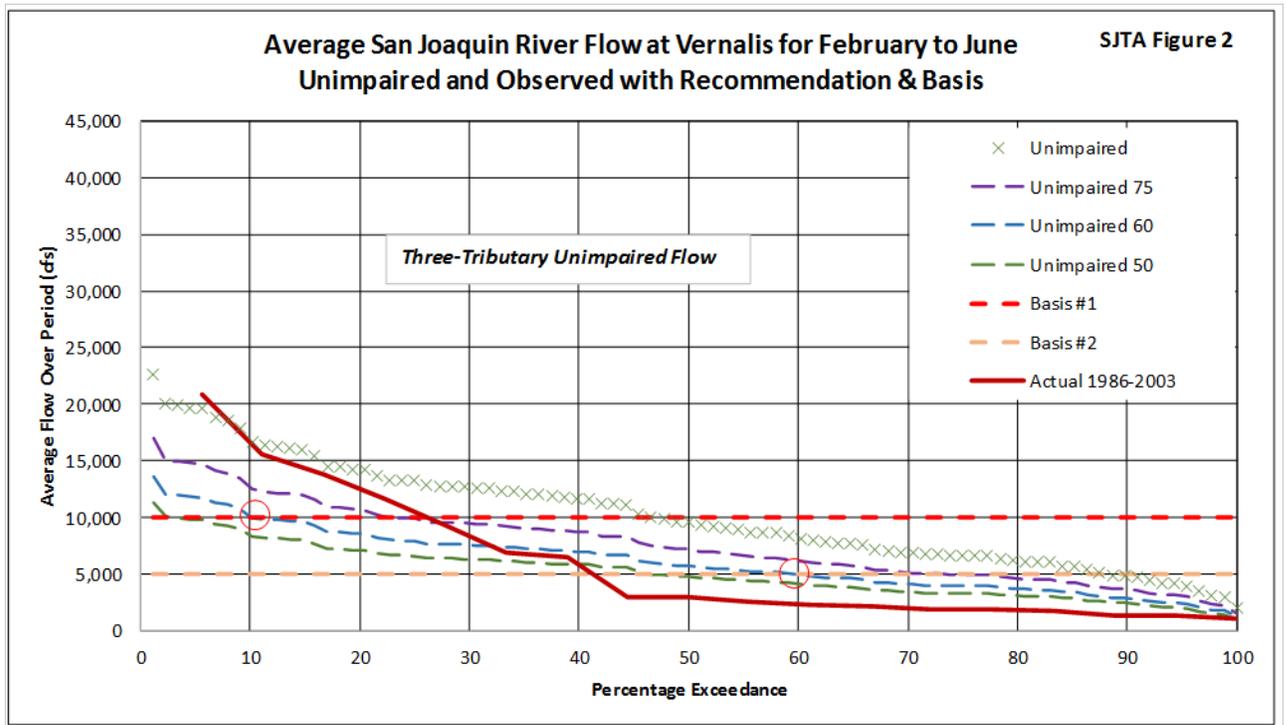
Figure 2. Frequency of occurrence of average February-June San Joaquin River flow at Vernalis. (Three-Tributary 60% Unimpaired Flow)

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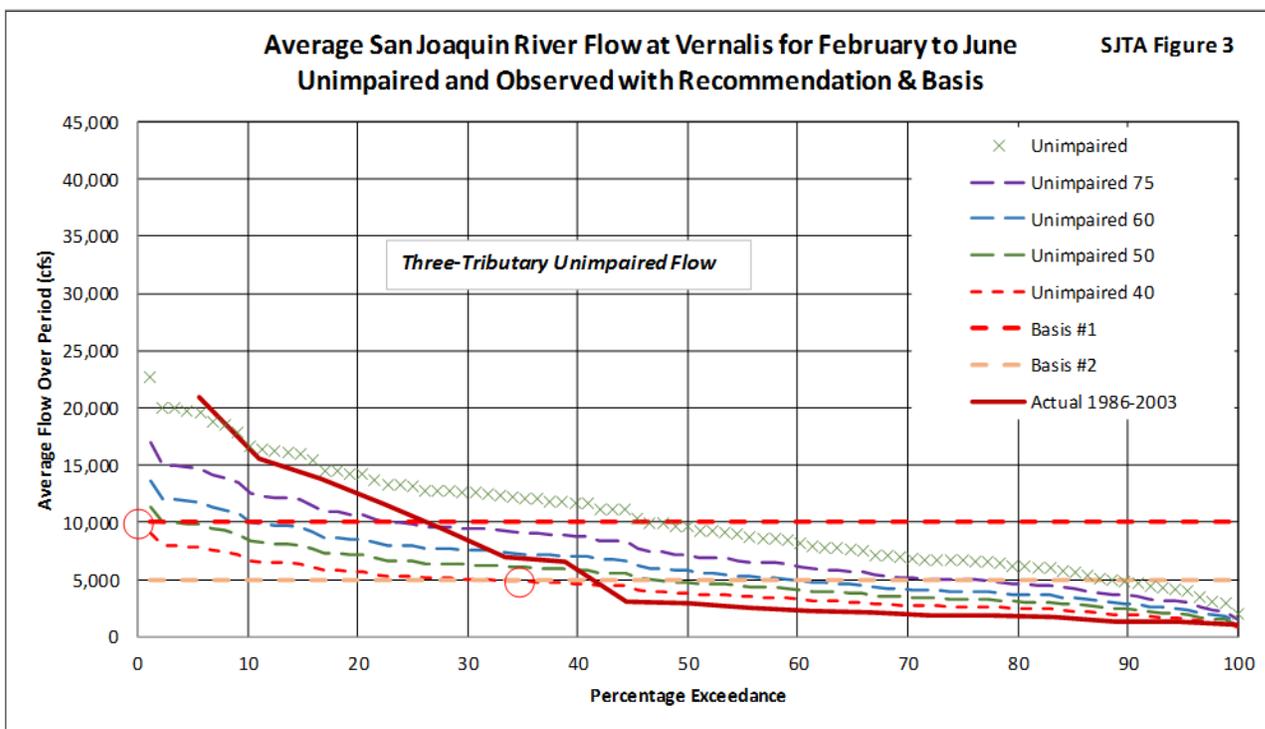
Figure 3. Frequency of occurrence of average February-June San Joaquin River flow at Vernalis. (Three-Tributary 40% Unimpaired Flow)

Table 1. Summarized frequency of occurrence of 5,000 cfs and 10,000 cfs at Vernalis at 60% UIF of the entire San Joaquin Basin (DFCR); 60% UIF of the Stanislaus, Tuolumne, and Merced rivers; 40% UIF of the Stanislaus, Tuolumne, and Merced rivers (Phase I WQCP) and under actual, historical conditions.

	Frequency	
Scenario	**5,000 cfs**	**10,000 cfs**
DFCR 60% UIF	85%	45%
Tributary only 60% UIF	60%	10%
Tributary only 40% UIF (Phase I WQCP)	35%	0%
Actual	41%	25%

15.   A second major deficiency is that the use of CDFW Exhibit 3 is not consistent with the Central Valley Project Improvement Act (CVPIA), which specifically called for the doubling of numerous anadromous species (various runs of Chinook salmon, steelhead, American shad, white sturgeon, and striped bass) in the Central Valley (CVPIA Section 3406(b)(1)). Production was

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1 defined as the number of Chinook salmon captured in ocean and recreational fisheries, in addition

2 to the number that returned to the spawning grounds (i.e., escapement). Chinook salmon susceptible

3 to the ocean fishery primarily consist of age-2, age-3, and age-4 fish. However, this contradicts the

4 text in CDFW Exhibit 3 (pages 34 and 35), Table 10, and Figure 20, which specifically states that:

5 "... improving stream flow in the spring time period in the SJR east-side tributaries, resulting in

6 increased SJR flows at Vernalis, is necessary to accomplish the State and Federal doubling goal by

7 doubling juvenile (smolt) abundance at Chipps Island." To be clear, doubling smolt production is

8 not the legal requirement specified in the CVPIA Doubling Goal, nor is doubling adult production

9 in the San Joaquin Basin or any given tributary.

10 16. Even if 200,000 salmon smolts were produced at Chipps Island, it would not result in

11 increased salmon abundance to meet the goal of doubling adult production. For example, in 1993,

12 the modeled smolt production under the revised flows estimated that there would be 200,000

13 additional smolts at Chipps Island over the historical number (Figure 20 of CDFG Exhibit 3 or

14 DFCR). To meet the doubling goal from 1992 to 2011 in any given year, roughly 750,000 fall-run

15 Chinook salmon naturally produced in Central Valley streams would have to be harvested or return

16 to spawn. Therefore, even if all (100%) of the 200,000 additional smolts at Chipps Island survived

17 to be harvested or returned to spawn, this increase would still be insufficient to meet the true intent

18 of the doubling goal. It follows that the DFCR has no basis to claim that increasing flow on the San

19 Joaquin River will double the natural production of Central Valley fall-run Chinook salmon.

20 17. It may seem reasonable to assume that increased abundance at Chipps Island would -

21 generally - result in increased adult abundance several years later. However, to suggest that

22 increased, or "maximized" flows during the spring months serve to increase "production" to Chipps

23 Island is unsubstantiated. I interpret "production" of smolts in the document to mean "survival to".

24 Recent scientific investigations have confirmed that high river flow cannot guarantee high survival,

25 as survival has been demonstrated to be low, even in wet years (e.g. 2011[1]).

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[1] Buchanan et al. 2018

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18.   A third major deficiency of the DFCR is that it references results from Version 1.6 of CDFW's SalSim model as presented in CDFW Exhibit 3 as the primary basis for the San Joaquin River flow recommendations. Peer-review of a more recent verson of the SalSim model (Version 2.0) in 2012, found that "much additional work is needed for SalSim to be management-ready"[2, p.11]. The panel detailed their concerns and provided several recommendations for improvements: "The panel was not confident that the existing model has sufficiently realistic representations regarding the effects of flow and temperature in the freshwater life stages. Better documentation and examination of diagnostics would alleviate some concerns, but several issues go beyond that. These include the focus on the San Joaquin data only; over-emphasis on flow in relationships and lack of inclusion of other covariates; and only limited results of calibration, sensitivity, and retrospective analyses being reported to date" [2, p. 8]. The modeling results therefore do not represent best available science and provide no sound basis for the San Joaquin flow recommendations made by the SWRCB in the DFCR.

19.   Version 2 of the SalSim model[3] was used in Chapter 19 of the SWRCB's Substitute Environmental Document (SED) for the Phase I Revisions to the Bay-Delta Plan, and presumably addressed some of the problems identified with Version 1 of the model. Simulated increases in adult FRCS production on the Stanislaus, Tuolumne and Merced Rivers over the base scenario were low (9.7% in the 40% UIF, 7.6% in the 50% UIF, and 6.5% in the 60% UIF scenarios; see Table 19-32). Furthermore, these increases are, in all cases, below 10%, which the SWRCB considers "a significant benefit or impact" in other modelling scenarios (i.e. pertaining to temperature targets, Chapter 19 p. 19-18, or floodplain inundation, p 19-56). According to the SalSim results in the SWRCB's more recent WQCP/SED analysis, the flows recommended in the DFCR would not provide significantly improved salmon production.

20.   Disregarding these flaws in the DFCR analysis, the question remains whether substantial increases in flow contribute substantially to doubling natural production of Central Valley fall-run Chinook salmon. The answer, unfortunately, is no. Recent scientific investigations

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[2] Anderson et al. 2012
[3] AD Consultants 2014

1   suggest that mortality factors in the San Joaquin Delta cannot be alleviated by increasing flows.

2   Similarly, recent attempts to boost Central valley steelhead and fall-run Chinook salmon on the

3   Stanislaus River through increased flows under the Biological Opinion have not resulted in

4   increased natural production. Worse, the actions resulted in unintended, but foreseeable impacts to

5   the very species that the actions were intended to protect.

6   21.   These findings have become available since the DFCR was released in 2010, and are

7   in direct conflict with the San Joaquin River flow recommendation of the DFCR. In the following

8   sections of my testimony I will discuss why the San Joaquin River flows recommended by the

9   DFCR are unsupported and will not achieve the doubling goal based on (1) the impacts of 60% UIF

10   flows on conditions on the San Joaquin tributaries using the Stanislaus as an example, (2) the

11   findings of survival studies conducted in the San Joaquin Delta relative to flow and other factors,

12   (3) the influence of ocean conditions, (4) the continued, unsustainable, ocean harvest rates which

13   thwart population growth, and (5) hatchery production which masks declines in natural production

14   and continues to erode genetic integrity of Central Valley fall-run Chinook salmon.

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16   **1.**   **Increased reservoir releases deplete coldwater storage needed to maintain suitable water temperatures**

17   22.   The DFCR failed to consider impacts of the proposed plan on coldwater pool

18   maintenance in upstream reservoirs, which may jeopardize populations of salmonids, including

19   threatened *Oncorhynchus mykiss*, that rely on the cool water temperature maintained by reservoir

20   releases. The DFCR spends a page and a half (pp. 57-59) discussing water temperature. While the

21   DFCR acknowledges "reservoir releases" as an important component, and states that "Temperature

22   and water supply modeling and analyses should be conducted to identify conflicting requirements to

23   achieve both flow and coldwater temperature goals", no analyses have been performed to evaluate

24   this component."

25   23.   The consequence of such management action is severely depleted reservoir storage at

26   New Melones as shown in Mr. Steiner's analysis if 60% unimpaired flow is required. This results in

27   a severe reduction, or elimination, of the reservoir's coldwater pool. Based on my experience

28   monitoring fish populations in the Stanislaus River, we can expect two consequences: (1) water

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1 temperatures downstream of Goodwin Dam will increase substantially, and (2) warm water

2 temperatures will have detrimental impacts to ESA-listed CV steelhead and FRCS.

3   24.   Storage in New Melones Reservoir under the DFCR's 60% UIF scenario would

4 frequently drop to dead pool of 80 TAF (Figure 4; see also SJTA-401, Figure 7), and deleterious

5 impacts to salmon and steelhead result as coldwater storage is depleted long before reaching dead

6 pool. Records from water temperature monitoring during the recent drought illustrate that as

7 reservoir storage decreases, water temperatures at Goodwin Dam increase (Figure 5). The modeled

8 scenario shows that mean storage under the 60% UIF scenario would be below the record low

9 storage observed in 2015 - corresponding to river temperatures approaching 70°F (21.1°C).

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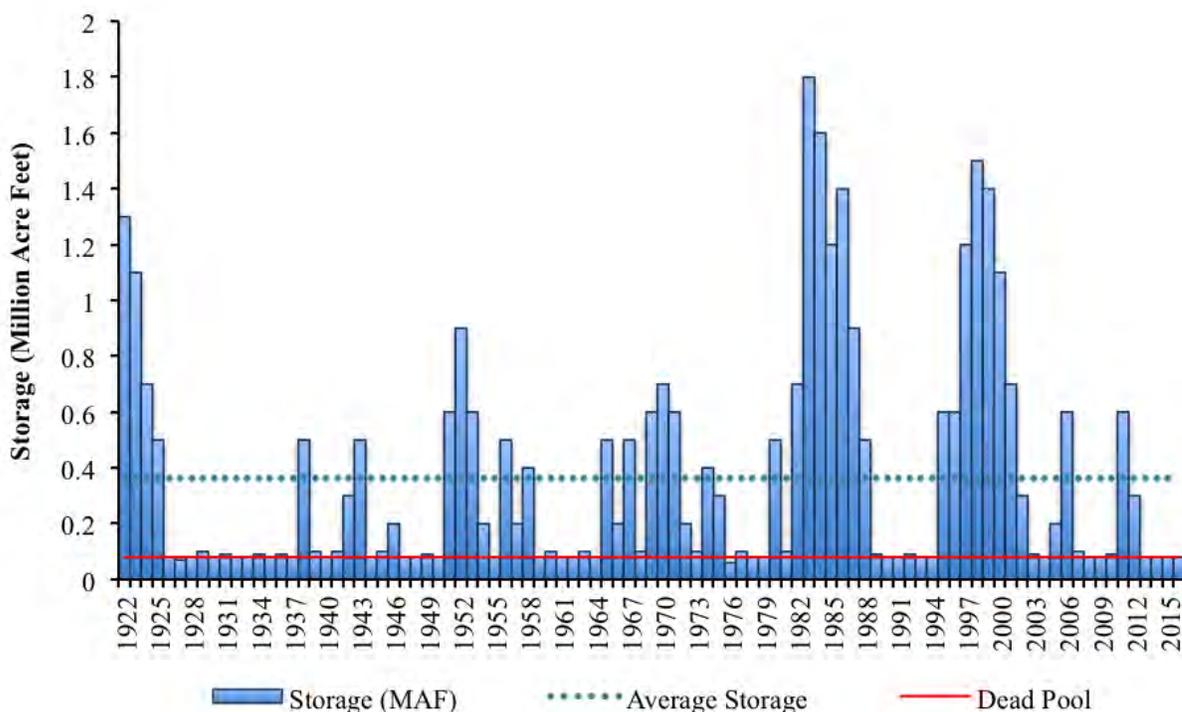
Figure 4. Simulated storage in New Melones Reservoir in late September, under the DFCR 60% UIF scenario.

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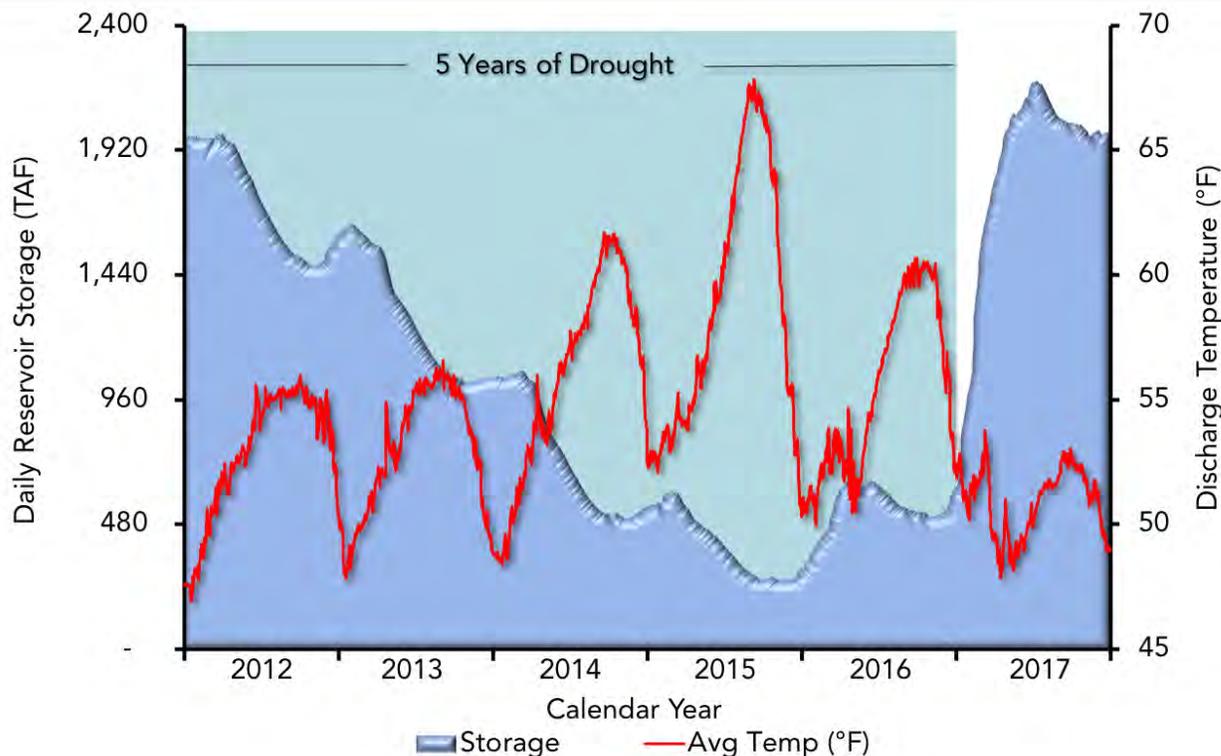
Figure 5. Relationship between average daily storage at New Melones Reservoir and mean daily water temperature below Goodwin Dam. (Source: FISHBIO hourly recording thermograph and CDEC reservoir storage for station NML)

25.   Anadromous *O. mykiss* (steelhead), a threatened species under the ESA, remain in freshwater for at least one, but usually two summers before migrating to the marine environment. However, some *O. mykiss* do not migrate, but remain in the river as residents. As a consequence, snorkel surveys during the summer months can provide population estimates that are inclusive of all size/age classes and life history variants: juveniles that may migrate to sea, and adults that have adopted the resident life history. FISHBIO has conducted annual snorkel surveys in the Stanislaus River since 2009 to estimate the abundance and distribution of over-summering *O. mykiss*, and to document population responses to flow, water temperature, and habitat[4].

26.   The population of *O. mykiss* in the Stanislaus River is composed almost entirely of resident fish, with few migrating individuals, and until recently, the population was fairly large and stable. The majority of *O. mykiss* are found upstream of Orange Blossom Bridge with the highest

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[4] Peterson et al. 2015

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1   densities found between Goodwin Dam and Knights Ferry (Figure 6). Elevated water temperatures

2   (above the typical summer temperature of approximately 55°F (12.8°C); monthly mean temperature

3   at Goodwin), beginning in 2014, coincide with the decline in *O. mykiss* densities across all reaches.

4   The warmest water temperatures of approximately 67°F (19.4°C) were recorded during the summer

5   of 2015.
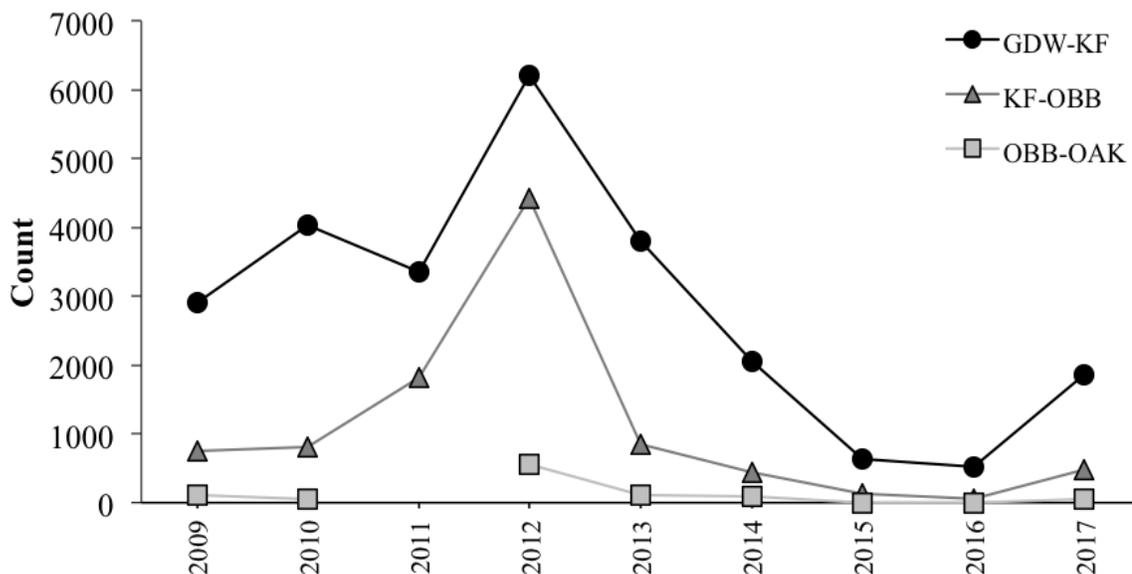
Figure 6. Fish per river mile (density) estimates made during fall snorkel surveys, 2009-2017 in the Stanislaus River. All reaches were sampled all years except for OBB to OAK in 2011. Reach names are Goodwin Dam to Knight's Ferry (GDW-KF), Knight's Ferry to Orange Blossom Bridge (KF-OBB), and Orange Blossom Bridge to Oakdale (OBB-OAK)(FISHBIO; unpublished data).

21   27.   From 2009 until 2014, overall abundance averaged about 20,000 individuals,

22   peaking in 2012 when a large number of young/small fish were observed following flood control

23   releases and unusually cool summer water temperatures the previous year. Following this peak,

24   overall abundance of *O. mykiss* declined sharply during drought, falling to a low of approximately

25   5,000 in 2015 and 2016. The population began to recover in 2017 (Figure 7).

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TESTIMONY OF DOUG DEMKO – SJTA REBUTTAL, EXHIBIT SJTA-402
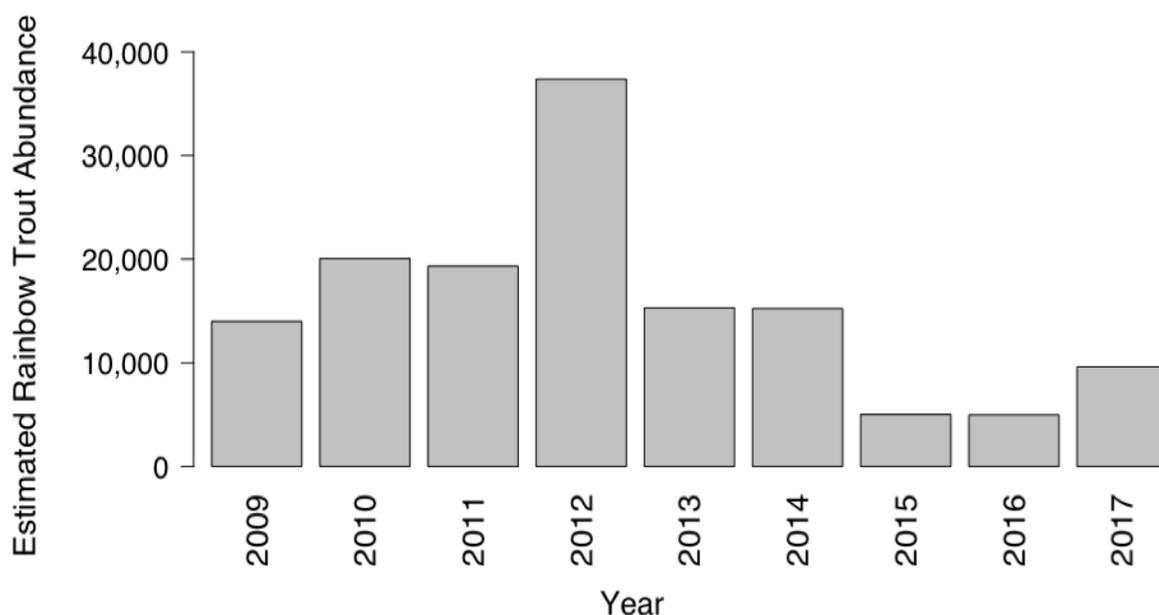
Figure 7. Annual *O. mykiss* abundance in the Stanislaus River during 2009-2017 (FISHBIO; unpublished data).

28.   Estimated *O. mykiss* abundance during 2009-2017 tracks very closely with water temperatures, and lower *O. mykiss* abundance was observed in years following warmer summer temperatures (Figure 8). It follows that carry-over storage and maintenance of an adequate cold-water pool to provide summertime releases of sufficiently cool water are integral to maintaining suitable habitat for *O. mykiss* in the Stanislaus River, as well as below other reservoirs.

29.   Trends in densities and abundance clearly indicate that these population indices of *O. mykiss* can be adversely impacted by elevated stream temperatures which, in turn, are a consequence of depleted storage in New Melones Reservoir during the recent drought. Under the current operational requirements and constraints, the cold-water pool in New Melones Reservoir was depleted during the recent drought, which inhibited the ability to provide cold-water releases during the summer months of this period, and resulted in a drastic decline in abundance of *O. mykiss*. Depletion of storage is expected to occur at a faster rate and more frequently under the flow regime proposed by the DFCR.

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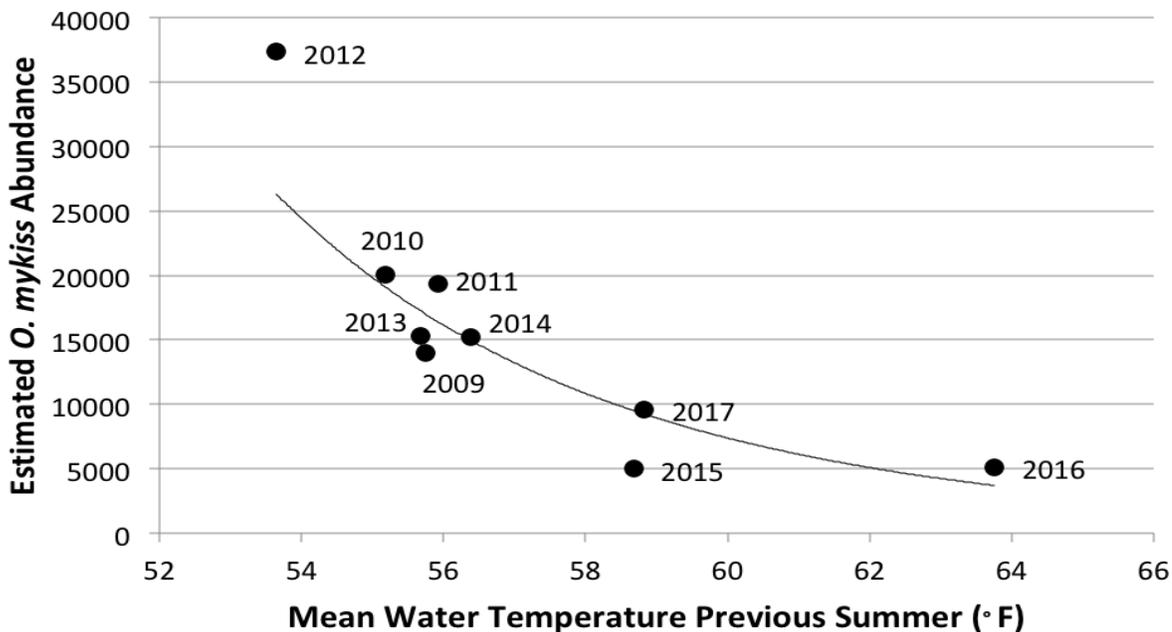
Figure 8. Abundance of *O. mykiss* in the Stanislaus River relative to the mean summer water temperature the previous year (June – August at Goodwin Dam)[5,6].

30.   Adult fall-run Chinook salmon that enter the Stanislaus River to spawn in fall can also be impacted by warm water temperatures when coldwater storage in the reservoir is depleted. The timing of their upstream migration and spawning has been monitored since 2003 and 2009, respectively, using a portable, resistance board weir and redd surveys. Monitoring data spanned the most recent drought, which included the years when the coldwater pool of New Melones was depleted (described above).

31.   It is believed reproductive timing of Chinook salmon (and many other fishes) is largely under genetic control and relatively fixed, an adaptation to long-term average temperature regimes that control and optimize the time of fry emergence[7]. In order for adult Chinook salmon to migrate to their spawning grounds, begin and complete spawning under less than optimal environmental conditions, adult Chinook salmon can adjust their migration rates and exhibit

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[5] Peterson et al. 2015
[6] FISHBIO unpublished data
[7] Quinn 2005

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1 behavioral thermoregulation if water temperatures exceed certain thresholds[8,9]. It is especially

2 important for them to conserve enough energy to complete the spawning process. Chinook salmon

3 may begin spawning when water temperatures near 60.8°F (16°C), the upper temperature limit for

4 50% mortality.[10] After arriving on the spawning grounds, female Chinook salmon tend to spawn

5 without much delay, which may serve to maximize the time guarding the red.[11]

6   32.   From 2009 to 2013, daily water temperatures from Goodwin Dam summarized from

7 October 1 to December 31 remained relatively consistent throughout the fall spawning season

8 (mean range 53.2°F - 54.1°F [11.8 – 12.3°C]). However, in 2014 and 2015, the average

9 temperatures were substantially higher during the fall (means = 57.7°F [14.3°C] and 64.0°F

10 [17.8°C], respectively). The timing of redd deposition was estimated from data collected during

11 annual redd surveys. Based on the timing of redd deposition and the patterns of water temperature,

12 during 2009 to 2013, almost all spawning was estimated to have occurred in 7DADM water

13 temperatures that were below or very close to the EPA[12] criteria for spawning Chinook salmon

14 (55.4°F [13ºC]; Figure 9). In these years, daily average water temperatures typically decreased to

15 55.4°F [13ºC] by early to mid-October. Due to the depletion of the coldwater pool during the

16 drought in 2014 and 2015, water temperatures often remained above 55.4°F [13ºC] until December

17 in both years, which resulted in more than 95% of spawning to occur at water temperatures above

18 13ºC. These observations suggest that the ability for adult Chinook salmon to adjust or delay spawn

19 timing is relatively limited relative to the ability to delay their migration rates. Notably, water

20 temperatures in 2014 and 2015 did not approach or exceed the upper thermal tolerances for adult

21 Chinook salmon[13] and no significant pre-spawn mortality was observed during these years.

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26 [8] Goniea et al. 2006
    [9] Strange 2012

27 [10] Alderdice and Velsen 1978
    [11] Quinn 2005

28 [12] EPA 2003
    [13] Eaton and Scheller 1996

TESTIMONY OF DOUG DEMKO – SJTA REBUTTAL, EXHIBIT SJTA-402
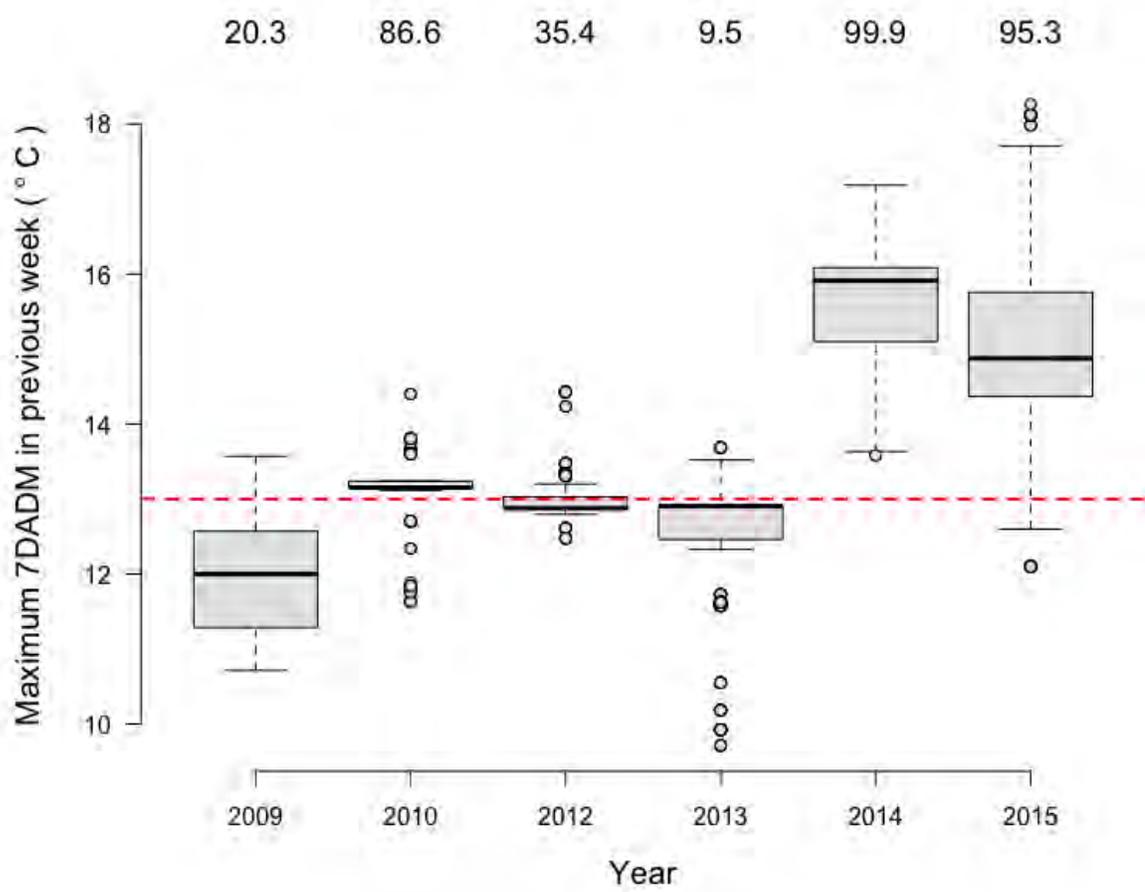
Figure 9. Distribution of Chinook salmon spawning activity (redd construction) in relation to water temperatures (7DADM; measured at Goodwin Dam [RM 58.4]) in the Stanislaus River. Horizontal red line represents 13ºC [55.4°F], the recommended temperature guidance for spawning for trout and salmon (EPA 2003). Numbers across top are the estimated percentage of redds that were constructed at water temperatures greater than 13ºC[14].

33.   While mortality of offspring (eggs or alevin) related to high water temperatures was not the focus of redd monitoring, there appeared to be a significant decline in the numbers of juvenile Chinook salmon produced (estimated by rotary screw trap monitoring at Oakdale) per female spawner counted at the weir in these years. The estimated numbers of juveniles per female spawner in 2014 and 2015 were 109 and 84, respectively, which was well below the average number of recruits per spawners (551 [range 84 – 1,155][16]). Further, juvenile outmigrants in 2014 and 2015 were the progeny of approximately 5,400 adult spawners in each year (fall 2013 and 2014), yet juvenile abundance in 2015 was only 30% of the estimated juvenile abundance during

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[14] FISHBIO unpublished data

TESTIMONY OF DOUG DEMKO – SJTA REBUTTAL, EXHIBIT SJTA-402

1   2014. Notably, water temperatures were far more favorable for incubation during fall 2013, and low

2   reservoir storage during fall 2014 resulted in high water temperatures during spawning and

3   incubation leading to a 70% reduction in juvenile production. These observations suggest that the

4   focus on improving survival in one life stage (the smolt stage by increasing flows) is likely to have

5   negative impacts on other life stages. It also shows that the full impact of the DFCR has not been

6   adequately assessed.

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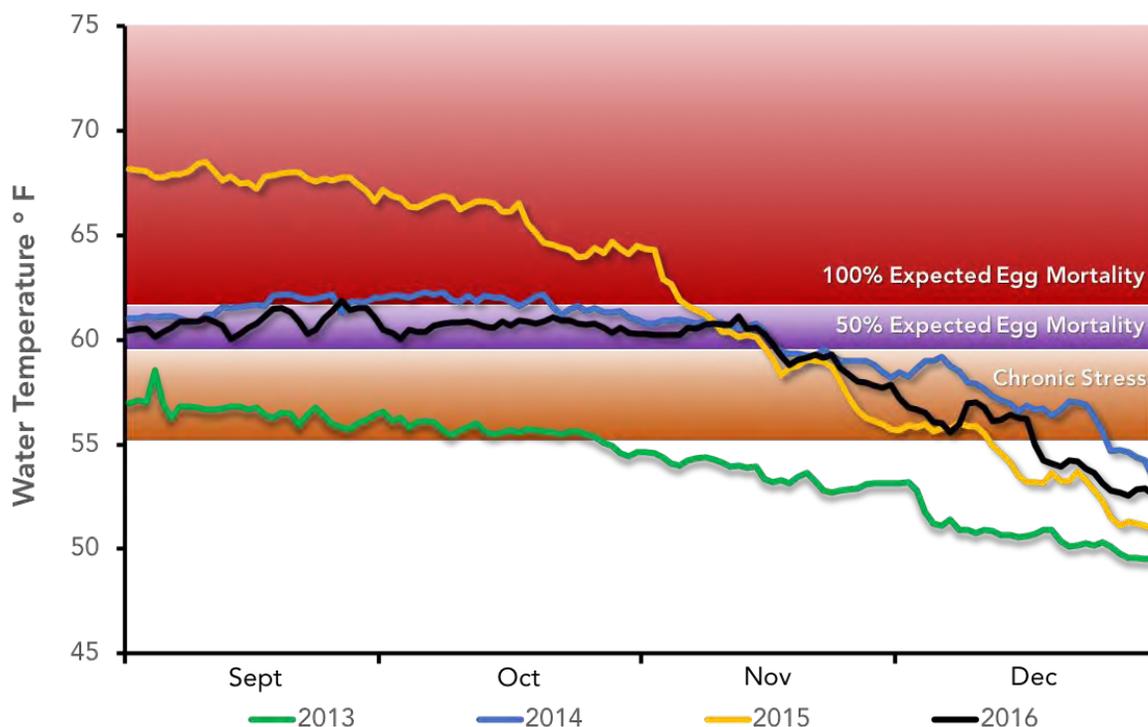
Figure 10. Stanislaus River water temperature below Goodwin Dam (RM 58.4) during fall spawning period 2013-2016 (note: 55.4ºF is equivalent to 13ºC; 60.0ºF is equivalent to 15.6 ºC, and 62ºF is equivalent to 16.7ºC)[15].

23   **2.**   **Increased San Joaquin River flows do not necessarily enhance juvenile**
24   **salmon survival through the Delta**

25   34.   The Vernalis Adaptive Management Plan (VAMP) investigated the relationship

26   between Chinook salmon smolt survival through the San Joaquin Delta and flow, exports, and

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[15] FISHBIO unpublished data

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1 operation of the Head of Old River Barrier between 2000 and 2011. In the 2010 independent panel

2 review of the Vernalis Adaptive Management Program, the panel repeatedly pointed out two

3 important conclusions relevant to the Delta Flow Criteria Report.[16] First, the panel pointed out early

4 on in their review that the reliance on flow alone would not consistently meet survival rates of

5 juvenile Chinook salmon in the San Joaquin River and Delta. The rationale for this conclusion was

6 that, particularly in recent years, survival rates at all flow levels was low. Since 2003, survival

7 through the San Joaquin Delta has consistently been < 12%, while flows at Vernalis ranged between

8 2,000 cfs and 27,000 cfs. This is a similar finding to that of Buchanan et al. (2018). Both this

9 conclusion of the review panel and the findings of Buchanan et al. (2018) present clear information

10 that the proposed flow regime will not reliably improve juvenile Chinook survival. This was

11 succinctly stated in the peer review panel's report: "These recent data serve as an important

12 indicator that high Vernalis flow, by itself, cannot guarantee strong downstream migrant survival"[18, p. 3].

13

14   35.   Second, the panel concluded that: "high and likely highly variable impacts of

15 predation appear to affect survival rates more than the river flow." Further, the panel noted that the

16 apparent high rates of predation observed during the latter portion of VAMP studies (i.e., when

17 acoustic telemetry was used) may be "a very substantial cause of downstream migrant mortality[18, p. 10]."

18 As noted elsewhere, the lack of inclusion of factors other than flow (i.e., predation, ocean

19 harvest rates, ocean conditions) in the development of the DFCR will severely limit any

20 improvements to juvenile Chinook salmon survival from DFCR flows.

21   36.   The DFCR (p. 59) states:

22   "In analyzing the relationship between Vernalis flow and cohort return
ratios of San Joaquin River Chinook salmon, TBI/NRDC found that

23   Vernalis average March through June flows of approximately 4,600 cfs
corresponded to an equal probability for positive population growth or

24   negative population growth. (TBI/NRDC 3, p. 24.) TBI/NRDC found that
average March through June flows exceeding 5,000 cfs resulted in positive

25   population growth in 84% of years with only 66% growth in years with
flows less than 5,000 cfs. (*Id.*) TBI/NRDC found that flows of 6,000 cfs

26   produced a similar response as the 5,000 cfs flows and flows of 4,000 cfs

27   or lower resulted in significantly reduced population growth of only 37%

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[16] Dauble et al. 2010

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1   of years. (*Id.*) The TBI/NRDC analysis suggests that 5,000 cfs may
2   represent an important minimum flow threshold for salmon survival on the
    San Joaquin River. (*Id.*) Based on abundance to prior flow relationships,
3   TBI/NRDC estimates that average March through June inflows of 10,000
    cfs are likely to achieve the salmon doubling goal. (TBI/NRDC 3, p. 16-
4   17.)"

5   37.   As a recent publication asserts, increased flows are not necessarily associated with

6   increased survival.[17] Moreover, factors beyond the freshwater and estuarine habitat have been

7   shown to exert substantial influence over salmon populations, not only in California, and not only

8   for Chinook salmon. Locally, the most prominent and telling example is the 2007/2008 collapse of

9   the Central Valley salmon population, attributed to unfavorable ocean conditions[18] (discussed in

10 more detail below).

11   38.   The DFCR flow regime, assuming the model predictions are realistic, only results in

12 appreciable increases in smolt production to Chipps Island in 3 of the 16 years (1993, 1996, 1997).

13 Even if such increases could be achieved, the survival of these fishes to adulthood and a subsequent

14 population increase is doubtful without addressing other limiting factors, primarily predation.

15 Predation by non-native species is finally being recognized as a severe stressor to the conservation

16 and recovery of native salmonids - and likely other species. The NMFS Draft Recovery Plan (2009)

17 for Chinook salmon and Central Valley steelhead considers predation one of the most important

18 stressors to the survival of juveniles. Although resource agencies have taken steps to circumvent the

19 extreme predation problem, namely by shifting the release location of hatchery-produced fish from

20 the tributaries to locations around San Francisco Bay (to avoid "conditions in the Sacramento River

21 and Delta detrimental to the survival of juvenile salmon"[19]), little has been done to address - rather

22 than avoid - the problem of predation.

23   39.   Recent research[20] provides further evidence suggesting that predation, particularly in

24 the lower reaches of the Delta, affects a large proportion of juvenile Chinook salmon, even in years

25 when flows are high (2011). During their study, upwards of 20% to 64% of study fish (depending

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27 [17] Buchanan et al. 2018
    [18] Lindley et al. 2009
28 [19] USFWS 2014
    [20] Buchanan et al. 2018

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on the year) were likely consumed by predators. Considering that these predation estimates apply to the area between Mossdale and Chipps Island only and do not include predation in the San Joaquin River or its tributaries, total predation losses of juvenile Chinook salmon originating from the Merced, Tuolumne and Stanislaus rivers are even higher.

3. **Unfavorable ocean conditions can severely limit marine survival of Chinook salmon**

40. The majority of Chinook salmon originating from Central Valley rivers and hatcheries enter the marine environment as sub-yearlings (they do not over-summer in freshwater environments). A relatively minor fraction of all Chinook salmon, particularly those belonging to the stocks of conservation concern (spring- and winter-run Chinook) remain in freshwater for at least one summer, and enter the marine environment the following year (as "yearlings"). In general,

41. Central Valley Chinook salmon remain at sea for 1 to 3 years, where they achieve more than 98% of growth (by weight) before returning to freshwater rivers to spawn.[21]

42. During that time, salmon must find sufficient food to survive and grow, escape predation, and avoid being captured in the fishery before reaching maturity. As expected, "the great majority of salmonids that migrate to sea do not return".[23] It has long been recognized that Pacific salmon, in general, experience long-term abundance trends associated with ocean-climate regimes.[22,23,24] Other research has identified the biological predictors of diatom and zooplankton abundance and oceanic current conditions as important predictors of survival and growth during the early ocean phase of Chinook salmon[25].

43. Until reaching maturity, Chinook salmon originating from the Central Valley largely remain in the nearshore coastal waters of California, and do not travel long distances like northern populations.[26] As a consequence, localized conditions such as wind stress and upwelling strongly

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[21] Quinn 2005
[22] Mantua et al. 1997
[23] Beamish et al. 1997
[24] Hare et al. 1999
[25] Sabal et al. 2016
[26] Weitkamp 2010

1   influence marine growth and survival of Chinook salmon.[27] As noted, a vivid demonstration of the

2   importance of ocean conditions on Chinook salmon survival was observed in 2007 and 2008 in the

3   Central Valley, when an unprecedented collapse in the salmon stock precipitated a statewide closure

4   of the ocean salmon fishery.[28]

5   44.   In the years prior, abnormal patterns of the California Current, higher sea-surface

6   temperature and weak upwelling (both considered detrimental to Chinook salmon[29]) were

7   implicated in various biological responses, ranging from emaciated whales and abandoned nests of

8   seabirds to unusual foraging patterns by sea lions. As expected, the unusual ocean conditions also

9   affected juvenile salmon entering or rearing in the ocean during this time. The affected salmon

10   brood years (2004 and 2005, respectively) entered the marine environment at abundance levels that

11   correspond well to the long-term averages (based on data from 1970 – 2007[30]), yet far fewer fish

12   reached maturity and returned to freshwater spawn. Ocean mortality was identified to be the

13   proximate cause of the collapse[30]. High mortality was attributed to a lack of food resources for

14   juvenile salmon, as the typical seasonal food web did not develop. This assertion was directly

15   supported by the poor conditions of salmon sampled in the Gulf of the Farallones. While the

16   2007/2008 escapement years were an anomaly, this example serves to demonstrate – once more –

17   that marine conditions can have profound effects of salmon survival, and factors beyond the control

18   of resource managers can ultimately determine the abundance of Chinook salmon.

19   45.   In order to safeguard against drastic fluctuations in population abundance resulting

20   from unfavorable marine conditions, which are beyond the control of resource managers, steps

21   should be taken to enhance the outmigration diversity of Central Valley Chinook salmon. As the

22   Central Valley (fall-run) stock relies heavily on hatchery production, a release strategy that is more

23   diversified and coordinated among hatcheries may be the most feasible near-term action that can

24   serve to increase the resilience of the stock. Arguably, ocean survival may be somewhat lower in

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[27] Wells et al. 2008
[28] Lindley et al. 2009
[29] Petrosky and Schaller 2010

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some years as a consequence, yet year-to-year or generation-to-generation abundance fluctuations are expected to be muted as a result.[30]

4.   Unsustainable ocean harvest rates thwart population growth

46.   Available information demonstrates that any effort by the SWRCB to double the natural production of CVFRCS in the San Joaquin River Basin will be ineffective due to the commercial fishery management protocols affecting the number of CVFRCS that are harvested in the ocean. Even if smolt survival to Vernalis or Chipps Island is improved under the DFCR proposal, the doubling goal can never be achieved because ocean harvest allotments prevent the necessary cohort-replacement rate.

47.   At the SWRCB's June 6, 2011 scoping workshop for the review of the Bay-Delta Plan, the National Marine Fisheries Service gave a presentation which, among other things, identified the fishery conservation and management considerations under the federal Magnuson-Stevens Act, 16 U.S.C. §§ 1801 et seq. (MSA), as part of the regulatory framework affecting salmonids in the San Joaquin River Basin (see NMFS' June 6, 2011 presentation, slide #2, found at http://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/bay_delta_plan/water_quality_control_planning/docs/060611wrkshp/nmfs.pdf). Due to the obvious link between the ocean harvest protocols developed under the MSA and the health and well-being of salmon populations in the San Joaquin River Basin, the San Joaquin River Group Authority (SJRGA) sued NMFS, the National Oceanic and Atmospheric Administration, the United States Department of Commerce, and the Pacific Fishery Management Council (PFMC) (collectively "the United States") regarding NMFS' adoption of the 2011 harvest of Sacramento River fall-run Chinook salmon (SRFC). Given the dire condition of CVFRCS as expressed by NMFS, USFWS, the DFG, and the non-governmental organizations, and as evidenced by the population crash in 2007 resulting in the closure of the ocean fishery in 2008 and 2009, the SJRGA was greatly concerned about the impact that overfishing was having on CVFRCS. The SJRGA concluded that because Sacramento River fall-run Chinook salmon, which are classified by NMFS as a "species of concern" (and more

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[30] Lindley et al. 2009

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1   recently "reclassified" as a candidate species for listing as threatened or endangered) under the

2   Endangered Species Act, 16 U.S.C. §§ 1531 et seq. ("ESA") are in peril, preventing the loss of 50-

3   65 percent of the SRFC adult population due to ocean harvest would be both wise and in concert

4   with the State's goal of doubling the production of salmon.

5   48.   Irrespective of the doubling goal, or any efforts to implement it, PFMC's

6   conservation objective is escapement (returning spawners) between 122,000 and 180,000, in any

7   given year. Assuming that PFMC adheres to this position, it will be impossible to achieve the

8   doubling goal.

9   *Deliberate harvest levels limit potential population growth*

10   49.   Currently, ocean harvest allotments are - generally - set to permit escapement of

11   hatchery and natural spawners ranging between 122,000 and 180,000 individuals annually.[31] The

12   mean relative proportion of Central Valley fall-run Chinook salmon escapement to the San Joaquin

13   Basin is 5.8% (based on GrandTab data from 1952 to 2017, including in-river and hatchery

14   escapement to the Stanislaus, Tuolumne and Merced rivers). Assuming that harvest and subsequent

15   escapement affects fish returning to the Sacramento and San Joaquin River basins equally, this

16   corresponds to managing for an escapement target of 7,512 to 11,083 individuals to the San Joaquin

17   River basin.

18   50.   The Department of Interior (comments to the SWRCB February 8, 2011) suggested

19   that a cohort replacement rate of 1.77 will result in doubling of the starting population size within 6

20   years, or two generations (assuming a 3-year life cycle). In the first generation, this would equate to

21   total production in the San Joaquin River Basin of about 19,617 individuals (11,083*1.77).

22   However, current management practices would allow for harvest of increased production, so

23   escapement would not increase to grow the next generation. Consequently, total production in the

24   San Joaquin River Basin would be "capped" at about 19,617 individuals (11,083*1.77). The

25   doubling goal for Central Valley FRCS is 750,000. If one considers returns of 122,000 to 180,000

26   to the Sacramento Basin and assumes that the harvest rate is 60%, this equates to production of up

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[31] PFMC 1984

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1   to 300,000 plus up to 19,617 for total Central Valley production of 319,617. This is only 42.6% of

2   the doubling goal.

3   51.   While the above calculation is clearly oversimplified, assumes a strict 3-year

4   generation time, assumes no hatchery contribution (counted towards the doubling goal), and

5   constant fractional escapement among the Sacramento River and San Joaquin River basins

6   (Cosumnes and Mokelumne rivers excluded), it serves to illustrate that current escapement targets

7   used to regulate the ocean fishery are clearly prohibitive of reaching the doubling goal.

8   *The problem of ocean harvest is exacerbated by inaccurate forecasts*

9   52.   A recent review of the forecasting method concluded that the forecasting methods

10   contain "substantial errors," highlighting the difficulty to accurately forecast this stock given the

11   limited data available.[32] The preseason forecasts are calculated using the escapement of jacks (early

12   maturing males) the previous year. Harvest is then set to population levels that are inflated as the

13   predictive models become less accurate in light of changing (increasing) proportions of jacks in the

14   fishery seen in California in recent years. In 12 of the last 15 years, PFMC predictions have

15   overestimated the size of the Chinook salmon population (Figure 11), leading to higher than

16   expected harvest rates and reduced escapement to Central Valley streams. The accuracy of

17   preseason predictions has not improved in recent years despite PFMC making several changes to its

18   forecasting method. In 2017, the preseason forecast for the Sacramento Basin population was

19   230,700; however, PFMC reported that the actual population in 2017 was only 139,997 fish,

20   meaning that the preseason forecast overestimated the actual population by over 65%. With harvest

21   quotas based on an inflated population estimate, the exploitation rate (percentage of the total

22   population that is harvested) in 2017 was 68.2%, leading to the 2nd lowest escapement year on

23   record in the Sacramento Basin. The inaccuracy in salmon escapement is a continuing concern for

24   management of the Central Valley population, as an underestimation can impact commercial

25   fishermen by allowing a lower catch allotment than could be supported, and an overestimation of

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[32] Winship et al. 2013

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1 the population can lead to overfishing, high take of stocks of conservation concern, reduced

2 escapement and subsequent low in-river abundance.
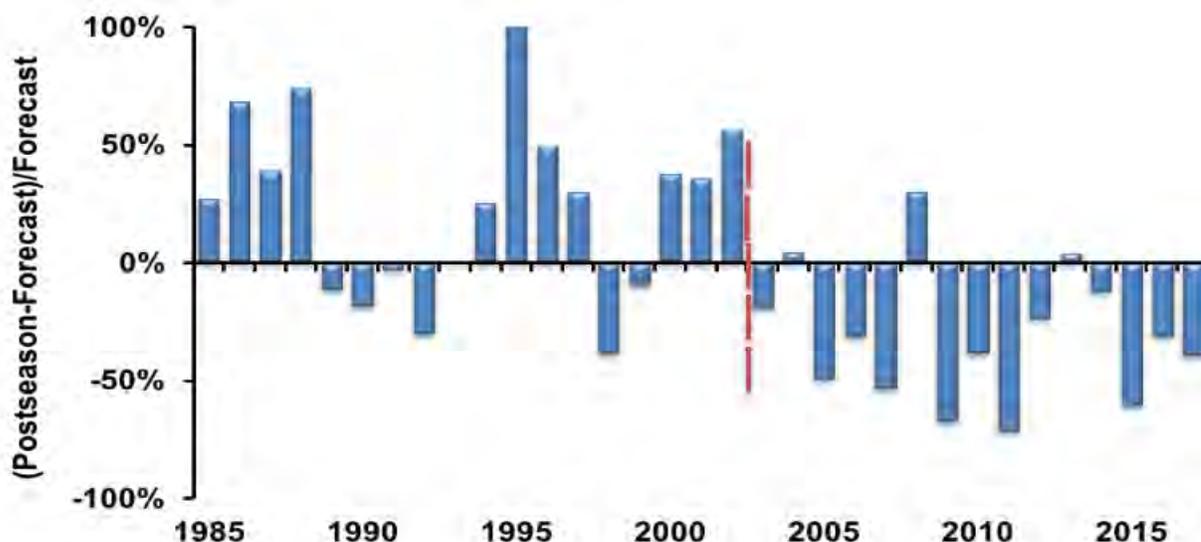
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Figure 11. Percent difference from PFMC average annual preseason forecast relative to the actual SI observed, 1985-2017[33].

5. **Natural production is hampered and cannot be accurately quantified due to hatchery practices**

53. The doubling goal is defined as a "doubling of the natural production of Chinook salmon from the average production of 1967-1991". However, natural production during the baseline period is unknown due to hatchery contributions of undetermined magnitude, and even combined (natural and hatchery origin) escapement estimates are not well supported. Similarly, though likely improved over historic estimates, current and recent levels of natural production continue to be confounded by hatchery-produced fish, often attributable to poor hatchery practices.

54. Figure 19-1 of the State Water Resources Control Board's (SWRCB) July 2018 Draft SED purportedly shows the difference in mean estimated "natural" production of fall-run Chinook salmon in (FRCS) Central Valley streams before (1967-1991) and after (1992-2011) the Central Valley Project Improvement Act (CVPIA). For reference the figure is shown in this

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[33] PFMC 2008-2017

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document as Figure 12. While the SWRCB concluded from this analysis that greater decreases in "natural" production have occurred in the San Joaquin Basin, they failed to recognize that, with the exception of Clear Creek and Butte Creek where passage barriers were removed, increases in "natural" production only occurred in streams with hatcheries.

55.   The figure, however, does not include the Sacramento River, creating the misperception that decreased Chinook salmon production is (nearly) exclusive to the San Joaquin River Basin. However, the largest decreases in both estimated natural production and escapement by far have occurred in the mainstem Sacramento River (Figure 13). The average reduction in fall-run Chinook salmon production in the Sacramento River mainstem is more than double the reduction of all San Joaquin River tributaries combined. Such a large decrease – bound to affect the salmonid recovery effort the most – clearly suggests that factors other than spring-time flows in the San Joaquin basin contribute to the decline in Chinook salmon production.

56.   Those tributaries depicting an increase in production are either associated with hatchery operations (Battle Creek, Feather River, American River, Mokelumne River) or large-scale restoration projects (Clear Creek and Butte Creek). The increase in adult returns to hatchery streams is likely related to the increased number of juveniles released from the respective hatcheries, which has increased by 52% from an average of 23 million during 1964-1988 to nearly 35 million during 1989-2013. While mean escapement to all Central Valley streams without hatcheries decreased slightly post-CVPIA, 2016 escapement to the Stanislaus River, a San Joaquin Basin stream, was the highest recorded since 1954, and was the fifth consecutive year of drought. This is due to a combined increase in production from the nearby Merced River Hatchery and a simultaneous shift to trucking hatchery fish to the Delta for release to circumvent high mortality rates during migration (that naturally produced FRCS experience). Trucking of hatchery origin FRCS results in an increased tendency to stray.

57.   Otolith analyses and CFM show that escapement of FRCS to all Central Valley streams is dominated by hatchery origin FRCS (81-90%). The impact of hatcheries is underestimated as progeny of hatchery origin FRCS that spawned in-river are considered naturally produced.

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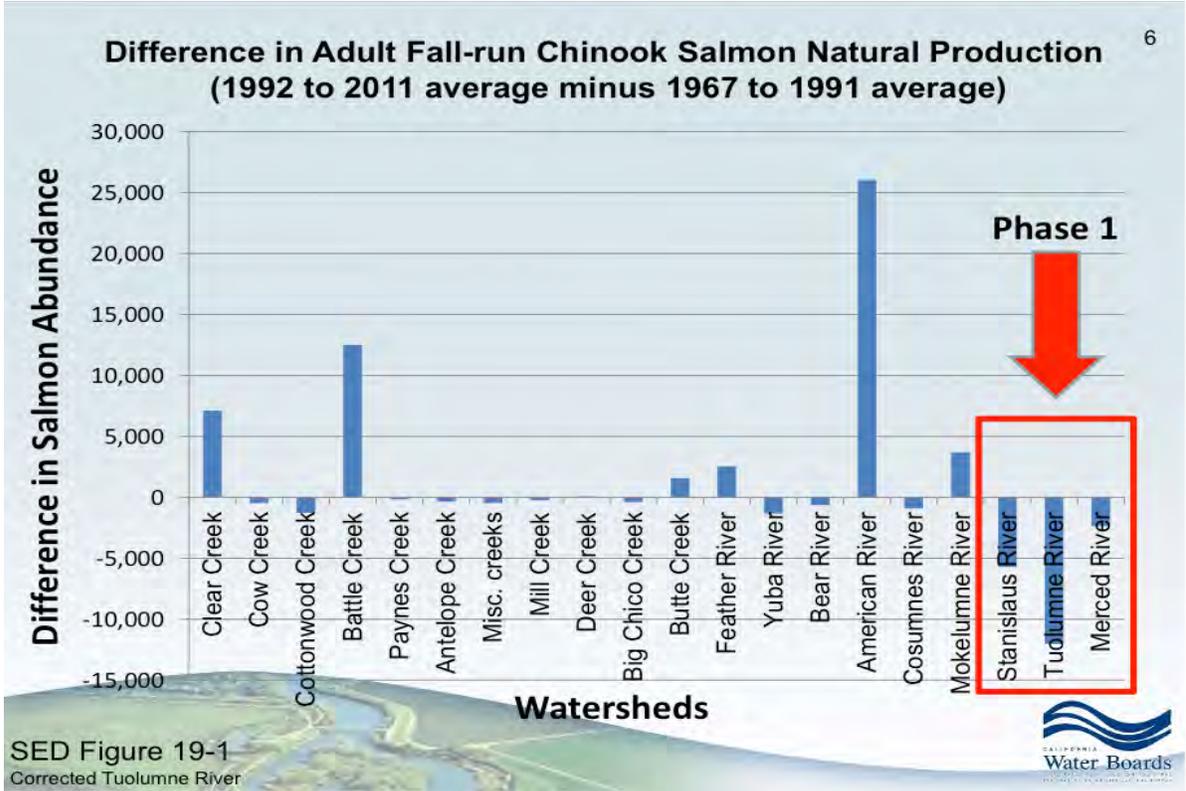
Figure 12. Difference in "natural" production of adult FRCS when comparing the 1967-1991 average to the 1992-2011 average in several Central valley streams (from SWCB staff presentation, December 2016).
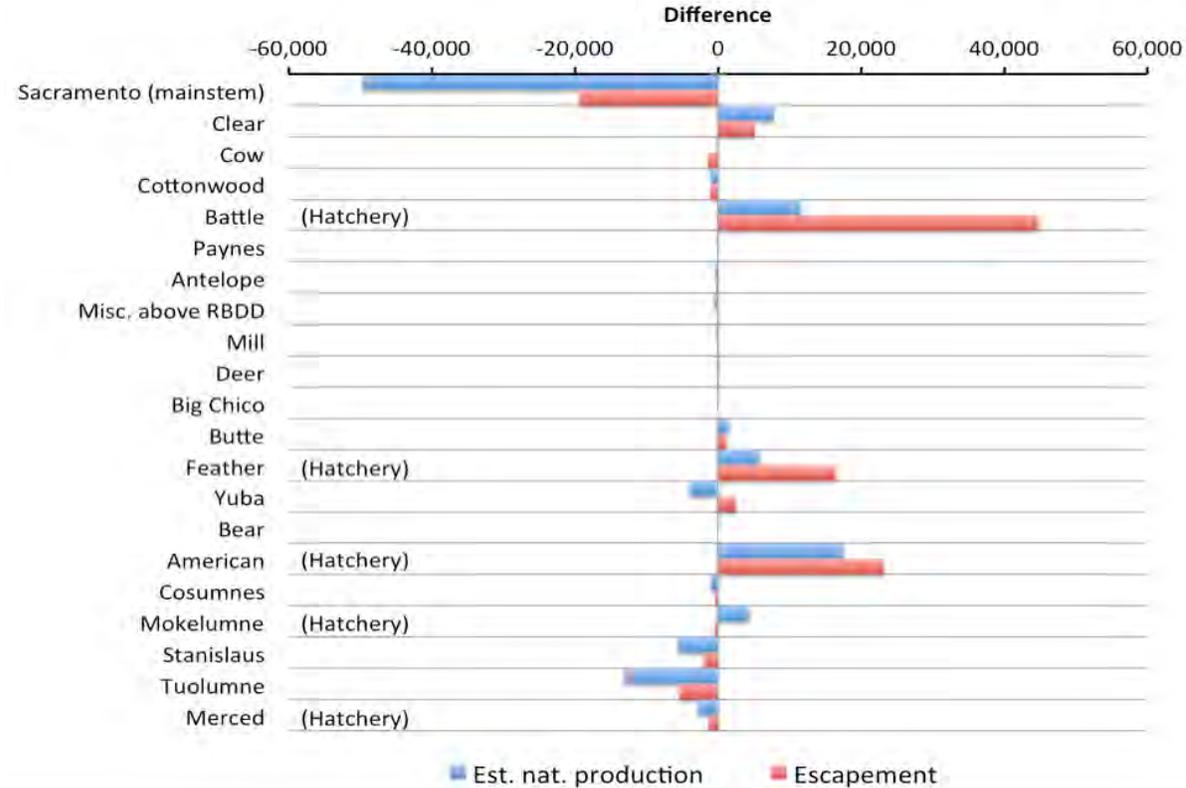
Figure 13. Differences in mean natural production and mean escapement of FRCS to between 1967-1991 and 1992-2016, including the mainstem Sacramento River.

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58.   Central Valley salmon hatcheries have been tasked with the nearly impossible effort of sustaining unrealistically large populations of Chinook salmon and steelhead. Broad-scale habitat degradation and destruction, and impairment of migration corridors continue to be primary factors limiting natural reproduction of these species.[34,35] However, current hatchery practices, which prioritize production and harvest over conservation of biological diversity, can also be implicated in the demise of wild fall-run Chinook. Decades of mass production (> 2 billion juveniles have been released) and off-site releases resulted in high rates of straying among tributaries, subsequently genetically homogenizing the fall-run Chinook population - hatchery and wild - through interbreeding.[36,37] Further, off-site releases to increase survival of hatchery fish exacerbates the differential survivorship with naturally spawned fish that must migrate through a gauntlet of predators. High straying and hatchery contribution to escapement along with low outmigration survival of naturally spawned fish has likely resulted in complete replacement of wild fall-run with hatchery fall-run Chinook salmon.

59.   The DFCR failed to account for high hatchery contributions in escapement estimates in the San Joaquin River basin. Research published prior to 2010[38,39,40] indicated that the direct numerical contribution of hatchery Chinook salmon is likely high (>0.90 hatchery contribution in the ocean fishery) and that Central Valley fall-run Chinook salmon population were genetically homogenous. More recent research has indicated that the population-level impacts of the Central Valley hatchery system may be more severe than previously thought (i.e., synchronous population dynamics[41] and the masking of true declines in 'natural' Chinook stocks[42]). Without properly accounting for the hatchery contribution to tributaries in the San Joaquin River, a proper assessment

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[34] Lufkin 1996
[35] NMFS 2014
[36] Williamson and May 2005
[37] Garza et al. 2008
[38] Johnson et al. 2007
[39] Williamson and May 2005
[40] Garza et al. 2007
[41] Carlson and Satterthwaite 2011
[42] Johnson et al. 2012

TESTIMONY OF DOUG DEMKO – SJTA REBUTTAL, EXHIBIT SJTA-402

1 of the effects of flow manipulations (or any other action conducted in freshwater) on Chinook

2 salmon populations cannot be considered reliable.

3   60.   The following list are critical issues with current hatchery practices that were

4 identified by the California Hatchery Scientific Review Group:[43]

5   ●   Production goals are based on numbers of juveniles with no clear link to adult

6 pre-fishery recruitment, harvest, or conservation goals.

7   ●   Program goals have not been clearly defined (most hatchery programs in

8 California do not have clearly defined purposes other than juvenile production targets).

9   ●   Hatchery Monitoring and Evaluation Programs and Hatchery Coordination

10 Teams are needed to provide accurate, timely, and objective information collected within a

11 sound scientific framework. Despite the importance of hatchery M&E programs, they have

12 generally received insufficient emphasis at California's anadromous fish hatcheries.

13   ●   Program size (as measured by juvenile production) has been set independent

14 of any consideration of potential impacts of hatchery fish on affected natural populations.

15 Therefore, hatcheries often focus more on production rather than conservation, despite the

16 "large number of possible negative impacts that release of millions of hatchery fish may

17 have on natural populations, including direct competition or predation among hatchery-and

18 natural-origin juveniles, transmission or promotion of disease from hatchery to natural

19 populations, competition between hatchery- and naturally-produced adults for spawning

20 habitat, and reduction in fitness due to interbreeding of hatchery and naturally-produced

21 adults on spawning grounds."

22   ●   Off-site releases improve survival rates and result in increased ocean harvest

23 of hatchery fish, but promote unacceptable levels of straying throughout the Sacramento-San

24 Joaquin system. Further, transporting and releasing hatchery fry to the Bay also causes

25 higher hatchery survival relative to natural fish that suffer low survival during outmigration.

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[43] CA HSRG 2012

TESTIMONY OF DOUG DEMKO – SJTA REBUTTAL, EXHIBIT SJTA-402

● No marking/tagging programs permit real-time identification of all hatchery-produced Chinook salmon, but, for the most part, consist of a constant fractional marking program in which 25% of fish produced are released with an adipose fin-clip and coded-wire tag (CWT). This marking program is adequate to allow reasonably accurate statistical estimation of the proportion of hatchery fish on natural spawning grounds and in hatchery returns and does a good job of supporting needs of fishery managers, but it does not allow real-time identification of all hatchery fish as being of hatchery origin.

The HSRG recommended that all Chinook salmon should be tagged with CWT and that 25 percent should be adipose fin-clipped to allow real-time identification of hatchery-origin fish (using electronic CWT detection devices), to enable

○ improved monitoring of hatchery and natural interactions throughout the entire life cycle,

○ culling of undesirable hatchery matings between out-of-subbasin and local stocks or between spring and fall Chinook stocks from the same basin,

○ improved management of hatchery broodstock (incorporation of known numbers of natural fish), and

○ to monitor and potentially control spawner composition in natural spawning areas.

● Standards for fish culture, fish health management and associated reporting are inadequate and need to be improved. Current practices often provide inadequate protection for both hatchery and natural fish populations from disease impacts, and fish culture protocols are outdated.

● Genetic studies on Central Valley fall-run observed genetic homogenization among wild and hatchery stocks, a direct result of the shortcomings in past (and, in some cases, current) hatchery operation. Rampant straying has resulted in genetic mixing across

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1 tributaries such that most genetic markers cannot be used to distinguish between fall-run

2 stocks.[44,45]

3 **Case example of hatchery effects: escapement to the Stanislaus River**

4 61.   The effects of hatchery operations on escapement can be illustrated by example of

5 the Stanislaus River, a river without a hatchery. On the Stanislaus River, recent estimates of

6 hatchery contribution have been exceedingly high, based on three reports produced by CDFW[46,47,48]

7 and updated estimates using data obtained from the Regional Mark Information System (RMIS).

8 Since 2010 (the first year of all cohorts of spawners subjected to CFM, adopted in brood year 2006),

9 the percentage of adipose clipped fall-run passing through the Stanislaus weir has been about 25%,

10 except in 2011 and 2012 when the observed percentage of marked individuals exceeded 50%.

11 During this time, the proportion of hatchery contribution to adult escapement has ranged from 50%

12 to 99% (Figure 14). Recoveries of CWTs from Stanislaus carcass surveys are overwhelmingly from

13 the Mokelumne River Hatchery, but CWTs from Coleman, Feather River, Nimbus, and Merced

14 hatcheries are consistently present as well (Figure 15).

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26 [44] Williamson and May 2005

27 [45] Garza et al. 2008
    [46] Kormos et al. 2012

28 [47] Palmer-Zwahlen and Kormos 2013
    [48] Palmer-Zwahlen and Kormos 2015

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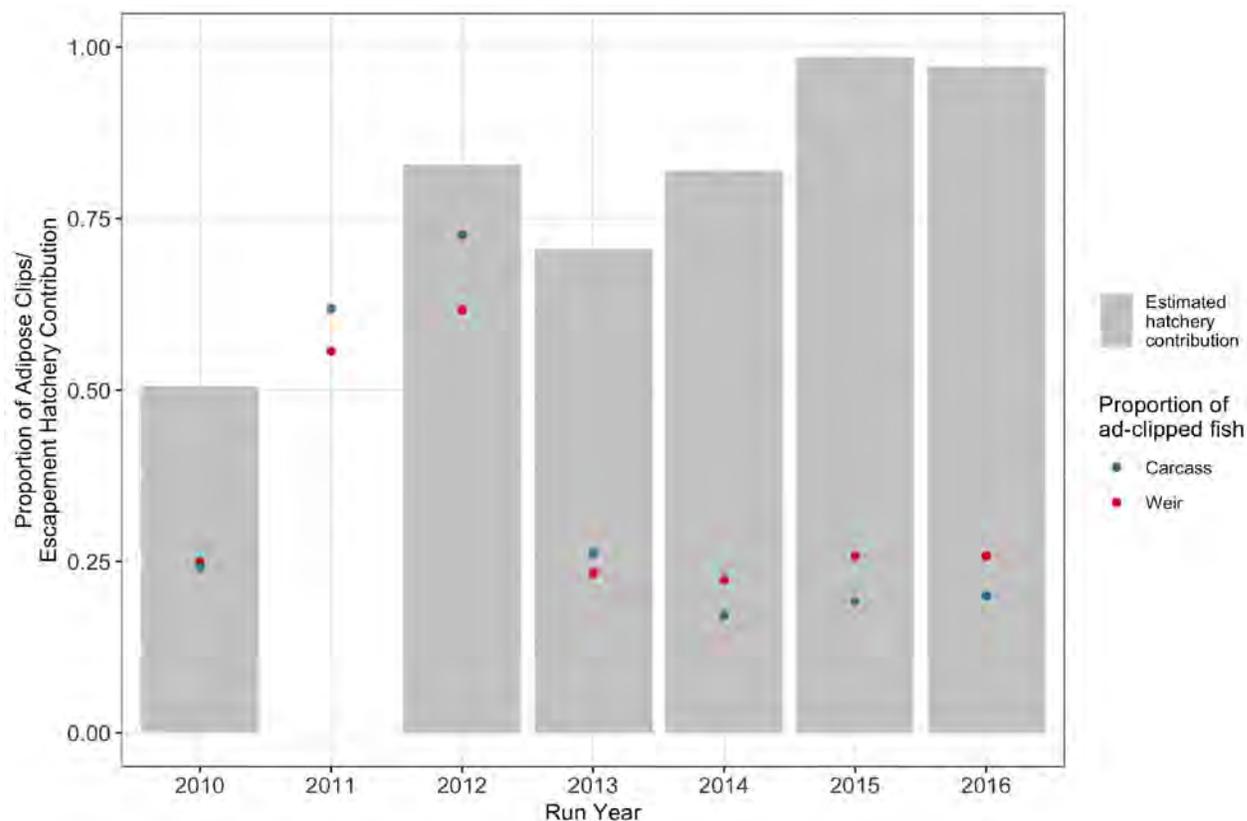
Figure 14. Estimated proportions of observed individuals with clipped adipose fins (i.e., marked as hatchery origin) from CDFW carcass surveys (blue) and from a weir and fish counting device (red) in the Stanislaus River. Grey bars show the estimated proportion of hatchery contribution to adult escapement. Data to estimate the proportion was obtained from the RMIS database.

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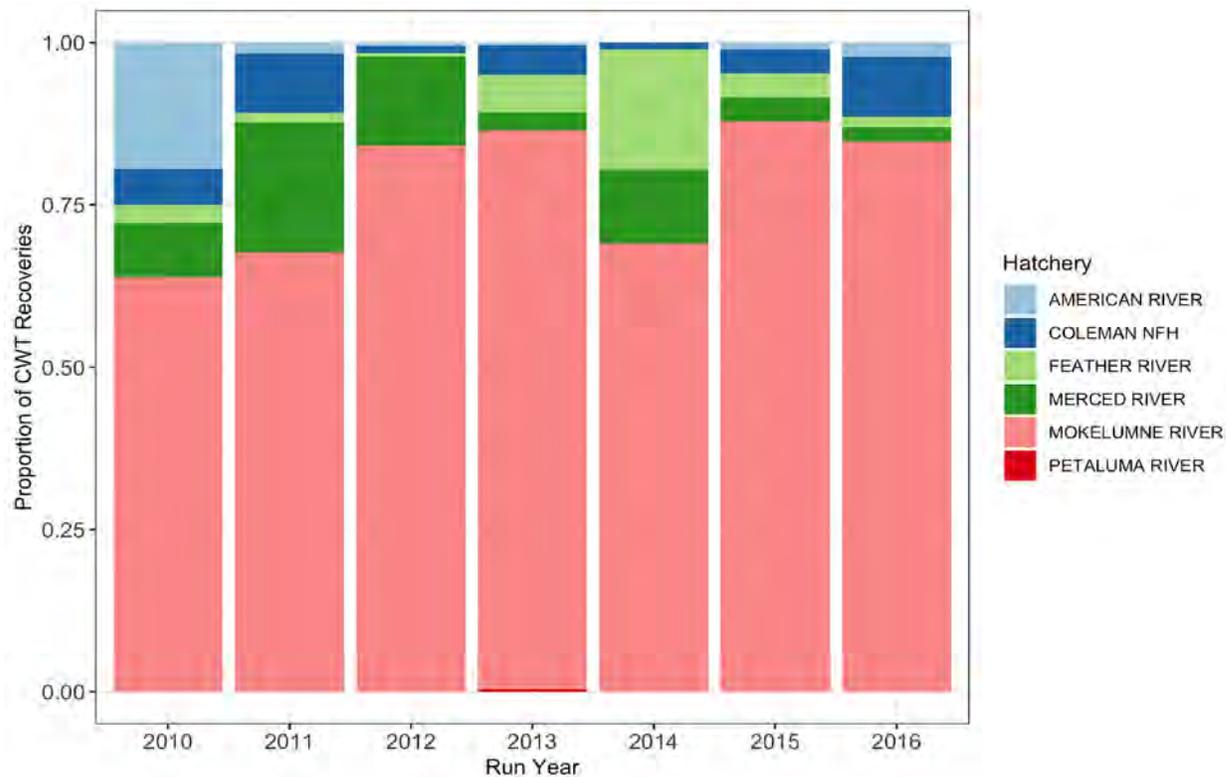
Figure 15. Hatchery of origin for CWT marked Chinook salmon observed during CDFW carcass surveys on the Stanislaus River from 2010 to 2016. Data to estimate the composition obtained from the RMIS database. Note that this figure does not reflect differences in the total number of CWTs recovered each year.

62.   The improper accounting of hatchery contribution to escapement on the Mokelumne River, elsewhere in the Central Valley, and even in the Columbia River, have led to the perception that certain salmon populations are faring well when in fact, the 'natural' or 'wild' component is not.[49] Further, such erroneous perception can lead to the faulty conclusion that management actions in the freshwater environment have improved survival, production or escapement even if no such improvement occurred.

63.   For example, GrandTab data for the Stanislaus would indicate a marked increase in the overall escapement over the last 20 years (1998 - 2017). However, if the estimates of hatchery contribution (recall Figure 14) are taken into account, as they should be, it becomes apparent that natural production has declined substantially, yet "escapement" has been obscured by the influx of

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[49] Johnson et al. (2012)

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1 | stray, hatchery fish. Of note, this decline occurred during management according to the 2009 NMFS

2 | Biological Opinion (BiOp; NMFS 2009, 2011), which purportedly provides improved river

3 | conditions conducive to salmonid production and survival. The perceived high escapement in recent

4 | years (2015 - 2017) consisted primarily of three-year-old adults that would have outmigrated during

5 | the years of 2013 through 2015, i.e., during the most recent drought.

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7 | Dated: July 10, 2018

_____ _____

8 | DOUG DEMKO

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TESTIMONY OF DOUG DEMKO – SJTA REBUTTAL, EXHIBIT SJTA-402

EXHIBIT 1

Doug Demko – FISHBIO President/Principal

Doug's 29 years of experience in fisheries research and monitoring, applied biology, facilitation, and negotiation have gained him the reputation of a regional fisheries expert with extensive knowledge of fish population and life-history research and monitoring. Doug is trained in biology and graduated from CalNorthern School of Law in 2001. He founded and is President of FISHBIO, Inc., a U.S. based corporation specializing in fisheries research, monitoring, and conservation. He is also the President of FISHBIO Laos Limited, a foreign company that specializes in fisheries research, monitoring, and conservation in the Mekong River Basin in South East Asia. Doug is the President of La Cuesta Roja, S.A., a Costa Rican company established to develop a research center for the purpose of conducting fisheries research, monitoring, and conservation of freshwater and marine environments in Central America. He is also the President of Roja Adventures, S.A., a Costa Rican company established for the purpose of promoting eco-tourism, education, and conservation practices in Costa Rica. Doug funds and led the development of the Mekong Fish Network (mekongfishnetwork.org), an international effort to promote research data sharing and collaboration among diverse governments and interests in the Mekong River Basin. He also funds FISHBIO's Three Rivers program, an effort to promote fisheries and environmental education for primary school children. Doug has testified as a fisheries expert witness before the U.S. House of Representatives, twice in front of the California State Legislature on Central Valley fisheries management issues, and several times before the SWRCB.

Doug began his career monitoring juvenile Chinook in the Sacramento River in 1989. His extensive technical experience with fish population research has enabled him to start and grow a company with a successful track record of developing and conducting basin-scale fish life-history monitoring programs and has led to several innovative approaches in the field of fish research, both regionally and internationally. He has established and managed a number of ongoing long-term fisheries research and monitoring programs throughout the Central Valley and has maintained client relationships for over two decades. He oversees research projects and monitoring programs domestically and internationally.

Doug has directed and managed a variety of field research and monitoring programs, including mark-recapture studies to evaluate fish survival and entrainment, mortality and behavioral studies, limiting factor analyses, salmonid outmigration and survival characterizations, and abundance and distribution analyses. His expertise includes fish life-history research and assessment; long-term population monitoring; and population dynamics of California fishes. Doug has researched, compiled, and analyzed historical databases on fish run size, spawn timing, age structure, ocean harvest rates, habitat utilization, and hatchery practices for a variety of species status reviews, and has authored status reviews for salmonid populations in California, Oregon, and Washington. He has co-authored several journal articles on California and Mekong fish populations.

Since 1991 Doug has led or been involved in numerous studies on the Stanislaus, Tuolumne, Merced, Mokelumne, and Calaveras rivers. A partial list of these efforts includes: establishing long term juvenile and adult salmon monitoring programs (rotary screw traps, seine, weirs, remote cameras, snorkel); Chinook salmon redd surveys to assess spawn timing and habitat preferences;

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radio tracking juvenile Chinook to evaluate migration rates and mortality; wire fyke trapping to evaluate non-native predator species abundance; boat electrofishing to evaluate fry habitat use; boat electrofishing to remove predators from Clifton Court Forebay; Vernalis Adaptive Monitoring Program; juvenile chinook and *O. mykiss* floodplain use; floodplain habitat assessments; habitat mapping; habitat restoration; hatchery assessments; mark-recapture studies; development of a 5 year program to assess predator abundance and influence on Chinook mortality in the Stanislaus River with NOAA Fisheries and CDFW; upstream *O. mykiss* monitoring; Habitat Conservation planning; benthic macroinvertebrate assessments; migration barrier assessments; Chinook salmon stranding surveys; Watershed Stewardship Group facilitation; and volunteer snorkel surveys.

Internationally Doug's fisheries research and monitoring experience includes projects in the Mekong Basin, including projects in Laos PDR, Vietnam, Cambodia, and Thailand. A partial list of these projects include: establishing fisheries monitoring programs including programs driven by large power companies and remote villagers; establishing and studying Fish Conservation Zones; Mekong Giant Catfish satellite telemetry; use of environmental DNA to identify species; establishing and training villagers in participatory fishery monitoring surveys; developing community water quality and water resource management programs; seasonal wetlands evaluation; state of the basin assessments; climate change and aquatic organisms assessment; fisheries management plans; fish hatchery assessment; establishment of turtle conservation zones; and macroinvertebrate assessments.

Since starting FISHBIO in 2006 Doug has worked for or partnered with many private companies, public agencies, Non-Government Organizations, non-profit groups, and universities for the purposes of researching fish populations domestically and internationally. A partial list of clients, partners, and grantors includes: U.S. State Department; World Wide Fund for Nature (WWF); Mohamed bin Zayed Species Conservation Fund; International Union for Conservation of Nature (IUCN), Laos, and Critical Ecosystem Partnership Fund (CEPF); The Asia Foundation; Sustainable Mekong Research Network (SUMERNET); International Crane Foundation; Fauna & Flora International, Myanmar; Theun Hinboun Power Company; Mekong River Commission; Nam Ngiep Power Company; The Agro Biodiversity Institute; University of Nevada Reno; USAID; Wildlife Conservation Society and Turtle Survival Alliance; Chiang Mai University and International Development Research Centre; Earth Systems Mekong; United States Bureau of Reclamation; California Department of Water Resources; San Joaquin Tributary Authority; Modesto and Turlock irrigation districts, Merced Irrigation District; Oakdale Irrigation District; South San Joaquin Irrigation District; West Stanislaus Irrigation District; Banta-Carbona Irrigation District; Patterson Irrigation District; Stockton East Water District; South Valley Water Association; River Partners; Nature Conservancy; NOAA Fisheries; Monterey County Water Resource Agency; and ICF International.

ATTACHMENT 12

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8

9   BEFORE THE CALIFORNIA STATE WATER RESOURCES CONTROL BOARD

10   IN THE MATTER OF

11   CALIFORNIA DEPARTMENT OF WATER   )   **TESTIMONY OF DANIEL B. STEINER**
     RESOURCES AND UNITED STATES   )   **(San Joaquin Tributaries Authority [SJTA]**
12   BUREAU OF RECLATION PETITION FOR   )   **SJTA REBUTTAL, EXHIBIT 401)**
     WATER RIGHT CHANGE RE: CALIFORNIA)
13   WATERFIX.   )
)
14   )
)
15   _____)

16   I, Daniel B. Steiner, declare as follows:

17   **STATEMENT OF QUALIFICATIONS**

18   1. I am a registered civil engineer in the State of California (C32666). I hold a Bachelor's of

19 Science Degree in Engineering from the University of California, Davis. My qualifications have

20 previously been submitted as SJTA Exhibit 102.

21   2. The basis for this rebuttal testimony, and the case-in-chief evidence to which it is

22 responsive, is set forth in SJTA Exhibit 404 (Declaration of Tim O'Laughlin).

23   **SUMMARY OF TESTIMONY**

24   3. The San Joaquin Tributaries Authority ("SJTA") asked me to review the State Water

25 Resources Control Board's (SWRCB) report entitled "Development of Flow Criteria for the

26 Sacramento-San Joaquin Delta Ecosystem", dated August 3, 2010, ("DFCR", California WaterFix

27 Exhibit No. SWRCB-25), as well as the draft of the DFCR dated July 20, 2010 ("Draft DFCR").

28 Specifically, I was asked to review Section 5.3 concerning the San Joaquin River, and to conduct

1   analyses and illustrate implications to San Joaquin watershed hydrology and operations assuming

2   implementation of the flow criteria set forth in the DFCR.

3   4.   The DFCR report states the following: "[a]vailable scientific information indicates that

4   average March through June flows of 5,000 cfs on the San Joaquin River at Vernalis represent a

5   flow threshold at which survival of juveniles and subsequent adult abundance is substantially

6   improved for fall-run Chinook salmon and that average flows of 10,000 cfs during this period may

7   provide conditions necessary to achieve doubling of San Joaquin basin fall-run." (DFCR, p. 119.)

8   The DFCR further states that "60% of unimpaired flow from February through June is needed in

9   order to achieve a threshold flow of 5,000 cfs or more in most years (over 85% of years) and flows

10   of 10,000 cfs slightly less than half of the time (45% of years)." (DFCR, p. 120.)

11   5.   My analysis shows (1) that flows of 5,000 cfs and 10,000 cfs at Vernalis are not achievable

12   in 85% of years or 45% of years, respectively, under reasonably anticipatable operations, using as

13   an example the proposed Phase I revisions to the Water Quality Control Plan for the San Francisco

14   Bay-Sacramento San Joaquin Delta Estuary (San Joaquin River Flows and Southern Delta Water

15   Quality) ("Phase I Revisions to Bay-Delta Plan"), and (2) that reservoir levels are drawn down

16   significantly with the implementation of a 60% unimpaired flow requirement. The DFCR

17   admittedly did not evaluate or report on the impact on reservoirs of imposing a 60% unimpaired

18   flow requirement.

19   **PART 1 ANALYSIS**

20   6.   Using publicly available data, I replicated what I believe SWRCB Staff prepared for DFCR

21   Figure 20 (DFCR, p. 122) purporting to illustrate hydrology at Vernalis. My replicate graph (SJTA

22   Figure 1) is shown below.

23   7.   The DFCR uses a 9-component unimpaired flow summation for the San Joaquin Valley as

24   its basis of San Joaquin River flow at Vernalis. (DFRC, p. 97.) These components include not only

25   the unimpaired flow of the Stanislaus, Tuolumne and Merced Rivers near their major reservoirs, but

26   also include the San Joaquin River at Millerton Reservoir, overflows from the Tulare Lake Basin,

27   the Fresno and Chowchilla Rivers, and a couple other San Joaquin Valley components. (DFCR, p.

28   97.)

TESTIMONY OF DANIEL B. STEINER – SJTA REBUTTAL, EXHIBIT SJTA-401

Average San Joaquin River Flow at Vernalis for February to June
Unimpaired and Observed with Recommendation & Basis

SJTA Figure 1
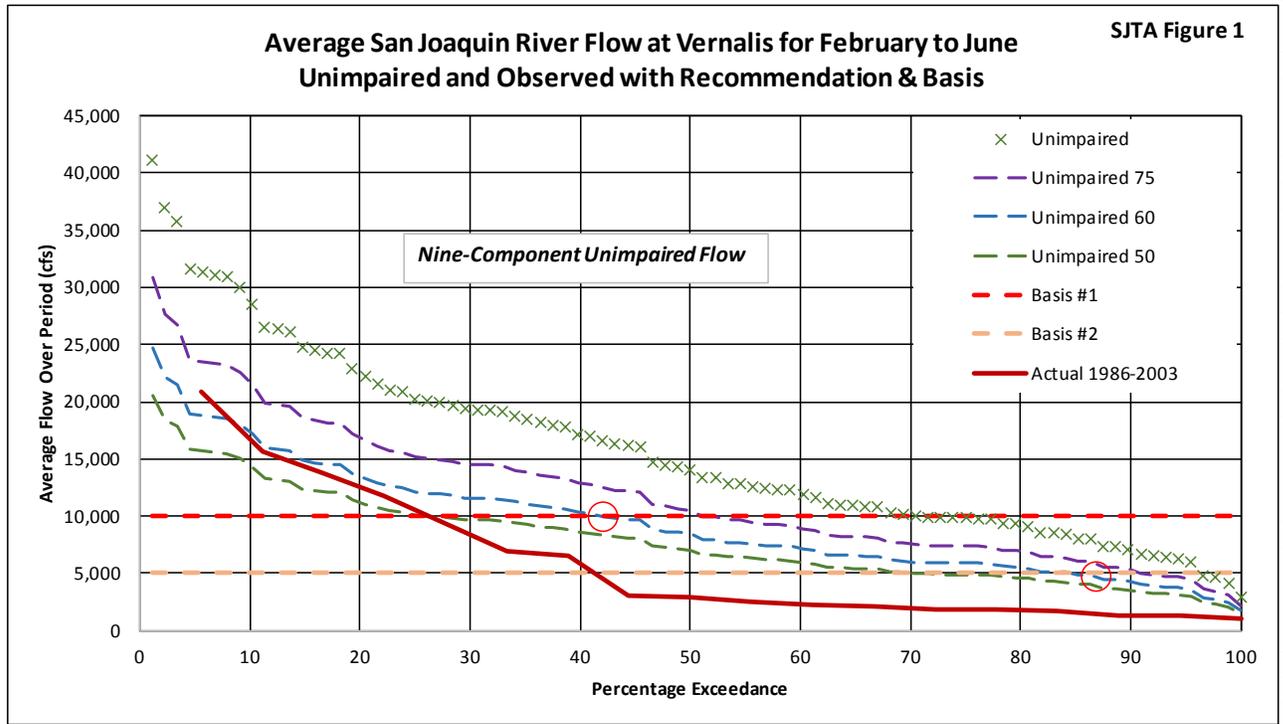
8.   "Unimpaired" flow in this analysis and used by the DFCR was acquired from the

Department of Water Resources ("DWR") and described by DWR to indicate theoretically available

flow at a location assuming existing river channel conditions absent storage regulation and stream

diversions. "Actual" flow indicates the flow that was measured at a location.

9.   More recently, DWR issued a report entitled, "Estimates of Natural and Unimpaired Flows

for the Central Valley of California: Water Years 1922-2014" (attached hereto as Exhibit 1), in

which DWR explained that the term "unimpaired" flow "is used to describe a theoretically available

water supply assuming existing river channel conditions in the absence of (1) storage regulation for

water supply and hydropower purposes, and (2) stream diversions for agricultural and municipal

uses." (Exhibit 1, p. ES-1.) By contrast, the term "natural" flow is used by DWR "to describe the

flows that would have occurred absent all anthropogenic influences and is considered to represent

the period circa 1850 prior to significant landscape changes following the California Gold Rush."

(Exhibit 1, p. ES-2.)

10. My graphic closely resembles Figure 20 in the DFCR. Differences may occur in the record

used for the analyses. While I used DWR records through 2008, the DFCR may have relied on

DWR's unimpaired analysis through 2003.

TESTIMONY OF DANIEL B. STEINER – SJTA REBUTTAL, EXHIBIT SJTA-401

1   11. The use of the Nine-Component Index for San Joaquin Valley unimpaired flow is

2 misleading in terms of the availability of water to achieve (1) the DFCR flow targets for the San

3 Joaquin River and (2) any Delta flow criteria that may be informed by the DFCR and ultimately

4 imposed upon the permits held by DWR and the United States Bureau of Reclamation ("USBR") as

5 part of the California WaterFix project. A more appropriate comparison would have been made to

6 the "Actual" flow which is illustrating the reported flow that has historically been measured at

7 Vernalis and which shows significant deficit to the DFCR requirement. Similarly, and as shown

8 below, the Nine-Component Index drastically overstates flow that could be provided under the

9 Phase I Revisions to the Bay-Delta Plan currently under consideration by the SWRCB.

10   12. Since the Phase 1 Revisions to the Bay-Delta Plan currently look only at the Stanislaus,

11 Tuolumne and Merced Rivers to meet future San Joaquin River requirements, it was of interest to

12 the SJTA to illustrate the "60% requirement" superimposed onto the DFCR "basis" flows as if only

13 the summation of the three-tributary unimpaired flows would be the water source metric. SJTA

14 Figure 2 illustrates the results. This graphic illustrates the overall downward shifting of available

15 flow to establish and support an objective at Vernalis. If still targeting 10,000 cfs and 5,000 cfs as

16 "basis" flows, having only the three-tributary flow components as the implied source of water to

17 establish the 60% flow requirement at Vernalis will produce the DFCR's basis flows less often. A

18 60% flow requirement based on a three-tributary unimpaired flow summation would result in the

19 10,000 cfs basis flow being achieved about 10% of the time and the 5,000 cfs basis flow would

20 likely only be achieved during about 40% of the time, nearing the frequency of wetter years when

21 such a requirement would be met incidentally without any unimpaired flow requirement.

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- 4 -

TESTIMONY OF DANIEL B. STEINER – SJTA REBUTTAL, EXHIBIT SJTA-401

Average San Joaquin River Flow at Vernalis for February to June
Unimpaired and Observed with Recommendation & Basis

SJTA Figure 2
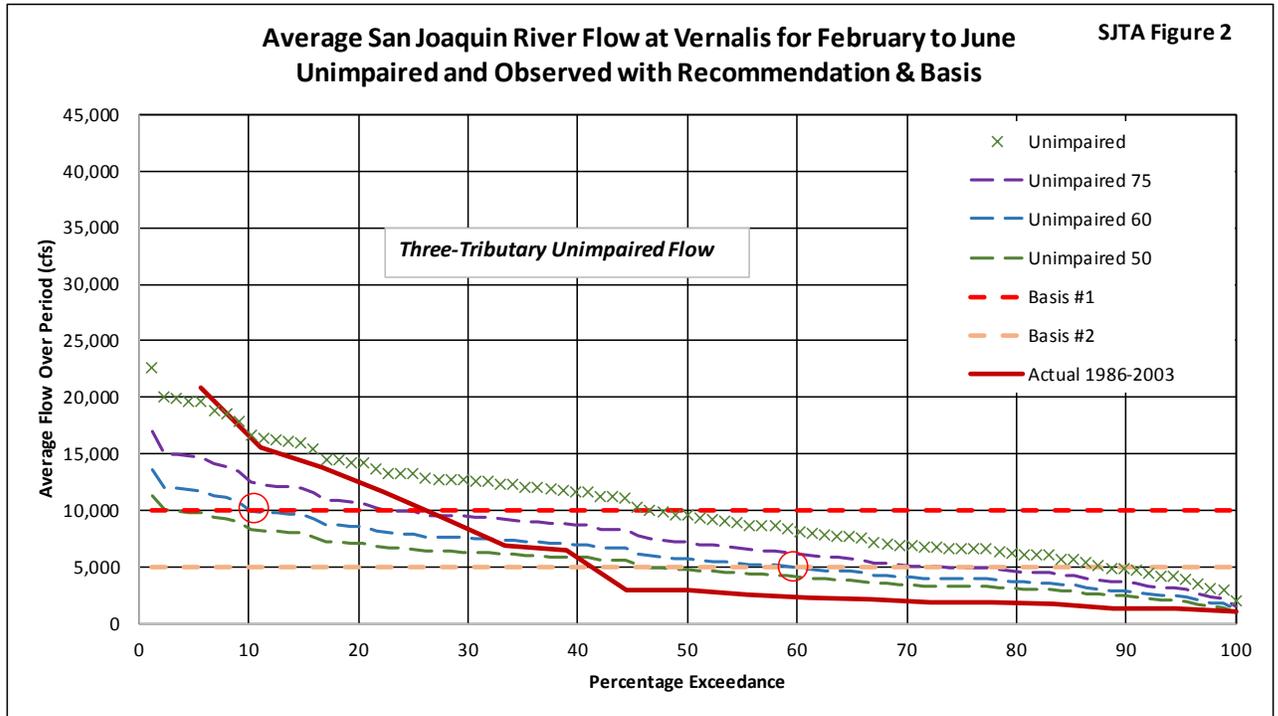
13. An additional graphic was developed to illustrate the hydrology associated with a linkage of a flow objective at Vernalis based on a 40% requirement at the Stanislaus, Tuolumne and Merced Rivers. This circumstance is reflective of the current Phase 1 Revisions to the Bay-Delta Plan. SJTA Figure 3 shows the results of the analysis.

Average San Joaquin River Flow at Vernalis for February to June
Unimpaired and Observed with Recommendation & Basis

SJTA Figure 3

TESTIMONY OF DANIEL B. STEINER – SJTA REBUTTAL, EXHIBIT SJTA-401
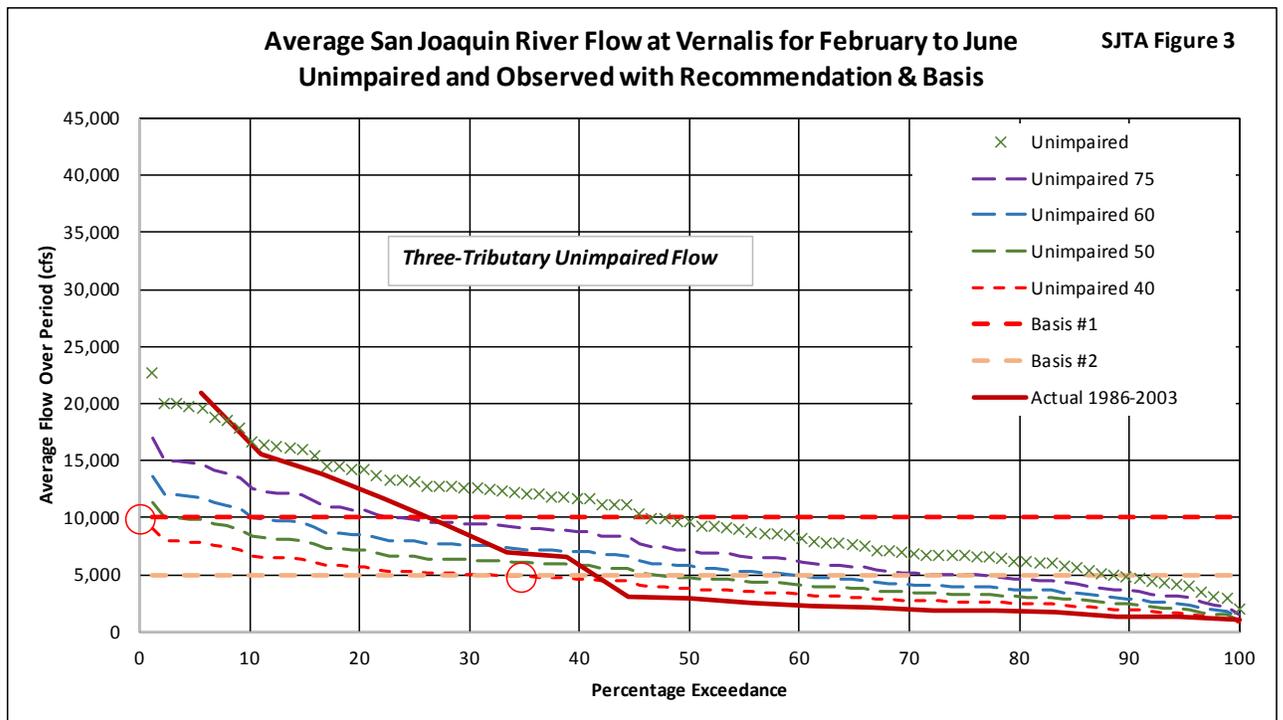
1   14. SJTA Figure 3 shows that a 10,000 cfs basis flow objective would not occur, and the 5,000

2 cfs basis flow would occur about 35% of the time, likely during wetter years when that flow

3 objective would be incidentally met without a flow objective.

4   15.   The significant effects that the DFCR suggested 60% flow requirement could have upon

5 the Stanislaus, Tuolumne and Merced Rivers was additionally analyzed through comparison

6 between the DFCR flow requirement and historical Actual flow that occurred at Vernalis (deficit

7 analysis).

8   16.   The deficit analysis compares the DFCR 60% flow requirement at Vernalis, herein defined

9 by 60% of the 150-day average daily flow during February through June using the unimpaired

10 Nine-Component Index San Joaquin River flow at Vernalis, and the 150-day average Actual daily

11 flow recorded at Vernalis. SJTA Table 1 shows the results of the comparison.

SJTA Table 1

WY	UF @ Vernalis TAF Feb-Jun	150 Days Ave CFS Feb-Jun	60% UF Ave CFS Feb-Jun	Vernalis Flow Ave CFS Feb-Jun	Deficit Ave CFS Feb-Jun	Deficit (TAF) 150-d Vol Feb-Jun	SWRCB 602020 Index Yr
1986	9,245	31,073	18,644	13,782	-4,862	-1,447	W
1987	1,859	6,248	3,749	2,526	-1,223	-364	C
1988	1,942	6,527	3,916	1,871	-2,045	-609	C
1989	3,205	10,772	6,463	1,751	-4,712	-1,402	C
1990	1,991	6,692	4,015	1,368	-2,647	-788	C
1991	2,933	9,858	5,915	1,073	-4,842	-1,441	C
1992	2,196	7,381	4,429	1,272	-3,157	-939	C
1993	6,591	22,153	13,292	3,023	-10,268	-3,055	W
1994	2,191	7,364	4,418	1,829	-2,590	-771	C
1995	9,394	31,574	18,944	15,618	-3,326	-990	W
1996	6,412	21,551	12,931	9,321	-3,610	-1,074	W
1997	5,058	17,000	10,200	11,702	Met	Met	W
1998	8,933	30,024	18,015	20,897	Met	Met	W
1999	4,833	16,244	9,746	6,943	-2,804	-834	AN
2000	5,406	18,170	10,902	6,513	-4,389	-1,306	AN
2001	2,915	9,797	5,878	2,926	-2,952	-878	D
2002	3,301	11,095	6,657	2,162	-4,495	-1,337	D
2003	3,966	13,330	7,998	2,287	-5,711	-1,699	BN
2004	3,237	10,880	6,528	2,498	-4,030	-1,199	D
2005	7,193	24,176	14,506	8,823	-5,683	-1,691	W
2006	9,193	30,898	18,539	17,734	-805	-239	W
2007	2,121	7,129	4,277	2,416	-1,861	-554	C
2008	3,057	10,275	6,165	2,159	-4,005	-1,192	C
2009	4,202	14,123	8,474	1,513	-6,961	-2,071	B
2010	5,040	16,940	10,164	3,686	-6,478	-1,927	AN
2011	7,838	26,344	15,806	14,461	-1,346	-400	W
2012	2,288	7,690	4,614	2,077	-2,537	-755	D
2013	2,154	7,240	4,344	1,787	-2,556	-761	C
2014	1,523	5,119	3,071	1,066	-2,005	-597	C

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1   17. The unimpaired flow values are available from "Estimates of Natural and Unimpaired Flows

2   for the Central Valley of California: Water Years 1922-2014", DWR, March 2016 (draft), and the

3   Actual "Vernalis Flow" is from USGS records.

4   18.   The deficits, which range widely from a 150-day volume of 364,000 acre-feet to over

5   3,000,000 acre-feet, would implicate required additional reservoir releases on the Stanislaus,

6   Tuolumne and Merced Rivers if compliance would be solely implemented to those entities. Within

7   this analysis period there were only two years during which supplemental releases would not

8   theoretically be required (1997 and 1998).

9   19. A similar analysis was prepared that defined the flow requirement as 60% of the 150-day

10   average daily flow during February through June using the unimpaired three-tributary components

11   of San Joaquin River flow, and the 150-day average Actual daily flow recorded at Vernalis. SJTA

12   Table 2 shows the results of the comparison.

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TESTIMONY OF DANIEL B. STEINER – SJTA REBUTTAL, EXHIBIT SJTA-401

SJTA Table 2

WY	UF @ Vernalis TAF Feb-Jun	150 Days Ave CFS Feb-Jun	60% UF Ave CFS Feb-Jun	Vernalis Flow Ave CFS Feb-Jun	Deficit Ave CFS Feb-Jun	Deficit (TAF) 150-d Vol Feb-Jun	SWRCB 602020 Index Yr
1986	5,513	18,529	11,117	13,782	Met	Met	W
1987	1,170	3,933	2,360	2,526	Met	Met	C
1988	1,262	4,243	2,546	1,871	-675	-201	C
1989	2,367	7,956	4,774	1,751	-3,023	-899	C
1990	1,389	4,669	2,802	1,368	-1,433	-426	C
1991	1,964	6,602	3,961	1,073	-2,888	-859	C
1992	1,443	4,849	2,909	1,272	-1,637	-487	C
1993	4,286	14,406	8,644	3,023	-5,620	-1,672	W
1994	1,471	4,945	2,967	1,829	-1,138	-339	C
1995	5,827	19,584	11,750	15,618	Met	Met	W
1996	4,248	14,277	8,566	9,321	Met	Met	W
1997	3,075	10,335	6,201	11,702	Met	Met	W
1998	5,323	17,890	10,734	20,897	Met	Met	W
1999	3,510	11,799	7,079	6,943	-136	-41	AN
2000	3,574	12,014	7,208	6,513	-695	-207	AN
2001	1,896	6,373	3,824	2,926	-897	-267	D
2002	2,313	7,773	4,664	2,162	-2,502	-744	D
2003	2,760	9,276	5,566	2,287	-3,279	-976	BN
2004	2,235	7,510	4,506	2,498	-2,008	-598	D
2005	4,830	16,234	9,740	8,823	-918	-273	W
2006	5,589	18,786	11,271	17,734	Met	Met	W
2007	1,531	5,145	3,087	2,416	-671	-200	C
2008	2,024	6,803	4,082	2,159	-1,922	-572	C
2009	2,948	9,907	5,944	1,513	-4,431	-1,318	BN
2010	3,290	11,057	6,634	3,686	-2,948	-877	AN
2011	5,121	17,212	10,327	14,461	Met	Met	W
2012	1,586	5,329	3,197	2,077	-1,120	-333	D
2013	1,503	5,050	3,030	1,787	-1,243	-370	C
2014	1,095	3,680	2,208	1,066	-1,142	-340	C
2015	862	2,897	1,738	585	-1,153	-343	C
2016	3,046	10,239	6,143	1,494	-4,649	-1,383	D
2017	7,364	24,750	14,850	23,243	Met	Met	W

20. This version of the DFCR flow requirement established for Vernalis based on 60% of an alternative unimpaired three-tributary flow still implicates large supplemental releases from the Stanislaus, Tuolumne and Merced Rivers to achieve the Vernalis flow objective. The 150-day volume deficits range from 41,000 acre-feet to over 1,600,000 acre-feet over every year type. There are several additional years during which supplemental releases may not be required.

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PART 2 ANALYSIS

21. The DFCR did not evaluate, or at least report, the potential effects on reservoir levels with the implementation of the DFCR's 60% unimpaired flow criteria on the San Joaquin River at Vernalis, particularly if it is imposed only on the three tributaries targeted by the Phase 1 Revisions to the Bay-Delta Plan. Such a requirement would significantly impact reservoir water levels and, by extension, cold water reserves that are dependent on reservoir levels. I was asked by the SJTA to illustrate the effects of a 60% unimpaired flow requirement from February through June through a surrogate analysis for the Stanislaus River.

22. The surrogate analysis of implementing a 60% flow requirement assumes the seasonal flow requirement is determined as 60% of the monthly average unimpaired flow (each month) of the Stanislaus River (calculated at Goodwin Dam) during the five-month period February through June. This flow requirement component occurs February through June, and during the other months of the year the current Stanislaus River flow requirements associated with the USBR's obligations to the Biological Opinion (Appendix 2E), Dissolved Oxygen objectives and D-1641 salinity objectives at Vernalis continue.

23. Other operational objectives for the Stanislaus River include providing diversions to Oakdale Irrigation District (OID) and South San Joaquin Irrigation District (SSJID) under their 1988 operations agreement and providing USBR's Stanislaus River CVP Water Contractors' annual allocations of water supply.

24. Current conditions of Stanislaus River operations are depicted by an operations study noted as "benchmark" and represent operational protocols identical to the surrogate study except for the February though June flow requirement. In the benchmark study, the flow requirement is defined by the Biological Opinion flows of Appendix 2E.

25. The benchmark study result for annual streamflow below Goodwin Dam is shown in SJTA Figure 4. The annual (March through September) minimum flow volume would range generally between a low of just over 200,000 acre-feet and up to about 600,000 acre-feet. Occasionally during wet years, the annual flow volume would exceed 600,000 acre-feet due to flood control releases.

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Total Goodwin Release to River — SJTA Figure 4
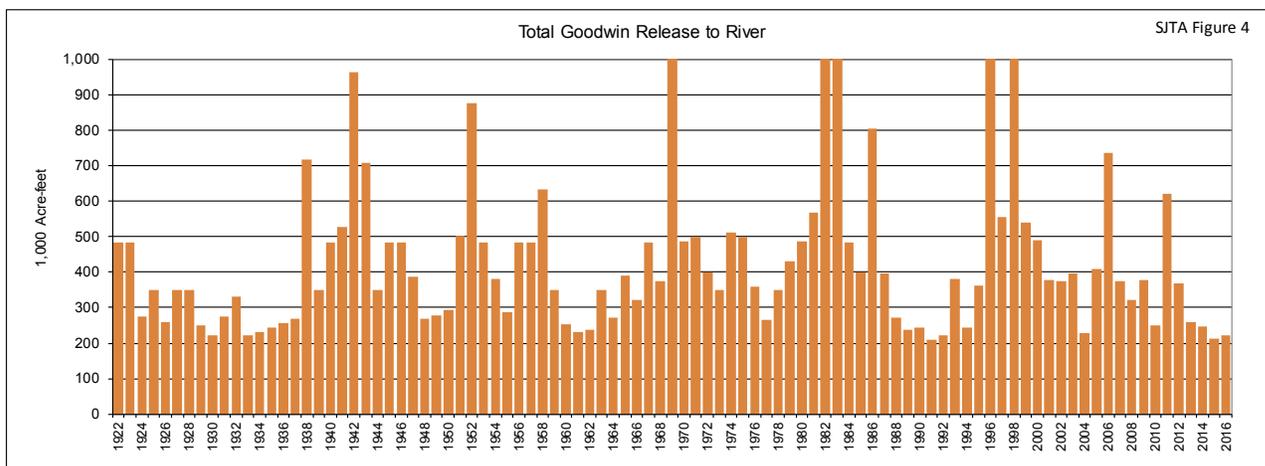
March-February Total; some year volumes may exceed graph maximum of 1,000,000 acre-feet.

26. For the surrogate study, requiring 60% Stanislaus River unimpaired flow to be released downstream during February through June, the annual flow volumes down the river are shown in SJTA Figure 5. The annual flow volume increases substantially in this study, generally always providing annual flow volumes of 300,000 acre-feet or more each year. Except for the year 1983, the annual flow volumes shown in SJTA Figure 5 also represent the "minimum" flow volumes required due to downstream objectives and requirements. The year 1983 is the only year during which flows in excess of minimum requirements were released, for flood control.

Total Goodwin Release to River — SJTA Figure 5
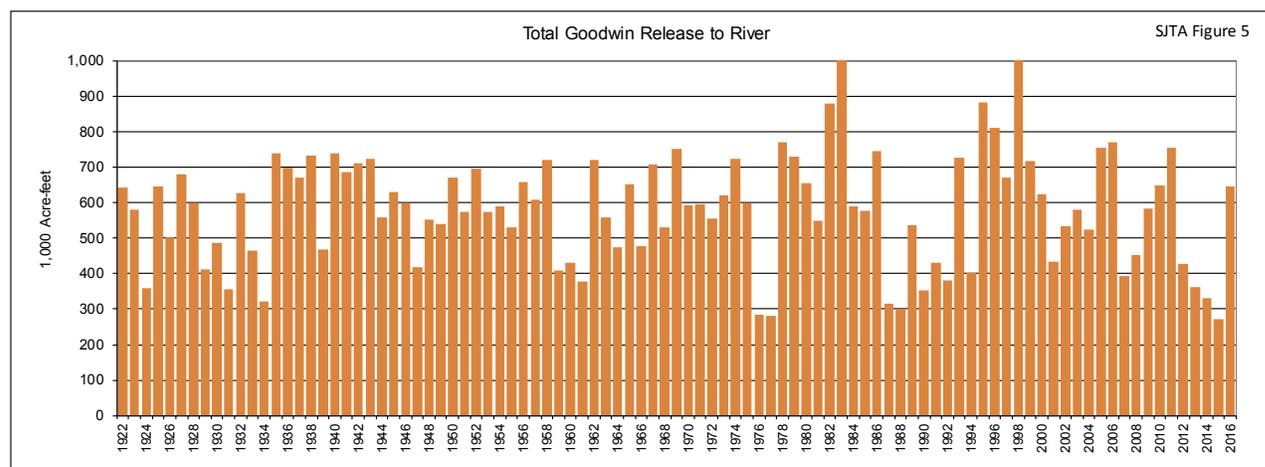
March-February Total; some year volumes exceed graph maximim of 1,000,000 acre-feet.

27. Another parameter to review concerning effects of the assumed 60% flow requirement is New Melones Reservoir storage. The storage that remains in the reservoir at the end of September is a typical parameter to review among alternative studies and provides an indication of the amount of reservoir storage "carried over" into the following water year. SJTA Figure 6 illustrates New Melones Reservoir storage at the end of each water year for the benchmark study.

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New Melones Reservoir Storage - End of September — SJTA Figure 6
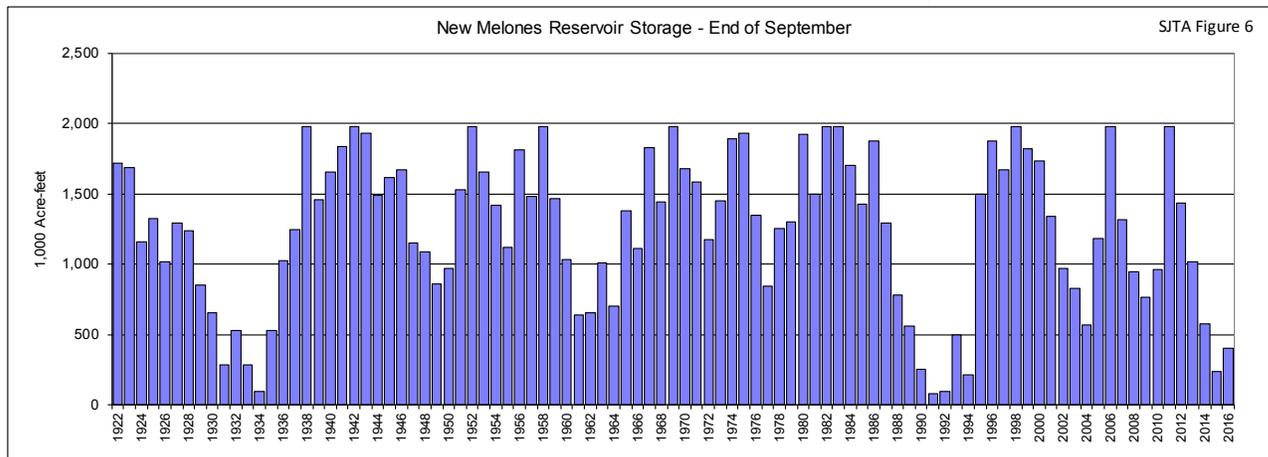
28. As seen in SJTA Figure 6, New Melones Reservoir storage fluctuates widely from a typical maximum carry over target of about 2,000,000 acre-feet (maximum desired level for ensuing flood control season) down to a low of about 80,000 acre-feet during drought cycles. Note that any year that results in an ending storage of near 80,000 acre-feet is a manifestation of the model applying cuts to the 1988 Agreement entitlement deliveries of OID and SSJID, at times drastically, to maintain the assumed minimum storage at New Melones Reservoir and required river releases.

29. SJTA Figure 7 depicts New Melones Reservoir storage at the end of each water year for the surrogate 60% requirement study.

New Melones Reservoir Storage - End of September — SJTA Figure 7
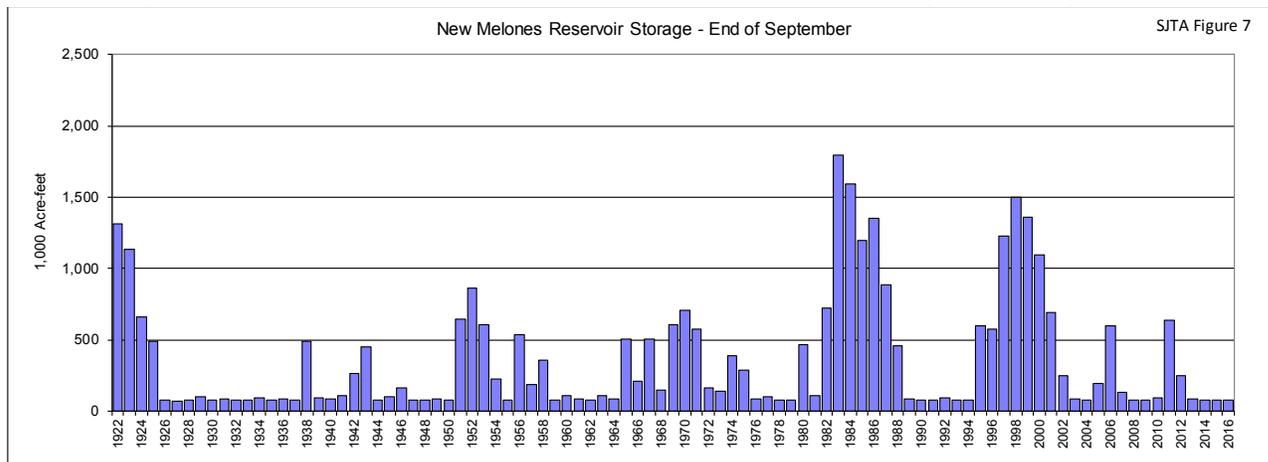
30. SJTA Figure 7 illustrates the significant draw from New Melones Reservoir to provide the larger flow requirement, many years requiring full use of reservoir storage down to the minimum assumed storage of 80,000 acre-feet. The maintaining of this minimum storage and the minimum flow requirements requires significant additional cuts to the OID and SSJID and CVP Water

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TESTIMONY OF DANIEL B. STEINER – SJTA REBUTTAL, EXHIBIT SJTA-401

1 Contractors' benchmark deliveries. The maintenance of a larger minimum reservoir storage as

2 suggested by the SWRCB in the Phase 1 Revisions to the Bay-Delta Plan would further exacerbate

3 water supply deliveries.

4   31. A summary of the results of the two Stanislaus River Operation Studies is shown in SJTA

5 Table 3.

SJTA Table 3

1922-2015/16	New Melones		Goodwin									OID / SSJID		
	New Melones Inflow	New Melones Storage	OID/SSJID Canals (Districts)	SEWD CVP Water	CSJWCD CVP Water	CVP Contracts	Instream Fish	Dissolved Oxygen	Vernalis Water Quality	Total Goodwin Release to River	Release above Minimum	OID/SSJID Formula Water	OID/SSJID Land Use & Commit Div Reqd	OID/SSJID Shortage other than Formula
Average	WY	EOS	WY	M-F	M-F	M-F	M-F	M-F	M-F	M-F	M-F	WY	WY	WY
Benchmark	1,067	1,247	505	27	59	86	352	7	5	462	82	581	523	5
60% Surrogate	1,067	362	395	15	22	37	626	15	2	650	7	581	523	116

11   32. In terms of hydrologic water supply effects compared to the benchmark study, on average

12 across the entire 95-water year study period, OID/SSJID needed to cut diversions an additional

13 average of 111,000 acre-feet more in the 60% surrogate operation to maintain reservoir minimum

14 storage and minimum flow requirements. The cuts to OID/SSJID range upward to almost 500,000

15 acre-feet a year, resulting in very little to no diversion. This was in addition to the CVP Water

16 Contractors incurring a reduction in allocations by an average of 49,000 acre-feet per year.

17   33. Even with the water supply effects described for the 60% surrogate scenario, storage at

18 New Melones Reservoir could be at minimum storage during about 46% of the years.

19   34. For this analysis the assumption used to formulate the 60% surrogate requirement for the

20 Stanislaus used 60% of the unimpaired flow of the Stanislaus River as the flow requirement. The

21 DFCR Nine-Component Index 60% requirement apportioned to the Stanislaus River could likely

22 result in a flow requirement larger than that assumed in my analysis. Therefore, my analysis may

23 understate the effects to the Stanislaus River due to the DFCR flow requirements.

24   I declare under penalty of perjury under the laws of the State of California that the foregoing

25 is true and correct and that this declaration was executed on July 10, 2018, in Sacramento,

26 California.

27

28   _____
                                          DANIEL B. STEINER

TESTIMONY OF DANIEL B. STEINER – SJTA REBUTTAL, EXHIBIT SJTA-401

EXHIBIT 1
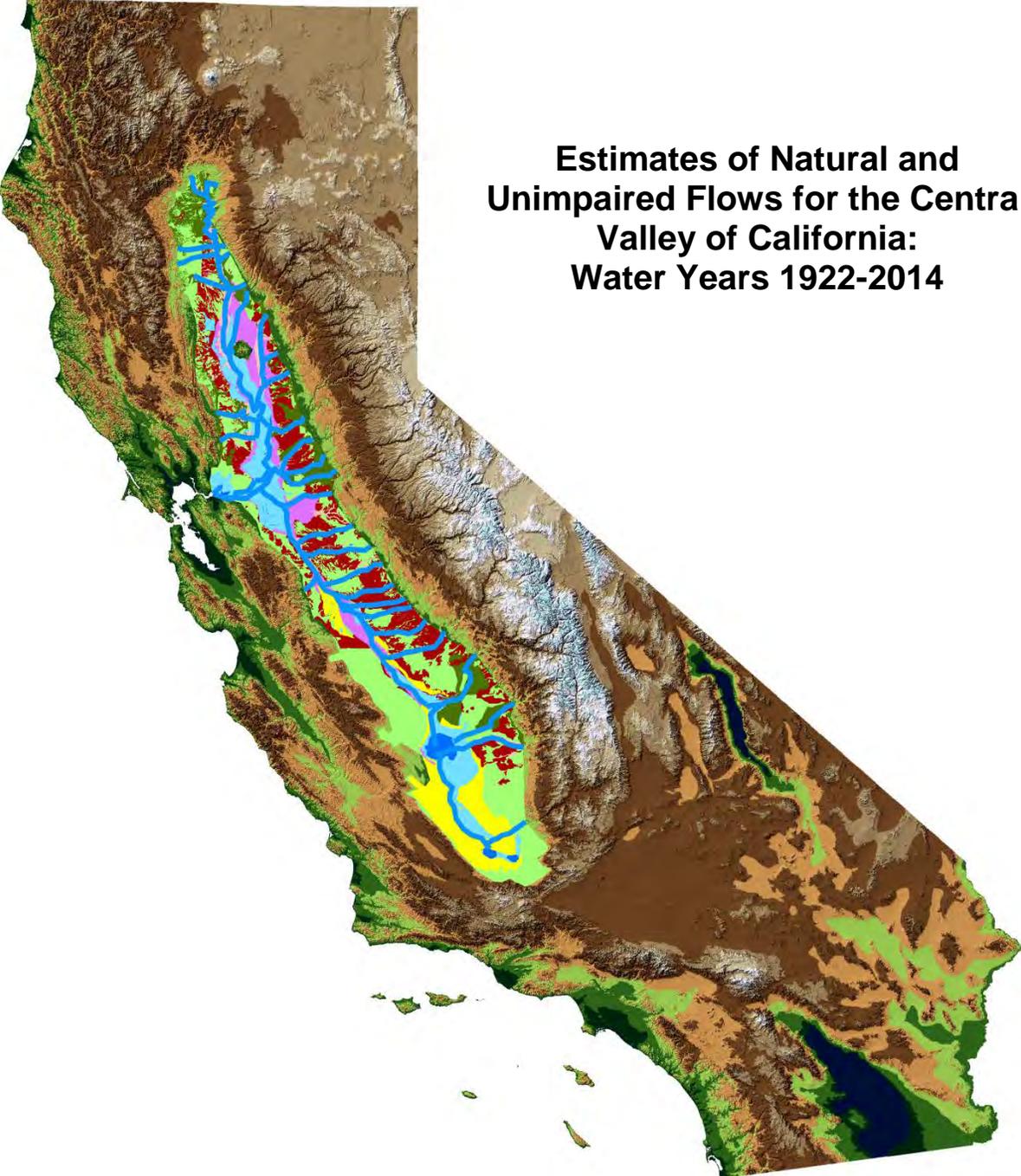
Estimates of Natural and Unimpaired Flows for the Central Valley of California: Water Years 1922-2014

March 2016 (DRAFT)

Department of Water Resources, Bay-Delta Office

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Estimates of Natural and Unimpaired Flows for the Central Valley of California:
WY 1922-2014

March 2016 – First Edition (DRAFT)

Edmund G. Brown Jr.	**John Laird**	**Mark W. Cowin**
Governor	**Secretary for Natural Resources**	**Director**
State of California	**California Natural Resources Agency**	**Department of Water Resources**

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State of California
Edmund G. Brown Jr., Governor

Natural Resources Agency
John Laird, Secretary for Resources

Department of Water Resources
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FOREWORD

This report summarizes estimates of "natural" and "unimpaired" flows for all areas in the Central Valley tributary to the Sacramento – San Joaquin Delta (Delta) for the period spanning water years 1922-2014. A major objective of this report is to clarify the conceptual differences between natural and unimpaired flows. In spite of the Department's previous attempts to distinguish between natural conditions and its calculation of theoretical unimpaired flows, unimpaired flow estimates have frequently been used as a surrogate measure of natural conditions, presumably because natural flow estimates were unavailable.

This report, which contains the Department's first published estimates of natural flows in the Central Valley tributary to the Delta, builds upon a series of publications that chronicled the Department's efforts to update estimates of unimpaired flow as new hydrologic data became available. The first edition, published in 1980, was titled *California Central Valley Natural Flow Data*. Subsequent editions in 1987, 1994, and 2007 were re-titled *California Central Valley Unimpaired Flow Data* in recognition of the conceptual differences between natural and unimpaired flows.

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EXECUTIVE SUMMARY

Purpose of Report

This report summarizes estimates of "natural" and "unimpaired" flows for all areas in the Central Valley tributary to the Sacramento – San Joaquin Delta (Delta) for the period spanning water years 1922-2014. A major objective of this report is to clarify the conceptual differences between natural and unimpaired flows. In spite of the Department's previous attempts to distinguish between natural conditions and its calculation of theoretical unimpaired flows, unimpaired flow estimates have frequently been used as a surrogate measure of natural conditions, presumably because natural flow estimates were unavailable. This report contains the Department's first published estimates of natural flows; these estimates are derived from complex simulation models and are based on published estimates of natural vegetation cover and associated evapotranspiration.

Summary of Findings

This report documents and compares a variety of natural and unimpaired flow estimates, including rim watershed inflows, valley floor water supply, and Delta inflows and outflows. Comparisons of Delta inflow and outflow estimates demonstrate that unimpaired estimates are consistently (and significantly) higher than natural estimates.

Annual average Delta outflow estimates are compared by 40-30-30 water year type, as well as over the long-term average, in Figure ES-1. For the long-term average, the annual unimpaired Delta outflow estimate (28.1 MAF) is 43 percent higher than the natural Delta outflow estimate of 19.7 MAF. Unimpaired outflow estimates are higher than natural flow estimates, primarily because the former estimates do not account for overbank flows and the resulting evapotranspiration associated with natural wetlands. The relative seasonal (i.e. monthly) distributions of unimpaired and natural Delta outflow estimates are not widely different. However, the relative distribution of unimpaired Delta outflow tends to be smaller in the winter (and larger in the other seasons) compared to natural Delta outflow. In sum, the findings of this report show that unimpaired flow estimates are poor surrogates for natural flow conditions.

Sensitivity analyses were conducted on several key model inputs and parameters. These analyses, supported by 30 model runs, suggested an uncertainty range of approximately ± 10 percent. Potential evapotranspiration from riparian and wetland vegetation was found to be the most sensitive model parameter.

Conceptual Differences between Natural and Unimpaired Flows

In this report, the term "unimpaired" flow is used to describe a theoretically available water supply assuming existing river channel conditions in the absence of (1) storage regulation for water supply and hydropower purposes and (2) stream diversions for agricultural and municipal uses. Unimpaired flow estimates are theoretical in that such conditions have not occurred historically. In pristine watersheds which have undergone little land use change, unimpaired flow estimates provide a fixed frame of reference to develop relationships between

precipitation, runoff, and water supply based on long-term hydrologic records. For many years these relationships were based on the assumption of stationarity, i.e. that the past is a good indicator of the future. However, global warming now requires hydrologists and water resources managers to analyze non-stationary processes, requiring more sophisticated tools and techniques to quantify future water supplies. This report updates and extends the Department's previous published estimates of unimpaired flows for 24 Central Valley subbasins and the Delta. Monthly unimpaired flows are presented for water years 1922-2014.

The term "natural" flow is used in this report to describe the flows that would have occurred absent all anthropogenic influences and is considered to represent the period circa 1850 prior to significant landscape changes following the California Gold Rush. These influences have dramatically affected Central Valley flows, including inflows to the Delta. For example, changes in land use, including (but not limited to) the clearance and drainage of wetlands, have affected the amount and timing of surface runoff. Groundwater pumping has impacted groundwater elevations and groundwater inflows to streams and rivers. Flood control measures, including an extensive network of levees, have ended the natural cycle of bank overflows and detention storage.

The estimates of natural flow provided in this report are not to be confused with estimates of actual flows that occurred under Paleolithic or more recent conditions prior to European settlement. Rather, these estimates assume the contemporary precipitation and inflow pattern to the valley floor (i.e. water years 1922-2014) with the valley floor in a natural or undeveloped state: before flood control facilities, levees, land reclamation, irrigation projects, imports, etc.

Summary of Methods

Methods used to estimate natural and unimpaired flows are detailed in the main body of the report. While methods used to estimate unimpaired flows generally follow the approach established in previous Department publications, those used to estimate natural flows are new. This new methodology relies on two complex models to simulate hydrology of the Central Valley rim watersheds and floor:

- SWAT (Soil Water Assessment Tool), a precipitation-runoff model, was used to simulate stream flows for most rim watersheds. SWAT, which is a public domain model developed by the U.S. Department of Agriculture, provides a tool for evaluating future potential impacts of climate change.

- C2VSim, an integrated hydrologic model, was used to simulate groundwater and surface water hydrology on the Central Valley floor. C2VSim is a Central Valley application of the Department's IWFM model.

The new approach to estimate natural flow, which is based on published estimates of the region's natural vegetation cover and associated evapotranspiration, was designed to overcome information gaps that were identified in previous unimpaired flow publications:

First, the ground water accretions from the very large area of the Central Valley floor probably were considerably higher under natural conditions but no data are available. Second, the consumptive use of the riparian vegetation and the water surfaces in the swamps and channels of the Central Valley under a natural state could be significant but are difficult to estimate. Third, during periods of high flow, Central Valley rivers would overflow their banks and water could be stored in the valley for long periods of time and could interact with item two. Fourth, the outflow from the Tulare Lake Basin under natural conditions is difficult to estimate.

SWAT-based estimates of natural rim watershed flows are somewhat different from the values used to estimate unimpaired rim watershed flows. These differences, as discussed in the main body of the report, were found to be small and therefore do not bias conclusions regarding differences between natural and unimpaired flows.

Previous Unimpaired Flow Reports

This report, which contains the Department's first published estimates of natural flows in the Central Valley tributary to the Delta, builds upon a series of publications that chronicled the Department's efforts to update estimates of unimpaired flow as new hydrologic data became available. The first edition, published in 1980, was titled *California Central Valley Natural Flow Data*. Subsequent editions in 1987, 1994, and 2007 were re-titled *California Central Valley Unimpaired Flow Data* in recognition of the conceptual differences between natural and unimpaired flows.
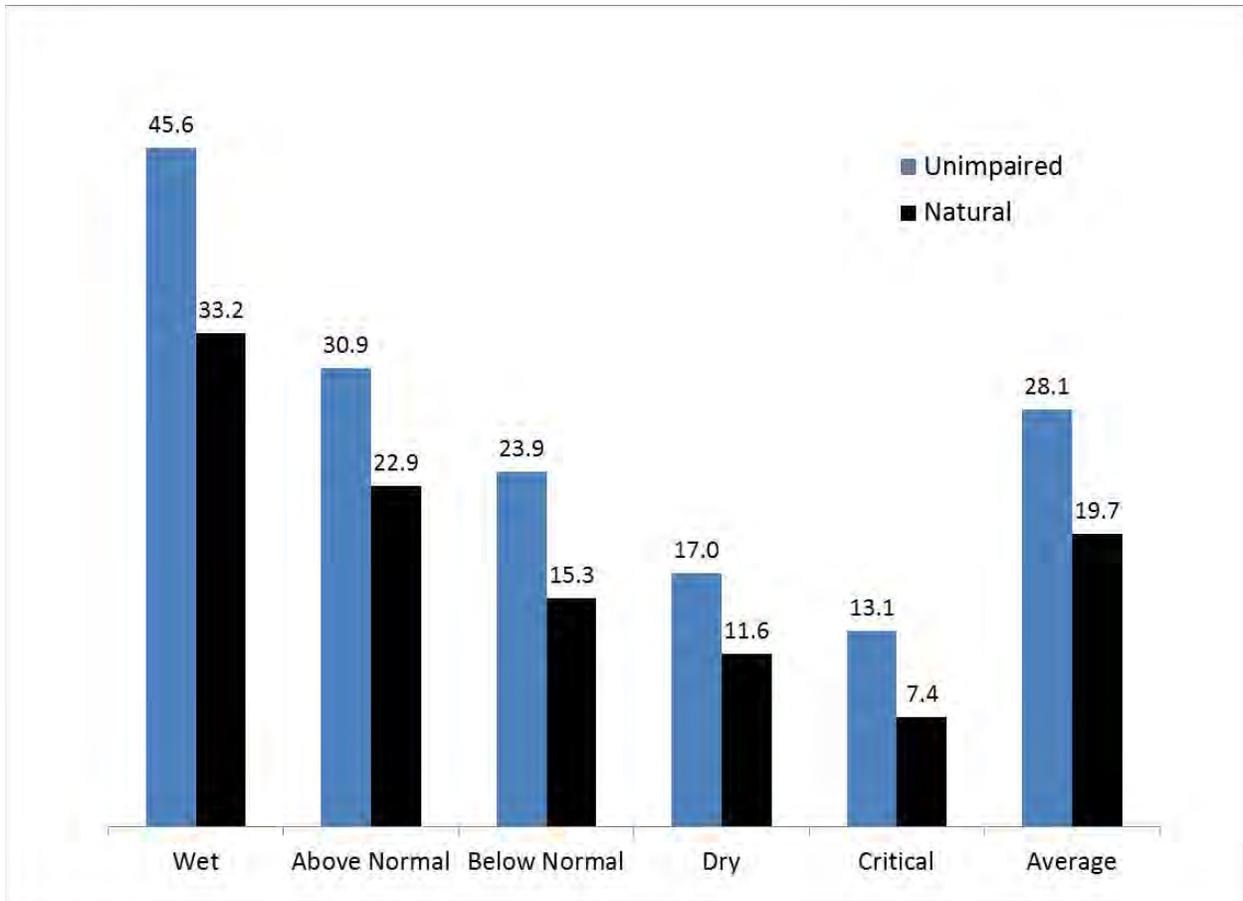
Figure ES-1. Average Annual Unimpaired and Natural Net Delta Outflow (MAF)

This chart compares annual average "unimpaired" and "natural" Delta outflow estimates (in units of million acre-feet) for the 93-year hydrologic period spanning water years 1922 through 2014. Comparisons are shown by 40-30-30 water year type as well as the full period average. This chart clearly shows that unimpaired flow estimates are significantly higher than natural flow estimates under all hydrologic conditions. Under average conditions, the annual unimpaired flow estimate is 43 percent higher than the natural flow estimate.

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ABBREVIATIONS AND ACRONYMS

AF	acre-foot
C2VSim	California Central Valley Groundwater-Surface Water Simulation Model
CSU Chico	California State University at Chico
DWR	California Department of Water Resources
ET	evapotranspiration
ET_c	Potential crop evapotranspiration
ET_o	Reference crop evapotranspiration
IWFM	Integrated Water Flow Model
MAF	million acre-feet
NF	natural flow
OWID	Oroville-Wyandotte Irrigation District
Reclamation	U.S. Department of the Interior, Bureau of Reclamation
SWAT	Soil Water Assessment Tool
TAF	thousand acre-feet
UF	unimpaired flow
USGS	U.S. Geological Survey
WY	Water Year

ACKNOWLEDGMENTS

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1. INTRODUCTION

Estimating regional water supplies that would have occurred absent human activities is a common practice in water resources planning. In this report, such theoretical water supply estimates are referred to as "unimpaired" flow. Since 1980, the Department of Water Resources (Department) has periodically published estimates of Central Valley unimpaired flows. In spite of the Department's previous attempts to distinguish between natural conditions and its calculation of theoretical unimpaired flows, unimpaired flow estimates have frequently been used as a surrogate measure of natural conditions, presumably because natural flow estimates were unavailable. A major objective of this report is to clarify the conceptual differences between natural and unimpaired flows.

In this report, the term "unimpaired" flow is used to describe a theoretically available water supply assuming existing river channel conditions in the absence of (1) storage regulation for water supply and hydropower purposes and (2) stream diversions for agricultural and municipal uses. Unimpaired flow estimates are theoretical in that such conditions have not occurred historically. In pristine watersheds which have undergone little land use change, unimpaired flow estimates provide a fixed frame of reference to develop relationships between precipitation, runoff, and water supply based on long-term hydrologic records. For many years these relationships were based on the assumption of stationarity, i.e. that the past is a good indicator of the future. However, global warming now requires hydrologists and water resources managers to analyze non-stationary processes, requiring more sophisticated tools and techniques to quantify future water supplies. This report updates and extends the Department's previous published estimates of unimpaired flows for 24 Central Valley subbasins and the Delta. Monthly unimpaired flows are presented for water years 1922-2014.

The term "natural" flow is used in this report to describe the flows that would have occurred absent all anthropogenic influences and is considered to represent the period circa 1850 prior to significant landscape changes following the California Gold Rush. These influences have dramatically affected inflows to the Delta. For example, changes in land use, including (but not limited to) the clearance and drainage of wetlands, have affected the amount and timing of surface runoff. Groundwater pumping has impacted groundwater elevations and groundwater inflows to streams and rivers. Flood control measures, including an extensive network of levees, have ended the natural cycle of bank overflows and detention storage.

The estimates of natural flow provided in this report are not to be confused with estimates of actual flows that occurred under Paleolithic or more recent conditions prior to European settlement. Rather, these estimates assume the contemporary precipitation and inflow pattern to the valley floor (i.e. water years 1922-2014) with the valley floor in a natural or undeveloped state: before flood control facilities, levees, land reclamation, irrigation projects, imports, etc.

The mountain and foothill watersheds that surround the Central Valley are relatively pristine. Land use changes have not dramatically affected the volume and timing of seasonal runoff in these watersheds. Furthermore, these watersheds have limited groundwater aquifers. Therefore, in these watersheds, unimpaired flows may be calculated relatively simply by adjusting observed gaged data to remove the effects of (1) upstream changes in surface water storage, (2) basin imports, and (3) basin exports. Given that anthropogenic impacts are relatively small in these upstream watersheds, unimpaired and natural flow estimates are likely to be similar, and for the purposes of this report are assumed to be the same.

The main body of this report, comprised of six chapters and references, provides conceptual differences between natural and unimpaired flow estimates, describes the methods used to develop these estimates, and presents summary results and conclusions. Details of the SWAT model, a model used as part of the natural flow methodology to estimate rim watershed contributions, are presented in Appendix A. Additional appendices summarize tables of monthly unimpaired and natural flow and differences between the two estimates.

2. CONCEPTUAL DIFFERENCES BETWEEN NATURAL AND UNIMPAIRED FLOWS

Full natural flow, natural flow, natural runoff and unimpaired flow are all phrases that have been used by the Department in various publications to represent the runoff from a basin that would have occurred had man not altered the flow of water in the basin. Of special interest here is a series of publications that reported updates to the Department's Central Valley unimpaired flow estimates. The first edition of this series was titled *California Central Valley Natural Flow Data*. Subsequent editions were re-titled *California Central Valley Unimpaired Flow Data* in recognition of the conceptual differences between natural and unimpaired flows.

The word "natural" connotes that the Central Valley landscape is in a pre-development or pristine state. The word "unimpaired", on the other hand, implies that certain items in the measured flows have been adjusted. Unimpaired flow could be synonymous with natural flow if all of the items in the unimpaired estimation procedure matched the natural flow estimation. In practice, this is not usually the case; it is customary to include only those items in the unimpaired flow estimation for which either reliable data are readily available or reasonable estimates can be made. In previous editions of the Department's *California Central Valley Unimpaired Flow Data* the data are better described as unimpaired data, primarily because of the difficulty in estimating four items of significance, as follows:

- First, groundwater accretions from the very large area of the Central Valley floor probably were considerably higher under natural conditions but no data are available.

- Second, the consumptive use of the riparian vegetation and the water surfaces in the swamps and channels of the Central Valley under a natural state were significant but are difficult to estimate.

- Third, during periods of high flow, Central Valley rivers would overflow their banks and water could be stored in natural low-lying basins for long periods of time, recharging groundwater and providing water for natural wetlands and perennial grasslands.

- Fourth, the outflow from the Tulare Lake Basin under natural conditions may have been significant in wet years, but are difficult to estimate.

The unimpaired flows in this report assume that the river channels of the valley are in their present configuration. Figure 2-1 shows the 24 subbasin boundaries established by the Department for reporting estimated monthly unimpaired flow time series data for the Central Valley beginning Water Year 1922 (DWR, 2007). The areas of the Central Valley (Figure 2-1) can be separated into three main regions: the upper watersheds of the Sierra Nevada and coastal mountain ranges (colored light blue in Figure 2-1); the valley floor, typically the areas below the 500-foot elevation contour, (shown in green in Figure 2-1); and the Delta. The Delta is part of the valley floor but for accounting purposes is identified separately (Area 24 in Figure 2-1). When referring to areas tributary to the Delta, the Tulare Basin (Area 23 and associated watersheds) contribute minimal surface water (flood flows from the Kings River to the San
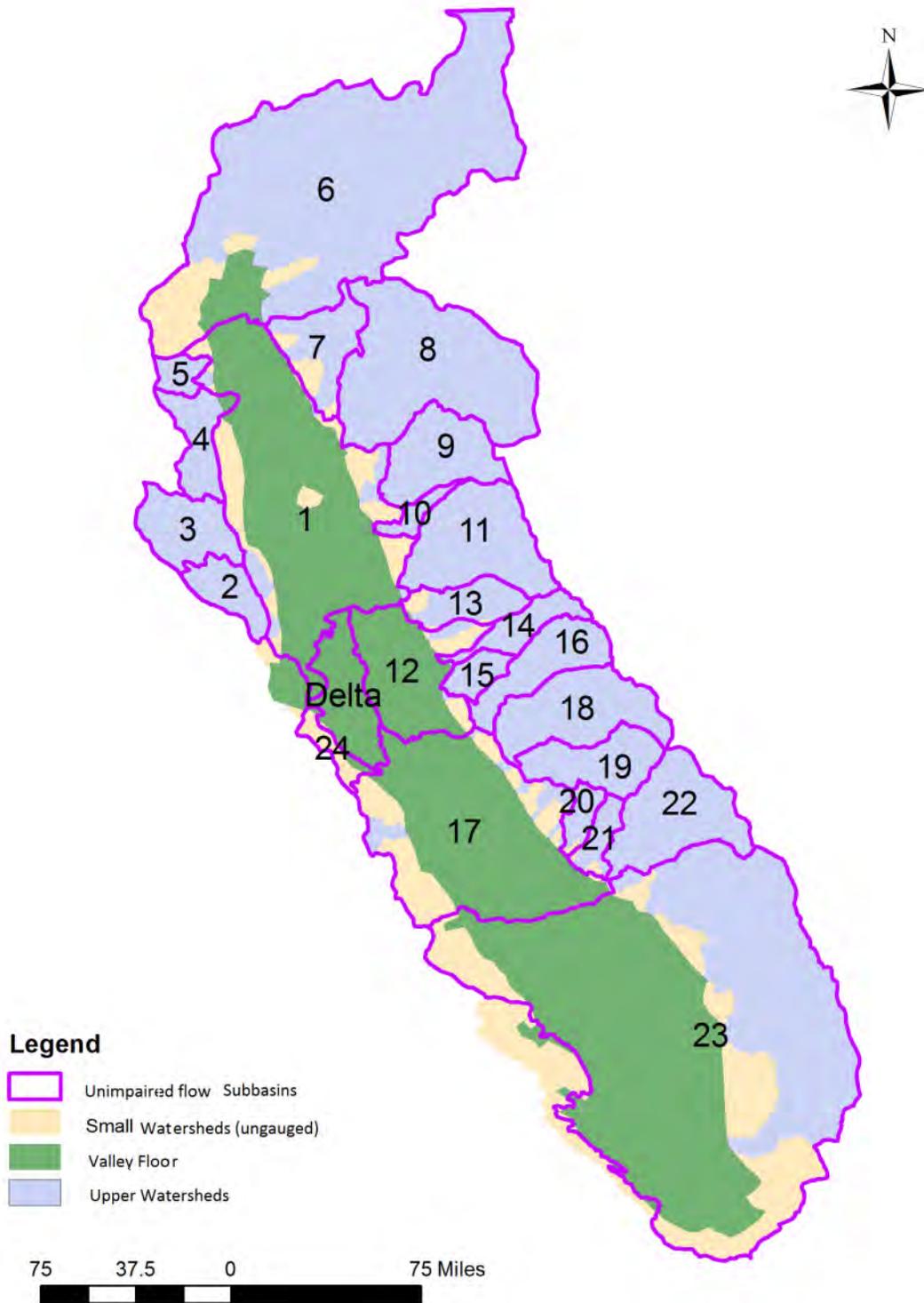
Figure 2-1. Unimpaired Flow Subbasins in the Central Valley

Joaquin River). However, the subsurface ground water system between the San Joaquin River Basin and Tulare Basin are connected.

The main source of natural water on any of the watersheds shown in Figure 2-1 is precipitation in the form of rainfall and snowfall. That precipitation is subjected to different physical processes (e.g., accumulation and melt for snowfall, runoff, soil moisture storage, deep percolation, evaporation and evapotranspiration). In addition, if the area is developed for agriculture and/or urbanized, streamflows from precipitation are subject to further modifications such as storage regulation, diversions and return flows. For general planning purposes and sometimes for regulatory needs, it is important to estimate the water supply generated in a watershed due to the precipitation that falls on that area prior to any human or anthropogenic development. One can approach this in two ways:

1. Start with a measured outflow (gaged) for an area, which represents impaired flow, and then "unimpair" (or modify) that flow for any anthropogenic impacts (e.g., diversions, return flows, imports into an areas, or exports from an area) to arrive at an estimate of unimpaired flow.

2. Use physically based computer models to simulate the outflow from the area under pre-development land use conditions to arrive at an estimate of natural flow.

How the unimpaired and natural flow estimates differ in magnitude and interpretation will depend on the degree of land use development (i.e., alteration of pre-development native conditions due to agriculture or urbanization). Figure 2-2 divides the major watersheds in the Central Valley tributary to the Sacramento – San Joaquin Delta into three distinct regions: the upper watersheds in the Sierra Nevada Mountains and Coastal Mountains (shown in green); the valley floor (shown in yellow); and the Delta (shown in red).

For the mountain watersheds, precipitation runoff (both rainfall and snowfall) is subject to changes in volume and timing as reflected in the watershed stream outflows. The causes for modifications to streamflows include vegetative evapotranspiration or consumptive use, sublimation, snow accumulation and snowmelt, overland and subsurface shallow flow, infiltration, and stream/groundwater interaction. Outflows from the upper watersheds become inflows to the Sacramento and San Joaquin Valley floor areas. Volumetrically most of these flows are surface streamflows (including shallow subsurface flows) while some are subsurface flows that feed the valley floor ground water systems. These outflows from the upper watersheds become inflows to the flat valley areas of the Central Valley. (Although the Tulare Basin contributes only a very small quantity of runoff to the Delta, selected flow estimates for this hydrologic region are included in this report for completeness.) Minimal runoff contributions to these upper watersheds are provided from areas outside of California.

For the valley floor, inflows from the upper watersheds along with local precipitation are modified in magnitude and timing before becoming inflow to the Delta. Causes of modifications include vegetative consumptive use (riparian, native vegetation, etc.), overbank flows from streams during high flow conditions, formation and disappearance of lakes and wetlands,

stream/groundwater interaction, infiltration, runoff, return flows, and uptake from groundwater to meet vegetative consumptive water demands.

Within the Delta, outflows from the Sacramento Valley, Eastside Streams, and San Joaquin Valley are subject to further modifications due to in-Delta vegetative consumptive use, evaporation from open water surfaces, wetlands, and lakes, and stream-groundwater interaction, before flowing into the San Francisco Bay and Pacific Ocean as Delta outflow.
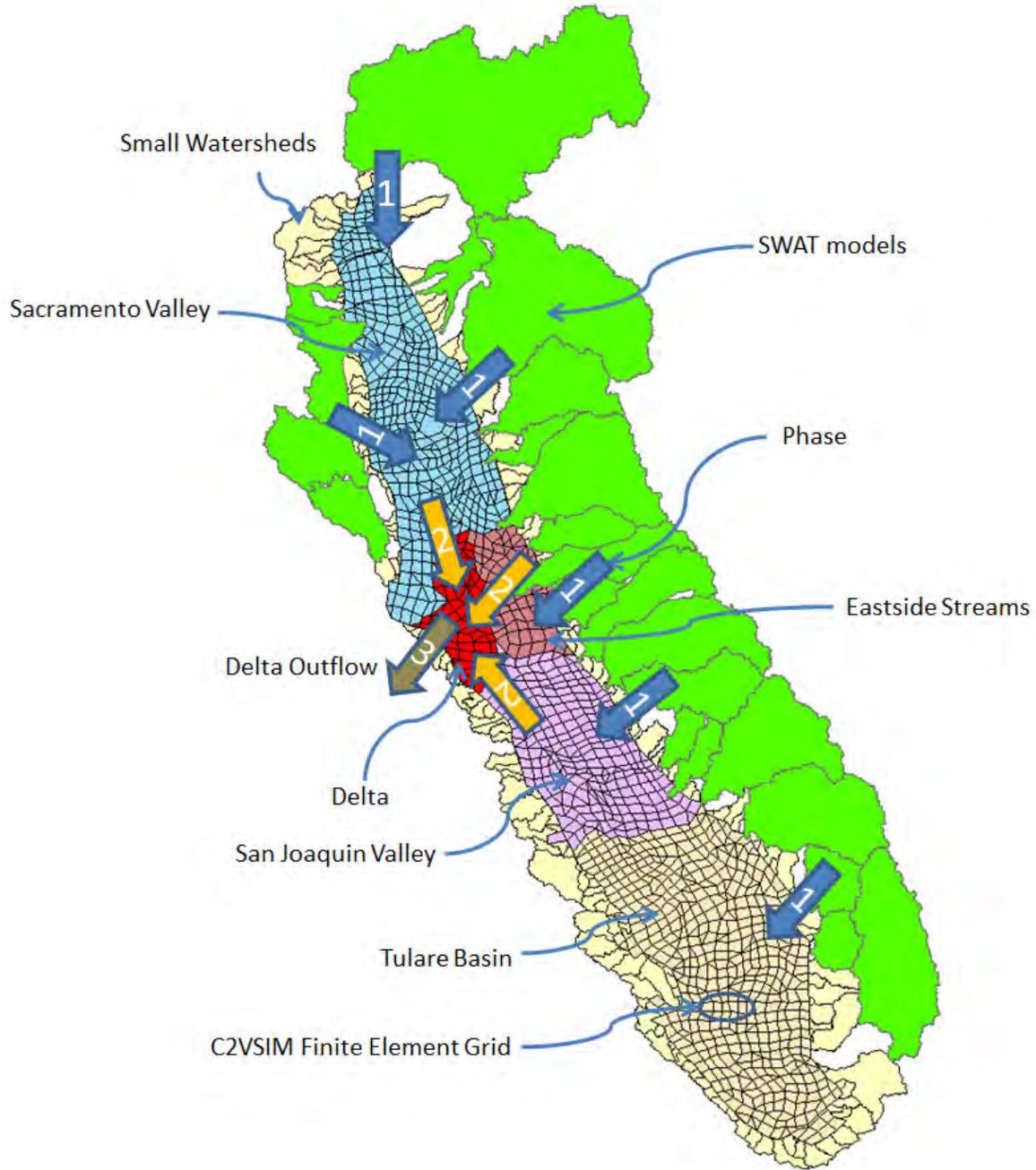
Figure 2-2. Three Major Phases Affecting Water Travel from the Upper Watersheds to Delta Outflow

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3. ESTIMATES OF UNIMPAIRED FLOWS

Introduction

The Department first published estimated unimpaired flows for 24 Central Valley subbasins and the Delta in a 1980 report titled Central Valley Natural Flow Data. The report presented monthly flows for water years 1920-1978. Data for October 1920 through September 1983 were published in a 1987 report titled California Central Valley Unimpaired Flow Data, Second Edition. The title of the second edition corrected the misuse of the term "Natural Flow." The extension of unimpaired flow data from October 1983 through September 1992 was published in August 1994 as the Third Edition. The Fourth Edition, published in 1997, added data for October 1992 through September 2003.

This chapter describes the extension of unimpaired flow data through water year 2014 of the 1921-2003 data found in the *California Central Valley Unimpaired Flow Data Fourth Edition - Draft* (DWR, 2007), prepared by the Bay-Delta Office. The text describing the procedures used to estimate the unimpaired flows is taken from the 2007 report (with minor editorial changes) and updated when necessary. The information below also explains any differences in calculations between the 2007 report and this report. For flow data taken directly from the Department's Snow Survey records, unimpaired flow estimation procedures are also provided where available.

The unimpaired flows as presented in this report are an extension in time of previous published values by the Department**. Appendix B contains tables of monthly unimpaired flows for each of the** 24 **subbasins in the Central Valley**. In addition, estimates are included of the total unimpaired inflow to the Delta, and the total unimpaired net Delta outflow.

Procedures Used to Estimate Unimpaired Flows

UF 1— Sacramento Valley Floor

These values represent the estimated unimpaired flow for the Sacramento Valley floor and the minor streams from the Stony Creek drainage area to the Cache Creek drainage area, from the Cache Creek drainage area to the mouth of the Sacramento River, and from the Feather River drainage area to the American River drainage area (Bulletin No. 1 areas 2-8, 2-9, 2-16, and 2-29). With Bulletin No. 1 mean seasonal runoff as a base, these minor streams were estimated to be 2.18 times the Bear River near Wheatland (776/356=2.18). In the unimpaired flow data published in the 1966 —Surface Water Hydrology of Yuba-Bear Rivers Hydrographic Unit office report, the 1911-1960 average runoff of the Bear River near Wheatland was 5.05 times that of Dry Creek near Wheatland. The resulting runoff for the 1921 through 1960 period was estimated by multiplying 11 (2.18 x 5.05) by the estimated monthly runoff of Dry Creek near Wheatland.

Unimpaired runoff for the 1961-1992 period was estimated as the product of 2.18 times the estimated unimpaired flow of the Bear River near Wheatland due to the discontinued Dry Creek

record. Since this estimation showed abnormally high summer flows, the June flows were reduced by one-half and flows for July, August and September were made equal to zero.

The unimpaired flow data for the 1993 – 2003 period was estimated using similar procedure as that of the 1961 – 1992 period flow data. However, we note the rationale for reducing June flows by one-half and setting the July to September flows to zero as subjective that need to be revisited and verified in future updates. For the 2011-2014 period, the subjective reduction for June-September was not applied.

UF 2 — Putah Creek near Winters

The unimpaired flow for Putah Creek near Winters for water year 1921 was obtained from the 1964 DWR office report —Surface Water Hydrology of Putah-Cache Hydrographic Unit. The unimpaired flow of Putah Creek near Winters for the 33 year period (1922-1954) was assumed to be equal to the historical flow USGS gage 11454000, Putah Creek near Winters. Flows for the 1955-1992 period were obtained from USGS gage 11454000, adjusted for the changes in storage and evaporation from Lake Berryessa starting in January 1957. Flows for the 1993 to 2014 period were extended similarly.

UF 3 — Cache Creek above Rumsey

These flows represent the estimated unimpaired flow of Cache Creek above Rumsey. The 1921 unimpaired flow was based on the 1964 "Surface Water Hydrology of Putah-Cache Creeks Hydrographic Unit" office report and was calculated by adding together Table 18 (Cache Creek at Lower Lake, unimpaired flow), Table 21 (Bear Creek near Rumsey), Table 22 (North Fork Cache Creek near Lower Lake), and data from an incremental ungauged area equivalent to 0.41 times the flow of North Fork Cache Creek. The factor 0.41 was used in estimating historical outflow of depletion Study Area 16 (Cache Creek above Rumsey) in the 1966 joint DWR – U.S. Department of the Interior, Bureau of Reclamation (Reclamation) Central Valley depletion study.

Unimpaired runoff for the 1922 through 1960 water year period was obtained by adding the differences between Table 18 (Cache Creek at Lower Lake, unimpaired flow) and Table 20 (Cache Creek near Lower Lake, recorded flow) of the 1964 office report mentioned above to the historical outflow of Joint Depletion Study Area 16 (Cache Creek above Rumsey). The difference between Tables 18 and 20 corrects the historical flow for upstream depletion and regulation due to Clear Lake.

Unimpaired flows for 1961-1970 were calculated by the same method except that the computer program OUTFLOW (developed by the DWR Statewide Planning Branch) was used to find Cache Creek at Lower Lake unimpaired flow instead of Table 18. This program determined the unimpaired outflow of Clear Lake with a given net supply. The net supply for Clear Lake was calculated by adding together the historical outflow of Cache Creek near Lower Lake, (USGS water supply papers), the average lake evaporation (lake area at average monthly gage height times average monthly evaporation), and change in gage height times average lake area).

Beginning with water year 1971, the unimpaired flow of Cache Creek above Rumsey was estimated as the sum of the estimated unimpaired outflow of Clear Lake plus the flows from Bear Creek near Rumsey, North Fork Cache Creek near Lower Lake and the remaining area between the gages at those three locations and the Rumsey gage. For water years 1971 through 1973 and 1976 through 1978, the accretions were calculated as the difference in measured flow of Cache Creek above Rumsey and the three upstream gages. For water years 1974 and 1975, the accretions were estimated by graphical correlation with the unimpaired flow of North Fork Cache Creek near Lower Lake. The equation is:

Accretions = 0.47674 (North Fork) – 11,688 acre-feet

Adjustments for the estimated changes in storage and evaporation of Indian Valley Reservoir began in December 1974. For water years 1981 through 1983, the unimpaired flow was estimated as the sum of the historical flow of Cache Creek at Rumsey plus the net effects of Indian Valley Reservoir and Clear Lake.

Flows for 1984-1992 were estimated as the sum of historical flow of Cache Creek at Rumsey plus net effects of Clear Lake and Indian Valley Reservoir. The net effect of Clear Lake is estimated as:

Clear Lake outflow from the Cache HEC-3 Model minus historical Clear Lake flow near Lower Lake (Clear Lake historical outflow).

For the 1993 to 2003 period, similar procedure as the 1984 to 1992 period was used except that USGS gage (11451000) data for Clear Lake outflow was used instead of HEC-3 model output. It is assumed that the gage data are more representative than the HEC-3 model output.

For 2004 to 2014 period, unimpaired flow estimate was made as the sum of unimpaired North Fork Cache Creek near Clear Lake Oaks, unimpaired Cache Creek near Lower Lake, and Bear Creek above Holsten Chimney Canyon near Rumsey, a scale factor of 1.28 was applied for drainage area between Cache Creek above Rumsey and these three subbasins.

UF 4 — Stony Creek at Black Butte

These flows are the estimated unimpaired flows of Stony Creek at Black Butte Reservoir. Unimpaired flows for water year 1921 were obtained from the DWR office report —Surface Water Hydrology-Upper Sacramento Valley, January 1968. Runoff for 1922 through 1949 was obtained from Reclamation Appendix I —Hydrology on Black Butte Unit, Stony Creek Division, Central Valley Basin, February 1951. Extensions of the flows were made in about 1960 by Reclamation personnel to cover water years 1950 through 1957. The flows for the 1958-1992 period were estimated by adding together the historical outflow of Stony Creek at Black Butte (USGS water supply papers), historical export of South Diversion Canal, and the changes in storage and evaporation from Stony Gorge, East Park, and Black Butte Reservoirs. Flows for the 1993 to 2014 period were extended similarly.

UF 5 — Sacramento Valley West Side Minor Streams

These flows represent the estimated unimpaired flow of the west side area between the Red Bluff gage on the Sacramento River and the Stony Creek drainage area on the west side of the Sacramento Valley. The runoff for water year 1921 was derived by adding the historical outflows of the Redbank Creek group, Thomes Creek at Paskenta, Thomes Creek above 500-foot contour, and Elder Creek near Henleyville. Flows for the 1922-1954 period were derived by adding the historical outflow of Thomes and Elder Creeks (Joint Depletion Study Area 5, Elder Creek group) to Tables 33 (Redbank Creek group) and 36 (unmeasured area, Thomes Creek above 500-foot contour) of the 1957 Joint Hydrology Study. Estimated historical flows for Thomes Creek at Paskenta are from a DWR 1968 office report, —Surface Water Hydrology-Upper Sacramento Valley.

The annual flows for Redbank Creek group and Elder Creek near Henleyville were derived by correlation with Elder Creek near Paskenta as set forth in the 1968 —Surface Water Hydrology-Upper Sacramento Valley report. The data on annual flows for Elder Creek near Henleyville were then distributed according to the monthly flows of Elder Creek at Paskenta. Annual flow data for the Redbank Creek group were distributed according to the nine monthly flows of Thomes Creek at Paskenta.

Thomes Creek above the 500-foot contour was correlated to Thomes Creek at Paskenta to obtain the yearly flows, which were then distributed according to the monthly flows of the same creek.

Unimpaired runoff for the 1955-1983 period was derived by adding the outflow of the Redbank Creek group, Thomes Creek at Paskenta, Thomes Creek above 500-foot contour, and Elder Creek at Gerber.

Flows for Thomes Creek at Paskenta, Elder Creek at Paskenta, and Elder Creek at Gerber were obtained from the USGS water supply papers. The gage Elder Creek at Gerber was discontinued in 1979, and flows after that time were correlated with Elder Creek near Paskenta. Also, the gage Red Bank Creek near Red Bluff was discontinued in 1982 and later flows were estimated by correlation with Thomes Creek at Paskenta.

Annual flows (1955-1983) for Thomes Creek above 500-foot contour were obtained by correlation with Thomes Creek at Paskenta and distributed according to the monthly flows of Elder Creek at Gerber and Thomes Creek at Paskenta after Elder Creek at Gerber was discontinued.

Annual flows (1955-1959) for the Redbank Creek group were obtained by correlation with historical flows of Elder Creek near Paskenta and distributed according to the monthly flows of Elder Creek at Paskenta. Monthly flows (1960-1983) for the Redbank Creek group were estimated by multiplying Redbank Creek near Red Bluff by an area precipitation ratio of 1.88. Since there was negligible historical development within this area, historical flows were assumed to be unimpaired.

Unimpaired runoff for 1984 to 1992 was derived by adding the outflows of the Redbank Group; Thomes Creek at Paskenta; Thomes Creek above the 500-foot contour; and Elder Creek at Gerber. Unimpaired runoff for the 1993 to 2003 period was estimated using the same procedure used for the 1984 to 1992 period unimpaired flow calculation.

UF 6 — Sacramento River near Red Bluff (CDEC ID SBB)

Data were taken from the Department's Snow Survey records.

In 1969 USGS moved the Red Bluff gage upstream to a new site 3 miles above Bend Bridge. The new gage no longer measures Paynes Creek flows. To be consistent with pre-1969 Sacramento River near Red Bluff, the flows of Paynes Creek near Red Bluff are added to the unimpaired flows developed by the Department's Snow Surveys Branch.

In 1970 USGS discontinued the gage of Paynes Creek near Red Bluff. Therefore, Paynes Creek was estimated by graphical correlation with Mill Creek near Los Molinos, using measured data from 1950-1960.

Monthly unimpaired flows are calculated from measured flows reported by USGS gage 11377100, Sacramento River above Bend Bridge, then adjusting by:

1. Change in storage at Shasta and Whiskeytown reservoirs.

2. Adding evaporation (gross) at Shasta Reservoir reported by Reclamation.

3. Less import from the Trinity River at Judge Francis Carr powerhouse.

4. **Adding an estimate for change in storage, irrigation, and consumptive use upstream in the Pit River and Redding basins. The monthly pattern of the 315 thousand acre-feet (TAF) annual depletion adjustment is, in TAF:**

October	28.5	April	37.0
November	2.5	May	54.0
December	4.0	June	56.0
January	6.0	July	43.0
February	7.0	August	35.0
March	7.0	September	35.0

Before WY 1969 the Sacramento River flows were measured 10 miles downstream near Red Bluff. The older location included the small Paynes Creek drainage of 93 square miles.

UF 7 — Sacramento Valley East Side Minor Streams

This area is located on the east side of the Sacramento Valley between the Red Bluff gage (Sacramento River) and the Feather River drainage area. Runoff for the 10/21-9/80 period was estimated by adding the historical outflow of Joint Depletion Study Areas 6 (Antelope Creek Group), 7 (Mill Creek), 8 (Deer Creek Group), 9 (Big Chico Creek), and 14 (Minor East Side Tributaries, Big Chico to Feather). Runoff for the 10/20-9/21 period was estimated by correlation with Deer Creek near Vina.

Unimpaired runoff is equivalent to the historical runoff within these basins minus the historical import from the west branch of the Feather River. Import for the period 10/20-9/30 is estimated. Data for the period 10/30-9/83 is taken from USGS Water Supply Reports. The data are listed under —Butte Creek near Chico.

The flows for 1984-1992 were assumed to be the same as historical outflow of depletion areas 66 and 14, minus the import from the west branch of the Feather River. Flows for the 2003 to 2014 period were extended similarly.

UF 8 — Feather River near Oroville (CDEC ID FTO)

Data were taken from the Department's Snow Survey records.

The unimpaired flow at this site is calculated from:

1. Observed flow at the USGS station No. 114070, "Feather River at Oroville", which is just upstream from the fish barrier dam.

2. Add Thermalito Afterbay releases to the Feather River. (In recent years the State Water Project provides the sum of Items 1 and 2 as "Oroville Complex River Release".)

3. Add diversions at the Thermalito Complex into Western Canal, Richvale Canal, the PG&E lateral, and Sutter Butte Canal.

4. Change in storage of the complex: Thermalito Diversion Pool, Thermalito Forebay, and Thermalito Afterbay.

5. Add evaporation at Thermalito Afterbay from the Department of Water Resources, Northern District.

6. Lake Oroville change in storage.

7. Lake Oroville evaporation (gross).

8. Add Palermo and Bangor Canal diversions.

9. Add Oroville-Wyandotte Canal (aka Forbestown Ditch), Hendricks and Miocene Canal (diversions above Oroville Lake).

10. Change in storage at Lake Almanor, Mountain Meadows, Butt Valley, Bucks Lake, Frenchman, Antelope, Lake Davis, Little Grass Valley and Sly Creek reservoirs.

11. Add estimated evaporation for the reservoirs listed in item 11, taken as 1.4 times Lake Almanor evaporation, based on a monthly capacity – evaporation table from Great Western Power Company (PG&E predecessor). Summer amounts can easily be 300 cfs on Lake Almanor.

12. Subtract Slate Creek Tunnel import from the Yuba River basin.

13. Subtract Little Truckee River import into Sierra Valley. This has been taken to be 6.6 TAF in recent years on a pattern:

April	0.1	July	1.2
May	1.9	August	.2
June	3.1	September	.1

14. Add depletion for upstream irrigation and consumptive use of 75 TAF per year.

Some data on Little Truckee River imports are available in Northern District watermaster reports. It is recommended that this data be obtained and reviewed to see if the standard pattern is still reasonable.

The Oroville-Wyandotte Irrigation District (OWID) Canal annual diversion of 16.5 TAF per year were from about 1970 through August 2014. The closing of Woodleaf Lumber Mill in 1962 and other factors have reduced OWID Canal usage to around 6 TAF in recent years. The monthly upstream depletion amounts have apparently been taken as constant since about 1970.

The monthly distribution of depletion and the OWID Canal is as follows, TAF:

Month	Depletion	OWID	Month	Depletion	OWID
October	0.9	.74	April	1.3	1.0
November	.2	.29	May	7.5	.37
December	.1	.13	June	22.5	.71
January	.1	.07	July	21.3	1.11
February	0	.04	August	13.6	1.29
March	0	.05	September	7.5	1.19

Before the construction of Oroville Dam and the Thermalito Complex, the gage was upstream a few miles with 17 (out of 3,624) square miles less drainage area before July 1962. The estimations before completion of the Afterbay in 1967 did not include Thermalito complex releases because all the water being diverted flowed by the gage.

UF 9 — Yuba River at Smartville (CDEC ID YRS)

Data were taken from the Department's Snow Survey records.

These flows are taken as the measured flow of the Yuba River below Englebright Dam near Smartville, USGS Gage 11418000, (now measured by PG&E) plus Deer Creek near Smartville, Gage 11418500.

1. Plus diversions from PG&E's Drum Canal and South Yuba Canal, at Gage YB 31, Nevada Irrigation District's D-S Canal, Cascade Ditch, and in earlier years (pre Merle Collins Reservoir in 1963) Browns Valley Canal.

2. Plus exports to the Feather River via Slate Creek Tunnel.

3. Less imports to the Yuba from the Bear River in South Yuba Canal at Gage YB 34.

4. Change in storage at the Lake Spaulding South Yuba System (from PG&E), Bullards Bar, Englebright (Narrows), Bowman Lake, French Lake, Jackson Meadows, and Scotts Flat reservoirs.

5. Evaporation and consumptive use are neglected.

In earlier estimations prior to 1975, the estimations included small amounts in Nevada Irrigation District's Excelsior Ditch, which apparently ceased functioning in 1967 and Snow Mountain Ditch until summer 1974, when its flows were combined with and routed into Cascade Ditch.

UF 10 — Bear River near Wheatland

The unimpaired flow for the Bear River for the period 1921-58 were obtained from the DWR Nov. 1966 Office Report —Surface Water Hydrology of Yuba-Bear Rivers Hydrologic Unit. Flows for 1959-63 were obtained from the Department's Snow Surveys Branch. The period 1964-1983 was calculated by adding the following:

1. Historical flow of Bear River near Wheatland – USGS water supply papers.

2. South Yuba Canal – DWR Snow Surveys.

3. Boardman Canal – USGS water supply papers.

4. Towle Canal – DWR Snow Surveys, until 1971, after which it was neglected.

5. Gold Hill Canal – Depletion Study Area 56 historical export data.

6. Bear River Canal – Depletion Study Area 56 historical export data.

7. Camp Far West Diversion – (Includes Camp Far West North and South Canals and South Sutter Conveyance Canal).

And deducting the following items:

1. Drum Canal – DWR Snow Surveys

2. Lake Valley Canal – Depletion Study Area 22 historical export data.

3. South Yuba Canal – DWR Snow Surveys

4. D-S. Canal to Bear River via Greenhorn Creek – DWR Snow Surveys.

Plus the changes in storage of the following reservoirs:

1. Camp Far West (1921-1958) – DWR Snow Surveys; (1959-1983) – USGS water supply papers.

2. Rollins – USGS water supply papers.

3. Combie – DWR Snow Surveys.

Unimpaired runoff for 1984 to 1992 was calculated by adding the following:

1. Unimpaired Bear River flow at the Van Trent gage (1922-29); flow at the gage near Wheatland (1929-92)

2. Evaporation from Camp Far West Reservoir

3. Evaporation from Combie Reservoir

4. Evaporation from Rollins Reservoir

5. Change in storage at Camp Far West Reservoir

6. Change in storage at Combie Reservoir

7. Change in storage at Rollins Reservoir

8. Total exports above Camp Far West Reservoir

9. Camp Far West Water District South Canal diversion

10. Camp Far West Water District North Canal diversion

11. South Sutter Water District diversion

12. Historical depletion

And deducting the following items:

1. Consumptive use of replaced native vegetation

2. Total imports above Camp Far West

Flows for the 2003 to 2014 period were extended in the same manner as that of the 1993 to 2003 extension.

UF 11 — American River at Fair Oaks (CDEC ID AMF)

Data were taken from DWR Snow Survey records.

The calculations of unimpaired flow start with observed flow of USGS station 11446500 then:

1. Add Lake Valley Canal diversion

2. Add diversion from the Folsom Lake pumps (old North Fork and Natomas Ditches.

3. Subtract imports from Echo Lake Flume (1.5 TAF per year estimate) and via South Canal (YB-90) from the Bear River Canal.

4. Change in storage at Folsom Lake, French Meadows, Hell Hole, Lake Valley, Caples Lake, Silver Lake, Ice House, Loon Lake, Union Valley, Slab Creek, Stumpy Meadows, and Lake Natoma.

5. Add Folsom Lake evaporation as estimated by Reclamation.

6. Add a constant estimate of depletion above Folsom Dam of 11.4 TAF per year on this pattern:

October	.4	April	.2
November	.2	May	.6
December	.2	June	2.1
January	.2	July	2.5
February	.2	August	2.6
March	.2	September	2.0

7. Add diversion through the American River Pump station near the site of the once-proposed Auburn Dam.

UF 12 — San Joaquin Valley East Side Minor Streams

These flows represent the estimated unimpaired runoff on the valley floor east of the Delta for the minor streams that lie between the Stanislaus River and the American River drainage areas. The runoff was estimated by multiplying the area precipitation ratio of 3.85 by the monthly runoff of Dry Creek near Galt.

UF 13 — Consumnes River at Michigan Bar (CDEC ID CSN)

Data were taken from DWR Snow Survey records.

Unimpaired monthly flows at this station consist of the observed flow of USGS station No. 11335000, Cosumnes River at Michigan Bar, adjusted by adding Camino Conduit diversions (shown as part of the Camp Creek near Somerset records), and adding change in storage at Jenkinson Lake. Data for both adjustments are provided by the Eldorado Irrigation District.

UF 14 — Mokelumne River at Pardee Reservoir (CDEC ID PAR)

Data were taken from DWR Snow Survey records.

The estimated unimpaired flow at this location is the total outflow from Pardee Reservoir plus change in storage at Pardee, and PG&E's Salt Springs and Lower Bear River reservoirs, and several small old upstream reservoirs (Upper Bear, Upper Blue, Lower Blue, Twin, and Meadow lakes). Pardee Reservoir outflows include:

1. Controlled releases through the powerplant and sluice valves.

2. Uncontrolled releases over the spillway overflow.

3. Estimated leakage.

4. Releases to Jackson Valley Irrigation District

5. Releases into the Mokelumne Aqueduct to the East Bay area.

6. Evaporation at Pardee Reservoir

The natural flow figures are estimated by East Bay Municipal Utility District and furnished to DWR Snow Surveys. Sometime prior to 1971, the estimated flows were developed by taking the measured flow at the USGS Station 11319500 "Mokelumne River near Mokelumne Hill",

adding Amador Canal diversions to the Jackson area, and adjusting for upstream PG&E storage. The exact time, prior to 1971, when the transition in methods took place is unknown.

UF 15 — Calaveras River at Jenny Lind

The unimpaired runoff of the Calaveras River at Jenny Lind was estimated to be the measured flow plus the change in storage and net evaporation of Old and New Hogan reservoirs. Occasional estimated negative flows were assumed to be zero. The estimated unimpaired flow for the 1921 to 1948 period of the Calaveras River above Jenny Lind was assumed to be equal to the historical outflow of Joint Depletion Study Area 32 (Calaveras River above Jenny Lind). Historical upstream depletions were considered to be negligible and probably offset by small imports from the Mokelumne River. Adjustment for the effect of Old Hogan Reservoir was made for the period January 1949 to December 1963. Before 1949, no records were kept on the storage of Old Hogan Reservoir. Since there were no gates prior to 1949 with which to regulate Hogan Reservoir, the only effect on the runoff was a short-term delay in heavy flood runoff. Unimpaired runoff of the Calaveras River then was assumed to be the same as the measured flow. Old Hogan Reservoir was inundated in the fall of 1963. No records of Old Hogan storage operation could be found from November 1, 1962 to December 1963. To determine the impairment during this period, the inflow to Hogan Reservoir was estimated from measured releases and estimates of net reservoir evaporation and storage changes. Inflow from November 1962 through December 1963 was estimated to be the sum of measured flow in the Calaveras River below Hogan Dam (159,360 acre feet (AF)) plus estimated net reservoir evaporation of 1,700 AF, plus the gain in storage at the end of December 1963 (1,240 AF in New Hogan Dam less the TAF in Old Hogan Dam on November 1, 1962). Thus, total inflow was 161,300 AF. The total inflow consisted of the sum of the North and South Forks of the Calaveras River plus Calaveritas Creek (all USGS stations) at 133,060 AF and an unmeasured accretion calculated to be 28,240 AF by difference. The monthly pattern of the unmeasured accretion was assumed to be distributed on the average of the pattern of the three upper stations and the pattern of Cosgrove Creek near Valley Springs.

After December 1963, unimpaired runoff was estimated by adjusting the Calaveras River flows for changes in storage in, evaporation from, and precipitation on New Hogan Reservoir. Storage and evaporation were reported in USGS water supply papers. Precipitation was estimated by multiplying precipitation at the Hogan Dam station times New Hogan Reservoir area. The surface area was based on the storage-capacity table in the 1972 USGS water supply paper.

The Calaveras at Jenny Lind station was discontinued in 1966. The Jenny Lind station was extended by adding estimated accretions between Jenny Lind and New Hogan to the runoff of Calaveras River below New Hogan Dam. The accretions were estimated to be 1.42 times those of Cosgrove Creek near Valley Springs. The factor 1.42 is the ratio of the drainage area (30 square miles) of the Jenny Lind to New Hogan Reach to that of Cosgrove Creek near Valley Springs (21.1 square miles).

Flow for 1984-2003 was estimated as the sum of historical flow of the Calaveras River below New Hogan Dam plus the net effects of New Hogan Dam, historical gross evaporation of New

Hogan Reservoir and accretions to Calaveras River between Jenny Lind and New Hogan Dam. Flows for the 2003 to 2014 period were extended similarly.

UF 16 — Stanislaus River at Melones Reservoir (CDEC ID SNS)

Data were taken from DWR Snow Survey records.

Estimations begin with the USGS gage No. 113020 of the same name which has been operated since 1957. To the observed flow are added Tuolumne Canal near Long Barn, Oakdale Canal, and South San Joaquin Canal diversions. (Diversions to the Central Valley Project contractors in eastern San Joaquin County via the new Stockton East tunnel at Goodwin Dam are currently being made and included, but did not start until after 1994.)

Adjust for change in storage at New Melones (Old Melones prior to November 1978) Relief, Strawberry, Lyons, Donnell, Beardsley, Tulloch, Spicer Meadows (since 1989) and, prior to 1989, the Utica system reservoirs. The Utica system includes Lake Alpine (4.1 TAF) and Union (3.1 TAF) Reservoirs and also the old 4 TAF capacity Spicer Meadows reservoir. When the Utica System was accounted for, the storage change for a month was considered the same each year as follows: units are TAF:

October	-3.2	April	11.6
November	-0.8	May	0
December	0	June	-1.7
January	0	July	-3.0
February	0	August	-2.0
March	0	September	-0.9

The estimated evaporation from New Melones Reservoir is added. Before completion of New Melones Reservoir an estimate of monthly evaporation was used which was based on a curve of storage verses evaporation.

UF 17 — San Joaquin Valley Floor

These figures represent the estimated unimpaired valley-floor flows of the minor streams from the San Joaquin River at Friant to San Joaquin River at Vernalis, and the west side of the San Joaquin Valley above the valley floor tributary to the San Joaquin River. With Bulletin No. 1 mean seasonal runoff as a base, these minor streams were found to be 2.615 (238,500/91,300) times the Chowchilla River flows at Buchanan Dam site. The 1922-1954 average runoff for the Chowchilla River at the gage was 66 TAF. Comparable minor-stream 1922-1954 runoff was 172,400 AF. Runoff from Joint Depletion Study

Area 43 (Chowchilla River above Buchanan Dam site) was 67,600 AF, slightly higher than the gage because some adjacent drainage area was included. The resulting monthly runoff for the minor streams was estimated by multiplying a factor of 2.55 (172,400/67,600) by the historical outflow of Joint Depletion Study Area 43.

Flow for 1984-1992 was estimated by multiplying the factor 2.55 by the sum of the historical outflow of DA43 Chowchilla River above Buchanan Dam site plus net effect of Eastman Lake.

Flows for the 2003 to 2014 period were extended similarly.

UF 18 — Tuolumne River at Don Pedro Reservoir (CDEC ID TLG)

Data were taken from DWR Snow Survey records.

The estimations begin with the measured flow at the USGS gage 11289650 "Tuolumne River below La Grange Dam" and add:

1. Diversions by the City and County of San Francisco through the Hetch Hetchy Aqueduct.

2. Change in storage at Hetch Hetchy, Lake Eleanor, and Lake Lloyd (Cherry Valley) reservoirs.

3. Estimated net evaporation of 2.0 feet per year at Hetch Hetchy, Lake Eleanor, and Lake Lloyd based on surface area. This is summed from daily estimations based on a fixed monthly rate and combined surface reservoir area.

4. Change in storage at New Don Pedro Reservoir beginning in November 1970 and at the Old Don Pedro Reservoir prior to then.

5. Evaporation at Don Pedro reservoir, estimated at 50.2 inches per year net, estimated from daily reservoir area and an average monthly rate, varying by month.

6. Diversion into Modesto and Turlock Canals near La Grange.

The natural flows at La Grange Dam are estimated by Turlock Irrigation District and provided to the Department.

UF 19 — Merced River at Exchequer Reservoir (CDEC ID MRC)

Data were taken from DWR Snow Survey records.

Estimated unimpaired flows start with measured flow at the above station, USGS gage 11270900, and add:

1. Diversions in the North Side Canal.

2. Change in storage at Lake McClure (Exchequer), enlarged in 1967, and McSwain Reservoir.

3. Estimated monthly average evaporation at Lake McClure and McSwain.

Estimated annual evaporation is 22.45 TAF and is listed below, by month, in TAF:

October	1.55	April	1.60
November	1.00	May	2.60
December	.60	June	3.25
January	.50	July	3.85
February	.70	August	3.30
March	1.30	September	2.20

UF 20 — Chowchilla River at Buchanan Reservoir

The estimated unimpaired flow for the Chowchilla River at Buchanan Reservoir was assumed to be equal to the historical outflow of Joint Depletion Study Area 43 (Chowchilla River above Buchanan Dam site). Historical upstream depletions and imports were considered to be negligible.

Flow for 1984-1992 was estimated as the sum of the historical outflow of DA43 Chowchilla River above Buchanan Dam site plus net effect of Eastman Lake. Flows for the 2003 to 2014 period were extended similarly.

UF 21 — Fresno River near Daulton

The estimated unimpaired flow for the Fresno River near Daulton was assumed to be equal to the historical outflow from Joint Depletion Study Area 45 (Fresno River). Historical upstream depletions and imports were considered to be negligible. Flow for 1984-1992 was estimated as the sum of the historical outflow of DA45 plus net effect of Hensley Lake (Hidden Dam). Flows for the 2003 to 2014 period were extended similarly.

UF 22 — San Joaquin River at Millerton Reservoir (CDEC ID SJF)

Data were taken from DWR Snow Survey records, as furnished by Reclamation. Unimpaired flow of the San Joaquin River is calculated from the observed flow of USGS gage 11251000 San Joaquin River below Friant and adding the following:

1. Diversions from Millerton Lake to the Friant-Kern and Madera canals.
2. Change in storage at Millerton Lake.
3. Evaporation from Millerton Lake, as determined by Reclamation.
4. **Change in storage at upstream reservoirs: Florence, Thomas A. Edison, Huntington, Shaver, Mammoth Pool, Redinger, Crane Valley (Bass Lake), and Kerckhoff reservoirs.**

UF 23 — Tulare Lake Basin Outflow

The amounts of unimpaired flow originating in the Tulare Lake Basin that would reach the Delta are subject to considerable conjecture. The historical outflow of Joint Depletion Study Area 60

(Tulare Lake Basin) was considered to be a reasonable estimate for present purposes. The outflow is measured by USGS gage 11253500, James Bypass (Fresno Slough) near the San Joaquin River. Gaged data were not adjusted for the effects of Pine Flat Dam on Kings River flows north to the Mendota Pool.

UF 24 — San Joaquin Valley West Side Minor Streams

The estimated unimpaired flows for the minor streams on the west side of the San Joaquin Valley that are tributary to the Delta were assumed to be equal to the historical outflow of Joint Depletion Study Area 51 (west side minor streams, south Delta). This consisted of the estimated historical flow of Marsh Creek near Byron.

Sacramento Valley Unimpaired Total Outflow

Flows for 1921-2014 were estimated as the sum of UF 1 through UF 11.

East Side Streams Unimpaired Total Outflow

Flows for 1921-2014 were estimated as the sum of UF 12 through UF 15.

San Joaquin Valley Unimpaired Total Outflow

Flows for 1921-2014 were estimated as the sum of UF 16 through UF 24.

Delta Unimpaired Total Inflow

Flows for 1921-2014 were estimated as the sum of:

1. Sacramento Valley Unimpaired Total Outflow

2. East Side Streams Unimpaired Total Outflow

3. San Joaquin Valley Unimpaired Total Outflow

Delta Unimpaired Net Use

Delta water use was estimated as the sum of Delta uplands net water use and Delta lowlands net water use. Delta net water use under unimpaired conditions assumes that existing Delta levees and islands would remain in-place.

In previous reports net use in the lowlands is estimated as the sum of water surface evaporation, consumptive use of riparian vegetation, and seepage from Delta channels, minus the precipitation on the lowland channels and riparian vegetation areas. Precipitation on the islands and seepage from the lowland channels are assumed to be fully depleted. The DOP Consumptive Use Model was used to estimate water surface evaporation and evapotranspiration of riparian vegetation. Seepage losses were estimated using data from Chapter 4 of the Appendix to DWR Bulletin 76 (1962).

In previous report net use in the uplands was estimated as the sum of the consumptive use of native vegetation, consumptive use of riparian vegetation, and evaporation from the water surfaces, minus the precipitation on the entire uplands. In the uplands, all historical irrigated agriculture and urban areas were replaced with native vegetation. Consumptive use of native

vegetation is limited to precipitation and stored soil moisture, whereas a full water supply is assumed available for riparian vegetation. Consumptive uses for the uplands were estimated using the Bay-Delta Office Consumptive Use Model.

In this report Delta net use was estimated as:

Delta net use = Delta Uplands net use + Delta Lowlands net use

Where:

Delta Uplands net use = Delta Uplands consumptive use – Delta uplands total precipitation

Delta Lowlands net use = Delta Lowlands consumptive use + Delta seepage -Delta lowlands total precipitation

Delta Unimpaired Total Outflow

Flow for 1921-1992 was estimated as the Delta Unimpaired Total Inflow minus the Uplands Net Use (DA55) minus the Lowlands Unimpaired Net Use (DA54). Flows for the 1993 to 2013 period were extended similarly.

4. SIMULATION OF NATURAL FLOWS

Introduction

As described in the previous California Central Valley Unimpaired Flow Report (DWR 2007), natural flow represents streamflows that would have occurred under a pre-development or pristine landscape. In contrast, unimpaired flows are theoretical values based on measured flows that have been adjusted to remove the influences of upstream diversions, storage, and exports and imports from other basins. A series of modeling tools and extensive input data have to be used in estimating natural flow conditions. Daily simulations of natural flows from October 1, 1921 through September 30, 2014 were developed using precipitation-snowmelt-runoff models for the upper watersheds that are tributary to the California Central Valley. Subsequently, these flows are routed through the Central Valley floor area using a modified version of the California Central Valley Groundwater-Surface Water Simulation Model (C2VSim) for water years 1922 through 2014. Natural Delta inflows and natural net Delta outflow are estimated for the 93-year period.

Upstream Watersheds

A precipitation-runoff simulation model provides two important advantages over the use of the upper watershed unimpaired flows described in Chapter 3. First, such a model facilitates the use of a daily time step, which is important in routing flood flows across the flood plain and determining overbank spills. Second, such a model can be readily applied to assess future potential impacts of global warming and climate change.

The Central Valley drainage area consists of upstream watersheds and the valley floor. Upstream watersheds include major river watersheds above designated stream gauging stations and/or foothill reservoirs and ungauged small watersheds (Figure 4-1). The upstream watersheds include subbasins UF2-UF11, UF13-16, and UF18-24 (Figure 4-2). The precipitation-runoff model tool, SWAT (Soil Water Assessment Tool), was the Department's choice to simulate the daily stream outflow time series data for most rim watersheds. SWAT is a public domain, generic, semi-distributed precipitation-runoff model developed by U.S. Department of Agriculture Agricultural Research Service (Arnold et al. 2012). Twenty-three SWAT models were developed and calibrated to match available unimpaired observed streamflow data at watershed outlets. For some watersheds, an area ratio factor was also applied to consider rainfall-runoff from small local drainage areas located between a SWAT watershed outlet and its corresponding C2VSim stream inflow node location. The SWAT models are based on existing land use conditions, land surface elevations, and stream geomorphology.

There are 36 stream inflows locations in the C2VSim model of the valley floor. SWAT simulated daily flow time series data provide over 90 percent of these model boundary inflows. Observed USGS stream gage data are used for several inputs, since SWAT models have not been developed for a few smaller watersheds such as Cottonwood Creek and Cow Creek.
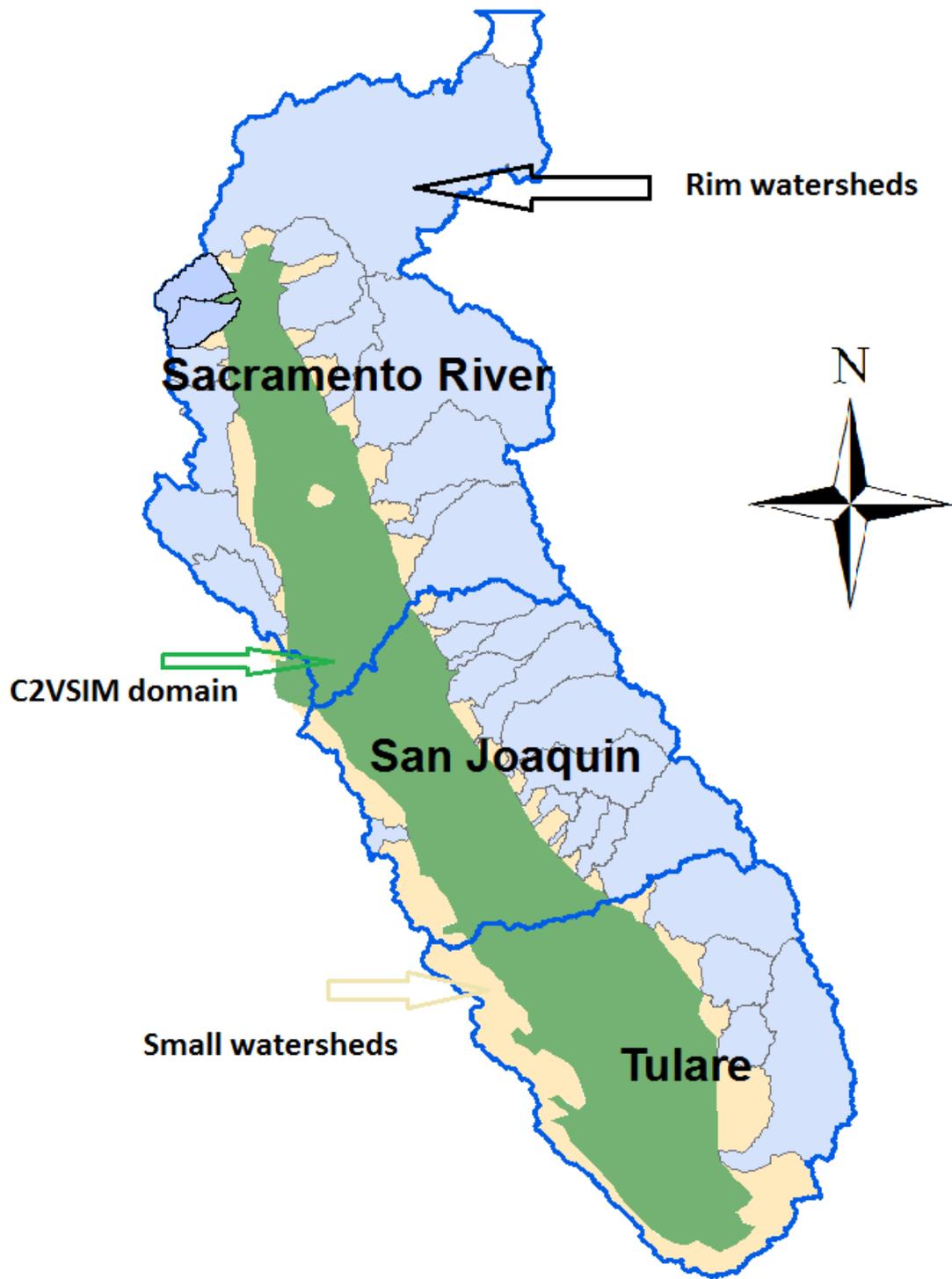
Figure 4-1. Drainage Area of the Central Valley and Natural Flow Model Sub Domains
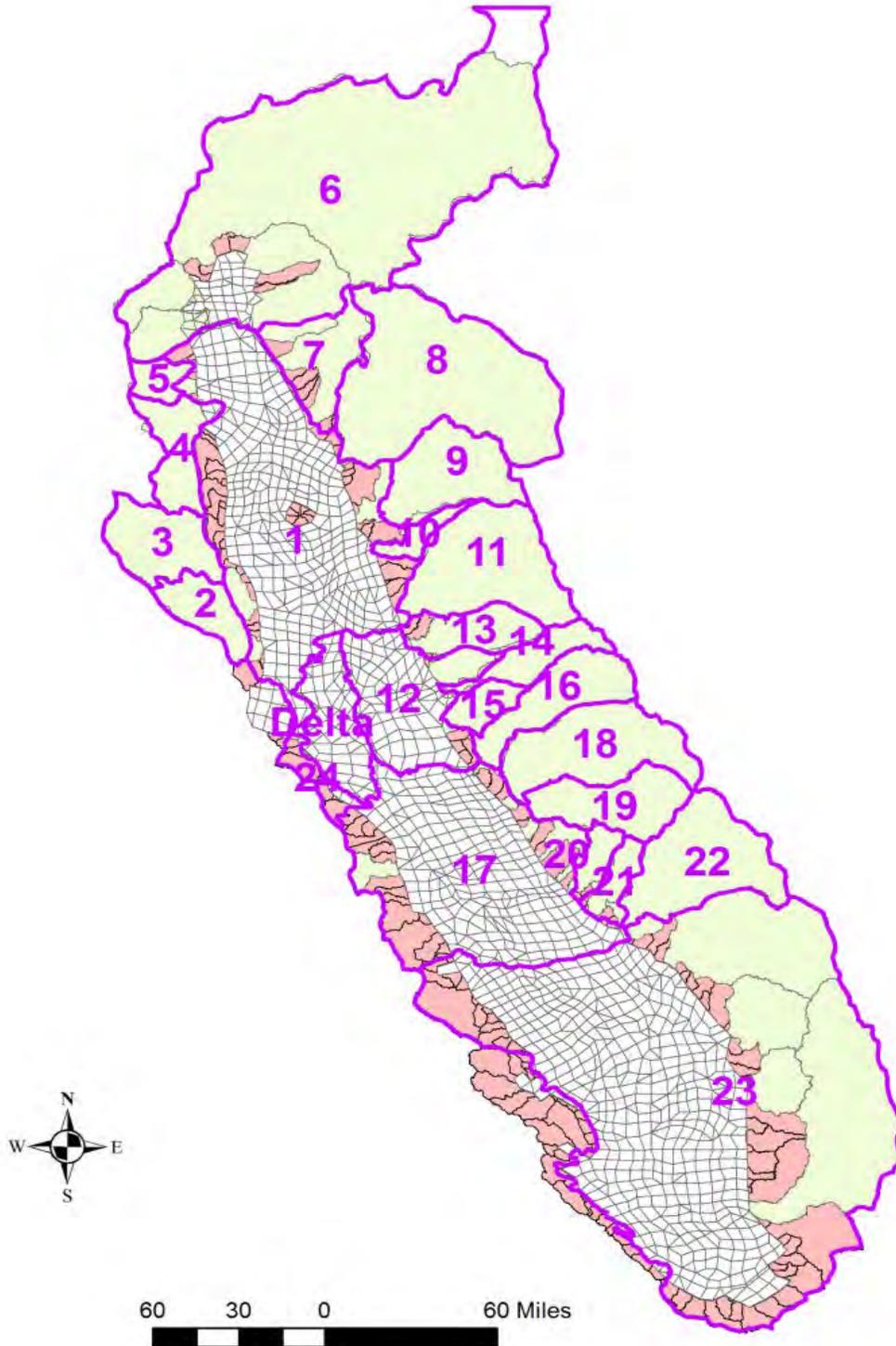
Figure 4-2. Comparison of the 24 Unimpaired Flow Subbasins and Natural Flow Modeling Domain

Sacramento Valley Rim Inflows

There are 19 stream inflow locations in the Sacramento Valley. They correspond to unimpaired subbasins UF2-UF11 (see Figure 4-2). UF1- Sacramento Valley Floor is mostly part of the C2VSim model domain. UF6 includes five separate stream inflows (Sacramento River at Shasta, Cow Creek, Battle Creek, Paynes and Seven Mile Creeks, and Cottonwood Creek) and a few small watersheds with a portion of Valley Floor rainfall-runoff in Subregion 1. Table 4-1 and Figure 4-3 compare average monthly simulated flows to unimpaired observed flows over the period of simulation (Water Years 1922-2014). A more detailed comparison for each subbasin is provided in Chapter 5.

Table 4-1. Sacramento Valley Simulated Rim Inflows and Corresponding Unimpaired Observed Flows

	UF2-UF11 basins: Average Monthly Flows 1922-2014 (TAF)												
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Unimpaired	521	941	2,032	2,781	3,061	3,222	2,880	2,510	1,383	649	444	417	20,842
SWAT	563	1,176	2,215	2,664	2,868	3,110	2,704	2,284	1,379	707	448	364	20,482

Key:

SWAT = Soil Water Assessment Tool

TAF = thousand acre-feet
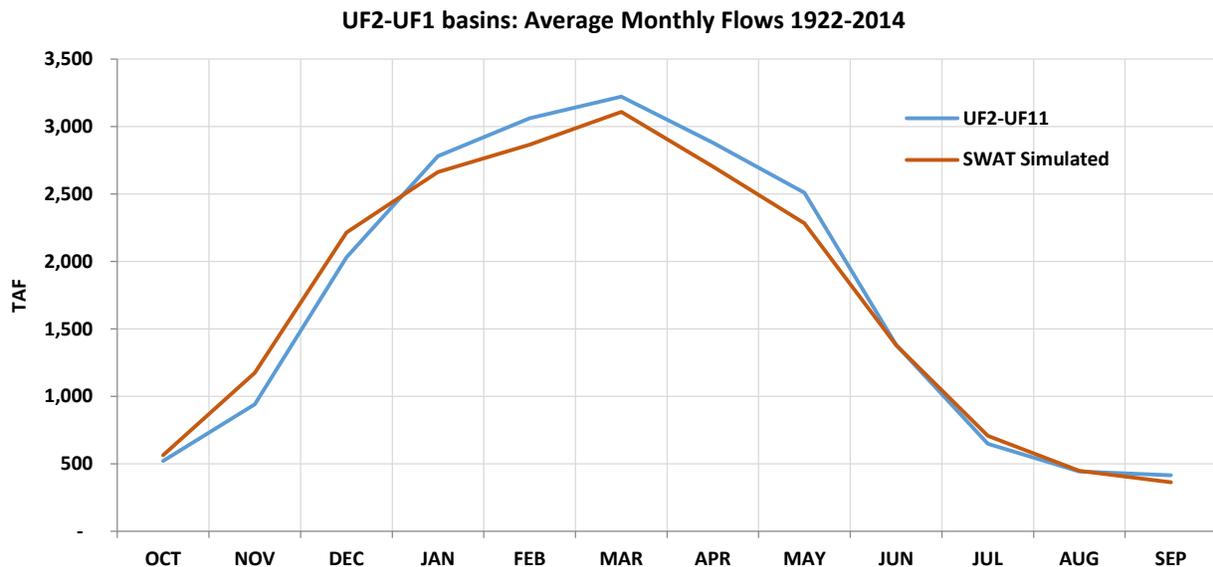
UF = unimpaired flow

Figure 4-3. Sacramento Valley SWAT Simulated Rim Inflows and Corresponding Unimpaired Estimated Flows

East Side Streams

East side streams rim inflows include Cosumnes River, Mokelumne River, Calaveras River and Dry Creek at Galt. This corresponds to unimpaired flow subbasins UF12-15. About three quarters of UF12 is within the C2VSim model domain. A small portion of UF12 is considered in stream inflow (Dry Creek at Galt). Table 4-2 and Figure 4-4 compare average monthly simulated flows to unimpaired observed flows over the period of simulation (Water Years 1922-2014). A more detailed comparison for each subbasin is provided in Chapter 5.

Table 4-2. Eastside Streams SWAT Simulated Rim Inflows and Corresponding Unimpaired Observed Flows

	UF12-UF15 basins: Average Monthly Flows 1922-2014 (TAF)												
	Oct	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Total**
Unimpaired	20	55	119	147	176	216	224	252	148	25	4	7	1,394
SWAT	9	33	95	161	190	220	228	247	139	32	7	4	1,364

Key:

SWAT = Soil Water Assessment Tool

TAF = thousand acre-feet

UF = unimpaired flow

UF12-UF15 basins: Average Monthly Flows 1922-2014
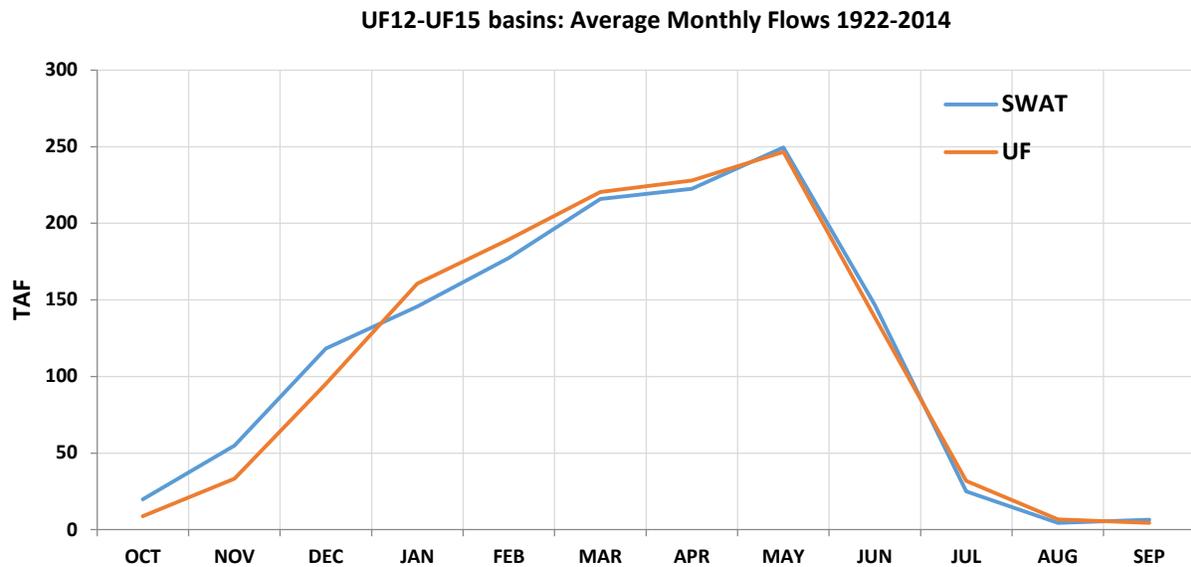
Figure 4-4. Eastside Streams SWAT Simulated Rim Inflows and Corresponding Unimpaired Estimated Flows

San Joaquin Valley

The San Joaquin Valley covers unimpaired flow subbasins UF16, and UF18-UF22. UF17 is a valley floor area that consists of a mix of C2VSIM elements, small watersheds and drainage area of stream inflows. And UF24 is for ungauged small watersheds draining into the Delta region. Table 4-3 and Figure 4-5 compare average monthly simulated flows to unimpaired observed flows over the period of simulation (Water Years 1922-2014). A more detailed comparison for each subbasin is provided in Chapter 5.

Table 4-3. Simulated San Joaquin Valley Rim Inflows and Corresponding Unimpaired Observed Flows

| | UF 16, UF18-UF22 basins: Average Monthly Flows 1922-2014 (TAF) | | | | | | | | | | | | |
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Unimpaired	59	131	268	390	469	629	911	1,460	1,113	412	104	48	5,993
SWAT	98	223	372	426	539	753	965	1,324	1,010	407	94	51	6,263

Key:

SWAT = Soil Water Assessment Tool

TAF = thousand acre-feet

UF = unimpaired flow

UF16, UF18-UF22 basins: Average Monthly Flows 1922-2014
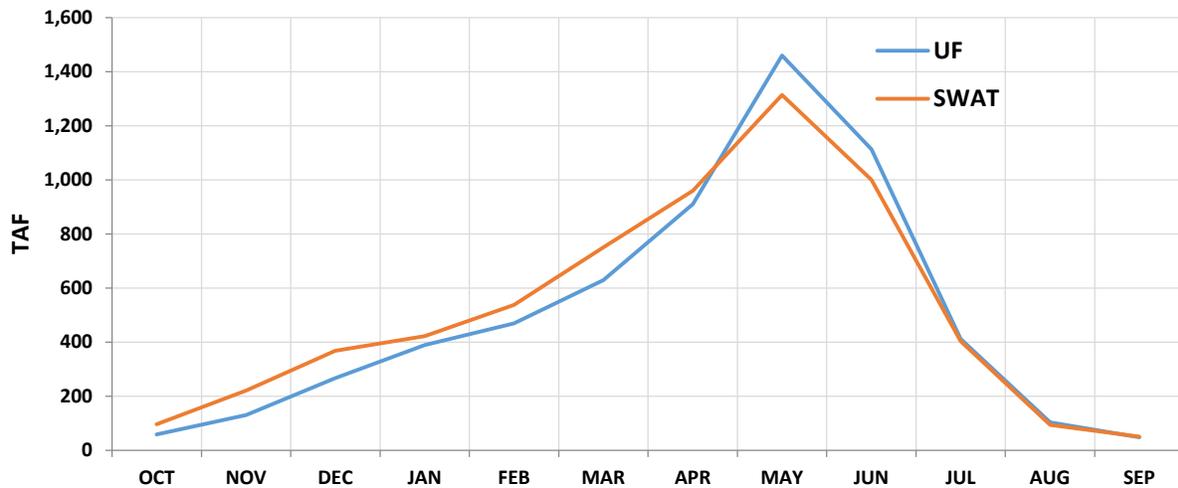
Figure 4-5. San Joaquin Valley SWAT Simulated Rim Inflows and Corresponding Unimpaired Estimated Flows

Tulare Lake Basin

The Tulare Lake Basin (UF23) is also fully simulated (see Figure 4-2). The Valley Floor rainfall-runoff is part of the Valley Floor integrated hydrologic modeling (UF1, UF12 and UF 17).

Valley Floor

Description of C2VSim Natural Flow Model Set up

The C2VSim is an integrated numerical model that simulates water movement through the linked land surface, groundwater and surface water flow systems in California's Central Valley. Valley floor hydrology is modelled with a natural flow version of C2VSim based on the Integrated Water Flow Model (IWFM) Version 2015 (DWR 2015). Although calibrated hydrologic parameters and main model framework are retained as in C2VSim-historical model from Brush et al. (2013), model inputs are substantially different.

The C2VSim natural flow model was run on a daily time step with a coarse finite element grid of 1,392 elements ranging from 1,366 acres to 21,379 acres. Daily historical precipitation, potential evapotranspiration, natural vegetation, and stream inflows spanning water years 1922-2014 were the main time series input data. The CAL-SIMETAW (California Simulation of Evapotranspiration of Applied Water) 4km × 4km grid based dataset (Orang et al. 2013) was used to prepare precipitation and reference potential evapotranspiration (ET_o). Since the CAL-SIMETAW dataset was not updated to Water Year 2014, we extended precipitation with PRISM data (PRISM Climate Group 2015) and ET_o with USGS Basic Characterization Model 270 meters × 270 meters grid data (Alan and Lorraine Flint, personal communication, 2015).

In C2VSim, the valley floor was subdivided into 21 subregions and the water balance was grouped into five hydrologic regions: Sacramento Valley, Eastside Streams, San Joaquin Valley, Tulare Lake, and Delta. The consumptive use of native vegetation was simulated with daily root zone soil water routing, allowing for groundwater uptake to root zone, and stream water contribution to the riparian vegetation. Stream overflow through natural levees to the flood basins were also considered. Permanent wetlands in the flood basins were simulated with the IWFM Lake option, thereby facilitating overflow from streams using a flow rating table/curve, wetland-groundwater interaction, and flood basin storage. Potential evapotranspiration of permanent wetlands was used for lakes/wetlands since wetland vegetation is assumed to cover the lakes, not just the water surface.

Native Vegetation Types and Spatial Distribution

Pre-development land cover classifications and spatial distribution was compiled and developed from best available sources. California State University at Chico (CSU Chico, 2003) produced a pre-1900 historic vegetation map of the Central Valley based on hundreds of historic maps and collections (Figure 4-6). Kuchler (1977) provides vegetation mapping for the whole California that shows potential or pristine land cover before European-American settlement and the part of Central Valley is reproduced in Figure 4-7. Fox et al. (2015) conducted the latest extensive study of Central Valley native vegetation and provide further details on flood plains vegetation and vernal pools combining information from the CSU Chico

base map, Kuchler's map and early soil survey data, but the final spatial extent is limited to Sacramento and San Joaquin Valleys (Figure 4-8). We used the Fox et al. (2015) mapping data for overlapping common area within the C2VSim boundary, and applied their methodology for the Tulare Lake basin and any other missing area gaps using the CSU Chico and Kuchler geographic information system maps (Figure 4-9). A summary of the vegetation types and acreage is listed in Table 4-4. The area of each vegetation type was specified for each element (grid cell) in order to simulate surface water flow processes: rainfall-runoff, infiltration, soil moisture, deep percolation and evapotranspiration. From comparison of the three above mentioned maps, (rain fed) grassland in the current simulation and CSU Chico (2003) relates to California prairie, and permanent wetland (large stand wetland) is tule marsh in the Kuchler map. The category of "Other floodplain habitat" in the CSU Chico map has been further identified and classified in Fox et a. (2015).

As stated in CSU Chico (2003), the confidence in identifying specific native vegetation under pre-development condition varies significantly for different vegetation types. Pre-development conditions is usually referred to period before the 1850s, however, the earliest source map is dated 1894. No early maps identified specific location of native grasslands; vernal pool locations are even more uncertain. Fox et al. (2015) used early soil survey data to infer vernal pool locations. On the other hand, riparian forest and wetlands along major streams have more reliable historic map data (Figure 4-10). Since riparian and permanent wetlands are the major source of stream water depletion, this actually reduces uncertainties for natural flow estimation. Finally, different vegetation types have different sources of water supply and potential evapotranspiration, as follows:

- Grassland, hardwoods, seasonal wetland, vernal pool, saltbush and chaparral can only utilize soil water and groundwater uptake.

- Riparian forest can access nearby stream water to meet potential evapotranspiration after using up soil water and groundwater uptake.

- When flood plains are emulated with the lake option (Figure 4-11), the lake elements are assigned with potential evapotranspiration of permanent wetlands, and any predefined vegetation set up for the lake elements are ignored. Lakes can receive stream water from main stream channel overflowing into them and also small creeks direct inflows.

Table 4-4. Area Distribution of Vegetation Types (Acres)

Valley	Subregion	Water Surface	Chaparral	Seasonal Wetlands	Vernal Pools	Grasslands	Hardwood	Riparian	Saltbush	Permanent Wetlands
Sacramento	1	-	-	-	7,808	88,240	198,754	33,476	-	-
	2	5,401	-	2,415	63,287	306,557	179,675	140,424	-	253
	3	3,321	-	27,302	228,734	246,112	60,453	53,147	-	70,039
	4	5,183	-	41,443	211	225	2,399	109,236	-	192,878
	5	5,318	-	232,900	79,483	40,891	104,192	137,254	-	13,718
	6	12,564	-	15,581	108,825	220,624	88,927	54,173	-	157,170
	7	5,324	-	34,455	115,461	30,862	95,474	26,011	-	42,271
Delta	9	21,226	-	58,361	31,608	99,388	481	3,276	-	511,115
San Joaquin	8	2,298	61	150,753	264,734	148,709	246,739	71,130	-	11,110
	10	2,516	369	139,218	159,519	235,025	-	2,483	102,335	26,608
	11	2,186	-	24,939	173,680	170,047	3,220	33,564	-	4,906
	12	1,273	-	14,092	118,518	163,300	3,731	32,373	-	7,050
	13	4,464	-	49,686	583,563	313,335	367	18,201	20,850	47,173
Tulare Lake	14-21	163,740	-	55,320	485,000	2,104,121	414,336	40,808	1,105,854	655,931
TOTAL		234,814	430	846,465	2,420,431	4,079,196	1,199,994	722,080	1,229,039	1,740,222
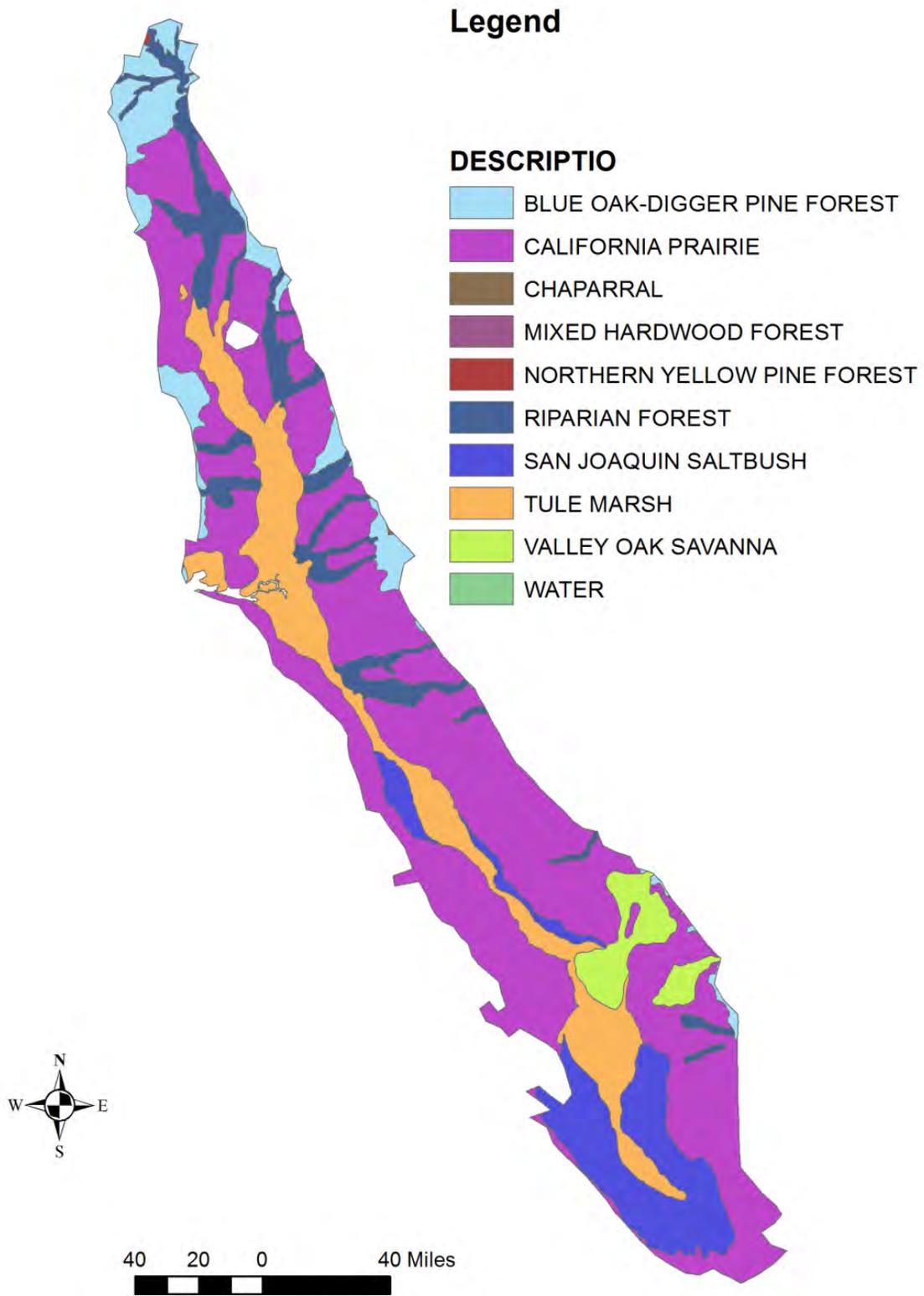
Figure 4-6. Valley Floor Native Vegetation from Kuchler (1977)
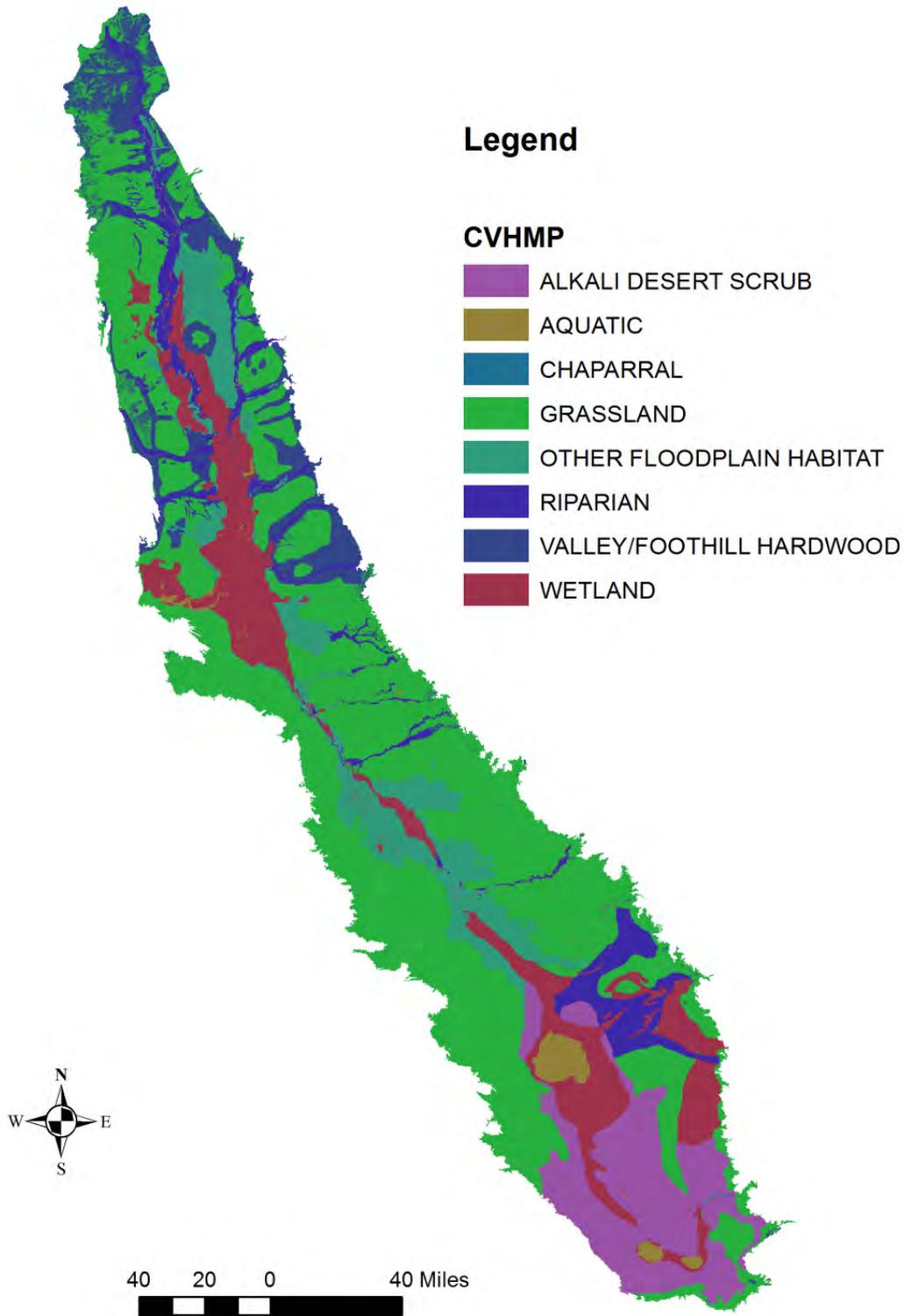
Figure 4-7. Valley Floor Vegetation from CSU Chico (2003)
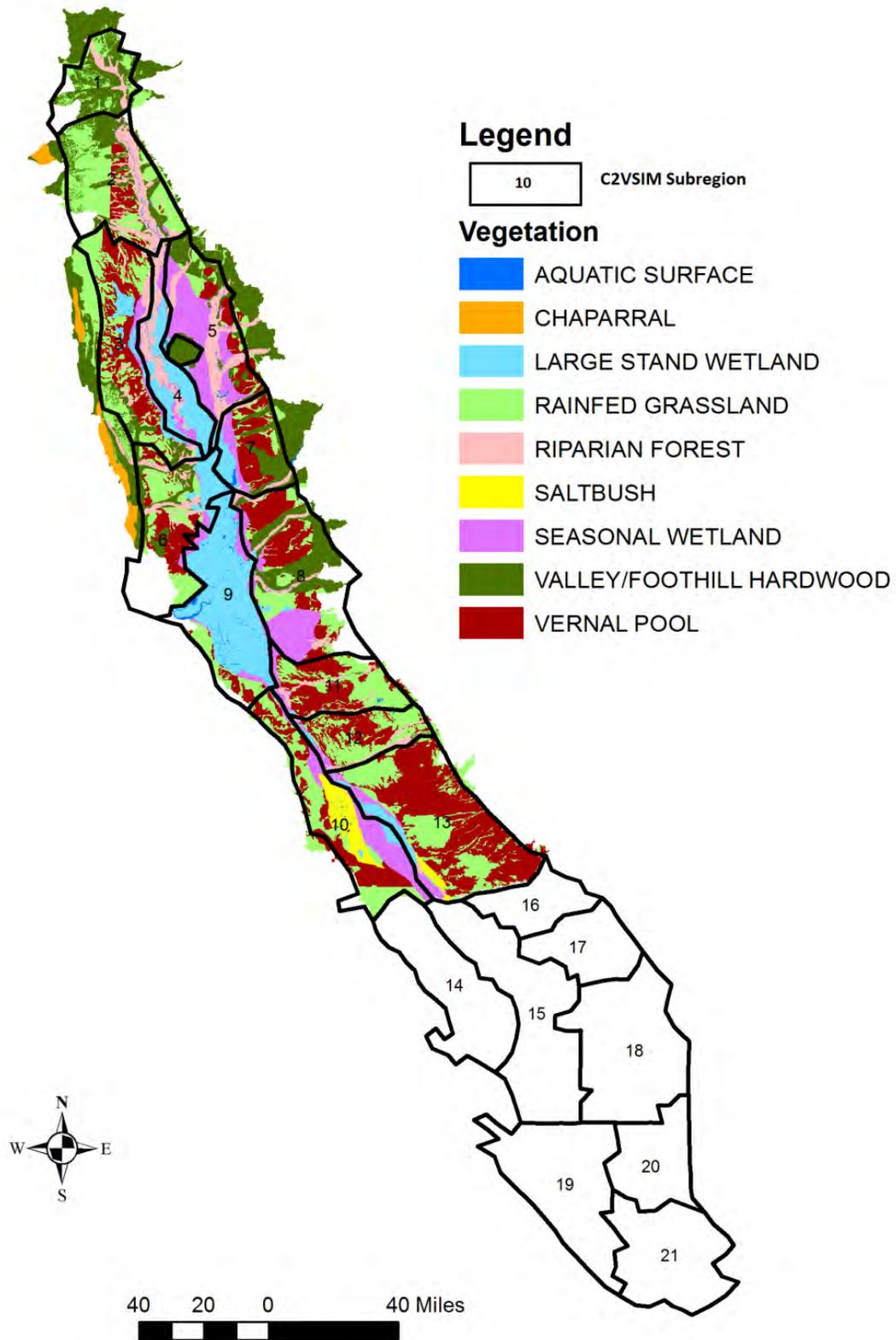
Figure 4-8. Valley Floor Vegetation from Fox et al. (2015)
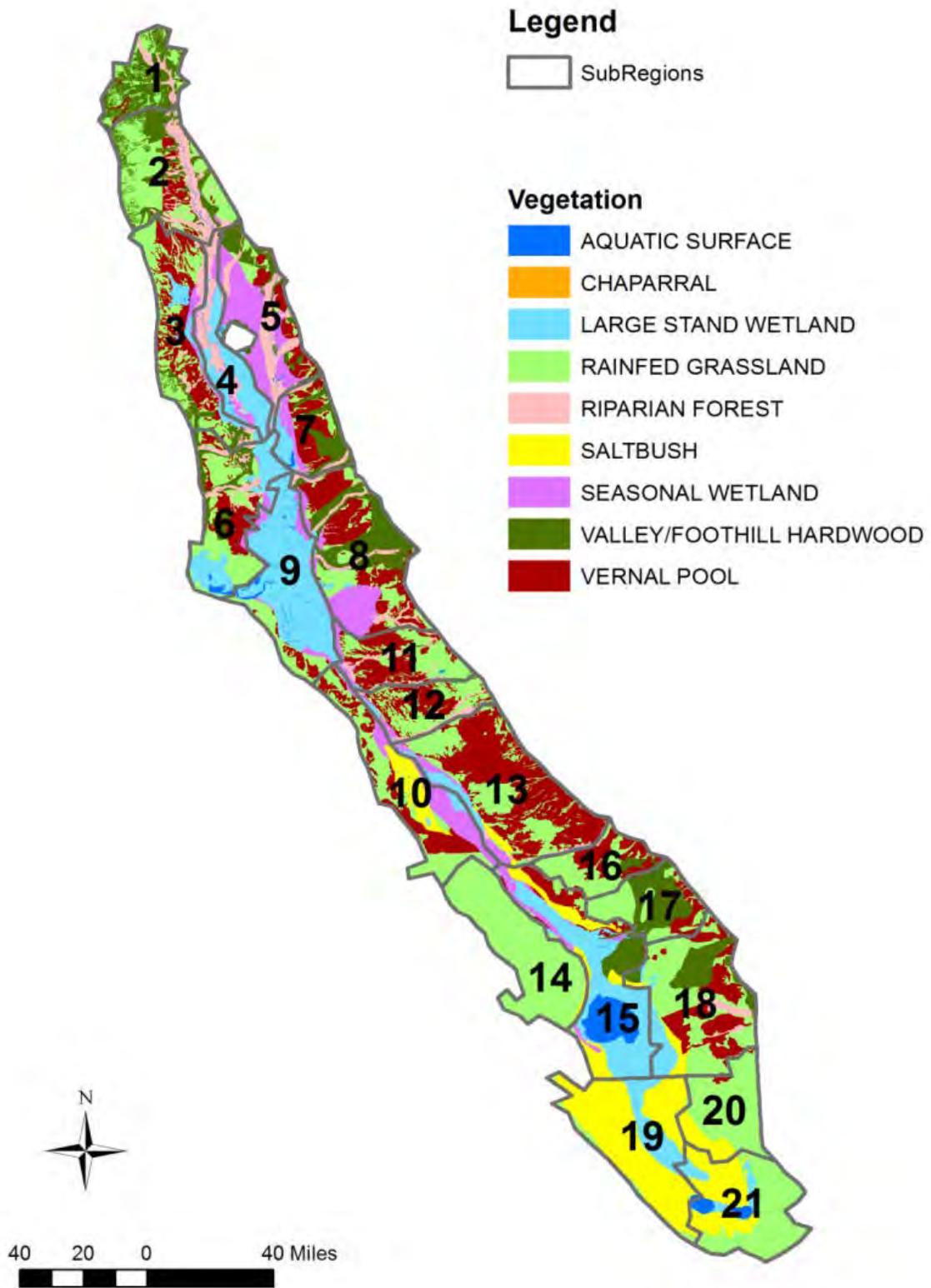
Figure 4-9. Native Vegetation Distribution under Pre-Development Condition Used in Natural Flow Simulations

Figure 4-10. Distribution of Mapping Source Ranking (>0.5) by CSU Chico (2003)
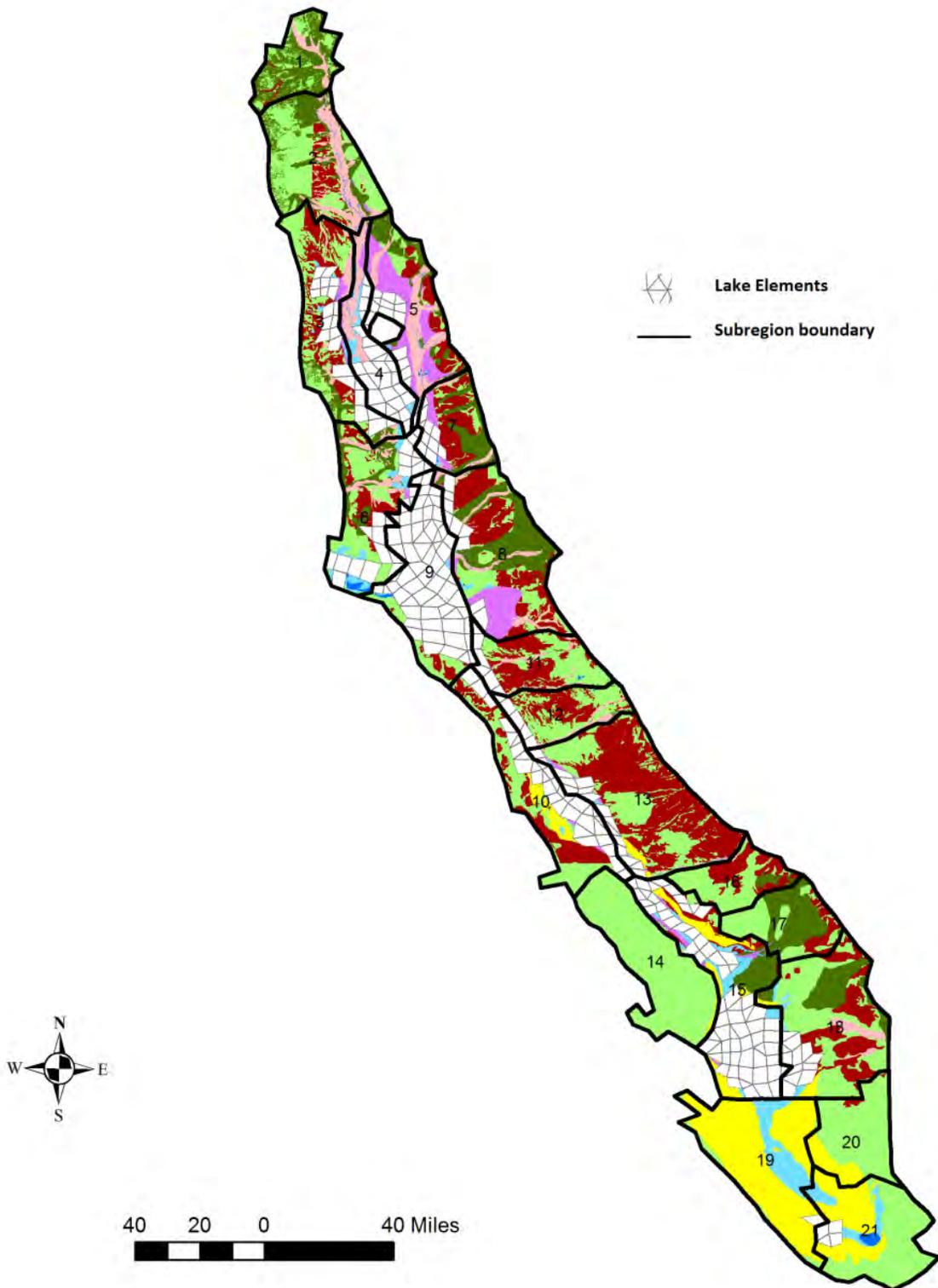
Figure 4-11. Permanent Wetlands and Some Vernal Pools are Represented as Lake Elements

Potential Evapotranspiration

Howes et al. (2015) is the best available data for evapotranspiration from natural vegetation in the Central Valley. We used their estimated monthly vegetation coefficients (Kc) with the grass reference crop evapotranspiration (ET_o) to estimate daily potential evapotranspiration ($ETc=Kc*ET_o$) for each vegetation type. Daily ET_o for each of 21 subregions was estimated from the CAL-SIMETAW model 4-km grid dataset (Orang et al. 2013). Actual evapotranspiration for all vegetation types is internally computed within C2VSim based on local water supply and ETc for each vegetation type at daily time step. Therefore, grassland, hardwoods, vernal pools, seasonal wetlands, saltbush, and chaparral all used potential evapotranspiration as evaporative demand input (Table 4-5).

Table 4-5. Monthly Vegetation Coefficients (Kc)

Vegetation	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rain fed Grassland	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Vernal Pool	1.00	1.00	1.00	1.00	1.05	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Permanent Wetland	0.70	0.70	0.80	1.00	1.05	1.20	1.20	1.20	1.05	1.10	1.00	0.75
Hardwood	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Seasonal Wetland	0.70	0.70	0.80	1.00	1.05	1.10	1.10	1.15	0.75	0.80	0.80	0.75
Riparian Forest	0.80	0.80	0.80	0.80	0.90	1.00	1.10	1.20	1.20	1.15	1.00	0.85
Saltbush	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Chaparral	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Aquatic Surface	0.65	0.70	0.75	0.80	1.05	1.05	1.05	1.05	1.05	1.00	0.80	0.60

Valley Floor Evapotranspiration and Delta Inflows

For long term averages under natural conditions, storage changes are negligible, and primary loss of water is through evapotranspiration. Actual evapotranspiration from each vegetation type is summarized in Table 4-6 with sources of water supply for Sacramento and San Joaquin Valleys and Eastside Streams regions, all draining into the Delta area. Soil water is derived from rainfall and groundwater uptake is limited by maximum root depths.

Since evapotranspiration demand peaks in the summer months, simulations reveal that seasonal storage changes play a key role in meeting the demand. As shown in Figure 4-12, for permanent wetlands, winter rainfall and overflowed flood waters fill up the flood basins before May, and then stored water will be used to meet evapotranspiration from June through October. As for riparian forest, stream water is consumed most during the summer months (Figure 4-13).

The overall long term water balance under natural condition for the Central Valley can be seen in Table 4-7 and Figure 4-14. From Figure 4-14, water supply sources (ignoring the Delta and Tulare Lake Basin) include rim stream inflows (28.1 MAF), ungauged small watersheds (2.6 MAF) and Valley Floor rainfall (9.7 MAF). However, 18.4 MAF was lost to evapotranspiration, and only 21.7 MAF reached the Delta boundary.
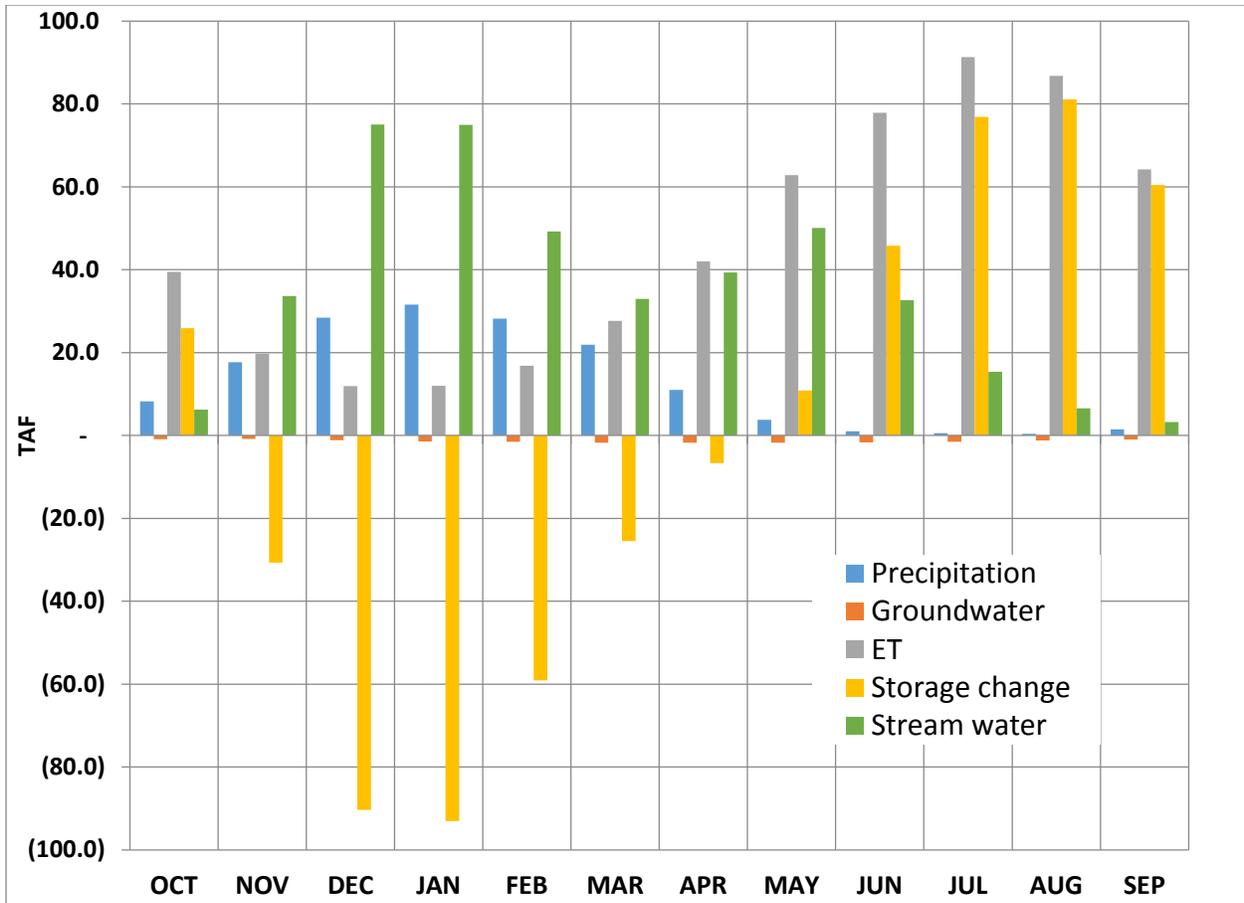
Figure 4-12. Stream Water Stored in the Wetlands/Lakes (negative yellow bar) and Used for Summer Month Evapotranspiration (positive yellow bar)

Table 4-6. Source of Simulated Water Supply for Different Native Vegetation Types

	Average Annual Evapotranspiration: 1922-2014 (TAF)[1]								
	Chaparral	Seasonal Wetlands	Vernal Pools	Grasslands	Hardwood	Riparian	Saltbush	Wetlands /Lakes[1]	Total
Soil water	0.3	419.4	773.1	1,992.4	1,555.3	1,929.2	44.7	0.0	6,714
Groundwater	0.0	194.1	53.5	367.1	1,235.4	430.8	59.8	-496.8	1,844
Stream water	0.0	0.0	0.0	0.0	0.0	3,688.8	0.0	4,220.1	7,909
Rainfall								1,570	1,570
Total	0.3	613.5	826.5	2,359.5	2,790.7	6,048.8	104.6	5,293.3	18,037

Notes:

[1] Excludes the Sacramento-San Joaquin Delta and the Tulare Lake Basin

[2] Riparian elements include vernal pools adjacent to streams. Lake elements are mainly permanent wetlands. Near the lake boundary, it could contain a small portion of seasonal wetlands, San Joaquin saltbush, and water surface or riparian forest.
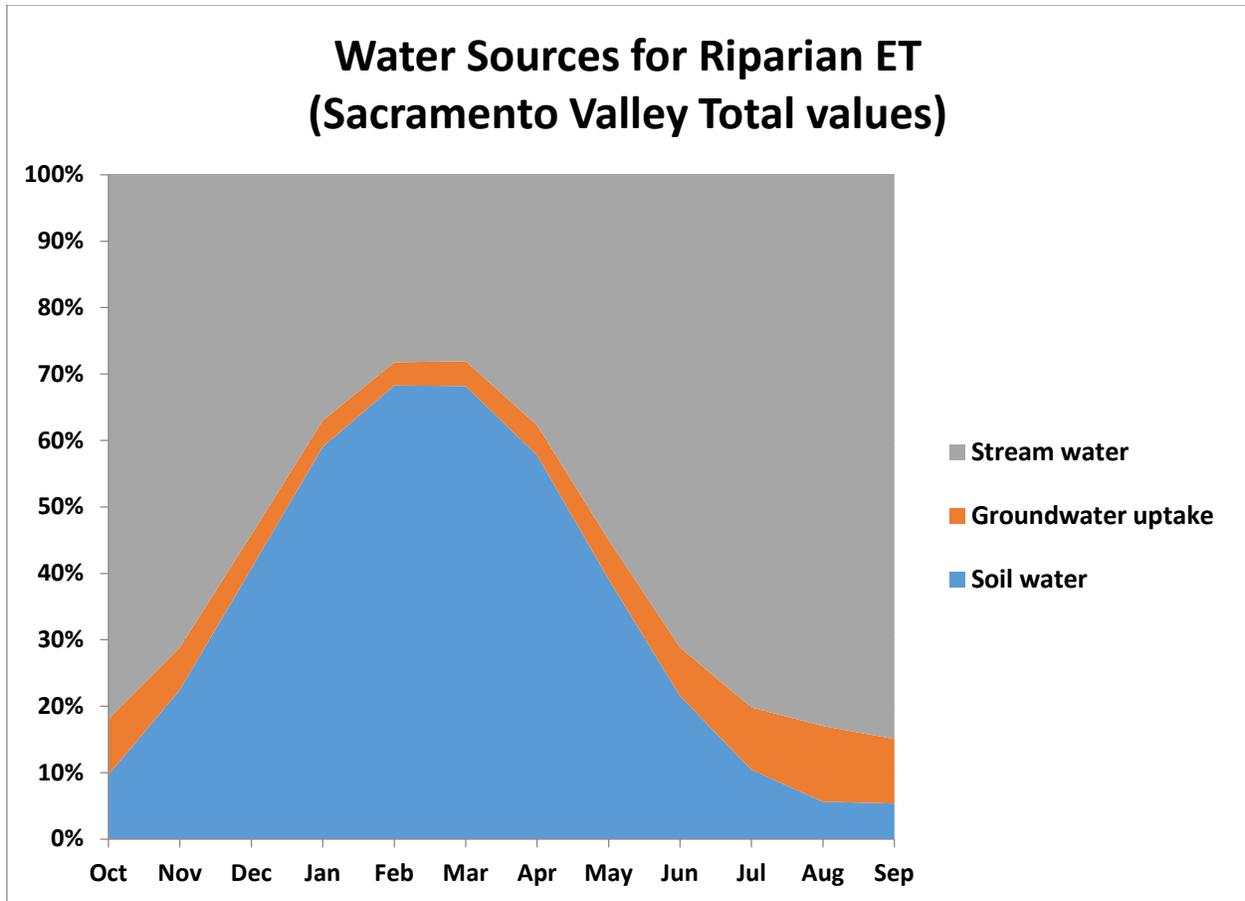
Figure 4-13. Partition of Water Sources for Riparian Evapotranspiration (Soil Water, Groundwater Uptake and Stream Water)

Table 4-7. Average Annual Water Budgets for Water Years 1922-2014 under Natural Conditions

Hydrologic Region	Area (sq. mile)	Average Annual Volumes: 1922-2014 (TAF)					
		Precipitation	Stream inflows	Small watershed inflows	Total Water Supply	Stream Outflows	Evapo-transpiration
Sacramento Valley	5,763	6,179	20,482	2,204	28,865	17,212	11,001
Eastside Streams	1,399	1,195	1,394	227	2,816	986	1,841
San Joaquin Valley	3,842	2,413	6,263	209	8,885	3,334	5,216
Subtotal	11,004	9,787	28,139	2,640	40,566	21,533	18,058
Delta	1,134	804	21,533	92	22,429	19,708	2,969
Tulare Lake Basin	7,852	3,310	2,438	350	6,098	41	6,057
Central Valley Total	19,990	13,901	30,577	3,083	46,664	19,708	27,169

Note:
Groundwater flows between boundaries are not significant.
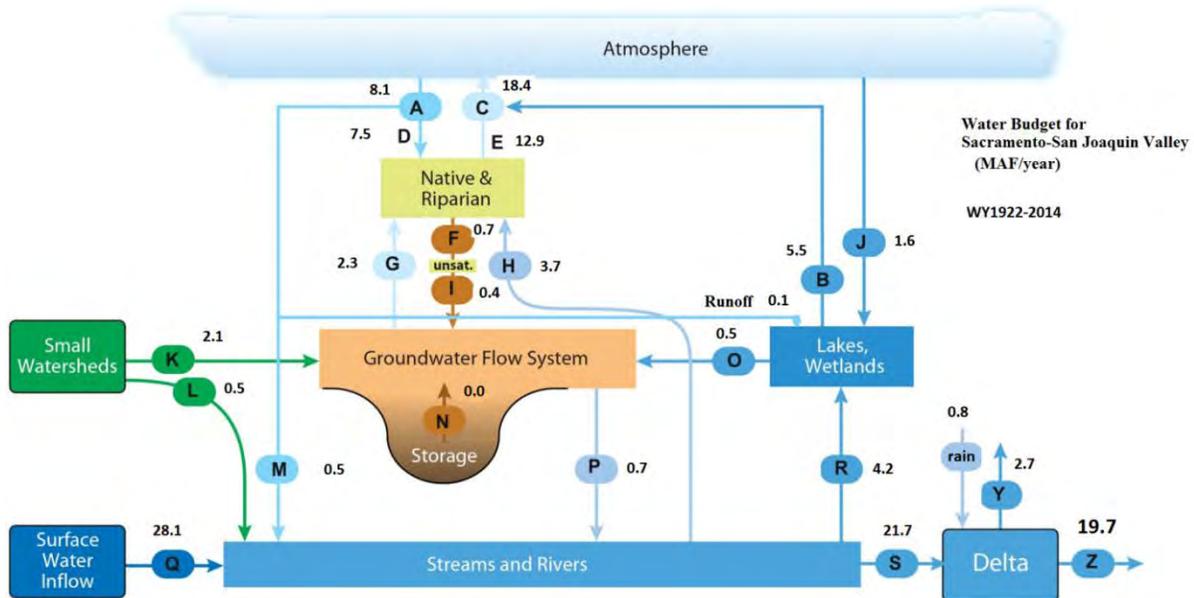
Note: Tulare Lake Basin outflow toward the Delta is only 41 TAF

A Precipitation

B Evaporation from lakes and wetlands

C Total evapotranspiration and evaporation

D Precipitation to native and riparian Vegetation (N&RV) areas

E Evapotranspiration from N&RV areas

F Deep percolation below root zone from N&RV areas

G Ground water uptake to N&RV areas

H Stream flow to riparian vegetation

I Net deep percolation from N&RV (unsaturated zone to ground water)

J Precipitation on lakes and wetlands

K Boundary small watersheds to valley floor ground water

L Boundary small watersheds to valley floor streams

M Precipitation runoff to streams

N Increase in ground water storage

O Net deep percolation from lakes and wetlands

P Stream – ground water interaction

Q Major Stream inflows to valley floor (upper watersheds SWAT model outflows)

R Overbank flows from streams to lakes and wetlands

S Delta inflow

Y Delta depletion

Z Delta outflow

Key: MAF = million acre-feet   SWAT = Soil Water Assessment Tool   TAF = thousand acre-feet

Figure 4-14. Schematic of Central Valley Overall Water Budget
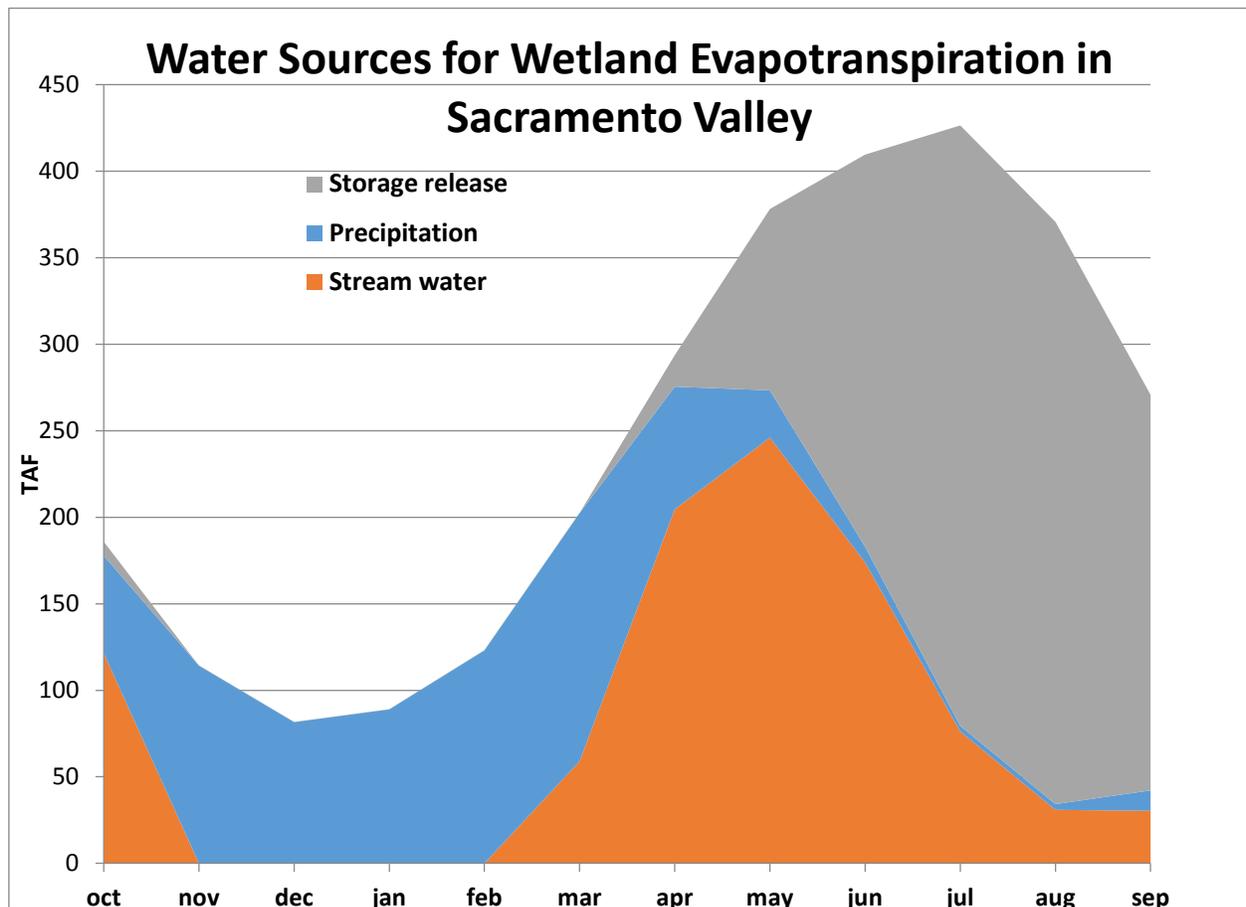
Note: Rainfall and overflowed stream water in the winter months fills up wetlands/lakes storage.

Figure 4-15. Stacked Area Plot of Monthly Water Supply Components for Wetlands (lakes) Evapotranspiration in Sacramento Valley

Sacramento-San Joaquin Delta Inflows and Outflows

Sacramento-San Joaquin Delta Inflows

Delta inflows consist of stream outflows at the Delta boundary from the Sacramento Valley, Eastside Streams, and San Joaquin Valley (Table 4-8 and Figure 4-16). Sacramento Valley inflow peaks in March while the peak flows in Eastside Streams and San Joaquin Valley are in May.

Because of evapotranspiration, the net stream depletion from natural rim inflows to Delta inflows actually peaks in May, comparing to unimpaired rim inflows, outflows from Eastside streams, and especially San Joaquin Valley have been greatly decreased, and as a result, the flow peak in May shown in unimpaired flows disappears from Delta Inflows (Figure 4-17).

Table 4-8. Estimated Natural Delta Inflows

Flow Items	Average Monthly Flows: 1922-2014 (TAF)												
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Sacramento Valley	262	792	1,860	2,490	2,727	2,966	2,525	1,973	1,028	348	131	111	17,212
Eastside Streams	14	40	86	106	125	148	149	182	115	15	2	5	986
San Joaquin Valley	35	90	197	263	307	426	522	701	516	196	52	30	3,334
Total Delta Inflows	312	922	2,142	2,859	3,159	3,539	3,195	2,856	1,659	559	185	145	21,533
Natural Rim Inflows	700	1,455	2,689	3,227	3,567	4,043	3,881	3,876	2,559	1,151	559	437	28,144
Net Stream depletion	388	532	547	368	408	504	686	1,020	900	592	373	292	6,611
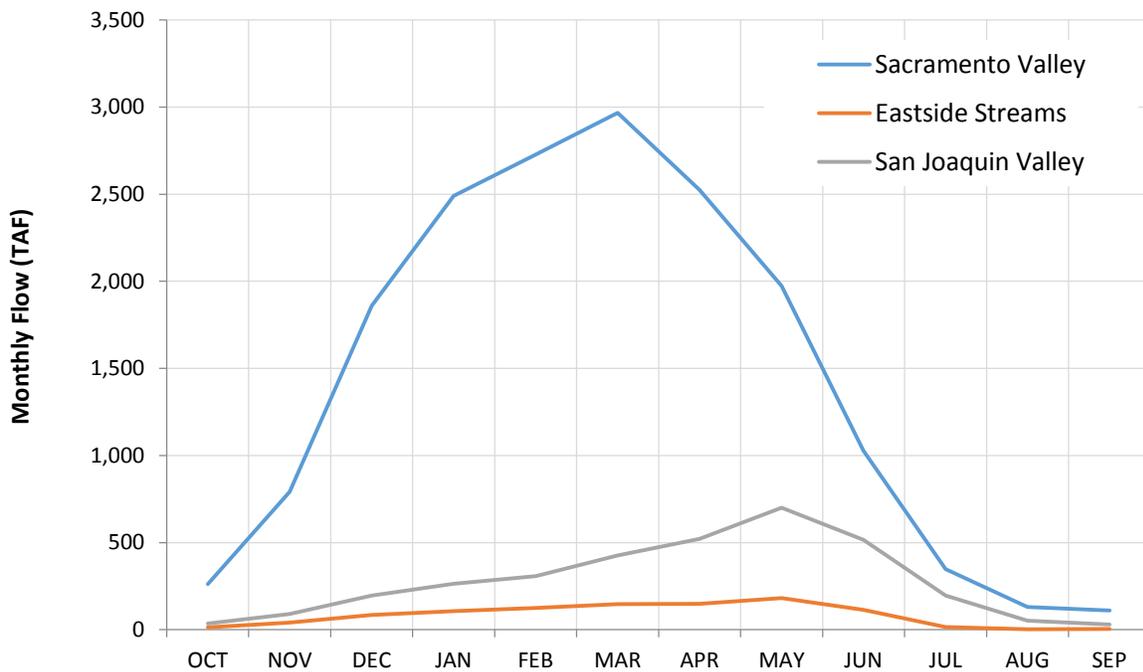
Figure 4-16. Estimated Natural Delta Inflows
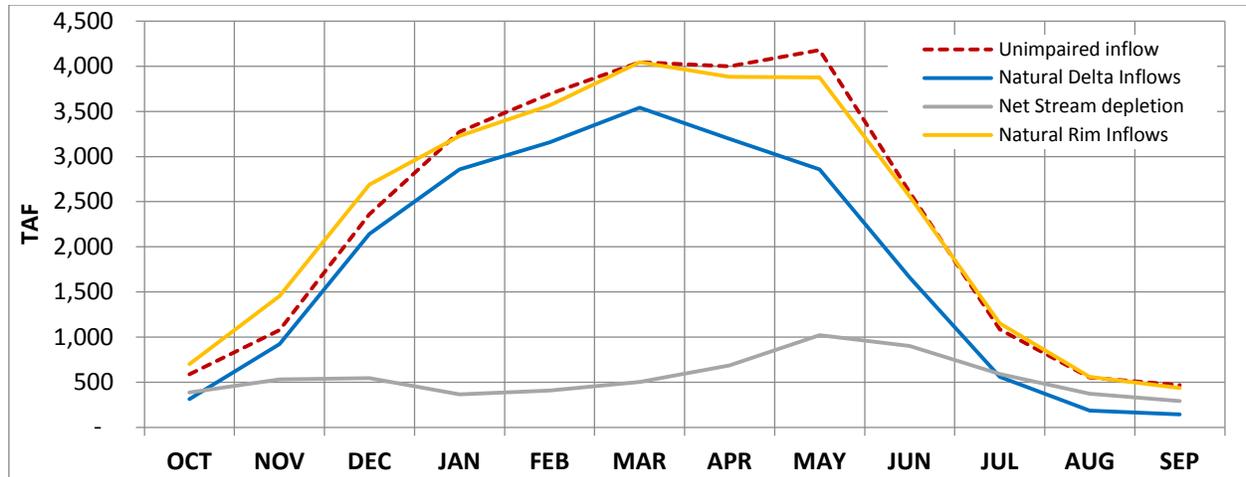
Figure 4-17. Natural Delta Inflows, and Natural/Unimpaired Rim Inflows Monthly Distribution

Sacramento-San Joaquin Delta Consumptive Use

Under natural conditions, about 86 percent of Delta area is covered with permanent wetlands or water surface. Of the remaining Delta area, riparian forest accounts for 4 percent and non-riparian native vegetation accounts for 10 percent. As shown in Table 4-9, at nearly 3 MAF, Delta evapotranspiration is significant. As shown in Table 4-10, this demand is effectively met by depletion of stream water (2.2 MAF) and rainfall (0.8 MAF).

Table 4-9. Delta Actual Evapotranspiration

	Average Annual Volumes: 1922-2014 (TAF)			
	Riparian ET	**Non-riparian Native Vegetation ET**	**Wetlands/Lakes ET**	**Total**
Delta	129	70	2,778	2,977

Table 4-10. Sources of Delta Water Supply for Evapotranspiration

Water Supply	Average Annual Volumes: 1922-2014 (TAF)	
	Wetlands	**Root Zone (Including Riparian)**
Stream water	2,138	109
Rainfall	709	96
Groundwater	(59)	10
Storage change	(10)	0
Total	2,778	215

Sacramento-San Joaquin Delta Outflows

Natural net Delta outflows equal Delta inflows minus Delta evapotranspiration. The baseline estimated net Delta outflow is 19.7 MAF. The water year 1922-2014 monthly distribution is listed in Table 4-11 and plotted in Figure 4-18. Compared to unimpaired outflow estimates,

natural Delta outflow is lower, particularly in the dry season. Under natural condition, riparian forests use stream water mostly in the dry season and wetland water storage in the flood plains is used for wetland evapotranspiration, with stream accretion occurring in the winter months.

Table 4-11. Average Monthly Natural Net Delta Outflow

	Average Monthly Flow: 1922-2014 (TAF)												
	Oct	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Total**
Delta Outflow	280	760	1,859	2,634	3,012	3,406	3,012	2,567	1,414	467	164	133	19,708
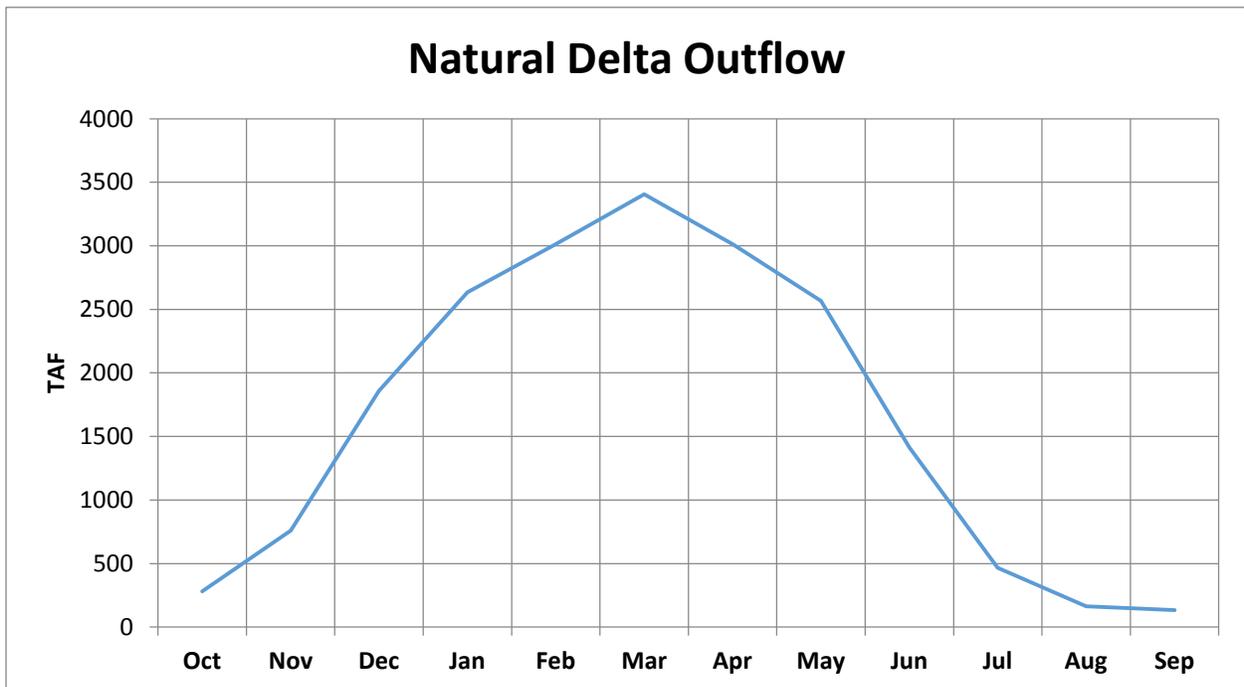
Figure 4-18. Estimated Natural Delta Outflow

Tulare Lake Basin

The Tulare Lake Basin water budget was simulated in detail as part of the Valley Floor. Tulare Lake Basin outflow into the Delta is through a stream reach (Fresno Slough) connecting to the San Joaquin River. The Kings River was assumed to generally flow south into Tulare Lake and spill into Fresno Slough only when Tulare Lake water levels exceed 206 feet elevation. Historically, Tulare Lake basin has been considered to be a closed basin.

Simulation results show that Tulare Lake Basin outflow into the Delta is very small; it averages only 41 TAF per year for the period spanning water years 1922-2014. The Kings, Kaweah, Tule and Kern River stream inflows are evaporated and transpired by riparian forest and wetlands (Tulare Lake and Buena Vista Lake). With all available stream inflows draining into Tulare Lake

before it can overflow to Fresno Slough, the lake rarely fills to the maximum water level (Figure 4-19). This demonstrates the very high evapotranspiration demand in the Tulare Lake Basin compared to its limited water supply under natural conditions.
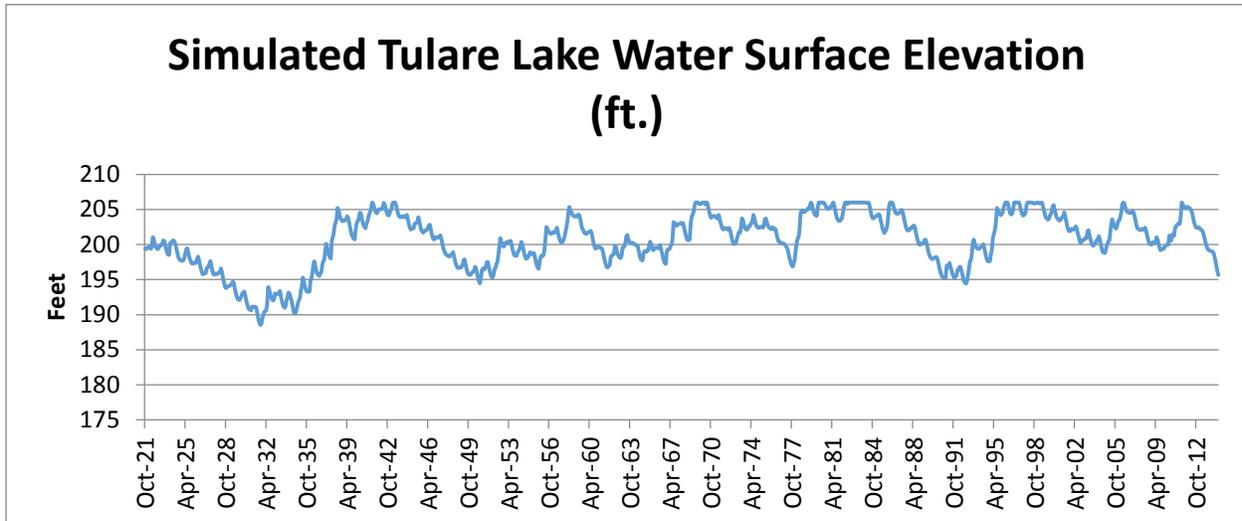
Figure 4-19. Simulated Tulare Lake Water Levels (WY1922-2014)

Delta Outflow ranges due to Model Input and Parameter Sensitivity and Uncertainties

Natural Delta outflow is fresh water that discharges into San Francisco Bay after Valley Floor and Delta evapotranspiration. Therefore, the main model simulation factors affecting Delta outflow are parameters for evapotranspiration (especially those for riparian vegetation and wetlands that have direct access to stream water), lake-groundwater interaction parameters, vegetation spatial distribution and the way each vegetation type is simulated, and extinction depth for groundwater uptake.

Potential Evapotranspiration (ET$_c$)

When the ET$_c$ input is uniformly changed by a constant factor with other parameters and inputs held constant at the base case values, the effect on the natural Delta outflow estimate is summarized in Table 4-12. Actual evapotranspiration from non-riparian vegetation (e.g. grassland and hardwoods) is water supply limited. Thus, when ET$_c$ for these vegetation classes is perturbed by -10 percent to +20 percent, the resulting change in Delta outflow is small (2 percent). However, when ET$_c$ for riparian forest and permanent wetlands is perturbed by the same amounts, changes in actual evapotranspiration are more significant and result in greater changes in Delta outflow.

Table 4-12. Changes in Delta Outflow Due to Potential Evapotranspiration Values

	Changes in Potential Evapotranspiration-ET_c		
Changes in actual ET and Delta Outflow	-10%	10%	20%
Non-riparian	-2%	1%	2%
Riparian	-7%	6%	13%
Permanent wetlands	-8%	7%	13%
Delta Outflow	7%	-6%	-11%

Simulating Permanent Wetlands as Lakes

In the C2VSim natural flow model, 26 lakes are defined for major historical flood basins (Butte, Sutter, Colusa, Yolo, American, and Sacramento Basins), known lakes (Tulare Lake) and minor local seasonal wetlands or vernal pools (Figure 4-20). Lake parameters include conductance of lake bed materials that controls lake-groundwater interaction, maximum lake elevation defining lake surface wetted area and outflow volume and timing and rating for stream overflow into lakes.

Lakebed conductance values have significant impact on lake-groundwater interaction. Under natural flow condition, a very small conductance of 0.003 is used to constrain the interaction flux. If a larger value is used (0.3~3.0), water in the lakes would easily be drained through groundwater interaction and show up in the Delta as groundwater inflow, with corresponding reduced stream inflow. Large groundwater flux from the Valley Floor to the Delta was considered to be unrealistic.

Overflow rating tables are defined and adjusted to have reasonable maximum stream flow rates in the main stream channels. For example, maximum daily flows at the Sacramento River below Verona cannot exceed 120,000 cubic feet per second. Overflow rating into Yolo Basin is adjusted to meet this requirement. Stream water into flood basins (lakes/wetlands) flow back into streams or downstream lakes when maximum lake elevation is reached.

Maximum lake elevation is determined by GIS map boundary of permanent wetlands. If a lake element node has a land elevation higher than the maximum lake elevation, it would be dry throughout the simulation process.

Figure 4-20. Distribution of Lakes/Wetlands

Vernal Pools

A significant portion of native vegetation is designated as vernal pools. Vernal pool hydrology is more complex than rain fed grassland. In addition to soil water and groundwater uptake, local runoff, perched groundwater, and flood water from local streams and creeks can supply water to vernal pools. The current model configuration and algorithm only allows riparian vegetation to have access to stream water. Therefore, without any special treatment in the C2VSim model, water available to vernal pools is limited to soil water and groundwater uptake (similar to grassland and hardwood vegetation classes).

For the base case, vernal pools in elements next to river reaches are treated as riparian vegetation and can access stream water when there is stream water available. This special treatment implicitly takes into account the small watersheds and local rainfall-runoff draining into nearby vernal pools. A sensitivity model run restricting water availability to vernal pools results in a long term annual average Delta outflow of 21.2 MAF, which is 1.5 MAF more than the baseline value of 19.7 MAF.

In Howes et al. (2015) and Fox et al. (2015), vernal pool water use in the San Joaquin Valley is about 2.2-2.9 feet per year or about 3.5 MAF. Our analysis does not support such a high overall water use, because San Joaquin Valley Floor non-lake land surface precipitation is 1.9 MAF (shared with grassland, hardwoods, etc. in the area), and there is very little local rainfall-runoff or small watersheds runoff. Furthermore, rim stream water inflows concentrate at a few major streams: San Joaquin River above Millerton, Merced River, and Stanislaus River (Figure 4-21). Vernal pools adjacent to smaller rivers such as Fresno River, Chowchilla, and Calaveras Rivers would have very limited water supply. Element level water balance is an advantage of this distributed, integrated modeling approach. It is possible that total vernal pool area in the San Joaquin Valley may have been overestimated. Instead of a continuous area distribution, the vegetation could be distributed more sporadically. Vernal pool area definition should be limited to pool surface.

Figure 4-21. Location of Vernal Pools, Streams, Small and Rim Watersheds

Groundwater Uptake

Even though the area of hardwood vegetation is only 24 percent of the total non-riparian vegetation, groundwater uptake from this class exceed 50 percent of total groundwater uptake in the Valley Floor. Almost all of this is located in the Sacramento Valley and Eastside Streams regions. The volume of groundwater uptake is determined by groundwater tables and the maximum rooting depth. Canadell et al. (1996) reviewed maximum rooting depth of vegetation types in the scientific literature. Root depths of large trees and some shrubs can be as deep as 50-100 feet. The ranges vary greatly by species and locations. Doubling the maximum rooting depths of all vegetation classes results in a 1.2 MAF decrease of Delta outflow relative to the base case. On the other hand, reducing maximum rooting depths by 50 percent will increase Delta outflow by 0.6 MAF.

Uncertainties from Combination of Impact Factors

When major model parameters and inputs are perturbed within certain ranges simultaneously, one would expect a distribution for range of natural Delta outflows. We used the PEST (Doherty 2015) package tool to do random samplings of five screened major factors with predefined ranges:

- Scale factor for ET_c: (0.9, 1.2)

- Lakebed conductance (0.001, 0.006)

- Extinction depths of groundwater uptake for riparian forest (10,40) and hardwoods (20, 160)

- Partition parameter of surface runoff and groundwater flow in small watersheds (0.0, 20.0).

Because the clock time for a model run on a current PC is about 2.5 hours, only 30 model runs were conducted. The results (Figure 4-22) are still revealing. The estimated Delta outflow range is between 17.1 and 21.5 MAF, with the most sensitive parameter being ET_c (Figure 4-23). Figures 4-24 and 4-25 show the sensitivity of simulated Delta outflow to vegetative crop coefficients and unit evapotranspiration.
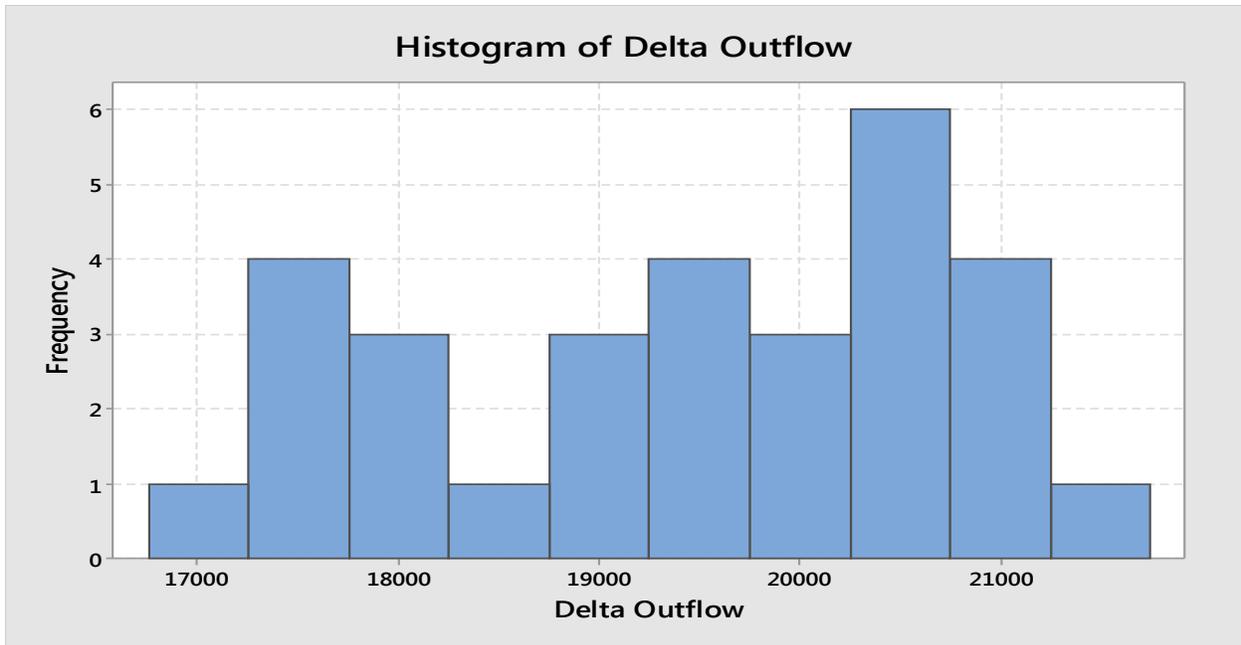
Figure 4-22. Histogram of Estimated Delta Outflows with 30 Sampling Combinations of Major Model Parameters and Inputs
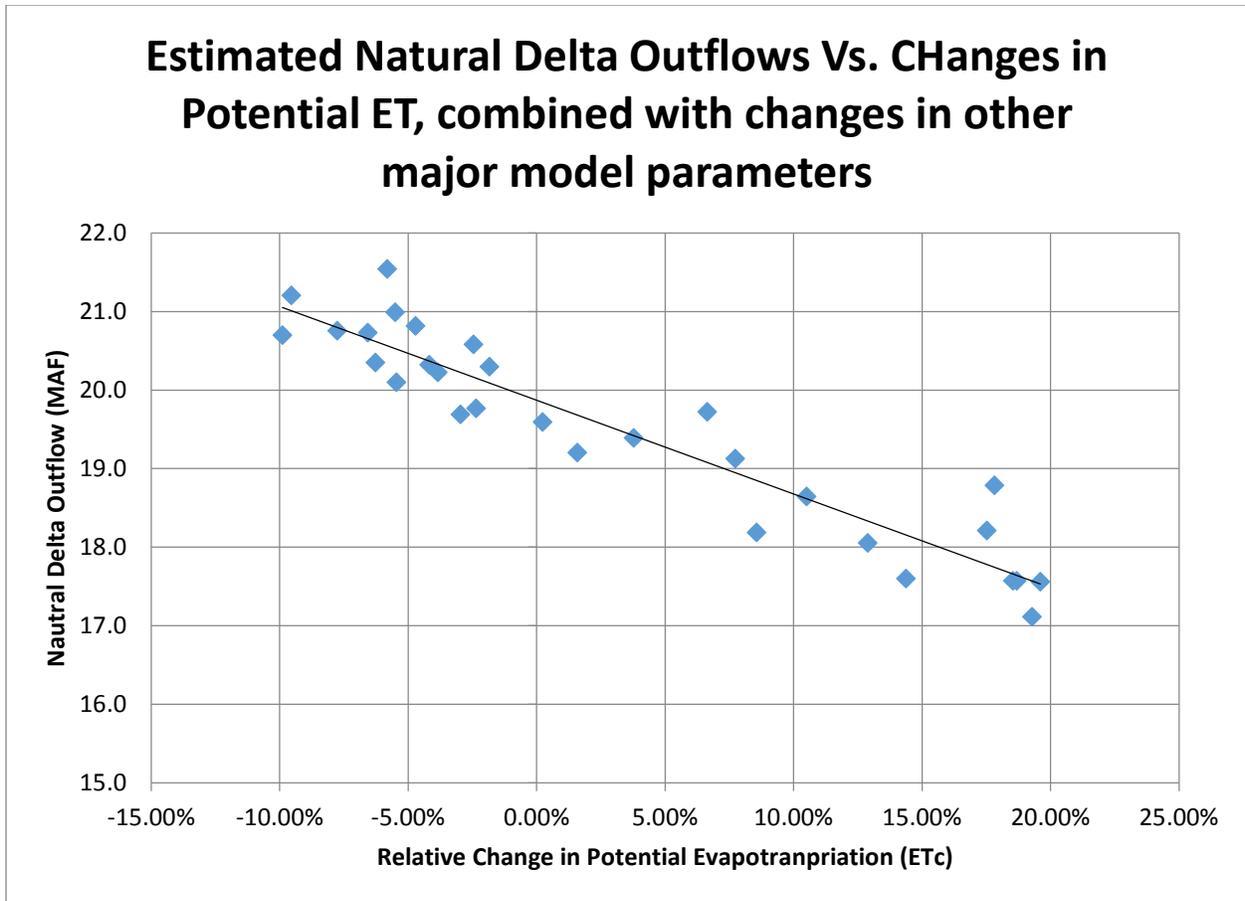
Figure 4-23. Sensitivity of Delta Outflow to Model Inputs and Parameters
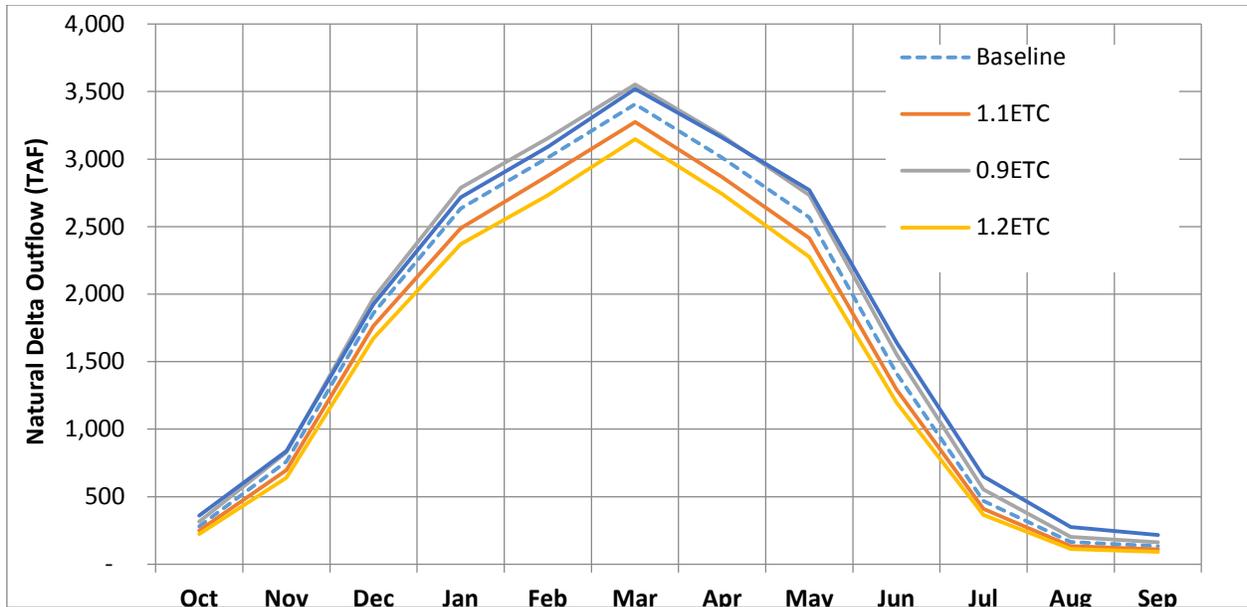
Figure 4-24. Monthly Distribution of Estimated Delta Outflow under Different Assumptions
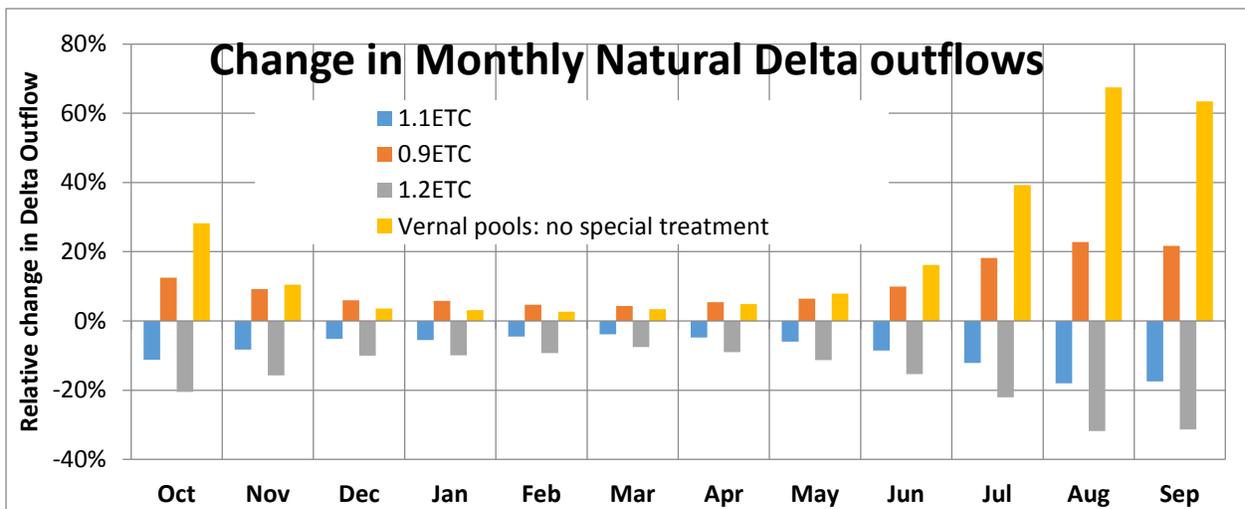
Figure 4-25. Changes in Monthly Delta Outflows for Different Sensitivity Model Runs

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5. COMPARISON BETWEEN NATURAL FLOWS AND UNIMPAIRED FLOWS

Estimated unimpaired flows reaching the Delta (i.e. Delta inflows) assume current channels and levees and, as a result, do not consider depletions or accretions on the valley floor other than depletions of valley floor rainfall runoff. The unimpaired flows estimates do not account for depletions from riparian vegetation, stream-groundwater interaction, and bank overflow to the flood plains and associated depletions from wetland vegetation. The natural flow estimates presented in this report, on the other hand, take into account all these depletions and accretions. The remainder of this chapter provides comparisons between natural and unimpaired flow estimates for rim watersheds, the valley floor and Delta inflow, and Delta outflow.

Rim Watershed Outflows

Upper rim watersheds, located in the foothill and mountain regions of the Sierra Nevada and California Coast Ranges, are relatively undeveloped. Precipitation-runoff processes are assumed to be assumed unchanged from natural condition for a given climate. Therefore, simulated natural outflows from these watersheds should be similar to estimates of unimpaired flows. As discussed in Chapter 4, the SWAT models used to simulate the upper rim watersheds were calibrated to match unimpaired flows. Table 5-1 compares SWAT simulated natural flows at unimpaired flow subbasin locations with unimpaired flow estimates for Water Years 1922-2014.

Unimpaired rim inflows entering the Valley Floor were not routed through main channels and bypasses. In the Delta, estimated natural inflows from Putah and Cache Creeks are very close numerically to estimated unimpaired flows but stream depletions or accretions from riparian vegetation and stream-groundwater interaction still applied before they directly entered the Yolo basin. Sacramento Valley, Eastside streams and San Joaquin Valley Delta inflows are significantly impaired after flowing through the valley floor before entering the Delta.

Table 5-1. Comparison of Natural and Unimpaired Average Monthly Flows

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Average Monthly Flows (thousand acre-feet)													
UF 2 – Putah near Winters													
SWAT	2	8	47	81	78	61	37	23	14	9	5	3	368
Unimpaired	2	11	55	87	98	68	34	11	4	2	1	0	373
UF 3 – Cache above Rumsey													
SWAT	3	20	58	94	105	90	64	44	26	16	8	3	532
Unimpaired	5	11	52	93	120	109	68	39	23	15	10	6	551
UF 4 – Stony at Black Butte													
SWAT	4	23	75	103	93	81	45	19	7	3	1	1	454
Unimpaired	2	11	50	89	97	77	49	27	9	1	0	0	412
UF 5 – Sacramento Valley West Side Minor Streams													
Elder	1	3	11	14	13	11	5	2	1	0	0	0	61
Thomes	3	8	28	38	41	37	24	14	9	7	5	3	217
SWAT Total	4	12	39	52	55	47	29	16	10	7	5	3	278
Unimpaired	3	15	51	78	90	81	65	40	13	3	1	1	441
UF 6 – Sacramento River near Red Bluff													
Cow	7	23	66	86	86	78	51	33	13	4	2	2	450
Paynes	1	3	8	12	12	9	4	2	1	0	0	0	52
Cottonwood	7	18	72	120	123	111	67	39	18	7	4	4	591
Battle	16	21	33	40	40	41	38	36	27	18	14	14	338
Sacramento at Shasta	233	395	593	635	721	791	630	447	322	263	218	187	5,434
SWAT Simulated	263	459	772	892	983	1029	791	557	380	292	239	208	6,865
Unimpaired Flow	308	441	844	1134	1244	1251	975	704	443	303	259	262	8,168
UF 7 – Sacramento Valley East Side Minor Streams													
Deer	9	26	53	65	67	65	43	28	12	5	3	3	379
Big Chico	3	9	22	28	30	28	19	14	6	2	1	1	162
Butte and Chico	18	28	61	83	95	98	86	65	37	22	18	15	627
Mill	6	18	34	40	39	36	27	20	10	5	3	3	241
SWAT Simulated	36	81	170	216	231	228	175	126	65	34	25	22	1,410
Unimpaired Flow	35	59	128	169	181	182	155	123	72	41	31	28	1,204
UF 8 – Feather River near Oroville													
SWAT Simulated	105	206	393	504	570	710	667	543	318	171	99	72	4,357
Unimpaired Flow	105	184	375	480	539	658	678	627	325	152	101	86	4,310
UF 9 – Yuba River at Smartville													
SWAT Simulated	63	152	262	268	277	310	334	377	200	40	14	15	2,312
Unimpaired Flow	32	87	200	256	285	330	361	404	207	57	23	19	2,261
UF 10 – Bear River near Wheatland													
SWAT Simulated	6	22	45	55	65	62	40	17	5	3	2	2	323
Unimpaired Flow	5	13	41	57	66	61	39	18	7	3	1	2	313

Table 5-1. Comparison of Natural and Unimpaired Average Monthly Flows contd.

	Average Monthly Flows (thousand acre-feet)												
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
UF 11 – American River at Fair Oaks													
SWAT Simulated	49	136	256	289	290	364	416	477	301	101	28	16	2,724
Unimpaired Flow	25	82	203	288	316	387	441	493	265	67	16	12	2,595
UF 13 – Cosumnes River at Michigan Bar													
SWAT Simulated	3	15	37	47	58	71	66	49	14	3	1	0	364
Unimpaired Flow	2	9	30	54	64	75	65	43	16	4	1	1	364
UF 14 – Mokelumne River at Pardee Reservoir													
SWAT Simulated	15	29	42	43	61	92	116	179	128	21	4	6	734
Unimpaired Flow	6	18	37	51	59	82	125	189	117	26	5	3	718
UF 15 – Calaveras River at Jenny Lind													
SWAT Simulated	1	7	26	40	40	31	21	8	1	0	0	0	176
Unimpaired Flow	1	4	16	31	39	36	22	7	2	1	0	0	159
UF 16 – Stanislaus River at Melones Reservoir													
SWAT Simulated	20	38	52	58	90	145	215	283	174	53	11	10	1,149
Unimpaired Flow	10	26	54	80	93	130	193	279	173	53	12	7	1,110
UF 18 – Tuolumne River at Don Pedro Reservoir													
SWAT Simulated	44	91	155	173	191	248	283	368	270	80	16	18	1,937
Unimpaired Flow	18	46	89	122	142	192	276	444	348	122	26	12	1,837
UF 19 – Merced River at Exchequer Reservoir													
SWAT Simulated	10	32	54	60	78	117	155	213	168	68	9	3	967
Unimpaired Flow	8	19	43	66	82	102	148	240	170	56	13	6	953
UF 20 – Chowchilla River at Buchanan Reservoir													
SWAT Simulated	1	4	12	17	23	23	11	3	1	0	0	0	95
Unimpaired Flow	0	1	6	12	17	17	11	4	1	0	0	0	69
UF 21 – Fresno River near Daulton													
SWAT Simulated	1	6	14	20	28	29	17	5	1	0	0	0	120
Unimpaired Flow	0	2	6	11	16	19	15	9	5	2	0	0	85
UF 22 – San Joaquin River at Millerton Reservoir													
SWAT Simulated	19	45	73	84	113	169	252	403	355	187	54	18	1,772
Unimpaired Flow	20	33	60	83	100	144	237	431	371	167	51	23	1,720

Notes:

[1] In C2VSim, UF 5 includes two separate stream inflows, Thomes Creek and Elder Creek. Furthermore, the Red Bank group and ungauged runoff in UF5 are part of small watersheds in C2VSim.

[2] UF6 includes five separate stream inflows: 1, Sacramento River (Shasta Lake), 2, Cow Creek, 3, Battle Creek, 4, Paynes and Seven mile Creek, 5, Cottonwood Creek, and a few small watersheds with a portion of Valley Floor rainfall-runoff in Subregion 1. Therefore, the sum of C2VSim stream inflows does not add up to unimpaired flow UF6.

[3] UF7 includes separate stream inflows from Mill Creek, Deer Creek and Big Chico Creek and adjacent ungauged runoff.

Key: SWAT = Soil Water Assessment Tool, UF = unimpaired flow

Valley Floor Water Supply and Delta Inflows

The valley floor water supply includes stream inflows from the major rim mountainous watersheds, inflows from the minor small watersheds, and valley floor rainfall. Water supply to the valley floor can be assumed to be the same for natural and unimpaired conditions. However, as previously discussed, natural Delta inflows are significantly reduced from rim inflows because of evaporative use of water from riparian forests, grasslands, and wetlands. Comparisons between natural and unimpaired Delta inflow estimates are provided in Table 5-2.

Table 5-2. Comparison of Natural and Unimpaired Delta Inflows

Flow Items	Average Annual Flows: 1922-2014 (TAF)												
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
	Natural Flow Estimates												
Sacramento Valley	262	792	1,860	2,490	2,727	2,966	2,525	1,973	1,028	348	131	111	17,212
Eastside Streams	14	40	86	106	125	148	149	182	115	15	2	5	986
San Joaquin Valley	35	90	197	263	307	426	522	701	516	196	52	30	3,334
Total Delta Inflows	312	922	2,142	2,859	3,159	3,539	3,195	2,856	1,659	559	185	145	21,533
	Unimpaired Flow Estimates												
Sacramento Valley	526	938	2,092	2,870	3,187	3,333	2,937	2,515	1,375	646	443	416	21,278
Eastside Streams	10	39	119	205	251	278	263	257	140	33	7	5	1,607
San Joaquin Valley	58	133	282	416	509	667	934	1,457	1,102	409	104	48	6,119
Total **Delta Inflows**	594	1,110	2,492	3,492	3,947	4,278	4,134	4,230	2,617	1088	554	469	29,003
Total Difference	-282	-188	-350	-633	-788	-739	-939	-1374	-958	-529	-369	-324	-7,472

Delta Outflow

Table 5-3 compares average annual and monthly natural and unimpaired Delta outflow estimates for the period spanning water years 1922-2014. Average annual estimates are significantly lower for natural conditions (19.7 MAF) relative to unimpaired conditions (28.2 MAF). Figures 5-1 displays a comparison between natural and unimpaired annual values by 40-30-30 water year type. Similarly, Figures 5-2 through 5-7 display comparison between natural and unimpaired monthly values by water year type.

The annual and monthly natural and unimpaired Delta outflow estimates for the period spanning water years 1922-2014 were also compared by plotting exceedance curves. These charts are provided in Appendix D.

Table 5-3. Comparison of Natural Delta Outflow and Delta Outflow in Unimpaired Flow Report

	Average Annual Flows: 1922-2014 (TAF)												
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Natural Net Delta Outflow	280	760	1,859	2,634	3,012	3,406	3,012	2,567	1,414	467	164	133	19,708
Unimpaired Net Delta Outflow	511	1,051	2,450	3,468	3,902	4,198	4,032	4,111	2,492	961	438	369	28,050
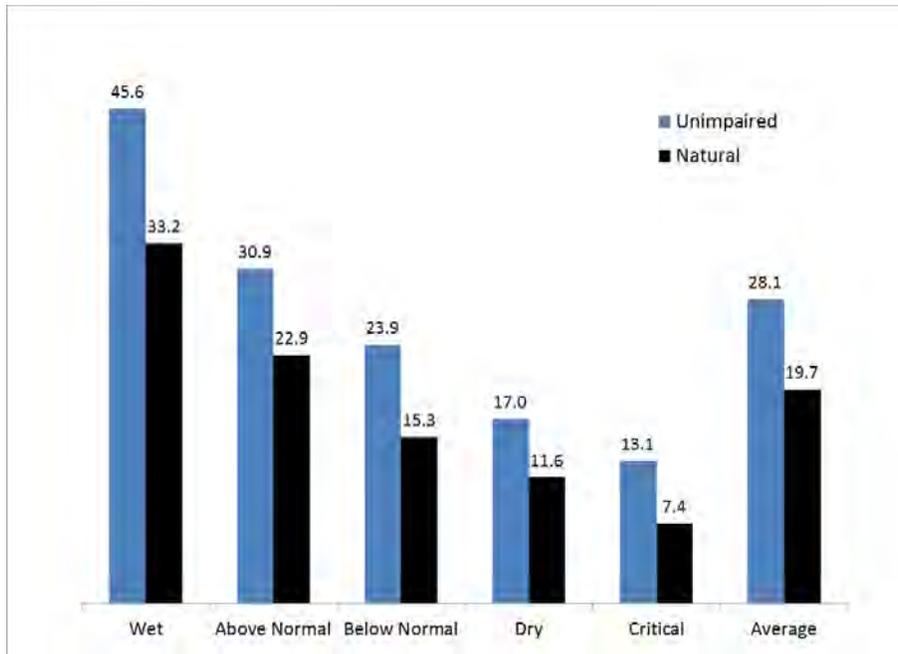
Figure 5-1. Comparison of Annual Natural and Unimpaired Net Delta Outflow Estimates by 40-30-30 Water Year Type: Water Years 1922-2014 Averages (in MAF)
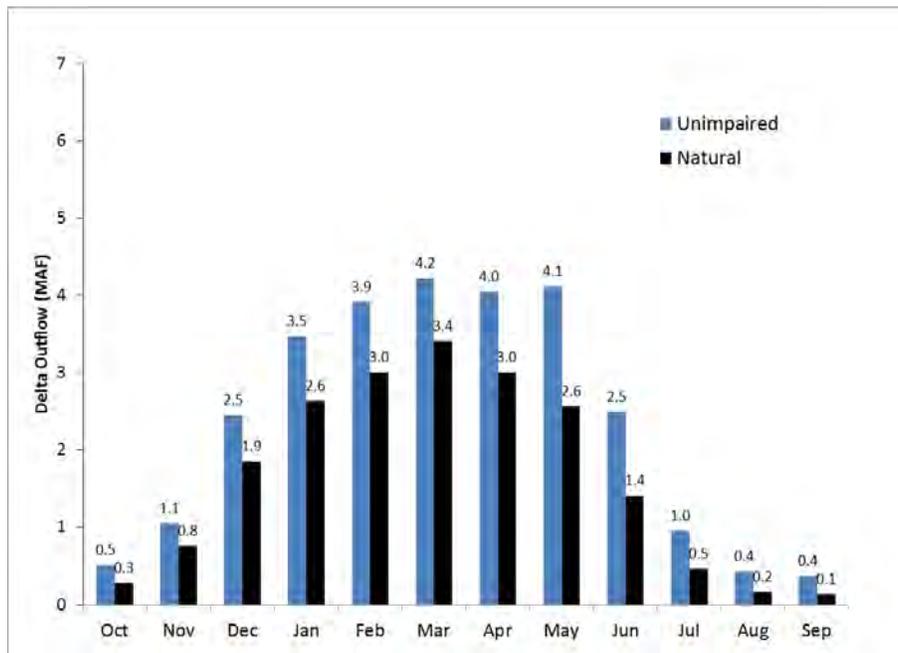
Figure 5-2. Comparison of Monthly Natural and Unimpaired Net Delta Outflow Estimates by 40-30-30 Water Year Type: Water Years 1922-2014 Averages
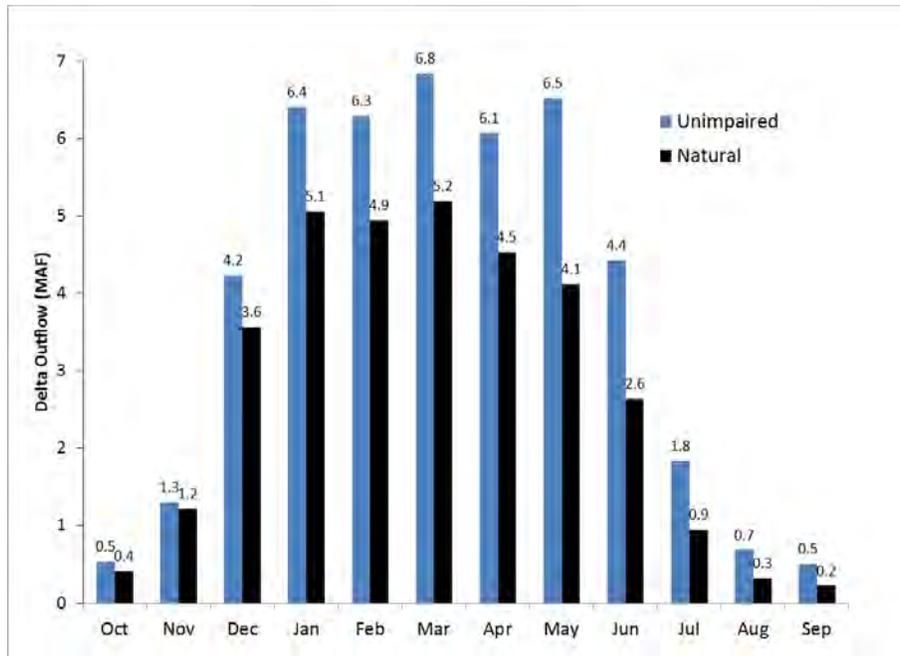
Figure 5-3. Comparison of Monthly Natural and Unimpaired Net Delta Outflow Estimates by 40-30-30 Water Year Type: Water Years 1922-2014 Wet Year Averages
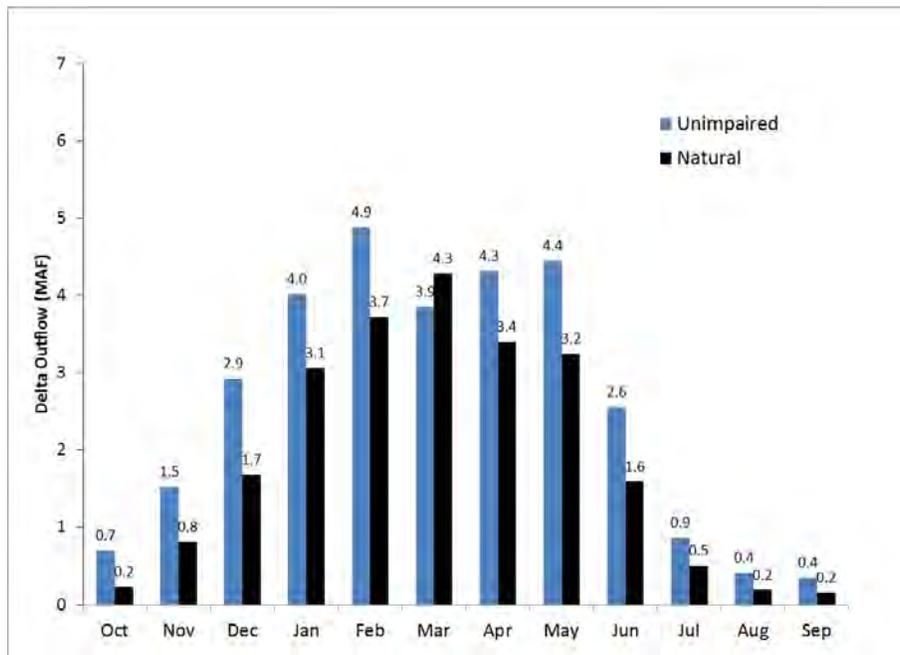
Figure 5-4. Comparison of Monthly Natural and Unimpaired Net Delta Outflow Estimates by 40-30-30 Water Year Type: Water Years 1922-2014 Above Normal Water Year Averages
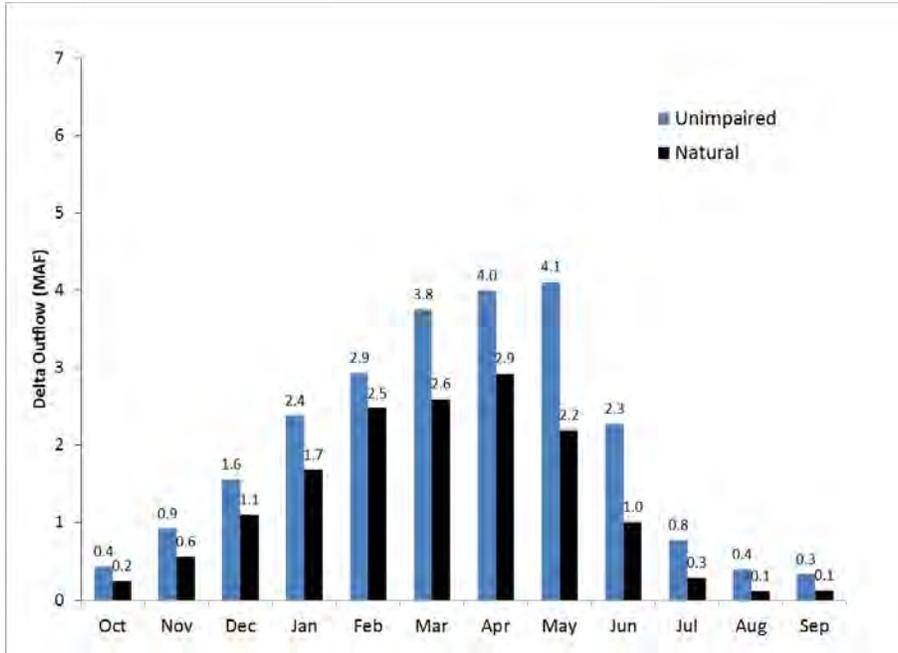
Figure 5-5. Comparison of Monthly Natural and Unimpaired Net Delta Outflow Estimates by 40-30-30 Water Year Type: Water Years 1922-2014 Below Normal Water Year Averages
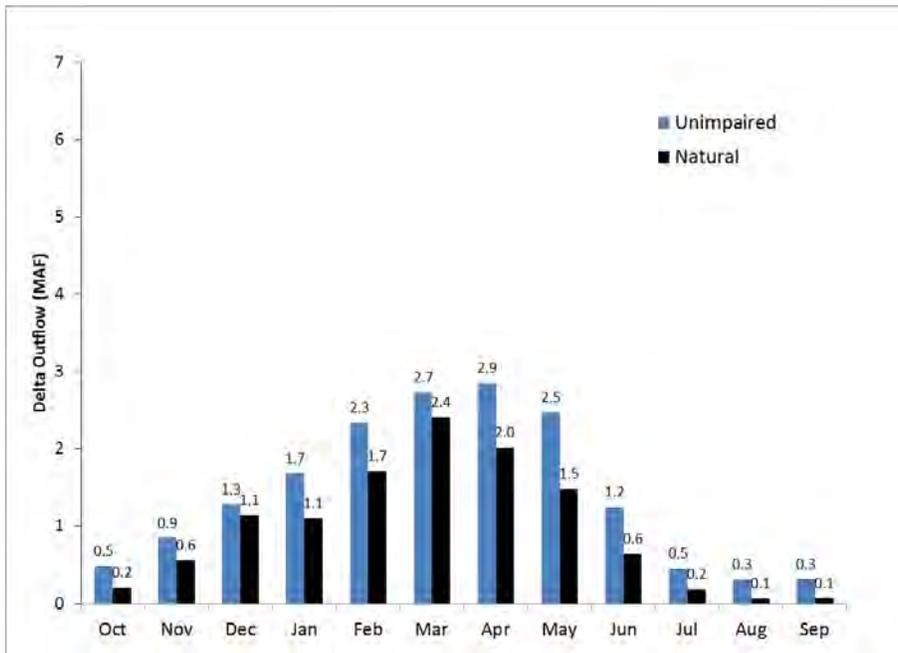
Figure 5-6. Comparison of Monthly Natural and Unimpaired Net Delta Outflow Estimates by 40-30-30 Water Year Type: Water Years 1922-2014 Dry Water Year Averages
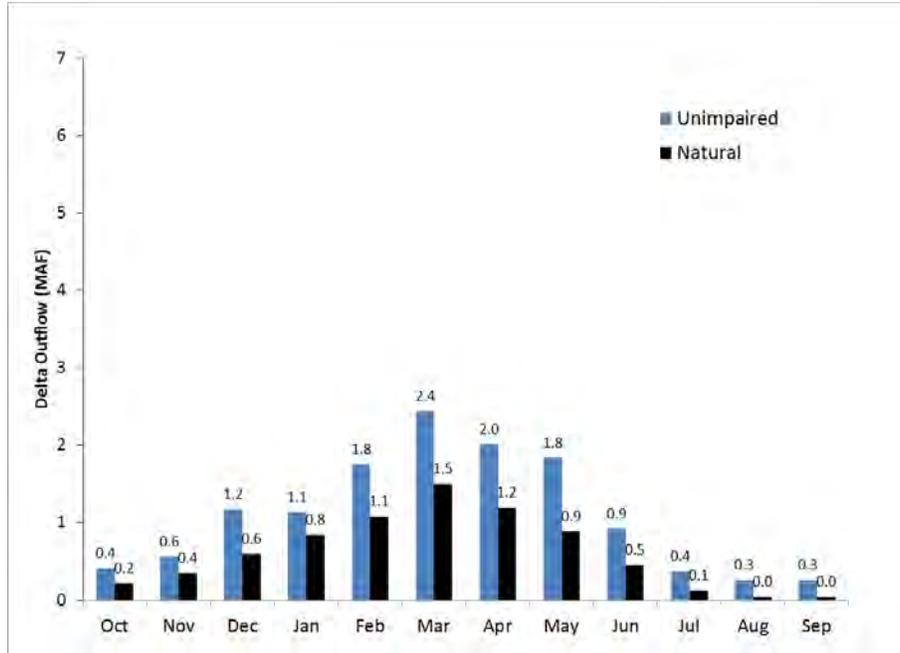
Figure 5-6. Comparison of Monthly Natural and Unimpaired Net Delta Outflow Estimates by 40-30-30 Water Year Type: Water Years 1922-2014 Critical Water Year Averages

6. SUMMARY

This report documents and compares a variety of natural and unimpaired flow estimates for the hydrologic period spanning water years 1922-2014, including rim watershed inflows, valley floor water supply, and Delta inflows and outflows. The natural flow estimates, the first to be published by the Department, were derived from complex simulation models (SWAT and C2VSim) and were based on published estimates of natural vegetation cover (Fox et al. 2015) and associated evapotranspiration (Howes et al. 2015). Methods used to estimate unimpaired flows generally followed the approach established in previous Department publications; the last update was published in 2007 (DWR 2007).

Comparisons of Delta inflow and outflow estimates demonstrate that unimpaired estimates are consistently (and significantly) higher than natural estimates. This difference is primarily the result of the unimpaired estimates not accounting for overbank flows and the resulting evapotranspiration associated with natural wetlands. The relative seasonal (i.e. monthly) distributions of unimpaired and natural Delta outflow estimates are not widely different. However, the relative distribution of unimpaired Delta outflow tends to be smaller in the winter (and larger in the other seasons) compared to natural Delta outflow. In sum, the findings of this report show that unimpaired flow estimates are poor surrogates for natural flow conditions.

To further evaluate the resulting annual average natural Delta outflow estimate of 19.7 MAF, sensitivity analyses were conducted on potential evapotranspiration, lakebed conductance, extinction depths of groundwater uptake (for riparian forest and hardwoods), and surface runoff and groundwater flow partition parameters. The sensitivity analyses, supported by 30 model runs, suggested an uncertainty range of approximately ± 10 percent. Potential evapotranspiration from riparian and wetland vegetation was found to be the most sensitive model parameter.

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APPENDIX A   SWAT MODELS FOR RIM WATERSHEDS

Introduction

Soil Water Assessment Tool (SWAT) is a public domain, physically based, semi-distributed precipitation-runoff model tool developed by the US Department of Agriculture Agricultural Research Service (USDA-ARS) (Arnold et al., 2012). A few previous applications of SWAT in California have been reported. US EPA (2013) developed a SWAT model for Sacramento Valley floor of the drainage area between downstream of Shasta to the confluence of Feather River and Sacramento River. Ficklin et al. (2009) applied SWAT to San Joaquin Valley watershed focusing on Valley floor water quality. And Ficklin et al. (2012) developed monthly SWAT models of Western slope Sierra Nevada rim watersheds for climate change impact study. Hundreds of worldwide SWAT applications have been documented in peer-reviewed literature (http://swat.tamu.edu/). Expanding from our earlier work on upper Feather River watershed (Huang et al. 2012), 23 individual SWAT models were developed for the major upper watersheds in the Central Valley. These daily SWAT models were calibrated and validated with observed or reconstructed unimpaired streamflow data for the period Water Year 1922-2014. Common and consistent database of digital elevation, land use, soil and climate data were used with GIS to develop the SWAT models in a relatively short development time. Daily climate data of precipitation, maximum and minimum air temperature are based on the Hamlet and Lettenmaier (2005) 1915-2003 complete 1/8 degree (about 12*12 kilometers) grid dataset and extended with the 4*4 kilometers PRISM grid data.

SWAT Models for the Watersheds in Sacramento Valley and Eastside Streams

Currently the following watersheds in Sacramento Valley and Eastside Streams hydrologic regions have SWAT models (see Figure A-1):

- Sacramento River at Shasta Lake CDEC: SIS)

- Feather River at Lake Oroville (CDEC: FTO)

- Yuba River at Marysville (CDEC:YRS)

- American River at Folsom Lake (CDEC: AMF)

- Bear River

- Sacramento Valley East Side Minor Streams (Mill, Big Chico, and Deer Creeks)

- Putah Creek

- Cache Creek

- Stony Creek

- Sacramento Valley west Side Minor Streams (Thomes and Elder Creeks)

- Cosumnes River (CDEC: CSN)

- Mokelumne River (CDEC: MKM)

- Calaveras River at Jenny Lind

- Stanislaus River

- Tuolumne River

- Merced River

- Chowchilla River

- Fresno River

- San Joaquin River at Millerton Reservoir (CDEC: SJF)

- Kings River

- Kaweah River

- Tule River

- Kern River

Each separate SWAT model set up started with watershed delineation using 30-meter digital elevation model (DEM) land surface elevation data. Sub watersheds and stream network are automatically generated within ArcSWAT GIS tool (see Figure A-2 for example). The 2001 U.S. Geological Survey national land use survey spatial data was used to determine land use types (Figure A-3). Forest and rangeland are the dominant land use in the upper watersheds. Soil type data was based on the State Soil Geographic (STATSGO) dataset (Figure A-4). Sub watersheds are further subdivided into hydrologic response units (HRU) that consist of homogeneous land use, soil characteristics and land slopes.

Observed daily precipitation, maximum and minimum air temperature time series data are processed for each sub watershed. Since at most, each sub watershed can only be assigned to a climate station in SWAT. Solar radiation and Wind speed can also be input to estimate potential evapotranspiration if available.

Hydrologic processes simulated by SWAT include snowfall/snowmelt, surface runoff, infiltration, evapotranspiration, lateral flow, groundwater flow, and flow routing through cannel network to watershed outlet. A large number of model parameters are set to default values based on HRU level physical characteristics. However, these parameters must be adjusted to local conditions to get a good fit of simulated streamflow with observed data.

Figure A-1. Location of SWAT Watersheds
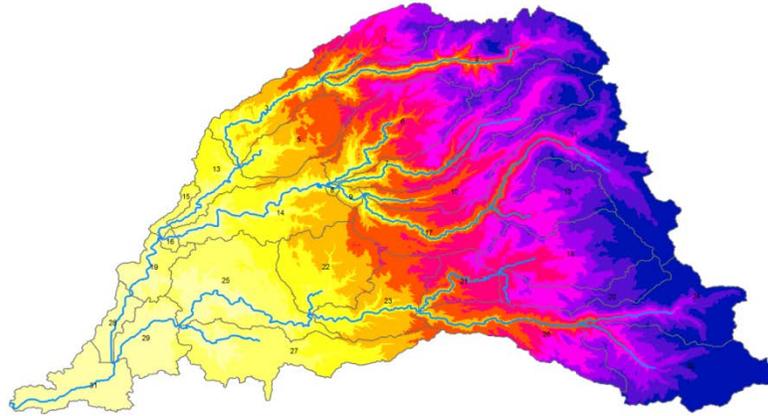
Figure A-2. American River Watershed: DEM, Subbasins and Stream Network
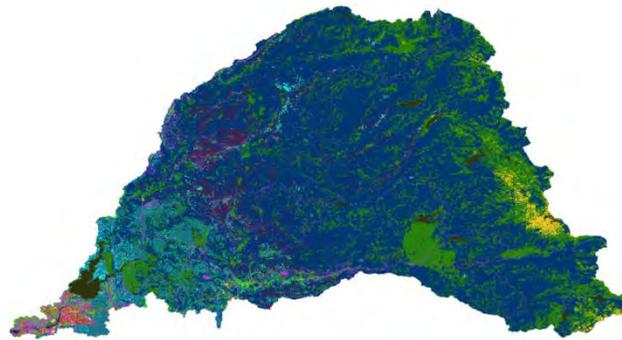
Legend

SWAT Land use Type

AGRR	SWRN	
FRSD	UIDU	
FRSE	URHD	
FRST	URLD	
HAY	URMD	
RNGB	WATR	
RNGE	WETF	
	WETN	

Figure A-3. American River Watershed: Land Use (Less than 1% of Urban and Agriculture Use Near the Watershed Outlet)

Figure A-4. American River Watershed: Soil Types

Model Calibration and Validation

Model calibration is a process of adjusting model parameters to get a better fit of simulated streamflows to corresponding observed data at selected sub-watersheds or watershed outlets. This is a time consuming and tedious process that may involve optimization and expert judgment. It could take hundreds of model runs for each target outlet to reach a satisfactory calibration result. Available observed streamflow data are usually split into two time periods for calibration and validation, respectively. During model validation, calibrated model parameters are fixed and simulated and observed streamflow are compared to see whether model prediction is still good.

In Central Valley, most upper watersheds are relatively undeveloped but streamflow is highly regulated by reservoirs and water diversion. Measured streamflow data at a U.S. Geological Survey stream gauge have to be unimpaired to correct for upstream reservoir storage and evaporation and water diversion. Therefore, observed streamflow data are already estimated. This complicates model calibration. Furthermore, most watersheds have only unimpaired monthly flow data for the whole time period. Unimpaired daily flow data are less reliable and of limited availability. For these reasons, model calibration and validation are performed and judged at monthly level.

Both SWAT-CUP: SWAT Calibration and Uncertainty Programs (Eawag. 2009) and manual calibration model runs were used in model development. Graphic time series or scatter plots (Figures A-6, A-7, and A-8) and statistical criteria (Tables A-1 and A-2) are used to guide calibration and validation. Although there is no absolute criteria for judging SWAT model performance, Both Nash-Sutcliffe efficiency >0.75 and R2 >0.75 is usually considered very good based on monthly flow data in reported SWAT applications (Arnold et al. 2012). The R2 statistic can range from 0 to 1, where 0 indicates no correlation and 1 represents perfect correlation, and it provides an estimate of how well the variance of observed values are simulated by the model estimates. Nash-Sutcliffe efficiency (NSE) values can range between -∞ to 1 and provide a measure how well the simulated output matches the observed data along a 1:1 line regression line with slope equal to 1. A perfect fit between the simulated and observed data is indicated by an NSE value of 1.

Poorer calibration results only occur at minor streams and San Joaquin and Tulare Basins where less effort in model development and calibration are made. Tables A-1 and A-2 summarize combined period of calibration and Validation statistics.

Model limitation and Further Work

Since model development spans in the past few years, the SWAT2009 version was used. Arc SWAT in Arc Map has also been evolved such that earlier model set up files for some watersheds can only be read by older Arc Map 9.x version.

To improve model accuracy, further calibration at sub watershed scale and other hydrologic variables such as snow water equivalent and soil moisture data are recommended.

Table A-1. SWAT Calibration and Validation Statistics Summary: Sacramento River and Eastside Streams

Watershed	No. of Subbasins	No. of HRUs	Drainage Area (km^2)	Observed Data	R^2	Nash-Sutcliffe Efficiency
Sacramento River at Shasta	25	98	16,261	1922-2014	0.90	0.89
Feather River	64	99	9,335	1922-2014	0.90	0.90
Yuba River	39	122	3,174	1922-2014	0.85	0.84
American River	31	200	4,943	1922-2014	0.89	0.89
Bear River	19	46	752	1922-2014	0.84	0.84
Putah Creek	27	51	1,506	1922-2014	0.83	0.80
Cache Creek	25	45	2,440	1922-2014	0.79	0.72
Stony Creek	29	63	1,963	1922-2014	0.68	0.67
Thomes Creek	36	156	699	1921-1979	0.73	0.73
Elder Creek				1949-1979	0.70	0.69
Mill Creek	23	101	1,034	1931-2014	0.75	0.74
Deer Creek				1922-2014	0.76	0.67
Big Chico Creek				1931-1985	0.83	0.83
Cosumnes River	38	132	1,387	1921-2011	0.85	0.85
Mokelumne River	23	77	1,502	1921-2014	0.81	0.80
Calaveras River	25	117	933	1922-2014	0.86	0.85

Key:
HRU = hydrologic Response Unit
km^2 = square kilometer
R^2 = Coefficient of Determination

Table A-2. SWAT Calibration and Validation Statistics Summary: San Joaquin River and Tulare Basin

Watershed	No. of Subbasins	No. of HRUs	Drainage area (km^2)	Observed data	R^2	Nash-Sutcliffe Efficiency
Stanislaus River	23	53	2,518	1922-2014	0.85	0.85
Tuolumne River	29	246	3,980	1922-2014	0.90	0.90
Merced River	27	83	2,742	1921-2014	0.86	0.86
Chowchilla River	27	50	669	1922-2014	0.77	0.76
Fresno River	21	58	757	1922-2014	0.71	0.71
San Joaquin River	31	136	4,296	1921-2014	0.91	0.91
Kings River	38	223	4,413	1921-2014	0.75	0.68
Kaweah River	75	75	1,453	1922-2014	0.81	0.80
Tule River	30	85	986	1931-2014	0.70	0.69
Kern River	26	184	5,372	1930-2014	0.68	0.67

Key:
HRU = Hydrologic Response Unit
km^2 = square kilometer
R^2 = Coefficient of Determination
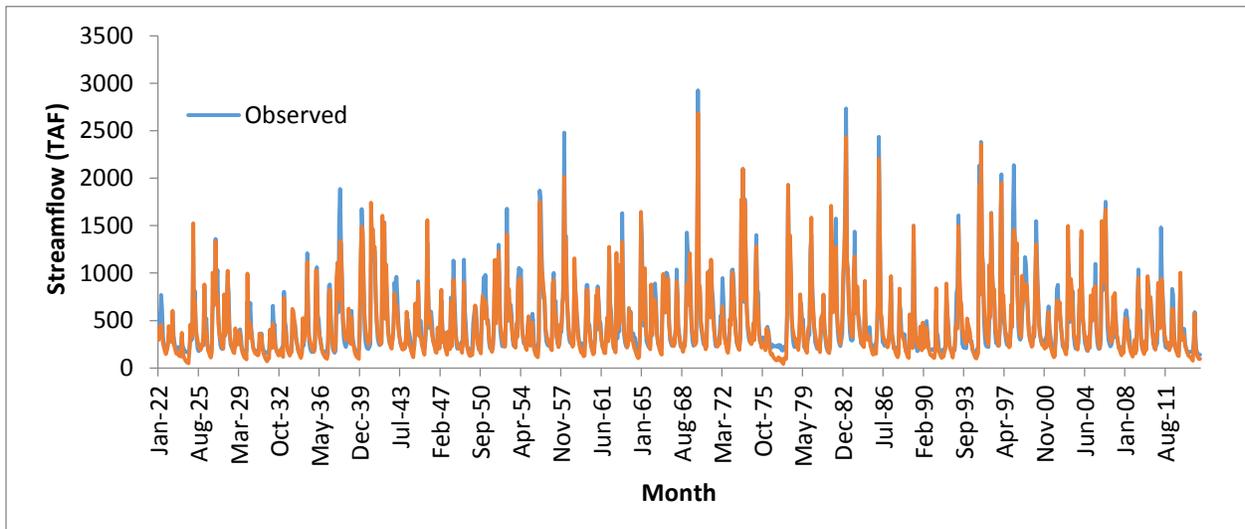
Figure A-5. SWAT Simulated and Unimpaired Observed Monthly Streamflow Sacramento River at Shasta: 1922-2014
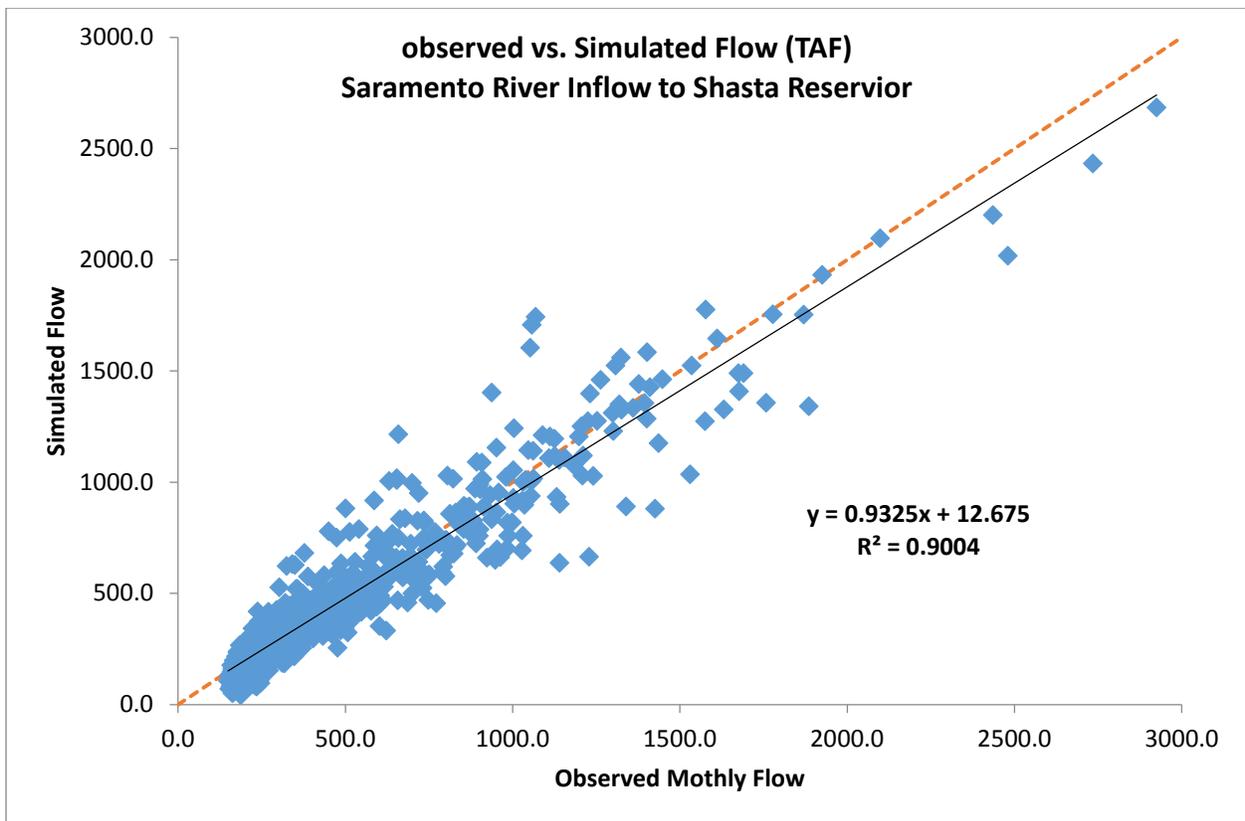
Figure A-6. Scatter Plot of SWAT Simulated and Unimpaired Observed Monthly Streamflow Sacramento River at Shasta: 1922-2014
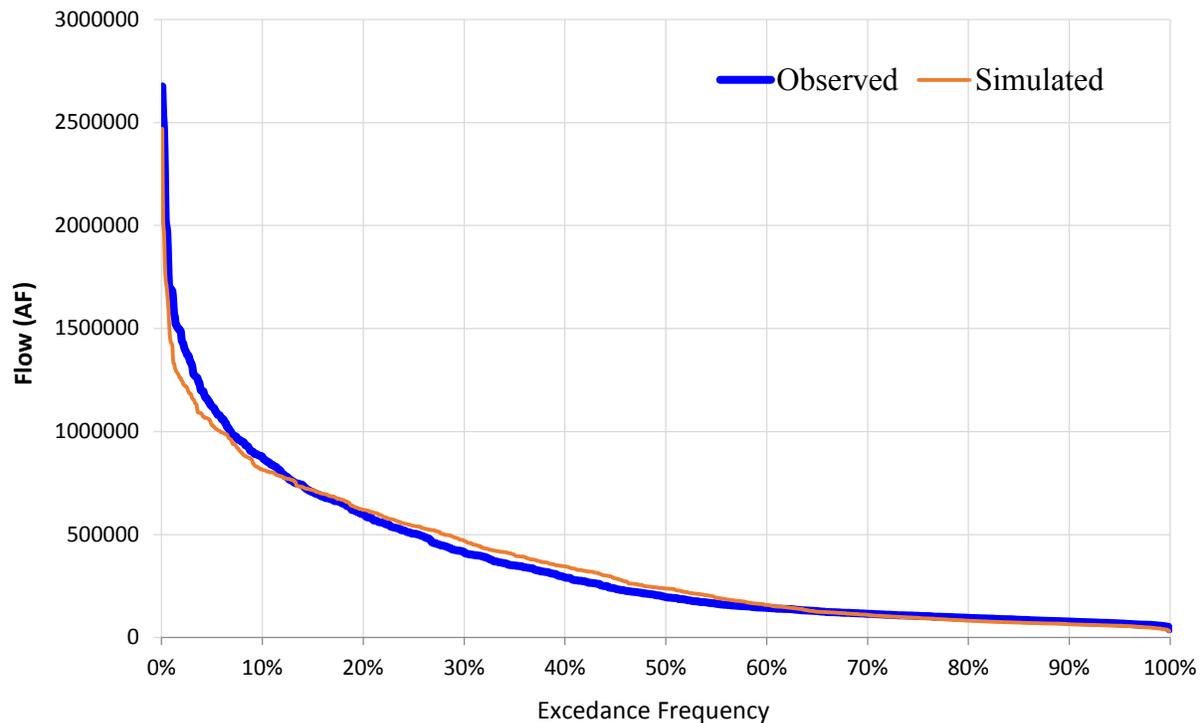
Figure A-7 Frequency Curves of SWAT Simulated and Unimpaired Observed Monthly Streamflow: 1915-2014

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APPENDIX B   UNIMPAIRED FLOW TABLES WY 1922-2014

Table B-1. UF 1 – Sacramento Valley Floor Unimpaired Flow in TAF

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1922	0	11	167	140	466	289	175	15	0	0	0	0	1263
1923	0	14	173	109	75	50	58	7	0	0	0	0	486
1924	0	0	4	8	17	2	3	0	0	0	0	0	34
1925	0	9	39	67	290	45	40	9	5	0	0	0	504
1926	0	3	8	20	113	23	25	2	0	0	0	0	194
1927	0	65	37	144	595	141	85	0	0	0	0	0	1067
1928	0	22	30	76	99	327	56	0	0	0	0	0	610
1929	0	3	11	8	25	22	17	0	0	0	0	0	86
1930	0	0	81	73	110	116	28	6	0	0	0	0	414
1931	0	2	1	8	8	10	1	0	0	0	0	0	30
1932	0	9	113	136	166	125	53	18	1	0	0	0	621
1933	0	0	5	18	13	54	12	10	0	0	0	0	112
1934	0	0	9	17	29	12	3	0	0	0	0	0	70
1935	0	14	28	109	147	107	195	23	0	0	0	0	623
1936	0	2	10	253	412	94	50	6	1	0	0	0	828
1937	0	0	5	14	142	136	104	25	0	0	0	0	426
1938	0	20	156	138	358	508	148	45	0	0	0	0	1373
1939	0	3	7	11	15	45	14	1	0	0	0	0	96
1940	0	0	7	194	395	267	49	4	1	0	0	0	917
1941	0	7	140	286	384	153	61	20	1	0	0	0	1052
1942	0	7	156	382	425	97	91	34	2	0	0	0	1194
1943	0	30	133	434	213	287	45	8	0	0	0	0	1150
1944	0	0	6	25	60	59	24	8	0	0	0	0	182
1945	0	14	37	38	270	59	35	8	1	0	0	0	462
1946	0	21	290	161	70	94	45	7	0	0	0	0	688
1947	0	2	28	3	70	115	37	3	0	0	0	0	258
1948	0	0	4	37	22	94	123	23	0	0	0	0	303
1949	0	0	16	7	30	278	13	10	0	0	0	0	354
1950	0	0	4	168	271	94	39	9	0	0	0	0	585
1951	0	353	493	371	103	47	20	30	5	0	0	0	1422
1952	0	4	235	744	170	302	19	3	0	0	0	0	1477
1953	0	0	63	285	27	153	41	13	0	0	0	0	582
1954	0	4	7	147	174	148	105	11	0	0	0	0	596
1955	0	2	41	131	20	12	21	5	0	0	0	0	232
1956	0	4	730	589	89	24	17	14	0	0	0	0	1467
1957	0	1	0	10	103	68	23	33	4	0	0	0	242
1958	1	1	21	119	401	207	406	20	1	0	0	0	1177
1959	0	1	4	39	211	13	6	2	0	0	0	0	276
1960	0	0	0	18	197	41	15	5	0	0	0	0	276
1961	2	22	26	15	53	57	31	18	3	0	0	0	227
1962	0	6	33	35	286	106	44	13	0	0	0	0	523
1963	187	22	86	66	178	95	251	62	8	0	0	0	955
1964	11	66	37	119	37	40	31	44	0	0	0	0	385
1965	11	35	464	341	48	44	147	29	6	0	0	0	1125
1966	2	40	53	88	66	66	42	22	2	0	0	0	381
1967	0	73	146	248	85	163	180	88	15	0	0	0	998
1968	10	10	32	66	164	71	22	8	0	0	0	0	383
1969	9	32	89	528	264	146	103	41	6	0	0	0	1218
1970	15	11	137	430	100	89	20	6	0	0	0	0	808

Table B-1. UF 1 – Sacramento Valley Floor Unimpaired Flow in TAF contd.

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1971	23	94	276	120	60	155	67	39	15	0	0	0	849
1972	1	10	73	46	97	61	48	17	1	0	0	0	354
1973	1	74	83	326	237	174	62	24	1	0	0	0	982
1974	12	172	202	262	84	292	161	36	13	0	0	0	1234
1975	0	7	19	41	195	197	100	46	1	0	0	0	606
1976	11	35	21	11	24	25	7	0	0	0	0	0	134
1977	0	2	1	19	11	10	0	3	0	0	0	0	46
1978	0	7	70	351	127	178	116	38	6	0	0	0	893
1979	0	17	10	93	134	141	54	43	0	0	0	0	492
1980	8	25	69	339	316	132	53	33	6	0	0	0	981
1981	0	1	18	55	29	95	20	0	0	0	0	0	218
1982	10	158	325	221	238	214	382	54	6	0	0	0	1608
1983	26	114	203	141	323	455	152	99	11	0	0	0	1524
1984	6	132	305	85	98	83	53	39	12	0	0	0	813
1985	19	49	30	23	66	81	49	20	5	0	0	0	342
1986	1	22	55	95	683	267	42	32	5	0	0	0	1202
1987	3	0	9	11	60	81	16	8	3	0	0	0	191
1988	0	1	40	101	16	21	19	12	4	0	0	0	214
1989	0	30	43	59	41	331	70	45	8	0	0	0	627
1990	5	16	14	63	61	58	20	8	16	0	0	0	261
1991	0	0	3	2	5	184	48	33	12	0	0	0	287
1992	0	5	6	13	145	61	22	7	0	0	0	0	259
1993	0	1	54	314	170	141	73	27	15	0	0	0	795
1994	4	0	27	15	58	34	15	12	2	0	0	0	167
1995	5	16	118	466	63	461	120	121	23	0	0	0	1394
1996	0	38	40	144	257	139	109	91	23	0	0	0	841
1997	5	29	392	535	52	34	23	36	12	0	0	0	1117
1998	4	0	90	303	435	140	141	113	33	0	0	0	1258
1999	13	17	80	168	328	151	92	61	15	0	0	0	925
2000	4	10	13	121	333	172	66	50	11	0	0	0	780
2001	23	10	9	15	68	54	31	15	4	0	0	0	230
2002	4	12	131	109	93	147	54	29	14	0	0	0	594
2003	9	4	123	91	52	77	115	104	15	0	0	0	591
2004	0	8	75	91	162	74	10	10	0	0	0	0	432
2005	12	7	68	135	81	161	85	127	28	0	0	0	705
2006	0	0	322	178	170	300	370	86	15	0	0	0	1439
2007	14	7	41	19	122	57	22	25	4	0	0	0	311
2008	2	2	45	78	99	44	25	0	5	0	0	0	299
2009	6	4	27	12	101	130	35	73	8	0	0	0	396
2010	23	0	0	34	52	36	62	74	38	0	0	0	319
2011	21	42	278	106	132	447	155	75	58	33	5	0	1354
2012	6	4	0	31	12	218	168	41	36	16	0	3	536
2013	8	33	286	45	26	28	12	18	24	16	4	0	501
2014	0	0	0	0	81	80	59	5	5	3	6	0	239
1922-2003 Average	5	25	90	149	159	127	68	25	4	0	0	0	653
1922-2014 Average	6	23	91	139	151	129	71	28	6	1	0	0	646

Table B-2. UF 2 – Putah Creek near Winters Unimpaired Flow in TAF

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1922	0	0	35	8	132	35	15	4	1	0	0	0	230
1923	0	13	141	54	23	9	32	5	1	0	0	0	278
1924	0	0	0	4	32	2	1	0	0	0	0	0	39
1925	0	8	26	10	215	28	31	23	6	1	0	0	348
1926	0	0	1	36	167	15	121	7	1	0	0	0	348
1927	0	63	38	57	236	39	98	9	3	1	0	0	544
1928	0	25	24	28	67	100	48	7	1	0	0	0	300
1929	0	1	13	5	32	10	4	1	0	0	0	0	66
1930	0	0	113	76	53	63	11	5	1	1	0	0	323
1931	0	1	1	15	4	10	2	1	1	0	0	0	35
1932	0	0	109	41	33	7	4	4	2	1	0	0	201
1933	0	0	2	38	12	27	9	5	1	1	0	0	95
1934	0	0	44	34	42	17	5	2	1	0	0	0	145
1935	0	7	5	122	18	114	70	12	3	1	0	0	352
1936	0	0	1	63	215	27	30	6	3	1	0	0	346
1937	0	0	1	7	148	90	24	6	3	1	0	0	280
1938	0	24	136	45	359	216	52	14	4	1	1	1	853
1939	1	1	4	7	9	15	3	1	1	0	0	0	42
1940	0	0	2	138	312	149	56	11	4	1	1	1	675
1941	1	2	179	237	215	164	162	28	9	4	2	1	1004
1942	1	2	134	141	254	56	87	25	9	3	2	1	715
1943	1	6	21	183	37	42	16	8	3	1	1	1	320
1944	0	1	1	12	62	83	10	6	2	1	0	0	178
1945	0	8	18	12	108	38	14	6	2	0	0	0	206
1946	1	15	162	39	16	13	11	3	1	1	0	0	262
1947	0	7	14	3	40	45	16	2	2	0	0	0	129
1948	1	2	2	16	4	23	63	18	4	0	0	0	133
1949	1	1	6	10	37	120	12	4	1	0	0	0	192
1950	0	0	2	49	91	20	15	4	1	0	0	0	182
1951	3	48	142	88	45	42	10	9	1	0	0	0	388
1952	0	7	119	243	98	86	22	8	3	1	1	0	588
1953	0	1	139	190	19	43	17	10	3	1	0	0	423
1954	0	5	4	77	82	55	52	8	1	0	0	0	284
1955	0	10	26	13	8	9	19	7	1	0	0	0	93
1956	0	0	314	229	237	48	16	11	3	1	1	1	861
1957	0	2	2	13	70	29	13	18	4	1	1	1	154
1958	14	4	32	84	347	153	184	20	8	4	3	2	855
1959	0	0	3	46	112	15	7	5	5	4	2	3	202
1960	0	0	2	24	134	53	14	9	5	5	2	1	249
1961	0	4	25	36	38	34	13	5	6	4	2	0	167
1962	0	5	19	9	169	85	11	5	4	3	1	0	311
1963	82	3	49	141	111	65	129	28	9	6	3	1	627
1964	2	29	4	58	9	12	6	6	6	6	4	3	145
1965	4	14	216	214	26	13	49	11	5	6	4	0	562
1966	1	24	36	128	62	20	12	6	4	3	4	4	304
1967	0	39	100	259	47	98	110	31	17	5	4	1	711
1968	1	2	13	105	74	52	12	6	4	3	1	0	273
1969	0	3	72	289	228	77	29	13	4	4	1	0	720
1970	0	1	117	416	103	67	15	13	7	5	1	0	745

Table B-2. UF 2 – Putah Creek near Winters Unimpaired Flow in TAF contd.

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1971	0	55	171	72	14	50	18	10	7	7	3	1	408
1972	0	1	23	13	28	11	11	8	4	3	1	0	103
1973	2	31	27	242	178	82	23	12	6	4	0	0	607
1974	2	123	69	155	55	200	76	17	9	5	0	1	712
1975	1	0	10	9	158	160	29	14	7	5	1	1	395
1976	2	0	2	2	6	7	7	6	4	0	0	0	36
1977	0	0	0	2	3	6	4	3	3	2	1	1	25
1978	1	13	44	284	147	111	36	12	3	2	0	1	654
1979	0	0	0	47	97	41	17	10	4	1	0	0	217
1980	4	7	61	166	238	74	24	10	6	5	0	0	595
1981	0	0	26	80	28	37	12	7	7	0	1	0	198
1982	1	85	147	144	105	140	252	23	7	3	0	0	907
1983	3	52	89	208	295	421	85	46	13	6	2	1	1221
1984	0	92	248	46	34	36	13	10	5	3	2	1	490
1985	0	44	19	10	54	32	12	5	5	2	2	0	185
1986	0	6	16	57	493	188	23	10	2	0	0	0	795
1987	0	0	0	8	35	49	7	3	2	0	0	1	105
1988	1	0	36	67	9	4	0	3	2	1	0	0	123
1989	0	7	8	7	4	83	9	3	1	2	0	2	126
1990	3	1	0	25	23	8	2	11	4	1	0	0	78
1991	0	4	0	1	5	172	13	5	1	2	0	1	204
1992	0	0	2	3	59	36	6	2	4	2	2	1	117
1993	3	0	50	278	157	47	18	7	5	0	0	0	565
1994	0	1	16	8	29	10	2	2	0	0	9	0	77
1995	0	5	16	466	49	382	49	39	10	0	0	0	1017
1996	2	0	63	105	198	113	43	27	7	3	0	0	562
1997	0	5	170	375	38	19	9	6	0	0	0	0	621
1998	0	26	41	157	459	78	63	42	21	5	1	0	894
1999	1	24	14	26	160	83	59	14	5	1	0	0	386
2000	0	2	0	38	171	76	18	10	4	0	0	0	320
2001	0	0	1	20	78	51	8	5	1	0	2	0	166
2002	0	16	119	115	20	21	7	5	2	1	1	1	309
2003	0	5	236	81	31	46	44	31	3	0	0	0	476
2004	0	1	122	67	220	55	12	5	2	0	0	0	483
2005	2	3	84	101	51	90	29	41	8	2	0	0	411
2006	0	1	216	126	72	194	197	29	12	4	1	0	851
2007	0	3	13	1	54	14	6	4	3	3	0	0	101
2008	0	0	4	119	70	13	5	3	1	1	0	0	215
2009	0	1	3	1	65	49	4	8	0	1	1	2	135
2010	3	0	5	137	56	50	56	16	7	3	2	2	335
2011	3	3	70	29	79	222	35	17	13	5	3	2	480
2012	0	3	0	20	6	92	41	9	4	5	4	2	188
2013	1	36	166	21	7	10	6	5	5	5	4	2	269
2014	0	0	0	1	28	18	17	4	4	3	1	1	76
1922-2003 Average	**2**	**12**	**54**	**91**	**103**	**67**	**34**	**11**	**4**	**2**	**1**	**0**	**380**
1922-2014 Average	**2**	**11**	**55**	**87**	**98**	**68**	**34**	**11**	**4**	**2**	**1**	**0**	**373**

Table B-3. UF 3 – Cache Creek Above Rumsey Unimpaired Flow in TAF

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1922	5	4	9	11	48	41	38	27	17	10	6	3	219
1923	3	4	28	35	32	23	33	18	12	7	4	2	201
1924	2	2	1	3	7	3	2	1	0	0	0	0	21
1925	1	5	20	14	108	43	59	54	37	23	14	10	388
1926	7	6	8	15	61	35	44	35	24	16	9	5	265
1927	4	27	53	111	280	176	114	64	38	23	15	9	914
1928	7	10	15	37	51	93	76	48	30	19	12	7	405
1929	5	4	9	9	16	12	11	7	5	2	1	0	81
1930	0	0	26	29	36	41	30	22	14	8	4	2	212
1931	1	1	1	9	4	7	4	2	1	0	0	0	30
1932	0	0	51	27	19	13	10	10	5	2	0	0	137
1933	0	0	1	9	9	20	9	8	4	1	0	0	61
1934	0	0	16	16	19	16	10	7	4	2	0	0	90
1935	0	5	4	50	28	61	68	45	27	17	10	6	321
1936	4	3	4	61	146	86	67	43	33	20	13	8	488
1937	5	3	3	4	52	65	48	32	22	15	9	6	264
1938	4	35	119	72	378	424	190	81	43	26	17	11	1400
1939	8	7	9	11	15	17	11	8	4	2	0	0	92
1940	0	0	0	59	179	172	116	61	37	22	13	9	668
1941	6	6	103	234	290	279	225	109	53	31	20	13	1369
1942	8	8	67	123	245	139	117	84	52	30	20	13	906
1943	9	12	36	142	94	85	62	49	33	21	13	9	565
1944	6	5	6	14	27	52	27	22	15	8	4	2	188
1945	1	6	16	15	64	41	34	25	16	9	5	2	234
1946	4	14	123	79	52	48	40	28	18	10	6	3	425
1947	2	3	7	3	15	31	19	12	7	4	2	1	106
1948	1	1	1	10	4	16	56	33	22	13	7	4	168
1949	2	2	6	9	21	88	41	29	18	11	6	3	236
1950	2	2	2	23	45	36	32	23	14	7	4	2	192
1951	5	21	73	109	107	85	51	50	28	17	10	7	563
1952	5	11	113	178	204	154	85	54	36	22	14	9	885
1953	6	5	85	191	87	77	57	50	35	21	14	9	637
1954	6	10	10	74	64	65	71	44	30	18	12	8	412
1955	6	9	22	23	20	20	27	23	12	7	4	2	175
1956	1	1	183	306	342	173	66	51	35	21	14	9	1202
1957	6	6	5	15	53	60	36	44	25	15	9	6	280
1958	28	12	44	110	431	375	275	119	58	33	23	16	1524
1959	11	8	7	29	75	46	33	25	17	10	6	3	270
1960	2	2	2	9	75	56	35	29	20	11	7	4	252
1961	2	4	21	20	41	44	36	29	19	12	7	5	240
1962	3	6	16	11	84	81	47	35	23	15	9	6	336
1963	26	10	23	48	73	63	129	78	45	29	19	13	556
1964	10	17	13	34	22	21	16	13	9	5	2	1	163
1965	1	10	186	249	119	62	79	55	34	21	15	10	841
1966	8	17	28	100	75	61	43	31	20	15	10	7	415
1967	5	15	62	157	89	94	114	86	52	35	22	14	745
1968	10	8	14	74	99	78	50	36	23	15	11	9	427
1969	6	6	41	190	274	257	125	57	35	23	15	12	1041
1970	8	7	56	347	216	124	63	42	29	19	13	9	933

Table B-3. UF 3 – Cache Creek Above Rumsey Unimpaired Flow in TAF contd.

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1971	6	22	95	106	60	73	59	45	33	25	15	11	550
1972	6	5	13	20	27	26	22	17	11	5	2	1	155
1973	1	12	22	166	222	183	82	48	29	18	10	9	802
1974	6	74	105	220	144	237	175	72	40	28	18	12	1131
1975	9	7	12	13	113	188	123	59	34	24	16	10	608
1976	9	8	5	6	5	10	10	4	2	1	2	0	62
1977	0	0	0	1	0	0	0	0	0	0	0	0	1
1978	0	3	18	192	161	191	118	63	39	30	17	13	845
1979	8	7	6	28	64	61	43	40	25	18	14	6	320
1980	6	12	44	166	245	167	101	38	30	22	15	10	856
1981	7	4	15	50	41	44	31	24	19	14	6	2	257
1982	4	44	117	157	141	157	243	102	50	35	22	16	1088
1983	14	32	78	227	321	662	320	149	69	43	28	21	1964
1984	16	86	330	150	94	81	52	36	21	10	4	2	882
1985	3	35	39	30	39	40	34	19	9	1	1	0	250
1986	1	5	16	41	422	310	97	51	31	18	9	6	1007
1987	4	2	3	11	25	42	21	14	8	2	1	0	133
1988	0	0	25	82	30	24	20	17	13	6	0	1	218
1989	0	4	6	11	7	64	30	17	4	6	1	3	153
1990	4	3	3	19	20	17	10	9	6	1	0	0	92
1991	1	0	0	1	2	66	25	15	8	2	1	1	122
1992	0	2	4	6	50	43	28	23	14	9	3	0	182
1993	5	3	49	264	291	176	74	56	43	29	16	8	1014
1994	5	5	14	19	43	27	24	19	27	0	1	2	186
1995	0	2	8	484	158	476	210	78	28	39	26	20	1529
1996	10	0	27	108	286	208	61	45	46	44	15	6	857
1997	10	3	92	404	245	20	15	19	20	23	35	12	898
1998	5	54	77	396	809	235	119	99	51	14	9	0	1867
1999	26	29	50	68	309	187	94	34	17	7	3	10	835
2000	3	12	7	84	327	159	47	32	17	3	3	10	703
2001	2	3	7	39	145	122	22	26	8	11	4	6	395
2002	5	46	226	193	43	47	24	25	16	6	5	2	637
2003	2	15	355	201	63	93	150	82	14	15	4	2	996
2004	12	12	229	148	389	92	37	21	30	28	17	15	1029
2005	11	8	114	177	89	178	85	83	27	16	7	0	796
2006	5	20	298	254	122	356	343	46	27	16	10	6	1504
2007	1	10	50	14	146	53	19	15	5	13	12	1	340
2008	8	4	25	242	183	41	15	13	15	5	11	9	572
2009	7	12	11	10	122	104	14	34	5	10	0	5	335
2010	5	0	7	193	78	71	79	22	10	4	2	2	472
2011	15	17	178	61	119	399	68	30	35	32	24	9	988
2012	5	4	1	40	12	135	93	8	3	27	20	7	355
2013	0	45	290	41	14	24	12	2	0	19	18	4	471
2014	8	0	0	0	48	50	35	1	0	16	14	8	180
1922-2003 Average	**5**	**11**	**44**	**91**	**120**	**105**	**67**	**40**	**24**	**15**	**9**	**6**	**538**
1922-2014 Average	**5**	**11**	**52**	**93**	**120**	**109**	**68**	**39**	**23**	**15**	**10**	**6**	**550**

Table B-4. UF 4 – Stony Creek at Black Butte Unimpaired Flow in TAF

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1922	1	1	12	12	68	36	50	41	13	0	0	0	234
1923	2	12	48	43	22	15	34	13	4	0	0	0	193
1924	1	1	3	6	16	4	2	0	0	0	0	0	33
1925	0	6	26	25	202	42	67	81	17	2	0	1	469
1926	2	3	5	22	137	27	72	12	1	0	0	0	281
1927	1	37	83	55	254	77	54	28	8	0	0	0	597
1928	1	9	23	47	87	98	62	18	2	0	0	0	347
1929	1	4	11	8	28	12	11	8	2	0	0	0	85
1930	0	0	33	33	44	69	26	14	4	0	0	0	223
1931	0	2	2	21	13	18	7	3	0	0	0	0	66
1932	0	2	49	48	23	37	21	22	7	0	0	0	209
1933	0	0	3	12	9	33	25	19	12	0	0	0	113
1934	0	1	29	39	37	27	11	5	2	0	0	0	151
1935	0	12	8	64	37	70	87	33	7	1	0	0	319
1936	0	1	4	83	143	48	41	15	9	0	0	0	344
1937	0	0	2	2	73	77	69	29	6	0	0	0	258
1938	1	44	133	51	214	248	101	79	27	5	0	0	903
1939	1	3	10	8	11	22	10	5	0	0	0	0	70
1940	0	0	6	114	225	119	63	21	4	0	0	0	552
1941	1	3	133	252	260	231	180	79	25	4	0	1	1169
1942	1	4	90	155	195	49	110	55	21	2	0	1	683
1943	0	11	39	162	52	69	29	23	6	1	0	0	392
1944	1	1	3	14	33	54	29	33	7	0	0	0	175
1945	1	10	27	25	76	28	32	14	4	0	0	0	217
1946	2	20	148	74	22	22	20	8	2	0	0	0	318
1947	0	8	14	2	36	53	19	2	1	0	0	0	135
1948	1	2	3	28	9	19	75	41	17	2	0	0	197
1949	0	2	6	7	21	134	57	24	5	1	0	0	257
1950	0	1	3	35	59	41	39	26	9	2	0	1	216
1951	5	36	96	102	93	49	24	38	9	4	0	0	456
1952	1	6	97	147	139	94	77	62	17	4	0	1	645
1953	1	2	104	233	39	45	45	47	18	5	0	1	540
1954	0	6	9	94	83	67	75	27	10	5	0	1	377
1955	1	13	29	15	13	16	22	24	3	2	0	0	138
1956	1	2	143	239	147	64	45	54	16	4	0	1	716
1957	5	3	2	17	83	45	45	45	16	5	0	2	268
1958	27	16	42	118	480	156	140	68	21	5	0	3	1076
1959	1	3	4	55	96	41	20	6	2	0	0	1	229
1960	0	0	0	14	139	79	22	16	5	0	0	0	275
1961	0	6	42	32	73	41	25	17	4	0	0	0	240
1962	0	4	24	11	100	75	44	16	5	0	0	0	279
1963	25	7	42	22	168	59	146	44	12	3	0	0	528
1964	3	23	8	30	18	11	9	6	2	0	0	0	110
1965	0	25	277	201	48	27	109	25	4	0	2	0	718
1966	0	36	22	115	64	45	40	17	5	0	0	0	344
1967	0	24	89	182	67	54	70	62	41	5	0	0	594
1968	1	3	15	82	142	47	19	9	3	0	0	0	321
1969	0	5	59	259	210	129	84	47	15	1	0	0	809
1970	2	3	80	406	89	65	19	10	4	0	0	0	678

Table B-4. UF 4 – Stony Creek at Black Butte Unimpaired Flow in TAF contd.

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1971	0	37	123	138	38	87	39	26	11	2	0	0	501
1972	0	5	16	38	37	51	20	11	2	0	0	0	180
1973	3	40	60	207	228	119	53	30	5	0	0	0	745
1974	3	83	123	250	54	166	99	30	11	1	0	0	820
1975	0	4	16	20	149	226	67	44	15	0	0	0	541
1976	4	6	7	4	12	18	12	4	1	0	1	0	69
1977	0	2	2	3	2	6	0	2	0	0	0	0	17
1978	0	4	49	320	190	146	57	28	13	2	0	0	809
1979	1	2	2	30	55	70	30	24	5	0	0	0	219
1980	5	23	45	192	257	95	35	17	7	0	0	0	676
1981	0	2	15	82	51	43	21	8	3	0	0	0	225
1982	5	77	150	109	115	93	163	56	16	5	0	1	790
1983	7	36	122	235	284	461	130	107	40	9	2	2	1435
1984	2	100	304	70	48	40	22	10	0	0	0	0	596
1985	1	54	39	13	27	22	26	2	0	0	0	0	184
1986	1	7	30	70	441	171	36	13	0	0	0	0	769
1987	0	1	2	9	27	47	10	2	0	0	0	0	98
1988	0	2	59	108	31	15	9	5	0	0	0	0	229
1989	0	13	7	16	11	95	26	5	0	0	0	0	173
1990	2	3	2	20	11	17	4	5	6	0	0	0	70
1991	0	2	2	2	3	83	34	6	0	0	0	0	132
1992	0	0	8	9	82	65	51	5	0	0	0	0	220
1993	1	2	43	243	206	108	48	27	18	0	0	0	696
1994	0	0	7	9	28	18	5	4	0	0	0	0	71
1995	0	3	12	558	108	367	87	75	21	6	0	0	1237
1996	0	1	41	126	211	148	47	41	12	1	0	0	627
1997	0	9	138	294	57	31	16	7	0	0	0	0	552
1998	2	16	46	218	552	174	114	102	78	15	2	1	1320
1999	1	13	30	30	108	113	74	32	10	0	1	0	411
2000	0	6	6	33	45	49	42	24	7	1	0	0	211
2001	0	3	4	17	38	107	19	8	0	0	0	0	195
2002	0	21	125	149	35	29	15	7	0	0	0	0	382
2003	0	6	167	142	39	51	45	58	10	1	0	0	520
2004	0	5	121	79	206	90	27	14	4	0	0	0	545
2005	1	5	83	120	115	132	60	82	24	5	0	0	627
2006	1	6	202	143	82	150	247	65	16	2	0	0	912
2007	0	3	24	12	40	29	10	4	0	0	0	0	123
2008	0	1	7	118	116	57	25	22	4	0	0	0	349
2009	0	3	4	7	36	55	11	15	3	0	0	0	133
2010	1	0	6	122	91	57	95	44	22	2	0	0	440
2011	6	7	74	57	36	163	88	34	48	9	0	0	522
2012	2	4	2	16	9	44	44	10	1	0	0	0	133
2013	0	15	159	42	17	16	12	2	0	0	0	0	263
2014	0	1	1	1	13	51	16	1	0	0	0	0	85
1922-2003 Average	**2**	**12**	**48**	**93**	**101**	**77**	**48**	**27**	**9**	**1**	**0**	**0**	**418**
1922-2014 Average	**2**	**11**	**50**	**89**	**97**	**77**	**49**	**27**	**9**	**1**	**0**	**0**	**413**

Table B-5. UF 5 – Sacramento Valley West Side Minor Streams Unimpaired Flow in TAF

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1922	0	3	38	49	53	44	117	78	10	2	0	0	394
1923	2	10	57	54	29	20	67	22	11	2	0	0	274
1924	1	1	4	8	29	7	6	3	0	0	0	0	59
1925	6	25	46	41	202	69	108	87	16	6	2	2	610
1926	3	6	14	19	117	43	57	14	4	0	0	0	277
1927	0	48	91	76	221	131	116	63	20	4	1	0	771
1928	0	52	31	64	104	161	87	30	13	2	0	0	544
1929	0	1	17	14	19	14	15	15	4	0	0	0	99
1930	0	1	68	32	59	60	38	14	5	0	0	0	277
1931	0	1	3	20	16	26	11	5	1	0	0	0	83
1932	1	4	17	25	22	52	28	27	8	1	0	0	185
1933	0	0	2	5	6	32	42	31	17	1	0	0	136
1934	0	1	18	31	32	35	19	10	2	0	0	0	148
1935	1	18	15	32	44	42	110	42	8	2	0	0	314
1936	0	2	5	103	106	52	41	18	9	1	0	0	337
1937	0	1	1	4	14	55	85	57	14	2	0	0	233
1938	2	82	143	44	114	220	185	141	39	7	2	1	980
1939	1	4	14	9	11	32	16	11	2	0	0	0	100
1940	0	1	22	108	206	146	82	31	8	2	0	0	606
1941	2	8	142	168	252	263	208	130	49	13	3	2	1240
1942	2	7	131	128	151	50	86	69	30	7	2	0	663
1943	0	19	57	130	71	74	44	23	9	2	0	0	429
1944	0	3	4	10	16	30	22	24	8	2	0	0	119
1945	0	16	31	19	71	24	45	26	9	1	0	0	242
1946	9	28	146	73	26	45	56	33	12	7	5	5	445
1947	0	9	13	4	36	51	22	7	6	0	0	0	148
1948	10	6	4	61	12	17	83	57	23	3	0	2	278
1949	2	7	14	6	16	94	92	36	9	2	0	0	278
1950	0	1	1	28	34	56	50	23	5	0	0	0	198
1951	22	32	71	80	100	34	30	30	7	1	0	0	407
1952	2	13	89	65	137	99	139	76	21	7	2	0	650
1953	0	3	54	198	55	40	65	47	28	8	2	1	501
1954	2	15	15	97	118	99	108	32	12	3	1	0	502
1955	0	24	39	20	15	15	29	35	6	1	0	0	184
1956	0	9	282	235	156	82	102	82	22	5	2	1	978
1957	3	4	4	13	94	69	38	40	8	1	0	1	275
1958	40	24	57	124	523	161	175	83	24	8	3	1	1223
1959	0	3	4	62	66	47	31	11	2	0	0	1	227
1960	0	0	2	9	144	89	31	22	7	1	0	0	305
1961	0	3	30	32	77	40	32	17	6	1	0	0	238
1962	0	2	15	7	77	62	52	15	4	1	0	0	235
1963	24	9	36	43	142	58	127	54	9	2	1	0	505
1964	1	36	8	24	19	10	11	6	12	0	0	0	127
1965	1	31	288	169	52	29	156	43	10	2	1	1	783
1966	1	44	15	97	52	64	62	20	4	1	0	0	360
1967	0	26	83	144	67	50	69	83	37	4	1	1	565
1968	1	2	12	86	134	43	25	13	3	1	1	0	321
1969	1	4	53	256	185	130	151	99	19	3	1	0	902
1970	1	3	86	364	67	67	18	14	6	2	1	0	629

Table B-5. UF 5 – Sacramento Valley West Side Minor Streams Unimpaired Flow in TAF contd.

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1971	1	34	92	142	53	95	58	41	14	4	1	1	536
1972	1	4	9	31	31	70	23	12	4	1	0	1	187
1973	5	41	71	148	120	93	74	38	8	2	1	1	602
1974	3	100	125	279	42	170	107	44	14	5	2	1	892
1975	1	2	16	15	111	232	71	75	20	5	2	1	551
1976	3	8	7	5	13	19	18	10	2	1	1	0	87
1977	0	1	1	1	2	6	5	5	1	0	0	0	22
1978	1	10	69	265	133	152	75	43	18	5	1	2	774
1979	1	1	1	22	43	74	34	27	6	2	0	1	212
1980	7	26	27	178	179	69	45	24	9	3	1	1	569
1981	1	1	26	80	68	55	29	11	3	1	0	0	275
1982	5	94	152	73	133	88	125	54	15	5	1	1	746
1983	8	39	112	169	203	300	134	178	70	16	5	3	1237
1984	3	102	209	62	38	51	28	20	8	2	0	0	523
1985	2	72	37	17	27	24	45	12	4	0	0	0	240
1986	2	4	20	65	391	158	43	20	6	2	0	3	714
1987	3	1	4	11	40	65	29	11	1	0	0	0	165
1988	0	3	84	61	40	26	21	15	8	2	0	0	260
1989	0	25	12	24	20	127	46	15	6	2	0	3	280
1990	6	4	3	24	12	24	9	17	13	1	0	0	113
1991	0	0	1	3	8	56	41	23	5	1	0	0	138
1992	0	3	4	11	70	76	51	13	4	3	0	0	235
1993	2	5	33	111	113	182	75	66	43	7	3	0	640
1994	1	1	6	10	14	25	11	10	2	0	0	0	80
1995	0	3	9	334	143	295	115	96	33	8	2	1	1039
1996	1	1	58	100	190	138	70	74	18	4	1	1	655
1997	3	13	161	245	62	33	17	9	4	1	1	1	550
1998	2	19	38	174	418	192	122	171	94	18	6	4	1257
1999	4	21	22	20	88	119	106	42	12	4	2	1	442
2000	2	7	7	36	194	119	116	39	12	5	2	2	541
2001	3	4	5	27	73	174	40	18	5	2	0	0	352
2002	1	21	124	178	39	35	30	14	5	2	0	0	448
2003	1	4	221	149	40	65	64	80	15	5	3	1	646
2004	1	7	103	82	219	106	39	17	6	2	1	0	583
2005	3	5	99	95	112	143	79	169	37	9	3	2	756
2006	2	5	189	117	68	129	252	72	18	6	3	2	863
2007	4	7	27	12	68	41	16	9	2	0	0	0	186
2008	2	2	7	104	105	53	40	33	6	2	0	0	354
2009	1	8	5	5	71	87	24	23	7	1	0	0	232
2010	4	2	7	138	107	66	130	62	25	6	2	1	550
2011	9	7	57	46	22	145	94	41	51	11	4	1	487
2012	5	6	5	23	11	56	74	17	4	1	0	0	203
2013	0	25	127	38	17	21	26	7	2	0	0	0	263
2014	1	2	3	3	20	72	31	6	1	0	0	0	139
1922-2003 Average	3	16	51	80	92	81	64	40	13	3	1	1	444
1922-2014 Average	3	15	51	78	90	81	65	40	13	3	1	1	441

Table B-6. UF 6 – Sacramento River near Red Bluff Unimpaired Flow in TAF

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1922	242	289	542	432	967	880	1067	896	511	338	263	239	6666
1923	256	339	646	678	446	422	884	431	398	314	240	233	5287
1924	232	250	269	306	517	286	269	263	266	246	199	191	3294
1925	211	439	445	463	2508	789	1275	700	466	299	246	237	8078
1926	220	274	343	437	1598	548	832	431	314	266	212	199	5674
1927	206	858	1167	1205	2589	1345	1505	781	490	337	249	239	10971
1928	221	633	550	722	1059	1585	1194	538	359	306	236	231	7634
1929	215	338	381	369	647	482	526	432	350	257	200	202	4399
1930	196	219	973	662	881	1106	575	487	324	258	198	217	6096
1931	219	232	235	470	385	461	300	243	214	186	177	174	3296
1932	204	213	781	548	420	845	556	608	310	215	198	184	5082
1933	180	201	246	390	319	1117	644	552	356	218	188	180	4591
1934	193	200	505	738	728	609	438	324	232	192	176	167	4502
1935	197	483	400	986	732	965	1895	822	371	248	204	190	7493
1936	219	209	282	1571	1779	780	724	482	401	247	195	186	7075
1937	200	196	224	262	682	1441	1194	731	425	250	186	188	5979
1938	250	1165	1908	950	2614	3185	1769	1286	632	375	282	261	14677
1939	305	326	466	426	406	750	454	339	249	225	209	215	4370
1940	207	212	443	1729	2577	2188	1458	581	346	275	231	246	10493
1941	270	320	1881	2528	2339	2111	2048	1124	650	413	325	305	14314
1942	311	321	1655	1733	2540	751	1340	990	658	382	300	280	11261
1943	305	364	628	1687	1077	1409	1002	668	490	331	275	263	8497
1944	290	291	294	387	694	696	485	463	378	274	229	221	4703
1945	268	527	723	495	1416	794	630	673	453	268	235	219	6699
1946	332	620	2161	1249	556	755	767	598	357	283	257	236	8169
1947	256	354	421	275	624	995	618	342	480	259	228	221	5074
1948	370	302	288	1031	343	821	1720	1151	745	338	268	273	7650
1949	274	286	350	277	504	1937	811	584	332	234	226	217	6033
1950	243	243	250	750	962	883	816	542	333	244	225	227	5718
1951	665	768	1517	1263	1517	922	654	702	345	252	244	235	9086
1952	295	520	1765	1463	1753	1429	1621	1111	575	404	305	302	11544
1953	283	300	1271	2746	687	897	861	913	734	388	295	293	9668
1954	308	490	442	1487	1625	1474	1445	650	437	318	308	298	9283
1955	302	516	789	566	447	473	767	682	335	278	250	257	5663
1956	256	414	2898	3226	1849	1200	951	1009	542	361	311	290	13306
1957	371	325	321	423	1115	1446	817	968	459	316	278	330	7170
1958	584	527	913	1482	4414	2085	2149	1069	731	458	362	346	15121
1959	355	326	361	1308	1283	789	631	476	343	284	257	326	6737
1960	288	265	300	546	1431	1216	622	615	403	270	248	254	6459
1961	281	423	965	576	1344	1043	691	627	418	283	259	256	7165
1962	283	425	830	477	1861	1100	772	564	382	274	251	245	7463
1963	898	400	918	558	1360	913	2402	1033	476	347	309	286	9899
1964	353	699	400	850	473	451	470	415	404	246	223	232	5218
1965	263	498	2500	2089	804	593	1632	682	406	330	297	267	10360
1966	283	725	485	1121	950	1186	913	490	337	275	254	259	7278
1967	253	691	1279	1406	1083	1338	1544	1273	714	375	294	261	10510
1968	303	302	437	764	1668	1061	597	500	343	306	327	301	6909
1969	321	356	980	2549	2209	1307	1482	1072	539	361	293	329	11797
1970	356	330	1486	4536	1369	1233	561	514	411	323	306	288	11711

Table B-6. UF 6 – Sacramento River near Red Bluff Unimpaired Flow in TAF contd.

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1971	343	1032	1705	1648	766	1493	1110	957	674	421	313	322	10785
1972	370	360	512	731	760	1236	872	525	376	297	277	289	6606
1973	381	655	818	1818	1746	1436	802	677	397	324	292	295	9639
1974	407	2107	1846	3355	1054	2579	1849	911	595	458	362	354	15876
1975	345	380	503	507	1452	2307	1177	1044	634	379	327	332	9387
1976	435	379	402	371	443	625	554	391	304	258	304	295	4763
1977	298	272	275	303	282	313	255	338	271	242	245	318	3412
1978	282	320	969	3115	1632	2074	1459	801	441	336	281	314	12024
1979	271	264	270	474	945	1010	668	706	271	267	232	240	5617
1980	379	497	690	1776	2262	1520	783	592	362	309	257	309	9736
1981	299	278	509	969	908	1227	661	468	312	273	243	244	6392
1982	324	1546	2104	1293	1737	1687	2208	929	534	376	313	310	13361
1983	383	542	1367	1915	2925	4677	1817	1530	853	475	341	356	17180
1984	377	987	2569	1029	824	1069	726	615	441	314	277	293	9520
1985	372	963	661	428	497	554	555	338	329	252	245	312	5507
1986	330	343	551	1100	3671	2288	764	623	361	338	260	318	10945
1987	323	275	330	463	751	1337	455	373	245	270	219	239	5280
1988	250	279	1015	1045	473	419	426	492	354	247	201	210	5410
1989	231	537	397	470	384	2242	903	455	288	229	223	264	6622
1990	414	262	250	680	370	616	327	663	477	257	215	208	4738
1991	241	244	225	247	269	981	516	439	263	208	189	191	4013
1992	238	226	269	336	1268	921	635	353	265	244	190	212	5157
1993	259	244	650	1573	1410	2167	1339	914	808	319	260	249	10191
1994	311	256	447	458	653	537	382	374	244	185	159	220	4226
1995	229	267	396	3867	1431	3904	1744	1513	693	416	333	354	15147
1996	307	274	786	1046	2277	1527	967	1053	481	307	284	282	9591
1997	330	495	2299	3075	1032	708	621	464	359	276	276	296	10230
1998	375	614	667	2621	3960	2100	1541	1650	1322	562	384	381	16176
1999	426	768	942	953	1741	1590	1113	799	513	354	321	335	9855
2000	373	426	413	1186	2500	1793	1027	662	439	305	299	347	9769
2001	375	337	408	533	924	1067	585	461	316	273	273	276	5828
2002	293	557	1507	1477	811	829	650	507	331	273	270	266	7770
2003	271	319	1899	1841	746	1015	1225	1249	489	321	283	286	9944
2004	286	350	1206	1099	2304	1307	715	520	365	316	243	246	8957
2005	348	308	883	970	752	1240	874	1698	623	362	295	275	8627
2006	299	392	2099	2255	1308	2204	2856	1282	604	376	317	313	14303
2007	332	389	720	428	911	675	441	365	264	242	222	227	5216
2008	326	261	427	997	1003	702	455	523	298	225	224	191	5631
2009	266	317	302	318	1044	1392	575	829	394	293	262	236	6226
2010	366	255	373	1577	1356	925	1112	835	679	352	284	263	8378
2011	311	358	1346	715	706	2335	1368	982	810	423	304	279	9937
2012	352	341	311	446	350	1184	1124	551	344	281	254	251	5789
2013	267	547	1601	573	469	540	566	335	294	235	232	235	5893
2014	236	226	241	219	419	878	529	294	238	215	213	211	3918
1922-2003 Average	**308**	**455**	**841**	**1169**	**1281**	**1255**	**977**	**699**	**442**	**304**	**259**	**264**	**8254**
1922-2014 Average	**309**	**443**	**847**	**1142**	**1247**	**1255**	**974**	**702**	**442**	**303**	**259**	**262**	**8185**

Table B-7. UF 7 – Sacramento Valley East Side Minor Streams Unimpaired Flow in TAF

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1922	39	37	109	83	228	167	188	259	149	51	36	32	1378
1923	37	69	227	123	70	70	150	75	45	31	29	33	959
1924	30	26	29	32	81	50	40	25	21	21	21	20	396
1925	25	38	57	42	245	92	154	73	38	25	22	22	833
1926	25	35	45	63	191	78	220	54	26	21	21	20	799
1927	26	146	85	138	372	178	206	128	54	34	28	26	1421
1928	29	96	64	70	131	379	152	82	44	29	28	25	1129
1929	27	37	43	34	66	60	59	53	35	23	20	20	477
1930	22	21	192	126	134	186	131	92	43	29	24	24	1024
1931	24	26	25	49	40	70	38	31	22	17	16	16	374
1932	23	26	140	75	61	103	121	126	53	27	22	20	797
1933	21	23	28	41	39	104	80	79	49	23	20	19	526
1934	23	22	98	88	106	86	58	37	26	19	17	17	597
1935	22	52	44	159	93	165	333	178	67	33	24	22	1192
1936	26	25	34	211	303	119	150	85	57	33	24	23	1090
1937	23	23	27	32	110	191	188	136	58	29	22	21	860
1938	31	137	395	129	419	461	272	333	208	96	52	44	2577
1939	36	36	44	39	42	95	67	44	29	22	20	21	495
1940	25	23	47	251	495	410	228	94	54	35	28	29	1719
1941	32	41	292	340	471	324	349	194	85	52	38	33	2251
1942	34	44	320	331	423	105	266	204	121	57	40	35	1980
1943	35	47	90	307	164	326	216	128	79	47	36	32	1507
1944	34	36	39	53	105	124	83	92	50	31	26	24	697
1945	29	67	109	62	249	132	104	107	63	37	28	26	1013
1946	41	75	370	146	73	97	119	96	47	34	28	26	1152
1947	28	54	79	34	106	116	114	46	38	26	24	22	687
1948	47	52	33	109	38	179	314	208	143	48	32	28	1231
1949	30	35	43	35	51	238	109	79	39	25	23	22	729
1950	24	27	29	111	218	123	169	117	56	32	25	23	954
1951	47	150	244	222	227	129	116	115	52	33	28	27	1390
1952	34	66	302	268	325	259	264	266	118	60	40	33	2035
1953	32	34	199	411	80	117	160	162	110	54	37	32	1428
1954	35	54	45	156	231	220	283	116	59	39	33	31	1302
1955	31	60	101	79	53	66	100	105	47	30	24	24	720
1956	26	37	556	533	347	152	140	192	95	49	35	32	2194
1957	37	34	35	52	157	180	96	153	61	35	29	43	912
1958	64	54	120	214	568	352	340	226	134	61	42	36	2211
1959	36	38	40	151	222	91	79	58	38	29	26	28	836
1960	29	27	31	60	183	159	89	74	46	28	25	24	775
1961	26	68	110	69	176	135	93	80	52	29	24	23	885
1962	25	39	114	62	296	139	122	96	54	29	24	22	1022
1963	217	48	183	123	209	139	385	164	64	39	32	29	1632
1964	34	80	40	117	54	53	74	67	45	28	24	25	641
1965	26	86	502	419	109	100	271	119	66	40	37	30	1805
1966	31	72	57	127	98	103	130	78	37	29	24	24	810
1967	25	109	186	298	142	234	244	270	143	56	35	30	1772
1968	35	37	59	172	248	150	89	68	41	30	32	25	986
1969	33	56	210	640	351	161	219	236	97	48	35	31	2117
1970	38	44	289	832	191	234	78	76	60	37	31	29	1939

Table B-7. UF 7 – Sacramento Valley East Side Minor Streams Unimpaired Flow in TAF contd.

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1971	33	162	251	195	85	237	149	147	96	52	38	32	1477
1972	34	37	67	65	91	142	127	74	45	31	28	29	770
1973	40	91	96	327	287	209	141	144	61	36	30	30	1492
1974	38	361	286	541	141	502	291	162	99	63	43	36	2563
1975	38	42	60	60	265	327	165	206	119	54	42	34	1412
1976	45	45	46	37	54	69	64	49	30	26	27	25	517
1977	27	27	28	34	27	34	30	34	24	20	19	23	327
1978	24	31	89	417	231	365	237	135	80	45	31	29	1714
1979	27	30	32	70	193	162	104	123	45	28	28	24	866
1980	46	68	148	416	432	189	105	108	61	40	30	27	1670
1981	32	30	69	143	97	137	77	56	33	26	23	23	746
1982	45	336	307	212	261	263	435	166	80	54	38	36	2233
1983	63	109	208	268	387	616	226	261	215	124	67	51	2595
1984	46	187	476	163	126	162	106	105	70	44	37	34	1556
1985	40	104	70	49	75	74	94	54	32	25	24	30	671
1986	33	52	64	150	741	346	113	103	64	43	32	38	1779
1987	34	36	40	61	104	218	79	59	28	22	20	21	722
1988	22	27	106	123	58	66	65	53	39	22	20	19	620
1989	24	53	46	60	56	394	142	71	48	28	25	29	976
1990	46	39	36	85	59	90	58	53	44	23	20	22	575
1991	22	25	28	29	34	173	91	63	36	23	19	17	560
1992	20	25	35	45	160	101	78	42	23	20	16	16	581
1993	27	30	70	273	214	264	198	197	163	78	47	35	1594
1994	33	32	63	49	80	74	58	64	36	24	20	20	552
1995	27	34	83	554	173	562	297	341	199	122	61	44	2498
1996	40	38	114	147	327	193	179	219	102	57	41	36	1494
1997	37	59	441	678	138	112	112	103	70	48	40	38	1876
1998	43	68	90	361	450	252	216	290	258	150	71	52	2301
1999	50	108	127	124	270	212	159	153	109	61	46	39	1458
2000	43	57	51	120	320	219	147	120	81	50	38	36	1284
2001	37	36	38	53	101	117	81	75	38	30	26	26	659
2002	29	57	143	149	79	119	121	88	62	36	30	26	940
2003	29	41	277	252	122	190	251	248	134	66	45	36	1690
2004	28	35	117	101	255	153	103	95	64	40	31	26	1048
2005	35	32	74	95	65	120	101	179	84	48	31	26	891
2006	32	46	364	265	187	335	418	236	121	72	48	39	2162
2007	32	39	65	43	102	75	55	52	32	25	21	20	560
2008	24	23	34	91	80	63	66	77	36	24	20	19	558
2009	22	30	28	39	140	165	63	100	43	27	21	19	698
2010	26	26	37	149	113	108	143	127	111	58	31	27	957
2011	47	51	217	96	134	338	259	246	210	122	62	44	1824
2012	43	41	38	59	41	178	167	106	59	36	29	26	824
2013	30	77	301	80	65	94	92	64	44	30	27	27	931
2014	25	26	26	26	54	128	66	41	25	21	20	19	475
1922-2003 Average	**35**	**62**	**130**	**178**	**191**	**185**	**157**	**124**	**71**	**41**	**31**	**28**	**1232**
1922-2014 Average	**35**	**59**	**128**	**169**	**181**	**182**	**155**	**123**	**72**	**41**	**31**	**28**	**1204**

Table B-8. UF 8 – Feather River near Oroville Unimpaired Flow in TAF

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1922	81	100	194	192	422	433	933	1570	721	210	119	89	5065
1923	95	129	347	309	206	362	651	482	230	125	85	75	3096
1924	84	79	92	107	298	122	168	101	64	63	63	56	1295
1925	78	137	140	155	754	378	534	422	192	113	93	80	3076
1926	89	115	139	156	619	408	862	324	139	94	78	74	3098
1927	81	448	299	369	1270	782	931	750	382	164	108	86	5670
1928	83	291	187	229	365	1410	727	440	163	118	87	72	4172
1929	74	93	118	101	185	259	268	350	177	91	66	62	1844
1930	59	57	890	326	420	618	650	452	209	115	85	70	3952
1931	72	102	83	148	146	280	202	143	89	68	58	53	1443
1932	79	82	264	237	210	554	606	681	326	129	84	73	3324
1933	70	73	85	147	89	261	343	398	295	106	71	62	2000
1934	67	68	205	278	314	372	264	156	99	75	65	54	2017
1935	63	140	139	276	240	347	1380	962	401	149	96	77	4270
1936	80	78	102	663	944	601	719	521	278	130	93	81	4290
1937	70	69	78	92	252	505	705	784	319	132	89	72	3166
1938	77	337	1130	346	748	1370	1500	1700	828	293	158	117	8604
1939	114	122	141	144	130	328	364	194	109	82	67	63	1857
1940	69	66	123	675	1220	1500	977	498	226	132	101	88	5675
1941	101	152	660	686	1100	949	839	1060	451	219	145	120	6482
1942	106	139	817	892	1060	483	1070	923	637	253	152	120	6652
1943	108	214	405	986	585	1180	892	529	321	172	124	104	5620
1944	93	108	118	159	247	400	478	608	274	211	98	78	2872
1945	82	217	295	214	780	392	527	617	276	143	107	86	3736
1946	121	222	851	483	250	460	673	569	228	135	106	87	4185
1947	81	204	214	117	359	515	419	212	165	93	81	71	2532
1948	140	122	97	404	140	272	934	838	533	181	107	86	3854
1949	80	112	137	101	146	453	638	504	179	100	80	65	2595
1950	60	81	77	333	568	557	834	698	318	138	98	79	3841
1951	178	767	1090	668	768	522	601	546	230	134	101	86	5691
1952	108	191	644	532	830	677	1830	1690	820	336	176	128	7962
1953	107	110	276	1260	352	443	738	793	620	254	143	120	5216
1954	108	194	168	321	504	766	1020	559	241	145	108	96	4230
1955	89	148	220	187	159	277	347	537	231	115	85	77	2472
1956	74	111	1960	1370	748	717	898	1060	513	261	142	120	7974
1957	142	136	124	155	649	708	447	635	290	136	104	98	3624
1958	154	176	341	392	1435	852	1146	1275	663	265	160	111	6970
1959	105	119	131	418	459	427	436	301	159	118	90	88	2851
1960	80	72	104	153	688	758	502	380	219	114	81	74	3223
1961	72	147	200	160	396	361	388	403	232	113	94	72	2637
1962	70	95	169	133	696	425	868	579	318	139	92	76	3659
1963	855	186	487	389	1082	408	1267	903	317	164	104	104	6266
1964	112	311	156	266	192	241	416	404	225	124	83	59	2588
1965	69	152	1997	1199	510	504	1005	728	358	173	146	70	6912
1966	93	224	164	266	199	436	662	401	151	106	86	68	2856
1967	61	273	481	749	559	880	609	1265	891	279	135	101	6283
1968	116	121	167	320	797	583	466	379	187	130	115	79	3459
1969	114	161	308	1635	733	600	1196	1341	560	208	116	98	7069
1970	116	130	824	2471	654	678	361	423	261	151	105	97	6269

Table B-8. UF 8 – Feather River near Oroville Unimpaired Flow in TAF contd.

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1971	99	348	551	491	375	1009	885	1041	694	242	113	111	5958
1972	115	140	217	264	348	708	527	427	205	112	81	89	3233
1973	123	210	339	745	597	629	687	783	286	138	107	97	4741
1974	139	1041	713	1489	444	1559	1131	882	504	243	127	89	8363
1975	114	123	155	182	536	864	611	1159	662	202	127	120	4854
1976	151	180	145	130	181	265	222	184	113	98	111	69	1849
1977	64	71	68	90	94	92	100	125	92	74	62	62	994
1978	57	83	320	1114	618	1120	792	742	438	194	92	113	5685
1979	63	123	101	235	301	493	505	670	222	134	97	79	3023
1980	149	144	196	1447	1158	650	580	565	282	158	72	130	5533
1981	94	91	234	263	362	407	386	281	119	89	76	78	2478
1982	147	1240	1326	655	1146	883	1689	999	442	221	126	123	8998
1983	213	350	633	713	1196	2029	1024	1427	1122	368	197	146	9418
1984	156	747	1398	595	495	711	513	511	278	154	98	111	5767
1985	131	324	195	158	239	329	560	290	132	102	84	99	2642
1986	93	140	199	518	2677	1489	584	446	224	133	101	158	6760
1987	122	104	120	172	313	583	299	190	107	80	73	65	2227
1988	64	85	353	290	185	251	238	220	139	93	75	56	2049
1989	58	243	120	142	205	1517	683	309	162	80	78	92	3687
1990	152	132	68	250	172	398	318	217	212	95	71	86	2171
1991	40	66	62	69	97	539	397	364	186	104	73	58	2057
1992	60	72	89	101	386	343	370	172	97	86	66	56	1898
1993	73	67	231	672	566	1361	950	905	521	167	107	93	5713
1994	99	96	154	152	226	330	271	250	108	77	66	62	1891
1995	60	104	204	1521	606	2283	1338	1682	870	354	153	105	9280
1996	104	108	351	460	1279	857	882	1018	337	170	111	104	5783
1997	105	223	1506	2539	530	532	497	325	187	116	101	92	6754
1998	103	192	233	970	1117	981	886	1082	977	370	161	126	7199
1999	129	339	420	568	952	811	683	695	319	146	117	100	5278
2000	98	151	123	432	978	761	698	488	208	131	94	82	4245
2001	111	96	123	138	212	396	339	297	107	86	71	65	2041
2002	63	171	366	492	304	446	506	341	161	95	75	64	3084
2003	53	135	662	743	370	569	639	839	347	135	117	84	4693
2004	74	106	399	323	783	724	519	405	192	109	92	75	3800
2005	124	109	233	299	326	684	598	1116	393	172	112	99	4266
2006	85	144	1353	1023	725	1133	1706	1206	422	193	127	94	8212
2007	98	138	283	181	467	441	310	225	110	114	93	80	2540
2008	91	74	116	229	239	364	358	418	145	88	66	52	2239
2009	64	127	113	172	476	777	410	607	176	85	78	61	3147
2010	93	75	113	348	315	438	618	683	549	181	94	80	3586
2011	136	153	787	362	373	1111	1165	983	906	351	147	104	6579
2012	124	118	85	187	156	680	694	399	150	113	90	63	2859
2013	74	282	950	271	234	415	351	175	138	92	78	70	3130
2014	77	80	74	78	257	462	291	127	79	73	68	57	1722
1922-2003 Average	**106**	**192**	**371**	**502**	**558**	**659**	**684**	**634**	**329**	**153**	**101**	**88**	**4376**
1922-2014 Average	**105**	**184**	**375**	**480**	**539**	**658**	**679**	**628**	**325**	**152**	**101**	**86**	**4311**

Table B-9. UF 9 – Yuba River at Smartville Unimpaired Flow in TAF

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1922	25	31	113	122	318	261	421	869	650	104	36	22	2972
1923	27	57	296	165	113	159	432	459	221	84	33	28	2073
1924	33	24	55	40	127	62	137	78	17	6	9	14	603
1925	33	53	121	111	563	232	403	396	127	38	25	21	2123
1926	25	38	55	64	411	220	454	213	72	20	17	19	1607
1927	30	314	201	226	745	422	586	539	366	67	23	21	3542
1928	22	149	135	178	155	798	465	380	87	33	17	17	2435
1929	20	36	48	42	84	145	190	275	118	23	0	30	1010
1930	13	13	291	179	209	321	345	269	113	26	19	19	1818
1931	5	48	17	61	61	148	140	94	37	8	9	12	641
1932	26	36	166	147	196	278	347	533	300	46	26	13	2114
1933	16	16	27	40	35	142	217	284	239	36	12	15	1078
1934	22	27	97	128	150	234	172	86	37	15	7	13	987
1935	17	66	72	153	150	199	672	558	274	44	21	16	2241
1936	27	32	42	345	528	332	500	461	226	54	21	21	2589
1937	17	16	31	32	231	281	415	566	198	42	18	13	1858
1938	22	107	496	141	423	711	590	845	527	114	36	23	4034
1939	34	39	47	56	55	214	263	126	48	13	3	9	907
1940	22	21	32	392	577	723	495	403	129	29	18	19	2860
1941	25	69	256	374	504	425	421	645	251	117	27	23	3138
1942	24	70	370	497	512	238	535	554	426	108	40	31	3406
1943	29	135	283	587	308	631	502	358	189	56	34	21	3133
1944	29	31	42	64	143	213	215	421	162	37	22	18	1395
1945	22	107	149	105	466	203	319	450	196	50	26	20	2112
1946	36	117	492	260	146	257	407	445	149	47	25	17	2401
1947	31	96	101	54	184	301	263	179	90	27	20	17	1365
1948	55	52	41	209	68	128	509	509	323	65	34	16	2010
1949	22	38	62	42	77	245	412	408	111	31	19	19	1485
1950	14	31	38	237	331	309	461	469	227	47	24	30	2219
1951	69	677	794	411	378	286	360	365	112	30	33	25	3539
1952	41	102	315	325	481	356	692	929	582	221	45	30	4118
1953	43	32	127	570	143	214	383	403	410	133	51	45	2554
1954	31	65	63	155	238	385	491	323	96	34	18	19	1917
1955	17	40	107	100	82	123	182	388	181	35	16	15	1285
1956	17	40	1192	776	308	287	334	576	296	86	23	28	3962
1957	45	48	44	65	313	389	252	493	222	45	23	19	1959
1958	41	59	140	182	686	443	582	799	434	99	32	32	3529
1959	20	37	33	201	226	189	232	171	71	25	12	21	1235
1960	10	17	19	74	389	418	313	265	133	32	15	11	1695
1961	14	50	64	37	155	176	219	251	108	22	17	12	1125
1962	17	21	73	56	435	219	454	363	204	44	25	13	1924
1963	451	79	248	214	596	205	557	608	204	56	31	24	3275
1964	33	212	77	133	108	123	247	320	152	40	19	16	1482
1965	16	63	1341	678	240	198	501	442	264	72	41	26	3883
1966	25	91	76	123	99	228	402	282	58	20	10	11	1424
1967	16	129	282	393	260	420	299	657	603	177	44	20	3299
1968	26	30	69	143	442	275	243	222	78	21	18	7	1573
1969	28	89	130	964	377	279	522	768	388	42	66	17	3669
1970	31	39	386	1278	263	287	173	275	127	34	14	8	2915

Table B-9. UF 9 – Yuba River at Smartville Unimpaired Flow in TAF contd.

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1971	0	184	338	288	205	394	358	562	374	86	44	24	2857
1972	31	47	104	136	214	358	294	291	162	35	15	30	1714
1973	47	152	243	512	353	308	324	502	146	27	19	27	2660
1974	35	559	394	706	176	681	492	500	285	109	29	18	3984
1975	12	39	49	83	285	398	272	598	443	100	52	41	2372
1976	72	79	59	49	72	127	128	134	33	9	15	15	791
1977	0	39	17	27	29	35	58	79	40	23	12	11	369
1978	9	23	179	557	286	527	430	494	328	84	29	40	2985
1979	17	29	37	130	170	315	296	521	133	28	20	32	1727
1980	36	74	127	946	599	316	336	397	224	86	25	19	3186
1981	21	25	55	101	166	227	249	179	47	17	12	0	1100
1982	40	613	777	376	669	468	885	636	305	101	26	29	4926
1983	119	191	361	310	566	926	428	715	713	275	62	33	4699
1984	51	519	816	308	244	326	255	396	175	41	14	19	3163
1985	34	172	97	61	127	162	328	233	61	14	13	17	1319
1986	36	53	112	275	1351	792	317	294	144	36	18	42	3472
1987	37	24	26	49	156	218	200	114	25	16	13	6	883
1988	6	17	141	156	93	146	157	124	53	14	8	3	919
1989	7	137	71	85	137	854	508	282	78	62	18	22	2262
1990	61	58	38	138	101	232	243	191	121	35	11	9	1238
1991	14	19	21	20	31	323	263	294	143	31	7	13	1179
1992	17	29	34	40	242	197	219	91	19	13	4	6	912
1993	20	20	111	452	294	565	425	555	330	82	29	20	2903
1994	29	23	69	52	103	172	186	168	44	17	4	10	878
1995	17	43	146	806	322	993	555	829	552	238	45	24	4570
1996	19	17	202	267	829	403	457	762	197	41	33	20	3247
1997	22	114	912	1482	299	215	292	247	102	21	8	15	3729
1998	28	66	86	529	566	454	433	587	595	201	44	34	3622
1999	37	106	191	354	523	371	306	466	284	67	18	21	2744
2000	34	41	39	255	539	400	386	364	103	35	15	19	2229
2001	19	42	44	48	94	210	202	205	28	10	9	11	922
2002	14	67	190	229	187	282	326	287	96	22	12	10	1723
2003	12	67	293	326	172	284	344	557	219	24	50	21	2370
2004	22	33	185	150	310	328	286	237	76	26	16	14	1684
2005	41	35	108	176	162	362	319	785	277	64	26	21	2376
2006	25	40	854	519	426	491	822	706	224	69	28	18	4221
2007	20	42	116	82	249	244	206	178	44	19	12	14	1226
2008	34	25	50	124	139	182	231	316	71	19	13	8	1213
2009	21	51	39	89	227	378	254	499	89	25	12	11	1694
2010	22	19	46	137	135	204	328	406	427	71	22	19	1838
2011	73	91	544	204	187	609	599	559	645	248	68	29	3855
2012	47	36	26	82	54	424	467	282	73	27	15	10	1543
2013	23	173	515	136	102	172	187	105	40	19	5	18	1494
2014	22	23	22	24	188	245	192	104	27	13	10	10	881
1922-2003 Average	**33**	**91**	**197**	**269**	**296**	**329**	**362**	**408**	**210**	**57**	**23**	**20**	**2295**
1922-2014 Average	**32**	**87**	**200**	**256**	**285**	**330**	**361**	**404**	**207**	**57**	**23**	**19**	**2260**

Table B-10. UF 10 – Bear River near Wheatland Unimpaired Flow in TAF

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1922	0	3	31	23	166	112	62	43	15	3	2	1	461
1923	7	14	110	63	35	33	79	25	16	6	5	4	397
1924	6	3	6	9	14	9	6	6	4	3	1	2	69
1925	5	6	18	17	99	43	53	21	11	7	6	4	290
1926	5	6	8	14	102	22	72	22	4	3	2	2	262
1927	4	41	19	58	221	55	112	20	10	6	4	3	553
1928	3	18	27	14	29	141	58	10	9	5	1	4	319
1929	6	10	16	11	33	21	13	7	4	2	1	0	124
1930	2	1	37	45	20	70	20	8	5	3	3	2	216
1931	4	9	13	12	14	14	4	2	0	0	0	0	72
1932	2	9	59	40	70	24	18	13	6	3	2	3	249
1933	4	5	12	13	16	35	14	16	3	2	1	0	121
1934	2	3	31	30	29	14	2	4	3	2	1	2	123
1935	3	14	21	52	39	70	114	21	10	5	3	4	356
1936	13	3	18	89	188	44	46	13	8	3	2	3	430
1937	4	4	16	13	94	99	58	18	7	5	2	3	323
1938	6	18	55	34	169	167	72	28	10	5	3	2	569
1939	6	8	13	12	19	37	14	5	3	1	1	0	119
1940	2	2	6	75	126	126	44	12	3	2	1	1	400
1941	2	9	71	106	106	74	74	22	9	4	3	1	481
1942	6	9	68	95	118	48	83	47	16	6	3	4	503
1943	4	21	39	134	62	134	33	18	9	4	3	2	463
1944	4	4	11	18	52	55	22	12	5	2	1	2	188
1945	3	26	25	13	111	52	28	12	8	4	2	4	288
1946	9	21	117	45	26	48	30	9	4	3	2	3	317
1947	6	16	23	9	35	51	17	4	3	2	1	1	168
1948	9	8	10	19	12	35	70	36	13	4	3	3	222
1949	5	7	20	14	24	104	21	14	4	2	1	0	216
1950	3	5	9	59	77	50	41	14	5	4	1	2	270
1951	7	108	149	133	74	74	18	24	4	2	2	2	597
1952	4	21	68	153	142	112	60	27	6	5	2	4	604
1953	3	6	28	95	13	37	35	26	9	2	2	3	259
1954	4	10	18	48	55	71	38	11	5	2	2	2	266
1955	4	8	33	44	20	20	23	16	3	1	0	1	173
1956	2	6	225	172	63	40	14	25	5	2	1	3	558
1957	7	7	10	14	46	59	23	51	7	3	1	2	230
1958	8	8	23	43	127	111	141	20	7	0	0	1	489
1959	1	6	4	28	57	20	6	1	0	0	0	0	123
1960	1	2	6	20	87	41	15	8	1	0	0	1	182
1961	1	10	12	7	24	26	14	8	3	1	0	2	108
1962	0	3	15	16	130	48	20	6	0	1	0	0	239
1963	85	10	39	30	81	43	114	28	7	1	0	2	440
1964	5	30	17	54	17	18	14	20	0	2	2	0	179
1965	5	16	211	155	22	20	67	13	6	3	3	0	521
1966	1	18	24	40	30	30	19	10	2	1	0	1	176
1967	0	33	67	114	39	75	82	40	14	0	0	0	464
1968	5	4	15	30	75	32	10	4	0	0	0	0	175
1969	4	14	41	242	121	67	47	19	5	0	0	0	560
1970	7	5	63	197	46	41	9	3	0	0	0	0	371

Table B-10. UF 10 – Bear River near Wheatland Unimpaired Flow in TAF contd.

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1971	11	43	127	55	27	71	31	18	7	0	0	0	390
1972	1	5	34	21	44	28	22	8	1	0	0	0	164
1973	1	34	38	149	109	80	28	11	1	0	0	0	451
1974	5	79	93	120	38	134	74	17	12	9	0	0	581
1975	0	3	9	19	89	90	46	21	1	0	0	0	278
1976	5	16	10	5	11	11	3	0	0	0	0	1	62
1977	0	1	0	9	5	4	0	1	0	0	0	0	20
1978	0	3	32	161	58	82	53	18	5	0	0	4	416
1979	0	8	5	43	62	65	25	20	0	0	0	0	228
1980	4	12	32	156	145	61	24	15	6	0	0	0	455
1981	0	1	8	25	14	44	9	0	0	0	0	0	101
1982	4	73	149	101	109	98	175	25	6	0	0	0	740
1983	12	52	93	65	148	208	70	46	10	3	0	0	707
1984	3	60	140	39	45	38	24	18	11	7	4	4	393
1985	9	22	14	11	30	37	22	9	5	4	0	2	165
1986	0	10	25	44	313	123	19	15	4	6	1	0	560
1987	1	0	4	5	27	37	7	4	2	1	0	1	89
1988	0	0	19	46	7	10	9	6	3	0	0	0	100
1989	0	14	20	27	19	152	32	21	7	8	0	4	304
1990	2	8	6	29	28	27	9	4	15	3	0	0	131
1991	0	0	1	1	2	84	22	15	11	6	3	0	145
1992	0	2	3	6	66	28	10	3	0	2	0	1	121
1993	0	0	25	144	78	65	34	12	13	7	3	1	382
1994	2	0	13	7	27	16	7	6	2	1	0	0	81
1995	2	7	54	214	29	211	55	56	21	18	6	7	680
1996	0	17	18	66	118	64	50	42	21	11	6	3	415
1997	2	13	180	245	24	16	11	16	11	7	6	7	538
1998	2	0	41	139	199	64	65	52	30	15	7	3	618
1999	6	8	37	77	151	69	42	28	14	3	2	1	438
2000	2	5	6	55	153	79	30	23	10	0	3	3	369
2001	10	5	4	7	31	25	14	7	3	2	0	3	112
2002	2	6	60	50	43	68	25	14	13	0	2	4	285
2003	4	2	56	42	24	35	53	48	14	4	0	0	282
2004	0	4	34	42	74	34	5	5	0	3	0	2	203
2005	5	3	31	62	37	74	39	58	25	8	0	1	345
2006	0	0	148	82	78	137	170	39	13	6	0	3	675
2007	6	3	19	9	56	26	10	11	3	1	0	2	147
2008	1	1	21	36	45	20	12	0	4	2	0	0	141
2009	3	2	12	6	46	60	16	33	8	3	0	1	190
2010	11	0	0	16	24	17	28	34	35	12	0	0	176
2011	10	19	128	49	61	205	71	35	27	15	2	0	621
2012	3	2	0	14	6	100	77	19	17	7	0	2	246
2013	3	15	131	21	12	13	6	8	11	8	2	0	230
2014	0	0	0	0	37	37	27	2	2	1	3	0	110
1922-2003 Average	**5**	**14**	**41**	**60**	**69**	**61**	**38**	**18**	**7**	**3**	**1**	**2**	**318**
1922-2014 Average	**5**	**13**	**41**	**57**	**66**	**61**	**39**	**18**	**7**	**3**	**1**	**2**	**314**

Table B-11. UF 11 – American River at Fair Oaks Unimpaired Flow in TAF

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1922	14	39	131	113	360	325	480	1027	677	94	14	6	3279
1923	19	56	398	275	183	225	564	616	283	97	18	18	2751
1924	23	21	27	42	112	58	123	105	26	4	1	2	543
1925	13	57	86	87	598	312	600	613	273	60	11	7	2717
1926	20	33	54	48	261	200	479	212	66	13	0	1	1387
1927	13	181	142	222	775	447	728	617	432	75	13	9	3652
1928	17	113	99	109	138	989	536	396	98	20	4	2	2521
1929	12	28	38	42	99	148	211	358	180	30	2	1	1147
1930	11	12	162	144	151	328	357	285	160	27	7	8	1652
1931	17	34	21	57	75	140	173	136	47	8	3	4	715
1932	16	30	165	161	320	298	403	659	426	93	17	9	2595
1933	11	14	23	43	47	135	239	354	342	42	10	9	1269
1934	22	34	108	159	171	255	196	106	49	11	7	6	1124
1935	11	59	54	156	148	213	818	668	360	70	17	11	2583
1936	21	30	34	408	775	432	636	587	358	83	18	14	3397
1937	11	15	23	44	336	396	503	688	234	52	15	12	2328
1938	20	54	436	130	539	806	732	1011	599	134	31	20	4511
1939	30	41	44	50	70	222	326	175	57	15	6	12	1046
1940	28	19	28	468	611	847	628	511	199	40	13	14	3406
1941	15	44	249	345	473	449	445	720	282	85	23	17	3145
1942	18	49	325	583	554	286	626	717	557	155	32	17	3917
1943	17	154	278	691	374	930	590	446	264	87	25	18	3875
1944	19	24	31	58	144	234	216	472	194	46	14	9	1462
1945	11	120	124	97	560	259	417	550	282	70	15	10	2516
1946	35	143	544	308	155	342	513	549	203	49	13	13	2866
1947	18	88	87	50	172	305	302	263	96	19	9	7	1417
1948	47	43	28	170	74	147	532	634	446	87	19	12	2239
1949	14	35	54	48	87	351	516	531	167	29	14	10	1857
1950	12	26	25	301	335	342	588	598	325	82	19	12	2664
1951	40	985	1054	576	425	431	431	456	156	44	18	14	4631
1952	30	98	317	540	545	501	817	1136	671	241	56	24	4976
1953	20	30	99	454	155	218	469	486	511	164	31	16	2653
1954	16	54	65	123	210	450	542	364	115	33	14	11	1997
1955	12	29	114	133	103	154	240	485	222	42	19	13	1564
1956	13	29	1247	952	327	306	408	754	431	124	34	21	4645
1957	32	31	49	58	284	443	305	567	289	53	18	8	2137
1958	22	37	98	164	588	553	846	1057	537	131	38	21	4090
1959	15	23	24	149	204	200	283	205	86	16	7	15	1226
1960	12	13	20	63	348	431	359	283	121	20	6	4	1680
1961	9	50	39	31	123	157	237	273	117	5	0	5	1045
1962	10	14	51	47	418	247	554	420	261	40	4	3	2069
1963	335	45	178	259	712	234	652	761	281	63	17	17	3552
1964	32	201	83	156	107	126	292	395	187	37	14	2	1632
1965	11	64	1509	774	282	238	618	510	316	95	52	15	4485
1966	26	75	81	122	113	237	412	276	48	3	0	0	1392
1967	7	77	278	421	266	540	439	898	751	241	34	15	3967
1968	19	45	85	143	450	292	291	250	92	11	18	4	1699
1969	14	100	128	1090	495	367	675	943	469	116	25	23	4445
1970	28	50	336	1315	334	341	208	295	199	40	10	7	3163

Table B-11. UF 11 – American River at Fair Oaks Unimpaired Flow in TAF contd.

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1971	10	179	342	297	212	405	414	554	419	107	25	10	2972
1972	14	54	134	110	194	456	333	381	160	26	5	7	1874
1973	25	93	227	597	395	355	419	637	199	34	13	15	3008
1974	31	430	349	819	187	585	649	539	468	163	34	18	4272
1975	27	30	46	99	252	448	303	762	503	105	30	14	2620
1976	82	84	66	44	67	120	141	152	22	3	11	9	801
1977	15	10	3	22	27	42	75	100	55	0	0	0	349
1978	0	19	181	550	293	568	522	595	377	88	7	24	3224
1979	2	22	32	181	217	360	364	653	170	34	4	2	2042
1980	31	66	94	1208	717	403	407	487	299	127	19	13	3871
1981	19	18	42	92	136	268	292	216	45	0	0	0	1128
1982	42	531	838	529	897	688	1130	842	387	136	41	61	6124
1983	169	278	565	454	696	1167	605	983	942	382	90	51	6382
1984	49	722	947	379	288	380	319	493	237	50	22	17	3901
1985	36	188	102	70	141	200	435	283	79	14	5	24	1574
1986	21	69	154	358	1866	967	402	419	310	51	25	12	4653
1987	28	12	12	50	133	209	212	177	31	9	3	4	880
1988	9	15	89	161	93	140	165	128	51	1	0	0	853
1989	6	85	62	66	109	866	553	316	145	17	3	19	2247
1990	36	40	29	101	101	241	271	181	109	6	2	3	1118
1991	4	7	12	11	24	331	276	327	169	25	0	8	1195
1992	17	32	24	25	231	210	239	92	17	14	0	0	901
1993	14	20	128	521	361	659	516	668	386	96	20	10	3399
1994	17	16	47	44	95	163	189	184	43	3	2	8	811
1995	10	62	152	926	304	1172	755	988	730	342	81	26	5549
1996	10	9	184	340	824	573	559	811	257	67	21	14	3668
1997	15	143	1024	1988	338	295	360	335	153	32	11	10	4704
1998	19	49	91	514	727	587	582	699	787	265	45	33	4398
1999	20	86	146	367	698	436	414	644	375	83	25	19	3316
2000	19	34	41	316	678	431	438	466	160	45	12	19	2658
2001	19	21	34	54	105	228	253	255	32	13	2	6	1022
2002	2	54	181	226	218	356	425	374	153	22	8	5	2025
2003	0	65	194	241	160	269	415	634	266	39	17	5	2305
2004	20	16	147	133	268	383	315	240	67	10	0	1	1600
2005	52	43	124	272	224	524	466	974	452	112	23	12	3278
2006	14	34	879	621	484	657	1254	915	365	88	25	13	5349
2007	0	47	100	85	257	282	251	223	46	3	0	4	1298
2008	17	15	47	120	137	185	252	325	86	12	0	0	1195
2009	6	45	35	102	240	449	332	606	107	23	3	5	1953
2010	24	11	53	144	161	254	403	521	537	78	13	8	2205
2011	104	104	680	270	236	884	734	684	763	310	49	25	4842
2012	46	24	23	100	64	431	561	292	79	20	7	0	1647
2013	19	134	545	156	109	217	240	155	66	15	7	6	1670
2014	6	11	11	20	237	232	234	143	34	10	3	5	945
1922-2003 Average	**25**	**88**	**198**	**302**	**329**	**384**	**439**	**497**	**269**	**68**	**17**	**12**	**2628**
1922-2014 Average	**25**	**83**	**203**	**288**	**316**	**387**	**441**	**493**	**265**	**67**	**16**	**12**	**2596**

Table B-12. UF 12 – San Joaquin Valley East Side Minor Streams Unimpaired Flow in TAF

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1922	0	0	35	39	270	104	69	23	0	0	0	0	540
1923	0	15	150	92	42	31	69	19	8	0	0	0	426
1924	0	0	0	0	0	0	0	0	0	0	0	0	0
1925	0	15	8	12	166	39	92	35	0	0	0	0	367
1926	0	0	4	4	77	12	27	0	0	0	0	0	124
1927	0	12	8	42	169	46	96	8	0	0	0	0	381
1928	0	0	4	8	39	135	69	4	0	0	0	0	259
1929	0	0	0	12	23	19	15	0	0	0	0	0	69
1930	0	0	0	19	12	65	8	0	0	0	0	0	104
1931	0	0	0	0	4	0	0	0	0	0	0	0	4
1932	0	0	39	46	208	12	4	0	0	0	0	0	309
1933	0	0	0	4	4	8	0	0	0	0	0	0	16
1934	0	0	12	42	46	15	0	0	0	0	0	0	115
1935	0	0	0	42	15	54	177	15	0	0	0	0	303
1936	0	0	0	77	497	50	50	8	4	0	0	0	686
1937	0	0	0	23	258	273	50	8	0	0	0	0	612
1938	0	0	8	19	389	296	54	15	0	0	0	0	781
1939	0	0	0	4	19	19	4	0	0	0	0	0	46
1940	0	0	0	62	112	131	65	4	0	0	0	0	374
1941	0	0	27	39	89	81	69	12	0	0	0	0	317
1942	0	0	23	196	177	58	73	35	8	0	0	0	570
1943	0	12	23	212	96	389	58	12	4	0	0	0	806
1944	0	0	0	0	54	92	12	0	0	0	0	0	158
1945	0	27	19	12	254	92	31	8	4	0	0	0	447
1946	0	4	173	46	27	39	31	4	0	0	0	0	324
1947	0	0	4	0	12	23	12	0	0	0	0	0	51
1948	0	0	0	0	4	42	65	19	4	0	0	0	134
1949	0	0	0	8	23	154	12	0	0	0	0	0	197
1950	0	0	0	46	108	35	39	4	0	0	0	0	232
1951	0	189	235	239	100	116	19	15	0	0	0	0	913
1952	0	4	104	331	127	262	46	12	0	0	0	0	886
1953	0	0	15	77	12	23	12	8	0	0	0	0	147
1954	0	0	0	8	23	62	27	0	0	0	0	0	120
1955	0	0	23	108	27	19	15	8	0	0	0	0	200
1956	0	0	335	389	65	35	15	15	0	0	0	0	854
1957	0	0	0	0	23	104	15	23	0	0	0	0	165
1958	0	0	0	39	189	246	466	19	4	0	0	0	963
1959	0	0	0	15	89	12	4	0	0	0	0	0	120
1960	0	0	0	0	50	42	8	0	0	0	0	0	100
1961	0	0	0	0	0	4	0	0	0	0	0	0	4
1962	0	0	0	0	123	58	4	0	0	0	0	0	185
1963	8	0	8	4	131	65	146	27	4	0	0	0	393
1964	0	12	4	58	12	12	8	0	0	0	0	0	106
1965	0	0	296	235	31	19	73	12	0	0	0	0	666
1966	0	0	23	35	39	8	4	0	0	0	0	0	109
1967	0	0	35	154	73	104	208	39	8	0	0	0	621
1968	0	0	4	23	58	46	15	4	0	0	0	0	150
1969	0	0	19	296	277	123	69	12	4	0	0	0	800
1970	0	0	27	196	58	112	15	4	0	0	0	4	416

Table B-12. UF 12 – San Joaquin Valley East Side Minor Streams Unimpaired Flow in TAF contd.

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1971	0	12	104	46	12	42	15	4	0	0	0	0	235
1972	0	0	31	8	31	8	4	0	0	0	0	0	82
1973	0	4	8	193	239	146	35	8	0	0	0	0	633
1974	0	19	112	154	31	112	85	12	4	4	0	0	533
1975	0	0	4	8	135	166	58	12	0	0	0	0	383
1976	0	0	0	0	0	0	0	0	0	0	0	0	0
1977	0	0	0	0	0	0	0	0	0	0	0	0	0
1978	0	0	4	146	85	123	112	23	4	0	0	0	497
1979	0	0	0	50	162	127	23	8	0	0	0	0	370
1980	0	0	8	219	262	89	23	8	4	0	0	0	613
1981	0	0	0	27	8	81	15	0	0	0	0	0	131
1982	0	19	58	273	227	262	347	27	8	4	0	0	1225
1983	0	85	293	358	296	535	139	104	19	12	8	8	1857
1984	4	129	289	82	84	65	20	10	3	1	1	1	689
1985	0	26	25	10	39	49	15	2	1	1	0	0	168
1986	0	5	22	45	613	286	34	12	6	1	0	0	1024
1987	0	0	0	2	23	51	5	0	0	0	0	0	81
1988	12	34	63	41	8	6	33	8	3	0	0	0	208
1989	3	33	45	13	19	54	4	0	7	0	2	33	213
1990	10	8	0	15	16	8	5	16	0	0	0	0	78
1991	2	2	10	2	19	49	4	2	2	0	1	0	93
1992	58	9	32	40	141	54	18	0	5	0	0	0	357
1993	0	1	12	111	88	119	72	39	20	4	1	1	468
1994	0	1	2	2	5	5	3	3	1	0	0	0	22
1995	1	4	16	202	64	315	139	166	56	18	4	2	988
1996	2	2	9	45	111	104	63	59	15	5	2	2	420
1997	2	12	177	485	79	39	28	17	7	4	2	1	853
1998	3	6	11	106	220	161	132	124	73	19	6	4	866
1999	4	6	13	49	158	83	65	44	16	5	3	2	447
2000	2	4	4	44	135	71	36	29	8	3	1	2	339
2001	2	2	3	5	12	18	17	10	2	1	0	0	72
2002	0	3	14	25	24	40	26	15	5	1	0	0	155
2003	0	3	12	13	11	16	48	52	10	2	1	0	169
2004	0	1	9	13	30	32	17	8	2	1	0	0	113
2005	3	4	17	70	46	118	82	95	30	7	2	2	476
2006	2	3	102	125	70	182	359	110	28	8	4	3	996
2007	2	3	5	6	24	23	14	9	2	1	0	0	90
2008	1	1	2	12	15	13	12	9	2	1	0	0	69
2009	1	2	2	7	23	51	22	36	4	1	0	0	148
2010	1	1	4	18	22	34	49	54	31	4	1	1	219
2011	5	11	123	67	61	259	143	89	62	18	4	2	844
2012	3	3	2	6	4	35	51	17	4	1	1	1	128
2013	1	3	43	13	9	13	13	4	1	1	0	0	100
2014	0	1	1	1	7	9	6	2	0	0	0	0	27
1922-2003 Average	**1**	**9**	**37**	**75**	**98**	**86**	**49**	**15**	**4**	**1**	**0**	**1**	**377**
1922-2014 Average	**1**	**8**	**36**	**70**	**90**	**84**	**52**	**18**	**5**	**1**	**0**	**1**	**367**

Table B-13. UF 13 – Cosumnes River at Michigan Bar Unimpaired Flow in TAF

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1922	0	1	14	18	104	70	84	97	33	4	1	0	425
1923	1	12	104	76	45	40	99	41	16	4	1	1	438
1924	2	2	3	5	11	5	8	3	0	0	0	0	40
1925	1	5	15	14	136	45	99	48	15	2	1	1	381
1926	1	2	4	4	52	23	48	12	2	0	0	0	148
1927	1	15	14	34	133	71	122	42	17	3	1	0	452
1928	1	8	13	12	25	146	80	22	5	1	0	0	315
1929	1	2	5	7	19	20	30	21	10	1	0	0	115
1930	0	0	6	20	19	57	35	20	6	1	0	0	165
1931	1	2	2	6	11	12	7	4	1	0	0	0	46
1932	0	2	32	28	91	47	43	51	17	3	0	0	314
1933	0	1	2	5	7	19	24	34	20	2	0	0	113
1934	1	2	18	31	31	23	10	5	3	0	0	0	123
1935	0	4	6	33	24	44	174	61	18	3	1	0	369
1936	1	2	3	58	234	74	86	39	21	4	1	0	523
1937	1	1	3	10	92	114	91	67	16	3	1	0	399
1938	1	3	30	19	149	201	125	106	39	8	2	1	683
1939	3	4	5	6	11	27	24	9	2	0	0	0	92
1940	2	1	2	77	130	160	94	28	7	2	0	0	502
1941	1	2	28	50	80	84	81	56	17	3	1	1	402
1942	1	3	24	110	106	47	85	86	37	8	2	1	510
1943	2	21	38	138	82	249	74	34	15	5	2	1	660
1944	2	3	5	11	34	47	33	39	12	2	0	0	188
1945	0	23	18	15	120	56	59	40	20	3	1	0	357
1946	3	15	108	56	28	65	65	37	11	3	1	0	390
1947	2	10	12	8	23	43	32	11	3	0	0	0	145
1948	3	4	3	9	9	33	96	76	30	5	1	0	269
1949	1	2	6	8	17	84	63	42	11	2	0	0	237
1950	1	3	3	40	69	57	92	47	15	3	1	1	331
1951	4	148	181	134	86	95	47	47	12	4	2	1	762
1952	4	10	59	141	117	131	141	117	43	13	4	3	782
1953	2	4	15	58	19	32	49	44	30	7	2	1	264
1954	2	4	6	16	35	66	65	25	7	2	1	0	229
1955	1	3	20	43	24	27	33	40	10	2	0	0	203
1956	0	3	211	202	67	53	48	76	21	5	2	1	689
1957	3	4	5	8	38	87	33	50	15	3	1	1	247
1958	2	3	8	26	112	152	225	92	36	8	3	2	669
1959	2	3	3	16	41	26	20	9	2	2	1	1	127
1960	0	1	2	7	47	51	30	19	4	2	1	0	165
1961	1	3	4	3	7	13	13	13	4	2	1	0	63
1962	0	1	3	3	79	49	63	29	11	2	1	0	241
1963	22	3	12	20	125	43	133	84	21	6	2	1	472
1964	2	16	9	28	14	17	27	29	9	3	2	1	156
1965	1	7	222	176	54	39	100	48	21	5	3	1	677
1966	2	11	20	24	26	36	39	13	4	3	3	0	181
1967	0	5	41	84	54	104	128	132	57	14	4	2	626
1968	3	4	9	19	55	45	28	14	5	3	2	0	188
1969	1	7	17	234	126	86	117	82	26	6	2	2	706
1970	3	5	31	212	66	78	28	26	10	4	2	1	466

Table B-13. UF 13 – Cosumnes River at Michigan Bar Unimpaired Flow in TAF contd.

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1971	2	19	72	75	32	63	55	44	20	5	2	1	389
1972	2	5	25	16	33	50	37	23	7	3	2	1	204
1973	2	8	18	125	107	91	59	47	12	3	2	2	475
1974	3	30	75	115	35	131	104	51	16	9	3	1	574
1975	2	4	7	13	59	105	71	85	31	7	3	2	390
1976	5	7	6	5	7	12	11	8	2	0	1	1	65
1977	1	1	1	2	3	3	3	4	1	0	0	0	20
1978	0	1	16	109	63	107	110	57	22	5	1	2	494
1979	0	2	4	32	58	93	71	71	9	0	0	0	342
1980	1	5	12	211	194	103	53	41	15	4	0	0	639
1981	0	2	4	16	13	52	28	14	0	0	0	0	129
1982	2	39	88	145	167	190	239	88	24	8	3	4	997
1983	12	50	149	146	194	329	135	138	67	23	7	4	1253
1984	4	103	201	68	58	67	39	26	11	3	2	0	581
1985	3	20	16	10	27	37	43	14	4	0	0	2	176
1986	1	8	20	48	350	199	46	25	9	3	1	1	710
1987	1	1	2	4	14	22	7	4	2	2	1	0	62
1988	0	1	2	15	7	11	11	8	5	3	2	1	65
1989	0	3	4	7	12	106	39	15	5	1	1	1	192
1990	3	4	3	9	13	33	19	9	9	3	0	0	107
1991	0	1	1	0	2	50	32	24	10	2	0	0	122
1992	0	1	2	4	40	41	19	4	2	2	1	0	116
1993	0	0	14	129	102	146	100	48	23	0	0	0	562
1994	0	0	5	5	16	16	11	11	3	1	1	0	67
1995	0	4	16	197	58	275	121	145	52	16	5	1	891
1996	0	1	10	53	125	111	66	63	19	8	4	2	459
1997	0	15	171	424	73	32	25	15	7	3	2	0	767
1998	2	5	9	104	217	145	119	112	69	19	7	5	812
1999	4	7	14	57	159	86	69	46	19	6	4	2	474
2000	1	4	4	52	152	77	40	33	10	5	3	3	383
2001	3	3	5	9	21	32	32	20	3	1	1	1	131
2002	1	4	21	37	35	59	37	22	7	2	1	1	226
2003	1	4	17	20	17	25	68	68	14	4	2	1	241
2004	1	2	14	20	47	52	25	12	3	2	1	1	181
2005	4	5	19	78	54	124	85	98	33	8	3	2	512
2006	2	3	95	115	62	159	313	98	26	8	4	3	889
2007	4	5	9	11	39	40	24	16	4	2	1	1	156
2008	2	2	4	22	27	27	23	18	5	1	2	2	135
2009	1	3	3	11	33	76	33	48	6	2	1	1	218
2010	2	2	6	23	29	45	64	66	39	6	2	1	285
2011	5	11	122	61	56	236	130	81	57	17	5	3	784
2012	3	4	4	10	6	53	75	24	6	3	1	1	191
2013	2	5	69	21	15	21	20	7	3	1	1	1	166
2014	1	2	2	2	20	28	18	5	0	0	0	0	80
1922-2003 Average	**2**	**9**	**29**	**56**	**68**	**74**	**64**	**43**	**16**	**4**	**1**	**1**	**368**
1922-2014 Average	**2**	**9**	**30**	**54**	**64**	**75**	**65**	**43**	**16**	**4**	**2**	**1**	**363**

Table B-14. UF 14 – Mokelumne River at Pardee Reservoir Unimpaired Flow in TAF

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1922	2	2	12	22	60	57	108	334	284	40	3	1	925
1923	4	11	60	47	35	46	129	231	111	31	2	4	709
1924	8	5	6	8	17	19	56	69	2	0	0	0	190
1925	6	20	24	23	108	84	169	247	129	20	2	3	835
1926	4	6	15	15	39	49	136	95	16	1	0	0	376
1927	2	31	37	42	105	82	159	211	189	32	3	2	896
1928	5	26	19	23	35	188	140	172	29	5	0	0	641
1929	2	2	6	9	14	29	66	148	61	5	1	0	343
1930	1	1	20	19	31	65	116	116	84	6	1	1	460
1931	2	5	3	6	15	30	73	64	11	0	0	1	210
1932	2	5	19	22	59	68	109	229	196	30	3	3	745
1933	0	2	3	5	9	28	64	126	163	16	4	5	424
1934	5	6	20	24	29	73	78	40	21	1	0	0	297
1935	0	13	13	23	33	41	179	229	153	16	2	1	704
1936	4	4	4	39	138	102	187	246	145	22	4	2	897
1937	3	3	7	7	61	73	127	279	117	15	2	2	696
1938	3	6	125	27	78	158	180	334	265	51	8	4	1238
1939	7	12	12	13	15	55	125	76	17	2	1	2	337
1940	8	4	9	81	95	157	168	240	89	8	2	2	862
1941	3	6	31	38	69	95	107	285	167	31	7	3	841
1942	4	11	66	96	76	59	154	221	241	51	8	4	989
1943	3	35	54	107	76	192	184	208	113	25	6	3	1004
1944	5	4	8	14	22	46	66	188	79	11	3	0	447
1945	2	33	34	28	112	56	122	208	148	23	5	2	774
1946	5	38	84	60	33	75	153	207	80	10	2	1	748
1947	4	19	21	14	28	57	91	130	29	1	0	0	394
1948	14	12	9	28	17	29	105	206	184	25	2	2	634
1949	3	4	9	8	9	47	146	204	78	4	3	2	517
1950	1	4	5	36	60	69	173	228	150	21	3	3	753
1951	10	270	264	93	83	88	122	156	59	10	3	2	1160
1952	3	13	53	78	93	96	223	374	268	94	17	11	1322
1953	5	8	15	64	35	51	130	139	181	42	6	4	681
1954	4	8	10	16	35	84	157	165	42	8	1	0	531
1955	1	5	19	20	24	38	63	168	90	8	2	0	437
1956	1	4	239	186	78	85	139	258	206	30	14	7	1247
1957	7	9	12	13	55	85	92	179	131	13	5	1	601
1958	5	9	18	25	85	97	188	343	223	55	12	5	1064
1959	5	6	7	30	36	55	102	89	33	7	0	6	375
1960	4	2	3	7	49	72	111	119	42	4	0	2	413
1961	0	4	8	7	19	29	73	102	33	3	0	1	279
1962	1	3	10	8	65	49	180	163	140	16	4	1	639
1963	19	7	18	37	176	47	128	263	145	23	7	4	874
1964	6	40	19	17	18	27	87	137	66	10	0	1	428
1965	3	15	295	151	68	57	156	205	168	47	27	4	1195
1966	8	28	21	22	28	64	139	127	15	3	0	2	457
1967	2	15	71	51	59	119	102	294	292	118	13	4	1140
1968	7	4	9	15	69	59	86	114	36	4	4	0	407
1969	4	34	22	195	96	88	208	385	228	60	6	3	1327
1970	16	12	65	238	81	81	79	192	125	21	3	0	910

Table B-14. UF 14 – Mokelumne River at Pardee Reservoir Unimpaired Flow in TAF contd.

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1971	14	27	46	57	51	74	111	176	190	38	0	1	783
1972	6	12	28	22	32	104	81	159	70	10	2	3	529
1973	7	13	42	73	64	65	128	284	105	11	3	1	795
1974	7	85	68	105	40	118	136	246	146	38	9	3	1002
1975	3	6	10	19	40	83	72	257	235	42	8	4	776
1976	23	24	14	11	14	28	44	72	8	2	5	2	246
1977	3	2	2	4	6	9	34	42	25	0	1	1	129
1978	1	3	28	76	57	124	147	237	213	52	6	14	959
1979	2	5	9	45	43	91	121	261	94	11	3	1	685
1980	9	18	19	252	163	97	127	206	176	66	6	2	1140
1981	2	2	7	16	26	45	110	125	32	0	0	1	368
1982	6	78	131	90	201	150	296	305	172	56	9	16	1511
1983	65	62	101	95	141	254	140	317	377	203	29	16	1800
1984	8	156	192	85	56	84	87	218	98	16	14	0	1014
1985	5	30	16	16	29	43	131	142	34	4	1	3	453
1986	2	12	25	68	331	246	140	212	140	22	5	2	1204
1987	2	0	4	8	21	41	80	80	12	3	1	1	252
1988	2	6	11	17	19	41	67	68	23	2	0	0	256
1989	0	9	9	10	24	144	152	130	64	6	1	4	554
1990	12	16	12	17	16	57	97	73	33	4	1	0	338
1991	0	1	3	3	2	42	65	132	80	9	1	0	337
1992	4	7	8	8	35	51	106	54	7	8	0	0	289
1993	2	4	16	89	63	154	152	276	191	46	7	3	1001
1994	5	4	6	8	17	38	77	92	18	2	1	2	270
1995	4	15	20	134	74	249	191	332	314	189	26	12	1559
1996	12	4	26	53	159	131	152	263	111	21	8	6	945
1997	5	36	141	437	84	85	120	163	68	8	6	5	1158
1998	5	9	12	73	126	159	152	215	348	142	17	10	1268
1999	13	14	30	57	123	83	112	240	154	26	13	4	869
2000	4	11	9	59	102	100	140	212	74	16	7	7	741
2001	8	9	8	13	19	63	92	142	13	4	3	4	380
2002	0	14	32	46	38	67	138	164	65	10	4	2	580
2003	2	19	20	43	36	60	99	223	145	19	2	2	672
2004	2	6	32	17	47	114	122	131	34	0	0	0	506
2005	7	12	25	71	67	118	125	304	200	56	11	6	1000
2006	8	11	139	145	94	139	311	359	204	35	8	8	1460
2007	3	14	18	20	44	80	87	99	20	2	0	0	389
2008	0	0	5	19	30	51	85	138	62	0	0	0	390
2009	3	15	9	34	39	96	107	248	53	9	1	0	614
2010	9	3	11	27	31	59	104	170	236	30	2	1	683
2011	34	27	128	72	52	171	200	222	320	148	17	7	1399
2012	12	8	6	25	16	61	146	110	23	5	3	2	418
2013	4	16	88	34	25	52	98	78	20	2	0	1	418
2014	1	3	1	5	33	47	76	72	12	1	0	0	250
1922-2003 Average	**6**	**19**	**37**	**52**	**61**	**81**	**124**	**191**	**118**	**26**	**5**	**3**	**722**
1922-2014 Average	**6**	**18**	**37**	**51**	**59**	**82**	**125**	**189**	**117**	**26**	**5**	**3**	**718**

Table B-15. UF 15 – Calaveras at Jenny Lind Unimpaired Flow in TAF

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1922	0	0	14	15	109	42	29	9	2	0	0	0	220
1923	0	5	64	33	26	11	20	8	3	1	0	0	171
1924	1	1	2	3	4	2	3	2	0	0	0	0	18
1925	0	3	8	6	83	12	39	6	2	0	0	0	159
1926	0	1	2	3	39	5	14	1	0	0	0	0	65
1927	0	18	4	13	81	17	41	5	2	0	0	0	181
1928	0	3	8	5	21	68	21	3	1	0	0	0	130
1929	0	1	3	5	12	9	8	2	1	0	0	0	41
1930	0	0	0	12	12	37	3	2	0	0	0	0	66
1931	0	0	0	4	5	3	1	0	0	0	0	0	13
1932	0	0	38	21	63	8	4	4	1	0	0	0	139
1933	0	0	0	10	7	8	3	3	1	0	0	0	32
1934	0	0	13	14	23	6	1	0	1	0	0	0	58
1935	0	1	4	34	8	32	58	9	2	2	0	0	150
1936	0	0	1	31	197	21	26	5	4	1	0	0	286
1937	0	0	2	13	99	82	24	8	3	1	0	0	232
1938	0	1	19	13	161	126	30	15	5	2	0	0	372
1939	1	2	3	4	10	8	4	2	0	0	0	0	34
1940	0	0	1	46	54	59	40	5	2	1	0	0	208
1941	0	2	18	24	47	50	49	8	3	1	0	0	202
1942	0	1	15	68	40	20	28	20	6	2	0	0	200
1943	0	10	19	63	43	110	19	8	3	1	0	0	276
1944	1	1	2	6	21	36	6	4	1	0	0	0	78
1945	0	11	9	5	67	41	15	5	2	0	0	0	155
1946	0	4	45	18	9	19	16	4	2	0	0	0	117
1947	0	6	6	3	10	16	6	1	1	0	0	0	49
1948	0	1	2	2	4	24	37	9	3	0	0	0	82
1949	0	0	3	4	11	50	9	2	1	0	0	0	80
1950	0	1	1	33	41	18	22	6	1	0	0	0	123
1951	1	64	84	61	31	46	9	9	2	1	0	0	308
1952	0	3	39	110	45	96	26	12	4	3	0	1	339
1953	1	2	13	34	5	13	9	6	3	0	1	0	87
1954	0	2	3	8	17	29	12	3	2	0	1	0	77
1955	0	1	16	37	14	10	9	6	1	0	0	0	94
1956	0	0	133	114	28	16	9	14	3	1	0	0	318
1957	1	1	2	4	12	34	5	11	2	0	0	0	72
1958	0	1	4	22	75	89	146	11	5	1	0	0	354
1959	0	1	2	7	39	6	3	1	0	0	0	0	59
1960	0	0	1	3	24	7	5	3	0	0	0	0	43
1961	0	0	2	1	2	5	3	1	0	0	0	0	14
1962	0	0	1	2	76	34	6	2	0	0	0	0	121
1963	1	1	3	14	37	22	60	14	4	2	1	1	160
1964	1	9	4	20	6	7	7	4	2	1	0	0	61
1965	0	6	104	81	14	12	49	8	3	2	1	0	280
1966	1	7	15	16	17	7	4	1	0	0	0	0	68
1967	0	2	28	62	18	49	112	26	7	2	1	0	307
1968	1	2	3	8	22	16	5	2	1	0	0	0	60
1969	0	2	16	159	113	52	34	10	4	2	1	1	394
1970	1	3	13	98	25	45	9	5	3	2	1	1	206

Table B-15. UF 15 – Calaveras at Jenny Lind Unimpaired Flow in TAF contd.

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1971	1	12	52	24	7	19	8	4	3	2	1	1	134
1972	0	2	25	7	19	5	5	3	1	0	0	1	68
1973	0	2	7	75	91	56	16	5	3	3	2	1	261
1974	1	8	37	40	9	69	41	7	3	3	1	1	220
1975	1	1	3	6	36	73	24	9	1	1	0	1	156
1976	1	2	1	2	2	4	2	1	1	0	1	0	17
1977	0	0	0	1	1	1	1	1	1	1	1	0	8
1978	0	0	4	65	49	56	51	12	3	1	0	1	242
1979	0	1	3	31	66	64	17	7	2	1	0	0	192
1980	0	2	8	92	82	35	12	5	3	3	1	2	245
1981	0	1	2	20	6	27	7	1	1	1	1	0	67
1982	0	11	28	98	82	103	113	13	5	3	1	2	459
1983	5	38	66	100	106	186	49	33	8	5	2	2	600
1984	3	53	84	20	25	23	10	6	3	1	0	0	228
1985	2	9	8	5	18	24	8	2	1	1	1	1	80
1986	1	5	6	13	188	83	13	6	2	0	0	1	318
1987	1	1	2	3	8	18	3	0	0	0	0	0	36
1988	0	0	1	5	1	3	3	1	0	1	1	0	16
1989	0	0	2	3	3	19	3	1	0	0	0	0	31
1990	1	1	1	4	11	11	3	1	1	0	0	0	34
1991	0	0	0	0	1	40	5	1	0	0	0	0	47
1992	1	0	1	4	38	15	3	1	0	0	1	0	64
1993	0	0	8	98	48	42	20	5	4	0	0	1	227
1994	1	1	3	3	14	4	3	2	1	1	0	1	36
1995	0	0	4	116	14	155	29	45	12	3	0	2	382
1996	2	3	7	44	84	43	20	10	4	3	2	1	225
1997	1	8	116	207	26	11	6	3	1	1	0	0	380
1998	1	3	5	80	189	62	65	34	12	5	3	2	460
1999	2	4	5	37	95	26	22	8	4	2	1	1	208
2000	1	2	2	36	108	38	11	9	3	1	1	1	212
2001	3	2	2	7	20	19	9	3	1	1	1	1	66
2002	0	2	19	19	14	27	6	4	2	0	0	0	92
2003	0	1	17	8	5	7	20	10	2	1	0	0	70
2004	0	0	11	16	27	12	3	1	0	0	1	0	71
2005	1	2	20	81	33	83	24	13	4	1	1	0	264
2006	1	1	33	62	16	104	176	16	5	2	1	1	418
2007	1	2	5	5	25	11	5	3	1	0	1	0	58
2008	0	0	3	25	23	7	3	1	1	1	0	0	63
2009	0	0	1	5	16	30	5	4	0	0	1	1	62
2010	1	0	4	31	21	26	27	11	4	1	0	0	126
2011	1	7	64	26	41	160	28	12	7	2	1	0	349
2012	2	1	1	5	3	20	25	3	1	1	1	2	63
2013	1	2	32	6	3	3	3	1	1	1	1	0	56
2014	0	0	0	0	5	6	4	0	0	0	1	1	18
1922-2003 Average	**0**	**4**	**16**	**32**	**41**	**35**	**21**	**7**	**2**	**1**	**0**	**0**	**161**
1922-2014 Average	**1**	**4**	**16**	**31**	**39**	**36**	**22**	**7**	**2**	**1**	**0**	**0**	**159**

Table B-16. UF 16 – Stanislaus River at Melones Reservoir Unimpaired Flow in TAF

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1922	4	6	25	35	107	103	170	495	378	87	17	4	1430
1923	6	16	79	78	55	77	207	356	161	73	12	10	1130
1924	12	9	10	12	27	24	70	85	11	1	0	0	261
1925	6	27	32	31	153	120	261	356	172	51	11	5	1225
1926	8	10	14	13	74	79	216	139	41	7	3	3	607
1927	5	23	61	52	162	134	267	332	245	63	14	7	1364
1928	10	41	26	31	48	253	214	240	67	13	5	3	950
1929	2	8	10	13	23	44	100	196	98	18	4	1	517
1930	1	4	20	31	48	104	184	169	133	27	5	6	732
1931	8	10	8	14	21	39	93	92	25	6	0	0	315
1932	3	5	58	43	132	117	204	385	299	85	19	5	1353
1933	6	4	8	12	14	38	106	178	206	28	6	4	609
1934	3	7	20	29	45	101	100	69	42	9	1	1	424
1935	4	16	20	43	47	70	315	379	249	53	13	4	1214
1936	8	8	8	54	206	154	288	332	193	51	12	8	1322
1937	7	6	12	23	110	124	192	411	167	39	11	5	1109
1938	7	9	178	50	174	239	301	541	392	113	28	12	2045
1939	18	21	16	22	22	74	179	110	44	13	2	5	526
1940	15	9	11	128	173	264	257	346	155	30	8	4	1400
1941	8	7	45	55	108	161	184	433	233	81	17	4	1338
1942	11	12	76	115	103	105	249	354	323	112	18	7	1485
1943	7	44	59	164	118	302	308	299	174	66	19	6	1565
1944	8	7	11	19	31	69	100	259	123	38	8	2	676
1945	7	48	44	37	183	97	208	333	230	70	14	7	1277
1946	22	50	126	86	49	115	238	306	135	36	10	5	1178
1947	10	30	32	22	45	94	136	182	62	14	5	2	634
1948	17	9	10	24	18	38	156	316	247	51	10	2	898
1949	5	13	17	15	19	61	194	277	115	20	7	2	745
1950	4	7	8	42	73	95	255	339	194	45	9	5	1076
1951	10	366	412	120	113	127	175	209	114	32	9	5	1694
1952	10	17	58	106	106	142	334	590	370	144	34	9	1919
1953	6	11	24	77	41	73	209	192	231	87	13	4	967
1954	7	10	12	21	44	145	264	261	90	25	6	4	888
1955	5	9	25	37	37	54	102	229	148	27	7	1	681
1956	4	9	365	274	102	121	204	396	283	93	20	10	1883
1957	11	16	14	15	61	116	136	281	189	38	11	7	894
1958	13	15	19	35	117	172	282	568	325	100	27	5	1678
1959	12	11	8	37	66	87	148	115	68	17	4	13	584
1960	6	5	5	14	61	102	161	157	71	10	1	1	594
1961	0	11	12	10	24	46	108	120	57	7	5	4	404
1962	3	6	9	11	95	76	271	251	206	56	7	3	995
1963	14	8	19	67	216	67	156	417	219	63	13	8	1268
1964	10	48	28	36	31	50	122	183	106	21	5	4	643
1965	5	22	368	221	104	101	241	308	244	96	38	10	1757
1966	8	46	38	42	39	101	205	167	41	12	4	1	703
1967	3	25	114	90	81	196	176	493	491	212	37	14	1932
1968	9	10	13	24	95	90	144	161	70	13	7	4	640
1969	8	39	49	355	181	154	346	595	336	116	24	9	2211
1970	17	20	74	355	118	143	123	255	172	30	11	4	1320

Table B-16. UF 16 – Stanislaus River at Melones Reservoir Unimpaired Flow in TAF contd.

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1971	5	39	72	79	71	109	172	239	209	65	11	3	1074
1972	7	21	51	32	54	141	135	208	107	16	2	2	776
1973	12	17	45	117	128	126	211	417	168	29	6	5	1281
1974	11	103	106	159	64	200	247	372	209	62	20	7	1560
1975	0	15	23	28	71	143	123	401	332	76	19	10	1242
1976	32	26	21	18	19	43	75	99	17	1	8	10	371
1977	2	5	4	6	8	13	35	44	36	0	0	2	155
1978	0	5	37	109	108	223	261	393	302	98	26	27	1590
1979	16	7	16	79	108	160	206	385	142	28	9	7	1164
1980	11	23	32	383	257	136	202	321	268	134	26	13	1804
1981	9	7	12	40	40	82	164	165	57	6	3	5	591
1982	10	100	187	169	329	253	433	441	251	109	26	38	2345
1983	88	122	160	183	245	411	213	504	632	287	77	29	2952
1984	24	225	153	144	98	137	157	297	148	41	10	0	1434
1985	11	48	31	26	48	79	206	171	53	3	0	2	678
1986	0	40	43	99	532	353	253	300	215	57	19	25	1936
1987	13	3	9	13	29	59	104	94	27	11	6	4	372
1988	3	10	14	27	35	59	86	83	40	12	6	3	378
1989	9	6	14	18	30	181	234	162	94	24	7	1	778
1990	22	17	13	25	24	83	134	87	51	12	1	0	469
1991	3	2	3	3	1	81	97	183	106	21	3	6	511
1992	12	14	13	18	72	78	136	95	17	19	6	6	486
1993	6	8	27	182	108	234	249	407	241	76	17	3	1557
1994	10	10	13	15	29	61	106	159	41	4	0	6	455
1995	5	24	26	230	100	415	276	484	460	261	50	18	2348
1996	11	10	42	86	276	215	255	377	175	38	4	0	1489
1997	7	50	265	659	90	129	180	231	110	22	11	4	1759
1998	12	17	20	146	250	231	245	341	511	245	40	28	2085
1999	15	31	39	101	197	124	173	370	215	49	16	17	1348
2000	9	18	12	91	189	160	222	292	128	24	7	10	1162
2001	13	13	12	23	36	96	134	200	28	5	2	4	565
2002	5	21	57	62	55	103	213	217	97	16	4	2	853
2003	3	30	48	58	55	91	152	323	178	20	11	5	974
2004	2	8	47	42	76	164	175	153	61	17	5	0	751
2005	17	23	41	146	111	194	211	533	292	101	15	6	1692
2006	13	11	210	199	138	229	470	538	277	77	23	16	2201
2007	16	13	29	27	78	112	124	124	32	5	2	1	565
2008	9	3	14	47	52	73	130	192	85	13	4	3	625
2009	2	24	15	53	73	168	186	331	96	26	7	4	985
2010	21	9	20	54	65	99	175	261	312	70	9	6	1101
2011	46	42	213	116	98	305	321	364	449	217	41	20	2231
2012	38	13	12	37	27	89	202	136	41	15	10	3	624
2013	8	23	119	45	43	86	132	111	36	10	10	4	627
2014	7	4	6	9	35	62	111	91	21	12	7	4	370
1922-2003 Average	**10**	**28**	**53**	**81**	**96**	**128**	**192**	**282**	**176**	**53**	**12**	**7**	**1117**
1922-2014 Average	**10**	**26**	**54**	**80**	**93**	**130**	**193**	**279**	**173**	**53**	**12**	**7**	**1112**

Table B-17. UF 17 – San Joaquin Valley Floor Unimpaired Flow in TAF

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1922	0	0	31	26	107	66	33	13	5	0	0	0	281
1923	0	3	36	41	28	13	43	10	5	0	0	0	179
1924	0	0	2	3	5	8	0	0	0	0	0	0	18
1925	0	2	3	3	38	15	26	8	2	0	0	0	97
1926	0	0	3	3	15	8	33	2	0	0	0	0	64
1927	0	18	13	10	84	33	38	8	3	0	0	0	207
1928	0	13	10	15	21	38	20	3	0	0	0	0	120
1929	0	0	3	3	8	10	2	2	0	0	0	0	28
1930	0	0	0	8	10	15	3	0	0	0	0	0	36
1931	0	0	0	3	3	2	0	0	0	0	0	0	8
1932	0	0	61	43	138	25	10	8	3	0	0	0	288
1933	0	0	0	10	10	16	5	5	0	0	0	0	46
1934	0	0	3	5	15	5	3	0	0	0	0	0	31
1935	0	2	5	59	28	51	87	23	5	0	0	0	260
1936	0	0	3	15	194	44	38	10	5	0	0	0	309
1937	0	0	5	13	174	94	48	15	5	0	0	0	354
1938	0	0	25	38	181	324	64	31	10	3	0	0	676
1939	2	3	3	5	15	20	10	3	0	0	0	0	61
1940	2	0	3	84	82	56	26	10	2	0	0	0	265
1941	0	0	38	41	125	99	79	20	8	3	0	0	413
1942	0	3	43	36	41	43	36	23	8	2	0	0	235
1943	0	5	5	56	38	112	31	13	5	0	0	0	265
1944	0	3	3	5	23	36	10	5	2	0	0	0	87
1945	0	8	5	5	87	74	30	10	5	0	0	0	224
1946	0	2	26	10	10	23	23	5	3	0	0	0	102
1947	0	8	13	5	13	8	5	2	0	0	0	0	54
1948	0	0	0	3	13	38	8	2	0	0	0	0	64
1949	0	0	0	3	8	36	10	2	0	0	0	0	59
1950	0	0	0	13	33	10	13	2	0	0	0	0	71
1951	0	69	76	41	31	25	10	8	0	0	0	0	260
1952	0	0	33	110	38	125	51	19	5	2	0	0	383
1953	0	2	13	31	8	8	8	5	2	0	0	0	77
1954	0	0	3	5	15	26	15	5	0	0	0	0	69
1955	0	0	2	13	5	7	6	9	1	0	0	0	43
1956	0	0	208	101	42	19	20	18	4	1	0	0	413
1957	0	1	2	3	9	14	6	13	2	0	0	0	50
1958	0	0	3	11	43	108	167	20	6	1	0	0	359
1959	0	1	1	4	24	6	3	2	0	0	0	0	41
1960	0	0	1	2	21	9	8	4	0	0	0	0	45
1961	0	1	2	2	3	4	2	1	0	0	0	0	15
1962	0	1	2	119	41	11	4	1	0	0	0	0	179
1963	0	0	1	21	44	19	67	25	6	1	0	0	184
1964	1	9	3	7	5	8	8	4	1	0	0	0	46
1965	0	7	64	76	18	16	59	14	5	1	0	0	260
1966	0	17	21	22	16	9	5	2	0	0	0	0	92
1967	0	0	41	31	23	64	166	54	15	3	0	0	397
1968	0	0	5	5	10	10	5	3	0	0	0	0	38
1969	0	0	13	191	196	125	71	20	8	3	0	0	627
1970	3	3	5	54	18	48	10	2	0	0	0	0	143

Table B-17. UF 17 – San Joaquin Valley Floor Unimpaired Flow in TAF contd.

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1971	0	3	20	15	8	8	5	5	3	0	0	0	67
1972	0	1	7	3	8	3	3	1	0	0	0	0	26
1973	0	1	3	22	99	85	30	9	2	0	0	0	251
1974	0	4	12	37	12	60	63	9	2	0	0	0	199
1975	0	1	4	6	55	66	45	18	4	1	0	0	200
1976	0	2	2	2	5	6	3	1	0	0	0	0	21
1977	0	0	0	0	0	1	1	1	0	0	0	0	3
1978	0	0	8	82	140	116	118	37	7	2	0	0	510
1979	0	4	4	42	60	76	32	13	4	3	0	0	238
1980	0	3	3	73	92	76	23	12	4	0	0	0	286
1981	1	1	2	14	7	18	9	3	0	0	0	1	56
1982	0	4	8	87	76	113	155	23	7	3	0	1	477
1983	4	32	90	139	183	274	88	55	15	6	2	2	890
1984	2	23	76	26	23	19	10	5	2	0	1	1	188
1985	1	5	4	4	12	17	8	2	3	1	0	0	57
1986	0	2	5	5	179	102	22	9	3	1	1	0	329
1987	0	1	1	2	7	13	3	1	0	0	1	0	29
1988	1	0	1	4	2	3	4	1	1	0	1	0	18
1989	0	0	2	2	4	13	3	1	0	1	0	1	27
1990	0	0	0	3	4	4	1	1	0	1	0	0	14
1991	0	0	0	0	1	41	8	2	4	2	0	0	58
1992	1	0	0	2	32	10	1	5	0	6	0	0	57
1993	0	0	4	121	52	50	24	8	5	0	0	1	267
1994	0	0	2	2	6	3	3	5	4	3	0	0	28
1995	1	0	1	89	21	198	44	38	11	1	0	3	407
1996	0	0	5	20	68	54	26	9	2	7	4	0	196
1997	1	18	157	320	59	24	11	4	1	1	1	0	598
1998	3	2	3	54	179	91	95	41	25	7	2	2	503
1999	0	2	4	13	31	13	20	6	3	1	1	0	96
2000	0	0	1	16	106	59	17	7	2	0	1	0	209
2001	0	1	1	5	13	24	11	3	0	0	0	1	59
2002	0	1	15	14	6	9	4	2	1	1	0	0	54
2003	0	2	15	8	5	8	11	10	1	0	0	0	60
2004	0	0	2	8	20	10	2	0	0	0	0	0	43
2005	3	2	23	125	58	91	35	23	4	0	0	0	363
2006	0	0	14	45	10	74	174	26	4	0	0	3	351
2007	2	1	2	2	8	5	2	0	0	3	2	0	28
2008	0	0	1	15	31	8	2	1	0	0	0	0	59
2009	0	0	1	7	17	17	5	3	1	1	0	0	54
2010	1	0	8	22	31	35	31	12	3	0	0	0	144
2011	1	3	80	54	59	155	52	22	12	4	1	1	443
2012	1	1	2	5	3	10	14	2	0	5	10	0	52
2013	0	0	28	7	4	3	2	1	2	4	1	0	52
2014	0	0	0	0	1	1	1	0	0	0	0	0	3
1922-2003 Average	**0**	**4**	**16**	**32**	**45**	**44**	**28**	**10**	**3**	**1**	**0**	**0**	**184**
1922-2014 Average	**0**	**3**	**16**	**32**	**43**	**44**	**28**	**10**	**3**	**1**	**0**	**0**	**179**

Table B-18. UF 18 – Tuolumne River at Don Pedro Reservoir Unimpaired Flow in TAF

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1922	6	6	55	72	189	181	260	718	752	195	27	10	2471
1923	11	32	124	114	80	113	266	521	319	158	27	22	1786
1924	29	14	14	25	42	38	139	209	17	17	0	0	543
1925	15	48	51	44	227	166	350	538	352	112	23	6	1932
1926	15	16	33	19	101	127	382	304	89	19	3	1	1110
1927	5	74	60	63	223	160	352	454	476	146	25	13	2051
1928	15	87	44	51	82	343	264	448	153	28	7	3	1525
1929	0	6	18	19	40	99	148	378	225	41	5	0	979
1930	2	1	23	39	70	147	246	275	286	49	10	0	1148
1931	9	20	11	26	44	66	154	209	49	10	1	2	602
1932	2	6	94	79	240	172	245	524	533	176	32	12	2114
1933	6	3	11	27	31	83	171	251	426	75	16	5	1104
1934	0	8	41	65	90	150	186	149	95	12	6	5	807
1935	11	48	52	106	107	137	465	531	511	110	21	4	2103
1936	12	20	18	105	352	208	393	520	390	122	18	3	2160
1937	4	9	27	31	274	210	296	634	399	91	17	5	1997
1938	9	19	313	102	323	425	422	720	712	305	55	20	3424
1939	40	43	37	43	60	144	282	216	74	17	7	17	981
1940	45	17	20	226	250	344	325	571	348	54	11	2	2213
1941	11	15	129	115	219	260	280	663	534	224	30	8	2489
1942	7	38	162	165	142	149	337	472	598	253	30	3	2356
1943	5	86	93	246	164	372	385	495	353	141	25	5	2370
1944	12	16	21	43	80	135	165	456	267	88	11	2	1295
1945	9	89	81	56	305	164	284	455	462	163	17	0	2086
1946	60	98	208	119	70	156	348	489	265	56	8	3	1879
1947	16	64	77	42	80	136	192	353	111	21	0	3	1094
1948	38	28	17	40	26	73	221	436	434	88	5	2	1409
1949	5	8	18	20	39	123	318	436	240	29	5	4	1246
1950	4	14	13	77	124	128	329	467	319	62	7	0	1546
1951	24	522	509	159	139	169	254	373	257	60	10	0	2475
1952	9	31	121	219	148	240	466	791	594	292	54	17	2982
1953	9	12	53	145	64	107	270	260	414	170	18	5	1525
1954	7	17	24	42	101	213	349	448	185	38	3	1	1429
1955	4	15	50	67	61	82	144	366	292	39	1	1	1124
1956	4	13	650	431	156	179	282	560	582	244	41	12	3153
1957	21	24	24	35	124	154	173	380	405	67	9	2	1418
1958	11	18	48	58	177	257	425	761	579	232	55	17	2638
1959	6	6	5	79	116	119	224	231	139	18	2	45	990
1960	5	10	12	25	119	150	238	303	162	16	6	5	1052
1961	5	16	33	19	47	71	165	220	122	19	13	4	732
1962	5	8	24	24	233	139	389	362	446	117	14	5	1766
1963	17	9	29	93	309	112	248	534	463	179	32	16	2041
1964	18	105	48	54	52	75	169	323	225	41	12	8	1130
1965	9	52	517	289	141	141	326	449	477	228	87	23	2738
1966	7	130	89	78	75	146	299	355	86	22	9	10	1306
1967	7	67	222	135	115	306	290	649	744	473	78	20	3105
1968	10	11	32	47	134	123	187	288	141	19	10	5	1007
1969	13	81	81	578	286	263	490	960	716	316	55	13	3852
1970	39	39	112	408	134	192	161	411	336	95	23	12	1962

Table B-18. UF 18 – Tuolumne River at Don Pedro Reservoir Unimpaired Flow in TAF contd.

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1971	11	87	123	121	94	146	194	349	418	111	20	10	1683
1972	6	35	77	59	78	182	156	344	220	28	11	11	1207
1973	11	36	86	140	186	173	259	655	400	57	20	6	2031
1974	17	171	136	180	69	229	274	561	442	123	29	10	2239
1975	15	12	35	54	144	224	176	582	596	151	28	15	2033
1976	70	56	32	8	38	71	100	209	40	14	21	14	671
1977	12	9	3	11	17	23	79	106	105	12	3	3	383
1978	2	12	96	190	196	331	354	602	663	316	61	82	2903
1979	12	29	33	154	151	239	260	626	315	67	17	10	1914
1980	29	42	49	532	394	221	313	497	539	347	59	22	3045
1981	11	8	26	48	63	126	243	328	151	22	19	9	1056
1982	29	174	220	228	388	340	660	693	567	323	80	104	3806
1983	153	176	245	261	328	560	304	696	1016	630	205	58	4631
1984	44	310	402	175	151	200	203	536	330	93	21	7	2471
1985	26	85	48	41	69	126	302	341	135	23	15	18	1229
1986	31	49	94	129	616	493	320	540	507	144	30	18	2971
1987	18	8	13	6	37	89	194	203	65	10	8	3	656
1988	11	26	50	70	57	105	159	213	98	24	6	1	821
1989	4	21	27	37	62	285	309	321	207	28	2	10	1312
1990	49	25	22	38	53	130	220	182	100	20	4	1	843
1991	1	8	5	5	8	168	180	336	295	67	19	7	1099
1992	16	25	18	25	93	115	230	189	46	59	14	4	835
1993	10	14	46	278	161	319	335	631	524	226	54	25	2624
1994	19	7	18	22	53	108	195	275	119	33	25	10	885
1995	10	64	58	348	160	579	385	659	811	652	162	35	3922
1996	12	7	72	129	348	290	323	576	389	133	26	11	2316
1997	8	112	387	1033	170	232	277	542	336	57	49	21	3224
1998	10	18	35	202	358	354	351	477	855	559	84	35	3338
1999	21	48	68	136	252	171	262	569	436	109	35	20	2127
2000	11	17	10	132	277	253	334	539	322	70	35	18	2019
2001	17	17	22	32	60	179	227	408	55	12	2	2	1034
2002	4	40	93	109	79	141	301	372	223	24	8	6	1401
2003	0	69	69	89	65	124	218	520	372	55	30	15	1627
2004	5	13	82	70	110	257	264	318	148	33	13	7	1321
2005	54	55	71	260	192	325	305	837	589	258	40	21	3006
2006	15	16	248	248	154	296	610	816	649	208	37	15	3313
2007	11	19	29	28	94	147	175	251	61	15	10	8	849
2008	7	7	18	78	101	124	189	360	204	32	5	4	1129
2009	4	62	27	105	118	228	260	563	225	57	9	7	1665
2010	54	11	39	90	103	161	250	386	629	143	14	6	1888
2011	108	81	336	172	139	414	433	520	773	446	78	25	3524
2012	41	19	5	48	33	107	289	251	57	13	8	4	875
2013	4	33	192	73	50	126	232	246	99	20	9	4	1087
2014	5	5	6	4	52	94	169	189	54	12	6	5	601
1922-2003 Average	**16**	**48**	**89**	**124**	**147**	**190**	**274**	**446**	**352**	**124**	**27**	**12**	**1849**
1922-2014 Average	**18**	**46**	**89**	**122**	**142**	**192**	**276**	**444**	**348**	**122**	**26**	**12**	**1837**

Table B-19. UF 19 – Merced River at Exchequer Reservoir Unimpaired Flow in TAF

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1922	3	4	44	40	163	117	124	417	400	86	16	6	1421
1923	6	16	58	66	50	56	158	288	155	66	13	9	942
1924	13	9	8	10	15	19	67	91	13	4	2	1	252
1925	5	22	23	21	106	78	180	261	147	49	15	5	910
1926	8	8	12	10	63	55	217	173	48	11	4	2	610
1927	2	31	27	33	137	87	179	296	226	54	10	3	1084
1928	9	43	22	21	48	159	142	206	68	15	2	0	737
1929	3	5	7	11	22	47	78	194	97	19	2	2	487
1930	3	2	4	13	26	73	118	137	112	18	3	4	513
1931	3	7	4	10	19	26	73	91	20	4	3	0	262
1932	1	4	85	52	152	79	131	278	251	64	12	4	1113
1933	5	3	5	14	15	44	88	133	179	25	3	3	516
1934	2	4	27	23	45	65	93	56	33	8	2	4	361
1935	5	17	23	79	50	86	276	322	258	41	13	2	1171
1936	2	8	8	37	254	100	219	299	163	52	10	0	1152
1937	4	5	19	22	226	131	163	400	192	45	8	0	1215
1938	1	6	142	67	240	326	229	442	442	140	32	12	2080
1939	22	20	17	19	28	72	151	101	32	10	1	5	477
1940	16	7	7	124	135	148	182	305	140	25	6	0	1095
1941	2	6	88	71	148	154	158	394	296	108	22	7	1454
1942	7	16	76	84	83	90	185	283	336	100	20	8	1287
1943	7	36	39	135	96	238	219	292	152	55	15	5	1289
1944	4	8	10	20	47	80	80	250	133	44	7	0	684
1945	1	36	33	26	184	113	156	264	207	60	15	3	1097
1946	20	42	103	55	33	82	194	262	115	32	6	0	942
1947	12	38	48	27	40	62	104	173	51	11	0	0	564
1948	9	11	8	13	11	34	107	237	217	38	5	0	688
1949	4	4	8	10	23	78	143	237	112	18	2	0	638
1950	2	6	7	37	61	53	172	233	125	22	2	0	719
1951	6	259	272	88	72	86	131	176	104	28	4	0	1225
1952	4	9	59	159	65	157	206	445	305	116	29	9	1563
1953	5	7	31	60	28	41	121	122	158	50	4	0	626
1954	3	6	8	20	48	99	170	223	74	17	0	0	668
1955	2	6	19	30	23	37	65	194	137	22	0	0	534
1956	2	4	373	224	82	88	154	319	287	109	24	9	1675
1957	8	13	10	14	41	63	88	201	176	30	5	0	648
1958	5	9	22	32	83	163	248	411	295	102	28	11	1409
1959	5	6	5	21	56	56	118	112	51	6	0	20	455
1960	6	3	4	10	55	61	125	147	64	8	0	0	483
1961	2	8	16	8	18	30	84	95	44	4	3	1	312
1962	1	3	10	10	159	74	198	206	205	52	10	0	928
1963	6	4	6	42	173	61	131	268	210	68	14	1	984
1964	6	38	22	22	19	28	76	140	81	14	0	1	447
1965	3	21	224	174	61	69	165	259	242	95	37	9	1360
1966	5	72	46	41	32	65	159	182	47	11	4	5	669
1967	12	14	112	60	51	168	213	363	428	237	43	15	1716
1968	7	8	14	17	48	48	94	121	50	10	4	5	426
1969	2	22	37	346	217	163	264	565	396	142	26	8	2188
1970	19	18	34	159	65	109	89	218	127	32	8	5	883

Table B-19. UF 19 – Merced River at Exchequer Reservoir Unimpaired Flow in TAF contd.

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1971	3	19	54	48	39	59	98	182	180	42	7	2	733
1972	1	11	39	23	33	80	79	166	95	11	1	12	550
1973	6	14	30	66	124	114	129	378	199	32	13	3	1108
1974	6	56	59	88	37	132	161	326	203	45	16	5	1133
1975	4	5	16	24	108	129	98	312	330	64	13	8	1108
1976	25	21	14	9	19	33	49	93	19	7	6	3	298
1977	5	3	1	3	4	8	31	39	46	8	2	1	150
1978	1	1	35	113	148	188	234	378	407	163	39	48	1756
1979	16	16	13	97	107	137	132	344	155	37	17	4	1075
1980	10	9	21	266	258	156	172	286	289	137	31	12	1646
1981	10	6	10	21	27	52	122	159	69	16	5	5	501
1982	6	50	64	135	203	189	429	418	263	123	36	31	1947
1983	51	84	150	186	232	370	197	382	656	352	97	29	2787
1984	28	114	204	93	81	97	129	265	114	47	8	0	1181
1985	8	28	21	19	33	59	147	171	57	12	5	6	567
1986	12	16	34	45	362	287	191	316	228	51	12	5	1558
1987	7	3	5	6	18	36	95	95	25	6	3	0	298
1988	4	15	13	28	24	48	93	107	55	19	6	3	415
1989	1	5	10	12	23	96	160	132	73	13	5	5	534
1990	15	11	9	15	21	56	114	87	48	23	6	2	406
1991	2	1	1	5	3	96	81	184	145	36	4	2	560
1992	5	11	8	13	54	51	131	105	31	33	6	2	448
1993	2	7	22	190	100	157	181	455	280	96	34	8	1531
1994	8	5	8	9	28	40	87	121	48	12	9	2	375
1995	16	22	25	200	70	364	206	388	471	340	59	13	2173
1996	11	7	30	66	191	161	197	317	157	51	14	6	1209
1997	2	57	230	634	102	116	169	278	114	29	13	6	1749
1998	1	7	17	103	253	168	201	251	478	286	51	29	1845
1999	15	19	28	49	111	67	128	282	154	35	11	7	905
2000	4	10	2	57	171	116	166	276	130	26	11	7	974
2001	4	6	10	13	31	86	108	215	33	10	3	1	521
2002	2	12	48	44	33	57	150	182	88	15	4	1	636
2003	1	30	32	41	34	63	117	258	189	32	14	6	816
2004	2	9	26	35	60	120	139	135	54	17	7	4	608
2005	20	22	41	200	105	191	152	467	325	126	25	12	1684
2006	8	7	74	129	68	171	344	496	332	85	17	9	1741
2007	13	10	15	16	37	69	94	103	29	13	8	6	413
2008	5	6	7	48	64	56	104	196	93	25	7	4	617
2009	3	22	13	50	61	105	149	288	96	32	12	6	837
2010	27	8	24	57	69	91	137	221	331	77	17	8	1067
2011	37	36	181	105	105	263	217	305	415	197	48	18	1927
2012	21	9	7	20	16	44	149	117	26	8	5	3	426
2013	2	9	81	32	25	59	123	102	33	9	3	1	479
2014	2	3	3	2	13	33	75	73	21	9	4	0	239
1922-2003 Average	**7**	**20**	**43**	**66**	**85**	**101**	**147**	**242**	**171**	**56**	**13**	**6**	**957**
1922-2014 Average	**8**	**19**	**43**	**66**	**82**	**102**	**148**	**240**	**170**	**56**	**13**	**6**	**952**

Table B-20. UF 20 – Chowchilla River at Buchanan Reservoir Unimpaired Flow in TAF

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1922	0	0	12	10	42	26	13	5	2	0	0	0	110
1923	0	1	14	16	11	5	17	4	2	0	0	0	70
1924	0	0	1	1	2	3	0	0	0	0	0	0	7
1925	0	1	1	1	15	6	10	3	1	0	0	0	38
1926	0	0	1	1	6	3	13	1	0	0	0	0	25
1927	0	7	5	4	33	13	15	3	1	0	0	0	81
1928	0	5	4	6	8	15	8	1	0	0	0	0	47
1929	0	0	1	1	3	4	1	1	0	0	0	0	11
1930	0	0	0	3	4	6	1	0	0	0	0	0	14
1931	0	0	0	1	1	1	0	0	0	0	0	0	3
1932	0	0	24	17	54	10	4	3	1	0	0	0	113
1933	0	0	0	4	4	6	2	2	0	0	0	0	18
1934	0	0	1	2	6	2	1	0	0	0	0	0	12
1935	0	1	2	23	11	20	34	9	2	0	0	0	102
1936	0	0	1	6	76	17	15	4	2	0	0	0	121
1937	0	0	2	5	68	37	19	6	2	0	0	0	139
1938	0	0	10	15	71	127	25	12	4	1	0	0	265
1939	1	1	1	2	6	8	4	1	0	0	0	0	24
1940	1	0	1	33	32	22	10	4	1	0	0	0	104
1941	0	0	15	16	49	39	31	8	3	1	0	0	162
1942	0	1	17	14	16	17	14	9	3	1	0	0	92
1943	0	2	2	22	15	44	12	5	2	0	0	0	104
1944	0	1	1	2	9	14	4	2	1	0	0	0	34
1945	0	3	2	2	34	29	12	4	2	0	0	0	88
1946	0	1	10	4	4	9	9	2	1	0	0	0	40
1947	0	3	5	2	5	3	2	1	0	0	0	0	21
1948	0	0	0	0	1	5	15	3	1	0	0	0	25
1949	0	0	0	1	3	14	4	1	0	0	0	0	23
1950	0	0	0	5	13	4	5	1	0	0	0	0	28
1951	0	27	30	16	12	10	4	3	0	0	0	0	102
1952	0	0	13	43	15	49	20	7	2	1	0	0	150
1953	0	1	5	12	3	3	3	2	1	0	0	0	30
1954	0	0	1	2	6	10	6	2	0	0	0	0	27
1955	0	0	1	5	2	3	3	4	0	0	0	0	18
1956	0	0	82	40	16	7	8	7	2	0	0	0	162
1957	0	0	1	1	4	6	2	5	1	0	0	0	20
1958	0	0	1	5	17	42	65	8	2	1	0	0	141
1959	0	0	0	2	10	2	1	1	0	0	0	0	16
1960	0	0	0	1	8	4	3	2	0	0	0	0	18
1961	0	1	1	1	1	1	1	0	0	0	0	0	6
1962	0	0	0	1	47	16	4	2	0	0	0	0	70
1963	0	0	0	8	18	8	26	10	2	1	0	0	73
1964	0	4	1	3	2	3	3	2	0	0	0	0	18
1965	0	3	25	30	7	6	23	6	2	0	0	0	102
1966	0	7	8	8	6	4	2	1	0	0	0	0	36
1967	0	0	16	12	9	25	65	21	6	1	0	0	155
1968	0	0	2	2	4	4	2	1	0	0	0	0	15
1969	0	0	5	75	77	49	28	8	3	1	0	0	246
1970	0	1	2	21	7	19	4	2	1	0	0	0	57

Table B-20. UF 20 – Chowchilla River at Buchanan Reservoir Unimpaired Flow in TAF contd.

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1971	0	1	8	6	3	3	2	2	1	0	0	0	26
1972	0	0	3	1	3	1	1	0	0	0	0	0	9
1973	0	1	1	9	39	33	12	4	1	0	0	0	100
1974	0	2	5	14	5	24	25	4	1	0	0	0	80
1975	0	0	2	2	22	26	18	7	2	0	0	0	79
1976	0	1	1	1	2	3	1	0	0	0	0	0	9
1977	0	0	0	0	0	0	0	0	0	0	0	0	0
1978	0	0	3	32	55	45	46	15	3	1	0	0	200
1979	0	1	1	16	24	30	13	5	2	1	0	0	93
1980	0	1	1	28	36	30	9	5	2	0	0	0	112
1981	0	0	1	6	3	7	4	1	0	0	0	0	22
1982	0	1	3	34	30	44	61	9	2	1	0	1	186
1983	1	13	35	55	72	108	35	22	6	2	1	1	351
1984	1	9	30	10	9	7	4	2	1	0	0	0	73
1985	0	2	2	2	5	7	3	1	1	0	0	0	23
1986	0	1	2	2	70	40	9	4	1	0	0	0	129
1987	0	0	0	1	3	5	1	0	0	0	0	0	10
1988	0	0	0	2	1	1	1	1	0	0	0	0	6
1989	0	0	1	1	1	5	1	0	0	0	0	0	9
1990	0	0	0	1	1	2	1	0	0	0	0	0	5
1991	0	0	0	0	0	16	3	1	1	1	0	0	22
1992	0	0	0	1	12	4	0	2	0	2	0	0	21
1993	0	0	2	48	20	20	10	3	2	0	0	0	105
1994	0	0	1	1	2	1	1	2	1	1	0	0	11
1995	0	0	1	35	8	78	17	15	4	0	0	1	160
1996	0	0	2	8	27	21	10	4	1	3	1	0	77
1997	0	7	62	126	23	10	4	2	1	0	0	0	235
1998	1	1	1	21	70	36	37	16	10	3	1	1	197
1999	0	1	2	5	12	5	8	2	1	1	0	0	38
2000	0	0	0	6	41	23	7	3	1	0	0	0	82
2001	0	0	0	2	5	9	4	1	0	0	0	0	23
2002	0	0	6	5	2	4	2	1	0	0	0	0	21
2003	0	1	6	3	2	3	4	4	0	0	0	0	24
2004	0	0	1	3	8	4	1	0	0	0	0	0	17
2005	1	1	9	49	23	35	14	9	2	0	0	0	142
2006	0	0	5	18	4	29	68	10	2	0	0	1	138
2007	1	0	1	1	3	2	1	0	0	1	1	0	11
2008	0	0	0	6	12	3	1	0	0	0	0	0	23
2009	0	0	0	3	7	7	2	1	0	0	0	0	21
2010	1	0	3	8	12	14	12	5	1	0	0	0	57
2011	0	1	31	21	23	61	20	9	5	2	0	0	174
2012	0	0	1	2	1	4	5	1	0	2	4	0	21
2013	0	0	11	3	1	1	1	0	1	2	0	0	20
2014	0	0	0	0	0	0	0	0	0	0	0	0	1
1922-2003 Average	0	1	6	12	18	17	11	4	1	0	0	0	72
1922-2014 Average	0	1	6	12	17	17	11	4	1	0	0	0	70

Table B-21. UF 21 – Fresno River near Daulton Unimpaired Flow in TAF

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1922	0	0	11	9	37	30	21	20	5	2	0	0	135
1923	0	2	18	17	12	9	31	16	8	3	0	0	116
1924	1	1	1	1	1	3	5	1	0	0	0	0	14
1925	0	1	1	1	18	7	16	9	6	1	0	0	60
1926	0	1	1	2	7	4	18	6	1	0	0	0	40
1927	0	7	5	4	32	15	20	10	6	1	0	0	100
1928	1	5	4	6	9	16	14	5	1	0	0	0	61
1929	0	1	1	1	3	4	6	6	3	0	0	0	25
1930	0	0	0	3	4	8	3	3	2	0	0	0	23
1931	0	1	0	1	1	1	1	0	0	0	0	0	5
1932	0	0	15	11	27	11	14	14	8	2	0	0	102
1933	0	0	1	2	3	6	7	6	6	0	0	0	31
1934	0	0	2	2	4	4	2	1	1	0	0	0	16
1935	0	1	3	5	11	17	35	17	10	3	0	0	102
1936	1	1	1	4	47	14	20	16	7	1	0	0	112
1937	0	1	2	4	55	34	20	16	10	3	0	0	145
1938	1	1	10	10	66	108	41	25	18	11	3	1	295
1939	2	3	3	4	6	10	13	5	2	0	0	0	48
1940	1	1	1	27	29	26	19	12	4	1	0	0	121
1941	0	1	15	15	42	47	29	15	14	6	1	1	186
1942	1	1	14	17	19	21	19	16	11	5	1	0	125
1943	0	3	4	20	15	44	20	13	5	2	0	0	126
1944	1	0	1	2	12	15	10	10	6	1	0	0	58
1945	0	6	3	3	34	35	18	12	8	2	0	0	121
1946	1	1	8	4	3	9	12	11	4	1	0	0	54
1947	0	3	7	3	5	5	5	4	1	0	0	0	33
1948	0	0	0	0	1	4	14	9	6	2	0	0	36
1949	0	0	1	1	2	12	6	10	5	1	0	0	38
1950	0	0	1	3	9	4	7	8	4	1	0	0	37
1951	0	16	25	14	12	11	8	8	3	1	0	0	98
1952	0	1	8	33	14	53	26	13	9	5	1	0	163
1953	1	1	6	14	5	6	7	7	6	2	0	0	55
1954	0	1	1	3	5	11	10	9	4	1	0	0	45
1955	0	1	2	5	4	5	6	9	4	1	0	0	37
1956	0	1	65	48	22	10	11	13	5	1	0	0	176
1957	0	1	1	2	4	8	6	10	5	1	0	0	38
1958	0	1	2	3	16	45	72	13	8	4	2	1	167
1959	1	1	1	3	8	6	5	4	1	0	0	0	30
1960	0	0	1	1	6	5	6	5	2	0	0	0	26
1961	0	1	2	2	2	3	3	2	1	0	0	0	16
1962	0	0	1	2	49	22	9	8	7	1	0	0	99
1963	0	0	1	5	21	11	21	14	7	3	0	0	83
1964	1	4	3	3	3	4	6	6	3	1	0	0	34
1965	0	3	18	30	10	10	30	9	6	2	1	0	119
1966	1	6	6	8	7	7	6	6	1	0	0	0	48
1967	0	2	20	11	11	25	80	30	14	6	2	0	201
1968	1	0	2	3	5	6	5	4	2	0	0	0	28
1969	0	1	5	75	84	52	36	17	11	6	2	1	290
1970	2	2	3	20	8	20	7	7	4	1	0	0	74

Table B-21. UF 21 – Fresno River near Daulton Unimpaired Flow in TAF contd.

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1971	0	2	8	8	5	7	7	8	5	1	0	0	51
1972	0	1	4	3	4	5	4	4	1	0	0	0	26
1973	0	1	3	9	36	32	17	10	4	1	0	0	113
1974	1	2	5	13	5	18	22	8	4	1	0	0	79
1975	0	1	2	3	11	21	17	14	8	2	0	0	79
1976	1	1	2	1	3	4	3	2	1	1	0	0	19
1977	0	0	1	1	1	1	1	1	1	0	0	0	7
1978	0	0	4	28	52	57	48	21	10	3	1	1	225
1979	0	2	1	12	20	29	14	10	5	2	0	0	95
1980	0	1	2	26	36	37	17	12	6	3	0	0	140
1981	0	1	2	3	4	8	6	3	1	1	0	0	29
1982	0	2	3	20	24	46	63	13	7	4	2	1	185
1983	3	11	34	54	73	115	41	27	9	5	3	2	377
1984	5	10	27	14	12	12	8	6	3	2	1	0	100
1985	1	2	2	2	5	8	6	3	2	1	1	0	33
1986	1	2	3	5	69	53	13	8	5	2	1	1	163
1987	1	1	1	2	4	9	0	2	4	0	1	0	25
1988	0	1	1	3	2	3	3	2	1	1	0	0	17
1989	0	0	1	1	2	6	3	2	0	1	1	0	17
1990	0	1	1	1	1	3	2	1	1	2	0	0	13
1991	0	0	0	0	0	18	6	4	2	2	2	0	34
1992	0	0	1	1	8	6	4	1	0	1	1	0	23
1993	0	0	2	43	27	25	15	10	8	4	1	0	135
1994	2	1	1	1	3	2	3	3	3	0	1	0	21
1995	0	1	1	37	16	80	20	20	6	2	1	1	185
1996	1	0	3	6	27	23	14	8	3	1	1	1	90
1997	1	9	48	116	24	12	8	5	3	2	1	1	231
1998	1	1	2	16	56	35	39	24	15	4	1	1	196
1999	1	2	3	7	12	8	11	6	3	0	0	2	54
2000	1	1	1	6	35	24	11	6	3	0	0	1	89
2001	2	1	1	2	6	10	7	4	1	1	1	0	35
2002	0	1	5	6	4	8	3	3	1	0	0	0	32
2003	0	2	3	3	3	4	5	6	3	2	1	0	33
2004	0	0	2	3	5	5	2	2	1	0	0	0	21
2005	1	1	5	31	21	36	17	14	6	3	1	1	136
2006	0	0	5	18	6	30	67	16	6	2	1	1	152
2007	0	1	2	2	4	4	3	2	1	0	0	0	19
2008	0	0	1	6	12	5	3	4	1	0	0	0	34
2009	0	0	0	4	7	8	4	5	1	0	0	0	30
2010	1	1	2	9	14	16	16	7	3	1	0	0	71
2011	1	1	28	24	19	64	27	15	10	4	1	1	195
2012	1	1	1	3	2	7	8	3	1	0	0	0	27
2013	0	1	5	3	2	3	2	1	0	0	0	0	15
2014	0	0	0	1	1	1	1	0	0	0	0	0	5
1922-2003 Average	0	2	6	11	17	19	15	9	5	2	0	0	87
1922-2014 Average	0	2	6	11	16	19	15	9	5	2	0	0	84

Table B-22. UF 22 – San Joaquin River at Millerton Reservoir Unimpaired Flow in TAF

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1922	11	10	59	66	99	105	205	685	758	266	69	24	2355
1923	13	28	84	63	66	97	221	506	304	194	50	28	1654
1924	28	16	14	14	21	26	95	164	35	17	9	6	444
1925	10	26	27	27	85	101	219	419	313	146	53	13	1439
1926	20	16	21	17	57	96	347	378	146	43	12	7	1161
1927	6	56	50	47	155	151	275	508	496	197	48	15	2001
1928	20	69	33	33	48	150	189	373	176	44	14	6	1154
1929	9	10	15	16	23	65	107	309	211	75	19	5	862
1930	5	6	8	18	36	80	165	214	244	61	17	6	859
1931	11	13	10	16	23	39	100	174	60	16	11	7	480
1932	6	8	72	59	168	157	238	492	544	239	51	15	2047
1933	13	9	15	27	30	73	159	213	410	119	29	15	1111
1934	7	10	38	47	50	109	166	146	69	27	13	8	692
1935	13	27	36	73	85	111	357	497	519	144	44	19	1923
1936	14	16	16	38	196	164	349	510	348	151	42	11	1853
1937	11	13	36	35	253	191	304	705	457	160	34	11	2208
1938	10	12	211	71	207	434	434	795	913	431	128	43	3688
1939	39	33	29	33	43	103	240	209	110	43	25	14	921
1940	35	14	11	134	140	210	290	559	363	97	21	7	1881
1941	10	12	98	106	183	209	242	711	642	331	86	23	2653
1942	22	30	96	113	103	129	299	466	633	284	65	17	2254
1943	10	43	43	170	113	268	335	503	325	179	50	16	2054
1944	11	15	20	31	55	112	141	408	280	143	35	16	1265
1945	13	58	56	44	238	148	276	477	488	240	74	27	2138
1946	59	66	118	79	54	126	310	464	280	118	37	19	1730
1947	29	65	85	48	64	100	171	348	146	43	17	12	1126
1948	23	18	15	19	20	43	165	391	373	108	26	15	1215
1949	11	8	15	16	26	73	235	410	268	63	26	15	1164
1950	10	16	17	43	90	90	280	379	263	87	22	14	1311
1951	17	247	300	111	104	119	202	322	278	115	32	12	1859
1952	12	20	83	133	99	177	385	820	641	335	101	33	2840
1953	17	19	43	85	48	72	197	211	320	172	30	13	1227
1954	9	17	17	33	65	127	278	440	218	80	20	9	1314
1955	6	18	31	42	49	74	127	338	348	88	30	11	1161
1956	6	13	461	271	141	170	278	568	614	318	87	34	2960
1957	26	22	21	30	67	90	142	327	440	115	32	16	1327
1958	16	19	43	43	113	181	363	796	622	288	108	41	2631
1959	16	15	15	37	89	114	203	209	153	41	17	42	949
1960	18	9	10	18	55	86	178	240	148	43	17	8	829
1961	8	22	31	19	31	49	124	172	128	27	25	10	647
1962	10	15	23	23	185	110	381	397	505	203	52	20	1924
1963	18	11	11	82	208	101	192	464	492	265	71	31	1945
1964	26	64	36	31	30	52	127	257	200	60	29	11	922
1965	10	34	204	188	114	128	250	432	473	267	138	35	2272
1966	18	101	66	62	56	126	277	362	148	51	25	9	1299
1967	6	29	213	92	101	243	250	660	823	595	154	67	3232
1968	27	23	34	37	75	83	146	231	131	44	22	9	862
1969	15	40	52	396	234	227	464	1096	874	463	137	41	4040
1970	33	32	47	159	83	137	146	376	279	107	37	11	1446

Table B-22. UF 22 – San Joaquin River at Millerton Reservoir Unimpaired Flow in TAF contd.

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1971	10	39	73	75	72	110	172	293	365	141	48	22	1418
1972	13	26	58	41	50	138	124	268	213	47	16	45	1039
1973	20	34	47	82	128	131	248	708	463	127	45	15	2047
1974	21	88	82	138	66	210	267	597	482	162	60	20	2191
1975	19	17	32	37	76	136	131	546	575	161	41	26	1796
1976	49	33	24	18	38	59	82	174	60	35	24	35	629
1977	20	10	7	12	15	19	57	75	111	20	11	4	362
1978	6	9	80	159	196	326	346	697	826	462	149	146	3402
1979	34	30	33	96	101	183	243	599	339	114	42	17	1830
1980	24	29	34	327	282	216	315	528	642	426	113	37	2973
1981	24	19	29	36	57	87	206	318	208	51	19	13	1068
1982	19	70	65	119	199	231	613	725	585	371	148	170	3316
1983	126	146	212	227	271	428	280	728	1166	686	280	92	4642
1984	53	149	227	126	107	162	203	489	266	162	67	36	2049
1985	31	50	41	40	56	84	254	308	169	55	22	19	1129
1986	24	38	68	93	472	426	361	624	593	222	76	32	3031
1987	24	14	15	21	40	66	172	229	121	33	15	10	758
1988	16	24	25	59	48	91	153	220	142	49	23	12	862
1989	7	14	20	22	37	133	237	240	149	41	19	19	939
1990	23	22	17	25	34	85	173	165	122	54	14	8	743
1991	8	6	9	10	11	118	135	277	321	102	24	13	1034
1992	12	19	18	21	68	77	209	238	76	46	17	9	809
1993	13	17	32	189	124	243	330	701	599	317	82	26	2673
1994	19	17	21	23	42	75	150	258	159	36	14	12	826
1995	43	45	48	213	122	485	350	634	881	752	239	66	3878
1996	24	15	50	70	229	222	333	589	412	184	55	18	2203
1997	18	99	213	735	181	219	302	539	280	130	44	21	2782
1998	18	24	36	102	210	232	288	446	886	686	159	72	3160
1999	36	39	50	69	111	102	182	446	337	105	32	17	1527
2000	12	12	16	80	155	164	280	530	351	91	37	15	1742
2001	20	17	16	26	42	126	188	445	115	47	13	10	1065
2002	10	22	58	64	57	94	247	323	223	53	13	8	1171
2003	7	62	45	62	60	109	158	436	375	89	34	12	1450
2004	8	14	44	48	69	192	223	284	173	55	13	7	1131
2005	36	41	58	165	133	226	257	818	662	343	73	17	2830
2006	18	22	110	163	113	198	498	884	763	326	64	23	3181
2007	20	14	26	24	47	96	137	197	71	25	14	11	684
2008	10	9	17	58	72	102	176	351	230	68	16	8	1117
2009	10	43	26	75	82	139	231	492	223	96	28	10	1455
2010	54	22	41	71	101	142	222	383	687	243	47	16	2029
2011	60	53	225	153	114	277	393	545	828	477	133	47	3305
2012	48	29	19	39	35	75	209	244	77	28	22	6	832
2013	11	28	88	52	45	96	190	200	96	33	13	5	857
2014	9	10	14	11	23	46	112	161	77	26	15	6	510
1922-2003 Average	**19**	**34**	**60**	**83**	**103**	**144**	**237**	**433**	**373**	**168**	**52**	**24**	**1730**
1922-2014 Average	**20**	**33**	**60**	**82**	**100**	**144**	**237**	**431**	**371**	**167**	**51**	**23**	**1718**

Table B-23. UF 23 – Tulare Lake Basin Outflow Unimpaired Flow in TAF

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1922	0	0	10	23	34	29	7	138	235	16	0	0	492
1923	0	0	32	16	3	0	9	95	16	0	0	0	171
1924	0	0	0	0	0	0	0	0	0	0	0	0	0
1925	0	0	0	0	0	0	0	8	0	0	0	0	8
1926	0	0	0	0	0	0	3	8	0	0	0	0	11
1927	0	5	1	0	13	1	1	54	54	0	0	0	129
1928	0	3	0	0	0	0	0	0	0	0	0	0	3
1929	0	0	0	0	0	0	0	0	0	0	0	0	0
1930	0	0	0	0	0	0	0	0	0	0	0	0	0
1931	0	0	0	0	0	0	0	0	0	0	0	0	0
1932	0	0	0	0	0	0	0	12	6	0	0	0	18
1933	0	0	0	0	0	0	0	0	0	0	0	0	0
1934	0	0	0	0	0	0	0	0	0	0	0	0	0
1935	0	0	0	0	0	0	0	3	14	0	0	0	17
1936	0	0	0	0	7	0	2	39	2	0	0	0	50
1937	0	0	0	0	73	27	31	121	104	0	0	0	356
1938	0	0	46	19	90	167	109	186	218	27	0	0	862
1939	0	0	0	0	0	0	0	0	0	0	0	0	0
1940	0	0	0	5	25	36	2	93	18	0	0	0	179
1941	0	0	15	44	80	96	71	151	159	19	0	0	635
1942	0	0	18	50	43	0	4	52	132	9	0	0	308
1943	0	0	4	37	48	101	83	89	35	0	0	0	397
1944	0	0	0	0	0	5	0	14	9	0	0	0	28
1945	0	1	0	0	67	13	12	80	86	6	0	0	265
1946	0	14	31	18	0	0	5	18	2	0	0	0	88
1947	8	12	6	0	0	0	1	0	0	0	0	0	27
1948	0	0	0	0	0	0	0	2	0	0	0	0	2
1949	0	0	0	0	0	0	0	0	0	0	0	0	0
1950	0	0	0	0	0	0	0	2	0	0	0	0	2
1951	0	29	44	0	0	0	0	1	0	0	0	0	74
1952	0	0	0	36	6	22	20	171	150	31	0	0	436
1953	0	0	0	4	0	0	0	0	0	0	0	0	4
1954	0	0	0	0	0	0	0	0	0	0	0	0	0
1955	0	0	0	0	0	0	0	0	0	0	0	0	0
1956	0	0	4	0	58	29	0	0	0	0	0	0	91
1957	0	0	0	0	0	0	0	0	0	0	0	0	0
1958	0	0	0	0	0	1	27	93	91	1	0	0	213
1959	0	0	0	0	0	0	0	0	0	0	0	0	0
1960	0	0	0	0	0	0	0	0	0	0	0	0	0
1961	0	0	0	0	0	0	0	0	0	0	0	0	0
1962	0	0	0	0	0	0	0	0	0	0	0	0	0
1963	0	0	0	0	0	0	0	0	0	0	0	0	0
1964	0	0	0	0	0	0	0	0	0	0	0	0	0
1965	0	0	0	0	0	0	0	0	0	0	0	0	0
1966	0	0	0	0	0	0	0	0	0	0	0	0	0
1967	0	0	3	0	0	0	49	194	150	89	0	0	485
1968	0	0	0	0	0	0	0	0	0	0	0	0	0
1969	0	0	0	38	184	286	279	302	318	133	11	0	1551
1970	0	0	0	0	0	0	0	0	0	0	0	0	0

Table B-23. UF 23 – Tulare Lake Basin Outflow Unimpaired Flow in TAF contd.

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1971	0	0	0	0	0	0	0	0	0	0	0	0	0
1972	0	0	0	0	0	0	0	0	0	0	0	0	0
1973	0	0	0	0	0	0	0	0	0	0	0	0	0
1974	0	0	0	0	0	0	18	20	48	0	0	0	86
1975	0	0	0	0	0	0	0	0	0	0	0	0	0
1976	0	0	0	0	0	0	0	0	0	0	0	0	0
1977	0	0	0	0	0	0	0	0	0	0	0	0	0
1978	0	0	0	0	7	95	199	202	49	0	0	0	552
1979	0	0	0	0	0	0	1	9	1	0	0	0	11
1980	0	0	0	57	87	252	78	70	12	23	0	0	579
1981	0	0	0	0	0	0	0	0	0	0	0	0	0
1982	0	0	0	0	0	0	158	213	63	19	0	0	453
1983	0	92	224	218	261	319	302	303	292	184	66	48	2309
1984	106	141	135	185	1	1	0	0	0	0	0	0	569
1985	0	0	0	0	0	0	0	0	0	0	0	0	0
1986	0	0	0	0	11	212	215	140	91	1	0	0	670
1987	0	0	1	1	0	0	0	0	0	0	0	0	2
1988	0	0	0	0	0	0	0	0	0	0	0	0	0
1989	0	0	0	0	0	0	0	0	0	0	0	0	0
1990	0	0	0	0	0	0	0	0	0	0	0	0	0
1991	0	0	0	0	0	0	0	0	0	0	0	0	0
1992	0	0	0	0	0	0	0	0	0	0	0	0	0
1993	0	0	0	0	0	0	0	0	0	0	0	0	0
1994	0	0	0	0	0	0	0	0	0	0	0	0	0
1995	0	0	0	0	0	33	159	228	87	77	2	0	586
1996	0	0	5	0	0	7	0	67	0	0	0	0	80
1997	0	0	5	170	224	39	0	0	0	0	0	0	437
1998	0	0	0	0	0	0	212	278	266	158	0	0	915
1999	0	0	0	0	0	0	0	0	0	0	0	0	0
2000	0	0	0	0	0	0	0	0	0	0	0	0	0
2001	0	0	0	0	0	0	0	0	0	0	0	0	0
2002	0	0	0	0	0	0	0	0	0	0	0	0	0
2003	0	0	0	0	0	0	0	0	0	0	0	0	0
2004	0	0	0	0	0	0	0	0	0	0	0	0	0
2005	0	0	0	0	0	0	0	38	22	0	0	0	61
2006	0	0	0	0	0	0	186	256	169	0	0	0	612
2007	0	0	0	0	0	0	0	0	0	0	0	0	0
2008	0	0	0	0	0	0	0	0	0	0	0	0	0
2009	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	0	0	0	0	0	0	0	0	0	0	0	0	0
1922-2003 Average	**1**	**4**	**7**	**11**	**16**	**22**	**25**	**42**	**33**	**10**	**1**	**1**	**173**
1922-2014 Average	**1**	**3**	**6**	**10**	**14**	**19**	**24**	**40**	**31**	**9**	**1**	**1**	**159**

Table B-24. UF 24 – San Joaquin Valley West Side Minor Streams Unimpaired Flow in TAF

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1922	0	0	1	1	3	1	2	0	0	0	0	0	8
1923	0	0	3	1	1	0	1	0	0	0	0	0	6
1924	0	0	0	0	0	0	0	0	0	0	0	0	0
1925	0	0	1	0	2	0	2	0	0	0	0	0	5
1926	0	0	0	0	1	0	0	0	0	0	0	0	1
1927	0	0	0	1	3	0	2	0	0	0	0	0	6
1928	0	0	0	0	1	2	1	0	0	0	0	0	4
1929	0	0	0	0	0	0	1	0	0	0	0	0	1
1930	0	0	0	0	0	1	0	0	0	0	0	0	1
1931	0	0	0	0	0	0	0	0	0	0	0	0	0
1932	0	0	2	1	1	0	0	0	0	0	0	0	4
1933	0	0	0	0	0	0	0	0	0	0	0	0	0
1934	0	0	0	1	0	0	0	0	0	0	0	0	1
1935	0	0	0	1	0	1	2	0	0	0	0	0	4
1936	0	0	0	2	9	1	2	0	0	0	0	0	14
1937	0	0	0	1	4	2	2	0	0	0	0	0	9
1938	0	0	2	1	10	6	4	1	0	0	0	0	24
1939	0	0	0	0	0	0	0	0	0	0	0	0	0
1940	0	0	0	2	2	2	2	0	0	0	0	0	8
1941	0	0	1	1	1	1	3	0	0	0	0	0	7
1942	0	0	1	3	1	0	2	0	0	0	0	0	7
1943	0	0	1	4	2	4	2	0	0	0	0	0	13
1944	0	0	0	0	1	1	0	0	0	0	0	0	2
1945	0	0	1	0	2	1	1	0	0	0	0	0	5
1946	0	0	1	1	0	0	1	0	0	0	0	0	3
1947	0	0	0	0	0	1	0	0	0	0	0	0	1
1948	0	0	0	0	0	1	1	0	0	0	0	0	2
1949	0	0	0	0	0	1	1	0	0	0	0	0	2
1950	0	0	0	1	1	0	1	0	0	0	0	0	3
1951	0	0	7	5	1	2	0	0	0	0	0	0	15
1952	0	0	3	9	2	3	1	0	0	0	0	0	18
1953	0	0	1	1	0	0	0	0	0	0	0	0	2
1954	0	0	0	0	0	0	0	0	0	0	0	0	0
1955	0	0	0	1	0	0	0	0	0	0	0	0	1
1956	0	0	5	7	2	1	0	0	0	0	0	0	15
1957	0	0	0	0	0	1	0	0	0	0	0	0	1
1958	0	0	0	1	5	4	10	1	0	0	0	0	21
1959	0	0	0	0	1	0	0	0	0	0	0	0	1
1960	0	0	0	0	1	0	0	0	0	0	0	0	1
1961	0	0	0	0	0	0	0	0	0	0	0	0	0
1962	0	0	0	0	2	1	0	0	0	0	0	0	3
1963	0	0	0	2	5	1	3	1	0	0	0	0	12
1964	0	0	0	1	0	0	0	0	0	0	0	0	1
1965	0	0	4	4	1	1	1	0	0	0	0	0	11
1966	0	0	0	0	1	0	0	0	0	0	0	0	1
1967	0	0	0	5	1	2	4	1	0	0	0	0	13
1968	0	0	0	0	1	0	0	0	0	0	0	0	1
1969	0	0	0	5	6	3	0	0	0	0	0	0	14
1970	0	0	1	6	1	1	0	0	0	0	0	0	9

Table B-24. UF 24 – San Joaquin Valley West Side Minor Streams Unimpaired Flow in TAF contd.

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1971	0	0	3	1	0	1	0	0	0	0	0	0	5
1972	0	0	0	0	0	3	0	0	0	0	0	0	3
1973	0	1	0	4	5	3	1	0	0	0	0	0	14
1974	0	0	1	1	1	2	2	0	0	0	0	0	7
1975	0	0	0	0	1	2	1	0	0	0	0	0	4
1976	0	0	0	0	0	0	0	0	0	0	0	0	0
1977	0	0	0	0	0	0	0	0	0	0	0	0	0
1978	0	0	1	5	3	3	1	0	0	0	0	0	13
1979	0	0	0	1	2	1	0	0	0	0	0	0	4
1980	0	0	0	5	8	2	1	0	0	0	0	0	16
1981	0	0	0	0	0	1	0	0	0	0	0	0	1
1982	0	0	1	14	5	4	6	1	0	0	0	0	31
1983	0	1	3	5	8	18	3	2	0	0	0	0	40
1984	0	2	2	0	1	0	0	0	0	0	0	0	5
1985	1	2	1	0	0	1	0	0	0	0	0	0	5
1986	0	2	2	2	4	3	0	0	0	0	0	1	14
1987	0	0	0	0	0	0	0	0	0	0	0	0	0
1988	0	0	1	1	0	0	0	0	0	0	0	0	2
1989	0	0	1	0	1	1	0	0	0	0	0	1	4
1990	0	0	0	1	0	0	0	1	0	0	0	0	2
1991	0	0	0	0	1	1	0	0	0	0	0	0	2
1992	1	0	1	1	3	1	0	0	0	0	0	0	7
1993	0	0	5	5	5	3	0	2	0	0	0	0	22
1994	0	1	1	1	2	0	1	2	0	0	0	0	8
1995	1	1	1	5	0	4	0	0	0	0	0	0	13
1996	0	0	3	0	3	1	0	1	0	0	0	0	8
1997	1	1	1	3	0	0	0	0	0	0	0	0	7
1998	0	4	2	5	9	2	2	4	0	0	0	0	27
1999	1	1	0	2	1	1	1	1	0	0	0	0	9
2000	0	0	0	2	3	0	1	0	0	0	0	0	8
2001	0	0	0	0	1	1	0	0	0	0	0	0	4
2002	0	0	2	1	0	1	0	0	0	0	0	0	6
2003	0	0	5	1	0	0	0	0	0	0	0	0	9
2004	0	0	1	1	3	1	0	0	0	0	0	0	7
2005	1	0	1	3	3	2	1	1	0	0	0	0	12
2006	0	0	3	6	1	5	7	1	0	0	0	0	24
2007	0	0	0	0	1	0	0	0	0	0	0	0	3
2008	0	0	0	2	1	0	0	0	0	0	0	0	5
2009	0	0	0	0	1	1	0	0	0	0	0	0	3
2010	1	0	0	3	1	1	1	0	0	0	0	0	9
2011	0	0	1	1	1	5	1	0	0	0	0	0	10
2012	0	0	0	0	0	0	1	0	0	0	0	0	2
2013	0	1	4	0	0	0	0	0	0	0	0	0	6
2014	0	0	0	2	1	0	0	0	0	0	0	0	5
1922-2003 Average	**0**	**0**	**1**	**2**	**2**	**1**	**1**	**0**	**0**	**0**	**0**	**0**	**7**
1922-2014 Average	**0**	**0**	**1**	**2**	**2**	**1**	**1**	**0**	**0**	**0**	**0**	**0**	**7**

Table B-25. Sacramento Valley Unimpaired Total Outflow Estimated Flow in TAF

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1922	408	518	1381	1184	3228	2623	3546	4829	2764	811	475	392	22160
1923	448	717	2471	1908	1234	1388	2984	2153	1222	665	414	393	15994
1924	412	407	489	565	1250	605	757	582	398	342	293	285	6387
1925	372	784	1023	1032	5784	2073	3324	2479	1188	574	419	384	19435
1926	396	519	680	894	3776	1619	3238	1326	651	433	339	320	14191
1927	365	2228	2215	2662	7557	3793	4535	2999	1803	711	441	394	29701
1928	384	1418	1185	1573	2285	6081	3461	1949	805	531	385	359	20416
1929	359	554	705	642	1234	1185	1325	1505	875	429	290	316	9418
1930	304	325	2866	1725	2117	2978	2211	1654	878	468	340	342	16207
1931	342	458	402	870	766	1184	882	660	412	288	263	259	6786
1932	351	411	1914	1485	1540	2336	2167	2701	1444	517	348	302	15515
1933	302	333	434	756	594	1960	1634	1756	1318	430	302	285	10102
1934	329	356	1160	1558	1657	1677	1178	737	455	316	272	259	9954
1935	314	870	790	2159	1676	2353	5742	3364	1527	569	375	326	20064
1936	390	386	536	3850	5540	2615	3004	2237	1383	572	366	336	21214
1937	329	326	410	506	2134	3335	3393	3072	1286	528	341	314	15975
1938	414	2023	5107	2080	6335	8316	5611	5562	2917	1056	581	481	40481
1939	536	589	799	773	783	1776	1542	910	502	359	306	319	9194
1940	353	344	716	4203	6923	6647	4196	2227	1011	538	406	407	27971
1941	455	661	4106	5556	6394	5422	5012	4130	1866	942	586	516	35645
1942	511	660	4133	5059	6477	2301	4411	3702	2529	1004	591	502	31880
1943	508	1013	2010	5443	3038	5166	3431	2258	1402	722	512	449	25951
1944	477	504	555	814	1583	2000	1611	2161	1095	613	393	354	12160
1945	417	1117	1553	1095	4171	2022	2185	2488	1310	583	417	367	17725
1946	590	1295	5405	2917	1392	2181	2682	2345	1021	569	442	390	21228
1947	423	841	1001	555	1677	2579	1846	1071	888	430	366	342	12019
1948	681	590	511	2094	727	1752	4479	3548	2269	742	470	423	18286
1949	431	525	714	556	1014	4042	2722	2223	865	434	369	336	14232
1950	357	416	440	2095	2991	2511	3084	2524	1292	556	396	376	17039
1951	1041	3946	5724	4022	3837	2621	2315	2365	949	517	436	396	28170
1952	519	1039	4064	4658	4824	4069	5626	5362	2849	1302	642	532	35484
1953	495	522	2444	6633	1657	2284	2872	2949	2478	1030	575	521	24461
1954	510	907	845	2780	3385	3800	4231	2144	1006	596	497	466	21167
1955	462	858	1521	1311	940	1184	1776	2307	1040	511	397	390	12698
1956	390	652	9730	8627	4613	3093	2990	3828	1957	914	564	506	37863
1957	648	597	596	835	2967	3496	2095	3047	1385	610	464	510	17250
1958	983	919	1831	3032	10000	5448	6384	4756	2618	1064	663	568	38265
1959	543	563	615	2485	3010	1878	1763	1261	723	486	399	486	14212
1960	422	397	486	990	3816	3341	2016	1705	960	480	383	373	15371
1961	407	787	1534	1015	2500	2114	1779	1728	967	470	403	374	14077
1962	409	620	1358	864	4552	2587	2988	2112	1254	547	405	365	18060
1963	3185	818	2289	1893	4712	2281	6159	3764	1432	710	516	477	28236
1964	596	1704	844	1842	1057	1106	1587	1696	1042	488	371	338	12671
1965	407	995	9492	6488	2259	1828	4634	2657	1474	742	598	419	31993
1966	470	1366	1040	2327	1807	2476	2736	1634	668	454	388	374	15740
1967	367	1489	3053	4369	2705	3946	3760	4752	3278	1178	569	442	29908
1968	527	564	917	1985	4293	2684	1824	1495	774	517	523	424	16526
1969	531	825	2111	8642	5446	3520	4633	4636	2137	806	552	510	34347
1970	601	623	3859	12591	3432	3226	1525	1671	1103	610	481	438	30161

Table B-25. Sacramento Valley Unimpaired Total Outflow Estimated Flow in TAF contd.

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1971	527	2190	4071	3551	1895	4069	3188	3439	2344	945	552	512	27283
1972	573	668	1202	1474	1871	3146	2299	1771	970	511	409	445	15339
1973	628	1434	2024	5238	4472	3667	2695	2906	1138	583	471	474	25728
1974	681	5130	4304	8197	2419	7106	5104	3210	2050	1084	615	528	40428
1975	546	638	894	1048	3606	5438	2964	4027	2439	874	597	553	23625
1976	819	841	770	663	888	1296	1167	934	511	396	472	414	9171
1977	404	426	396	511	482	547	527	689	486	362	338	415	5583
1978	374	516	2020	7326	3877	5514	3895	2968	1748	786	459	539	30023
1979	389	504	496	1353	2282	2792	2140	2836	881	511	395	383	14963
1980	675	955	1533	6990	6547	3676	2493	2286	1293	750	420	509	28128
1981	474	451	1018	1940	1901	2584	1786	1249	587	419	362	347	13118
1982	627	4799	6393	3870	5551	4780	7688	3885	1848	936	568	577	41521
1983	1017	1794	3831	4704	7344	11923	4991	5541	4058	1701	794	664	48362
1984	709	3733	7742	2927	2333	2976	2111	2252	1258	626	457	481	27604
1985	646	2028	1302	870	1322	1555	2160	1265	660	413	374	484	13078
1986	518	711	1242	2772	13049	7099	2440	2026	1151	626	445	577	32656
1987	556	456	550	849	1670	2885	1334	955	452	399	329	337	10773
1988	353	430	1967	2239	1035	1122	1130	1076	666	386	303	289	10995
1989	326	1148	793	967	994	6725	3001	1539	746	433	348	438	17458
1990	730	565	449	1435	958	1728	1270	1358	1023	422	318	328	10584
1991	323	367	355	386	480	2992	1727	1584	834	402	292	289	10031
1992	353	395	479	595	2760	2081	1708	803	443	394	281	292	10583
1993	404	391	1444	4845	3860	5735	3752	3434	2343	784	485	417	27894
1994	502	430	862	823	1356	1405	1150	1094	508	307	262	321	9020
1995	351	547	1198	10197	3387	11107	5326	5819	3180	1541	706	582	43941
1996	493	503	1884	2910	6796	4363	3425	4184	1501	706	512	465	27740
1997	529	1105	7313	11861	2815	2015	1971	1567	920	524	477	472	31569
1998	582	1104	1499	6382	9692	5256	4283	4886	4245	1616	731	634	40910
1999	714	1521	2059	2755	5328	4141	3141	2968	1673	726	535	527	26088
2000	576	753	705	2677	6237	4258	3014	2278	1051	576	467	518	23108
2001	600	558	677	951	1869	2551	1592	1372	543	427	387	393	11921
2002	412	1028	3171	3369	1870	2379	2185	1692	853	457	403	379	18197
2003	381	663	4483	4108	1820	2693	3345	3930	1527	610	518	437	24515
2004	443	576	2738	2315	5190	3345	2069	1569	806	534	400	380	20365
2005	636	559	1900	2503	2014	3708	2735	5314	1977	799	497	438	23079
2006	463	689	6924	5583	3721	6086	8634	4682	1835	832	558	486	40493
2007	506	689	1458	887	2471	1935	1346	1112	513	421	361	349	12049
2008	505	408	782	2257	2216	1725	1482	1730	671	377	334	278	12766
2009	396	600	578	760	2568	3645	1737	2827	841	467	378	341	15139
2010	578	389	647	2993	2488	2227	3054	2824	2440	766	449	402	19255
2011	736	852	4359	1993	2083	6858	4637	3685	3566	1558	667	493	31487
2012	633	584	491	1018	722	3541	3511	1735	771	533	419	364	14323
2013	426	1382	5072	1424	1071	1551	1510	876	624	438	377	363	15115
2014	375	368	378	372	1382	2252	1495	730	416	354	338	310	8771
1922-2003 Average	**528**	**978**	**2063**	**2985**	**3298**	**3331**	**2938**	**2522**	**1383**	**646**	**444**	**420**	**21536**
1922-2014 Average	**526**	**938**	**2092**	**2870**	**3187**	**3333**	**2937**	**2515**	**1375**	**646**	**443**	**416**	**21277**

Table B-26. Eastside Streams Unimpaired Total Outflow Estimated Flow in TAF

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1922	3	4	74	93	543	273	290	463	319	44	4	1	2111
1923	5	43	378	248	148	128	317	299	138	36	2	5	1745
1924	11	8	11	16	32	26	67	74	2	0	0	0	248
1925	7	43	55	55	493	179	400	335	146	22	3	4	1742
1926	5	9	25	26	207	89	226	107	18	1	0	0	713
1927	3	76	63	131	488	217	418	266	208	35	4	2	1910
1928	6	37	45	48	120	537	310	201	35	6	0	0	1345
1929	2	5	14	33	67	78	118	170	72	7	1	0	568
1930	1	2	26	70	74	224	162	138	90	6	1	1	795
1931	2	7	5	16	35	46	81	68	13	0	0	1	273
1932	2	6	128	118	421	135	160	284	214	32	4	3	1507
1933	1	3	5	24	26	63	90	164	183	18	4	5	585
1934	6	7	62	111	129	116	90	45	25	1	0	0	593
1935	1	18	23	133	80	171	588	314	173	22	2	2	1526
1936	5	6	8	206	1066	246	350	298	173	26	5	2	2392
1937	4	4	13	52	510	542	292	362	136	19	3	2	1939
1938	4	10	182	78	777	781	389	470	309	61	10	5	3074
1939	11	18	20	28	56	109	157	86	19	2	1	2	509
1940	10	5	12	266	390	507	366	277	98	11	3	2	1946
1941	3	10	104	151	285	310	306	361	186	36	7	3	1761
1942	5	15	127	470	399	184	340	361	291	61	10	5	2269
1943	4	77	134	519	297	940	335	262	136	31	8	4	2746
1944	8	8	15	30	131	222	117	231	93	14	3	0	871
1945	2	94	81	60	553	245	228	261	175	26	5	2	1733
1946	8	61	410	180	97	198	265	252	93	12	2	2	1580
1947	6	35	43	25	73	139	141	142	33	2	0	0	639
1948	17	17	14	39	34	129	303	310	222	30	3	3	1119
1949	3	6	19	29	60	335	230	248	90	6	4	2	1032
1950	2	8	9	156	279	179	326	285	166	24	4	3	1440
1951	14	672	764	527	301	345	197	227	72	15	5	4	3144
1952	7	30	255	660	382	585	436	515	315	110	21	14	3329
1953	9	14	57	234	71	119	201	197	214	49	9	5	1180
1954	6	15	19	47	110	241	261	194	51	10	2	0	957
1955	2	8	77	208	89	94	120	222	102	10	2	0	934
1956	1	7	918	890	237	189	212	363	230	37	16	8	3108
1957	11	14	18	25	128	310	145	263	149	16	6	2	1085
1958	7	13	30	112	461	584	1025	465	268	64	14	7	3049
1959	7	10	12	68	205	99	129	99	35	8	1	7	681
1960	4	2	5	18	169	172	154	140	46	6	1	2	721
1961	1	7	15	11	28	51	89	116	36	5	1	2	361
1962	2	3	14	13	342	190	253	194	151	18	5	1	1186
1963	50	11	41	75	469	178	467	388	174	30	10	6	1899
1964	9	78	36	123	50	63	129	170	77	14	2	2	751
1965	4	28	917	642	167	127	378	273	192	54	31	5	2818
1966	10	46	80	98	110	115	186	142	18	6	3	2	815
1967	2	22	175	350	204	376	550	491	363	135	18	7	2694
1968	10	10	25	65	204	166	134	134	42	7	6	0	805
1969	5	43	74	884	612	349	428	489	262	68	9	5	3228
1970	20	20	136	744	229	316	131	227	138	26	6	6	1998

Table B-26. Eastside Streams Unimpaired Total Outflow Estimated Flow in TAF contd.

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1971	16	70	274	202	102	198	189	227	213	45	3	3	1541
1972	8	19	109	53	115	167	128	185	77	13	4	5	883
1973	9	27	75	466	501	357	238	344	120	17	7	4	2164
1974	11	143	292	415	115	430	367	316	169	54	13	6	2329
1975	6	11	23	46	270	427	225	363	266	50	11	6	1705
1976	29	33	21	18	23	44	57	80	11	2	7	3	328
1977	3	4	3	7	10	13	38	47	27	2	2	1	157
1978	1	5	52	396	254	410	421	328	242	57	7	17	2191
1979	2	8	16	158	330	375	232	347	105	13	3	1	1589
1980	10	25	46	774	700	324	215	259	198	74	7	4	2638
1981	2	5	13	80	54	205	160	140	33	1	1	1	695
1982	8	147	305	606	678	705	994	433	209	71	14	22	4192
1983	83	235	609	698	737	1304	463	593	471	244	45	30	5510
1984	19	441	766	254	223	239	156	261	115	21	16	1	2513
1985	9	86	65	41	113	152	196	160	40	6	2	5	877
1986	4	29	73	174	1482	813	233	254	157	26	6	4	3257
1987	4	3	8	18	66	132	95	84	13	4	3	1	430
1988	14	41	77	78	35	61	114	85	31	6	3	1	545
1989	3	45	60	33	58	323	198	145	76	7	4	38	990
1990	26	29	16	45	56	110	124	98	44	7	1	0	557
1991	2	3	13	5	24	180	106	160	92	11	2	0	599
1992	63	18	43	56	254	161	146	59	14	10	2	0	826
1993	3	5	49	427	301	461	344	367	238	50	8	4	2257
1994	6	6	15	17	52	64	95	108	23	4	2	4	395
1995	4	24	57	649	210	995	480	689	433	225	36	18	3820
1996	16	10	53	195	480	389	300	395	149	37	16	11	2049
1997	8	71	604	1553	262	166	179	197	84	16	10	7	3159
1998	10	23	37	363	751	527	468	485	503	185	32	21	3405
1999	22	32	63	200	535	278	268	339	193	38	21	9	1998
2000	7	21	19	191	497	285	226	284	94	25	12	12	1675
2001	16	17	18	34	71	132	151	175	19	7	4	6	650
2002	2	23	86	127	111	193	206	204	78	14	6	3	1053
2003	3	27	66	84	69	108	235	354	171	25	5	4	1152
2004	3	10	66	65	151	211	168	152	40	3	2	1	872
2005	15	23	80	299	199	443	316	511	267	73	17	10	2253
2006	13	17	369	446	243	584	1159	583	263	54	17	15	3763
2007	11	24	37	42	132	155	130	126	27	5	2	2	693
2008	3	4	14	77	94	97	123	166	70	3	2	3	656
2009	5	19	16	56	111	253	167	336	64	12	3	1	1042
2010	12	6	25	98	102	164	244	301	309	42	5	4	1313
2011	45	56	436	226	209	826	501	405	446	186	27	13	3376
2012	20	16	14	45	29	169	296	154	34	10	6	6	800
2013	7	26	232	74	52	89	134	91	25	4	2	2	740
2014	2	5	4	7	65	90	104	80	13	2	1	1	375
1922-2003 Average	**9**	**41**	**120**	**215**	**268**	**277**	**258**	**256**	**140**	**32**	**7**	**5**	**1629**
1922-2014 Average	**10**	**39**	**119**	**205**	**251**	**278**	**263**	**257**	**140**	**33**	**7**	**5**	**1607**

Table B-27. San Joaquin Valley Unimpaired Total Outflow Estimated Flow in TAF

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1922	24	25	248	282	781	658	836	2489	2535	651	128	45	8703
1923	36	98	449	411	305	369	953	1796	970	494	103	69	6054
1924	83	49	50	67	113	121	376	550	76	39	11	7	1539
1925	35	127	139	129	643	492	1064	1602	993	359	102	28	5714
1926	51	52	85	64	323	373	1229	1012	325	79	22	13	3629
1927	19	221	221	214	841	594	1149	1664	1507	461	96	38	7023
1928	55	266	143	164	266	977	852	1275	464	100	28	11	4601
1929	14	30	56	64	122	274	443	1085	633	153	29	8	2910
1930	10	13	55	115	198	434	720	797	777	155	35	15	3325
1931	31	52	33	71	113	174	421	566	154	37	16	9	1676
1932	12	24	410	305	911	570	847	1715	1644	565	113	36	7153
1933	30	20	39	96	107	265	537	789	1227	246	54	26	3436
1934	12	29	132	174	255	436	550	421	240	56	23	17	2344
1935	33	112	140	388	339	492	1570	1780	1569	351	91	29	6896
1936	35	52	55	261	1341	701	1326	1730	1110	377	82	22	7093
1937	26	34	103	135	1237	849	1075	2308	1337	338	70	21	7532
1938	28	47	937	373	1362	2156	1630	2753	2708	1031	246	87	13359
1939	124	125	105	127	180	430	879	645	262	84	35	41	3038
1940	115	48	55	764	867	1109	1113	1899	1030	207	45	13	7265
1941	32	40	445	464	955	1066	1077	2395	1888	774	157	43	9337
1942	47	102	502	597	550	554	1144	1675	2043	766	134	34	8149
1943	29	219	250	855	608	1484	1395	1708	1052	442	108	32	8182
1944	35	50	67	122	259	467	510	1403	821	313	61	20	4130
1945	29	249	225	172	1134	675	997	1634	1487	541	120	37	7301
1946	163	274	631	375	222	519	1139	1557	804	243	60	28	6016
1947	74	223	272	148	252	409	616	1061	370	89	22	16	3554
1948	87	66	50	99	90	236	686	1395	1277	287	46	19	4338
1949	24	33	58	66	119	399	910	1373	741	132	39	21	3915
1950	21	43	46	222	404	384	1062	1432	905	217	39	19	4793
1951	57	1534	1676	554	484	549	784	1100	756	236	54	17	7802
1952	35	78	379	847	492	968	1510	2857	2076	926	220	68	10454
1953	38	52	176	429	196	309	815	799	1132	481	65	22	4513
1954	26	51	66	126	284	632	1092	1387	571	162	29	14	4440
1955	18	49	129	200	181	262	452	1150	930	177	37	14	3598
1956	16	41	2212	1397	621	623	958	1880	1777	766	171	66	10527
1957	67	77	73	99	310	451	553	1216	1217	251	56	25	4395
1958	45	62	139	188	571	973	1659	2670	1928	729	220	74	9257
1959	40	39	35	182	371	389	702	674	412	82	22	119	3066
1960	36	27	32	72	326	416	719	858	447	76	24	14	3047
1961	15	60	97	61	125	204	487	609	353	57	45	19	2133
1962	19	33	69	190	812	449	1256	1227	1369	429	82	28	5963
1963	55	31	68	320	994	381	843	1732	1400	580	129	56	6590
1964	61	272	141	156	142	221	510	914	616	137	46	24	3242
1965	26	142	1424	1012	457	472	1094	1476	1448	689	302	77	8619
1966	39	379	273	261	232	458	952	1075	323	96	42	25	4154
1967	29	137	741	436	392	1029	1293	2464	2670	1616	313	116	11235
1968	54	52	103	135	372	363	583	809	394	86	44	21	3017
1969	37	183	243	2059	1466	1321	1977	3564	2662	1181	255	72	15019
1970	113	115	278	1183	435	668	541	1270	919	264	77	31	5894

Table B-27. San Joaquin Valley Unimpaired Total Outflow Estimated Flow in TAF contd.

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1971	28	190	362	353	292	443	650	1079	1181	360	86	36	5057
1972	27	95	238	162	230	552	502	992	636	102	30	69	3635
1973	49	104	215	448	745	698	908	2181	1238	246	84	30	6945
1974	57	426	406	629	259	875	1079	1897	1390	392	123	41	7574
1975	38	51	114	153	488	747	609	1879	1848	455	100	59	6540
1976	177	140	96	58	123	219	312	577	137	58	59	62	2018
1977	39	26	17	33	45	65	204	266	298	39	16	11	1060
1978	8	28	265	717	905	1384	1607	2345	2267	1044	276	303	11150
1979	77	90	101	496	574	855	901	1992	962	252	85	39	6424
1980	73	108	141	1697	1451	1126	1130	1730	1761	1069	229	84	10601
1981	55	43	81	169	201	382	755	977	486	96	46	32	3324
1982	63	401	551	807	1254	1221	2578	2536	1745	953	292	346	12746
1983	427	677	1153	1328	1673	2603	1464	2719	3793	2151	731	261	18978
1984	263	983	1256	774	483	635	713	1599	864	345	108	44	8069
1985	80	222	151	133	228	381	926	997	419	95	43	46	3721
1986	67	151	251	381	2316	1969	1384	1942	1642	477	140	82	10802
1987	63	30	44	52	138	277	569	624	241	61	34	17	2149
1988	35	77	105	194	170	311	499	626	337	105	42	19	2520
1989	21	46	75	93	159	719	948	857	523	108	34	37	3620
1990	109	76	61	109	137	362	645	524	322	112	25	11	2494
1991	14	18	18	23	26	538	510	987	875	232	53	28	3321
1992	47	69	59	82	341	342	711	635	169	166	44	21	2686
1993	32	46	139	1056	598	1051	1145	2216	1659	719	188	63	8912
1994	58	42	65	74	165	291	545	826	375	88	49	29	2608
1995	76	157	160	1156	496	2235	1458	2466	2731	2086	513	138	13672
1996	58	40	211	386	1169	995	1159	1949	1141	418	106	37	7669
1997	37	354	1368	3796	873	781	952	1601	845	241	120	55	11022
1998	46	74	115	649	1386	1148	1472	1878	3046	1948	338	169	12267
1999	88	143	194	383	728	491	785	1682	1149	300	96	64	6104
2000	38	59	41	390	977	800	1036	1654	935	212	93	51	6285
2001	56	55	62	104	193	532	679	1276	233	76	22	19	3307
2002	21	96	285	306	237	417	921	1100	633	111	30	17	4175
2003	12	197	223	265	225	403	666	1557	1118	200	90	38	4992
2004	18	44	206	210	351	753	807	893	437	123	38	18	3899
2005	132	144	248	979	646	1100	992	2740	1902	830	154	57	9925
2006	55	57	670	827	494	1033	2425	3044	2203	698	142	67	11714
2007	64	59	106	100	271	436	536	678	194	62	38	26	2571
2008	30	25	58	260	347	372	606	1105	613	139	33	20	3608
2009	21	151	84	298	365	673	837	1685	642	212	56	26	5050
2010	160	52	138	315	397	558	843	1275	1967	534	88	36	6364
2011	252	217	1096	645	558	1544	1464	1781	2491	1346	304	110	11809
2012	150	73	47	156	118	337	878	753	202	72	58	17	2860
2013	24	94	527	214	170	374	681	661	268	78	37	15	3143
2014	24	22	30	30	127	238	469	515	174	58	33	15	1734
1922-2003 Average	**55**	**140**	**280**	**423**	**530**	**667**	**931**	**1468**	**1114**	**414**	**106**	**50**	**6176**
1922-2014 Average	**58**	**133**	**282**	**416**	**508**	**667**	**934**	**1457**	**1102**	**409**	**104**	**48**	**6119**

Table B-28. Delta Unimpaired Total Inflow Estimated Flow in TAF

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1922	434	547	1703	1560	4552	3554	4672	7782	5618	1507	607	438	32974
1923	489	857	3297	2567	1687	1884	4254	4248	2330	1195	519	467	23793
1924	506	464	550	648	1394	752	1200	1206	477	381	304	292	8174
1925	414	954	1217	1216	6920	2744	4787	4416	2328	955	523	416	26891
1926	452	580	789	984	4306	2080	4693	2445	994	513	361	333	18532
1927	387	2524	2499	3006	8887	4603	6103	4929	3517	1206	541	434	38635
1928	445	1721	1373	1785	2672	7595	4623	3425	1304	637	413	370	26362
1929	375	589	775	740	1423	1536	1886	2761	1580	589	320	323	12896
1930	315	340	2947	1909	2390	3637	3093	2589	1745	629	376	358	20327
1931	375	517	440	956	914	1403	1384	1294	578	324	279	269	8734
1932	364	441	2452	1907	2872	3042	3173	4700	3303	1114	466	341	24175
1933	332	355	479	876	727	2288	2261	2708	2728	694	360	316	14123
1934	346	391	1354	1842	2041	2229	1819	1203	720	373	295	276	12891
1935	347	1000	952	2680	2095	3016	7901	5458	3270	942	468	356	28486
1936	430	444	599	4317	7947	3562	4679	4265	2666	976	453	360	30699
1937	359	364	526	693	3881	4726	4759	5742	2759	885	414	337	25445
1938	445	2080	6226	2531	8474	11252	7630	8785	5934	2148	837	572	56914
1939	670	732	925	927	1019	2316	2579	1641	783	445	341	362	12740
1940	478	397	783	5233	8181	8262	5675	4403	2140	756	453	422	37183
1941	490	711	4655	6171	7634	6798	6394	6886	3940	1751	750	563	46743
1942	563	777	4762	6127	7426	3039	5895	5738	4863	1831	735	541	42297
1943	541	1309	2393	6817	3943	7590	5161	4229	2590	1196	628	485	36880
1944	520	562	637	967	1973	2689	2238	3795	2009	940	458	374	17160
1945	449	1461	1860	1327	5858	2941	3410	4383	2972	1150	542	407	26759
1946	761	1630	6445	3473	1711	2898	4086	4153	1918	824	504	419	28824
1947	503	1099	1315	728	2003	3127	2603	2274	1292	521	389	358	16211
1948	785	673	575	2233	850	2116	5468	5252	3768	1058	519	445	23743
1949	459	565	791	651	1193	4776	3863	3844	1696	572	412	359	19178
1950	380	467	494	2473	3674	3074	4473	4241	2362	796	438	399	23272
1951	1113	6152	8164	5104	4622	3516	3295	3692	1777	769	496	417	39115
1952	562	1147	4697	6164	5698	5622	7572	8733	5240	2337	882	614	49267
1953	542	589	2677	7296	1924	2712	3887	3945	3825	1559	649	548	30154
1954	543	972	930	2953	3779	4672	5585	3725	1628	768	528	481	26563
1955	481	916	1728	1719	1209	1540	2349	3679	2072	698	436	404	17231
1956	407	700	12859	10914	5471	3905	4160	6071	3964	1716	751	580	51498
1957	726	688	687	959	3404	4258	2792	4525	2751	876	526	537	22730
1958	1034	993	2000	3332	11032	7005	9068	7892	4814	1856	897	649	50572
1959	590	611	662	2736	3586	2366	2595	2034	1170	576	422	611	17959
1960	462	426	524	1079	4311	3929	2890	2703	1453	563	408	389	19139
1961	423	853	1645	1086	2652	2369	2356	2453	1357	533	449	394	16570
1962	429	656	1441	1067	5706	3226	4497	3532	2774	994	492	394	25209
1963	3290	860	2398	2288	6176	2840	7469	5883	3007	1320	655	539	36725
1964	666	2054	1021	2121	1249	1390	2226	2780	1736	638	419	364	16664
1965	438	1164	11833	8143	2882	2427	6106	4406	3114	1485	930	502	43431
1966	520	1791	1393	2685	2149	3048	3874	2851	1010	555	433	401	20709
1967	398	1648	3969	5156	3301	5352	5603	7707	6311	2928	899	565	43837
1968	591	626	1044	2184	4870	3213	2542	2439	1210	610	573	446	20348
1969	573	1051	2428	11584	7523	5190	7039	8688	5061	2054	816	587	52594
1970	734	759	4273	14518	4096	4210	2197	3167	2160	900	564	475	38053

Table B-28. Delta Unimpaired Total Inflow Estimated Flow in TAF contd.

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1971	571	2450	4707	4105	2289	4710	4027	4745	3737	1349	640	551	33880
1972	608	781	1549	1689	2215	3865	2929	2948	1683	626	443	520	19858
1973	686	1565	2313	6151	5718	4722	3841	5431	2496	847	562	507	34838
1974	749	5699	5002	9240	2793	8411	6549	5423	3609	1530	751	575	50331
1975	589	700	1032	1247	4363	6612	3798	6270	4554	1378	709	618	31870
1976	1025	1013	887	739	1034	1558	1536	1592	658	456	538	479	11517
1977	446	455	416	552	537	626	768	1003	811	402	356	427	6800
1978	384	549	2338	8440	5036	7308	5922	5641	4257	1888	742	860	43364
1979	468	602	613	2007	3185	4022	3274	5176	1949	776	483	422	22976
1980	759	1088	1720	9461	8699	5126	3838	4276	3253	1893	656	597	41366
1981	531	499	1112	2189	2156	3171	2701	2365	1107	517	409	380	17136
1982	698	5347	7249	5283	7483	6706	11260	6854	3802	1960	874	945	58460
1983	1526	2706	5594	6730	9754	15830	6917	8852	8322	4095	1571	954	72851
1984	990	5158	9764	3956	3039	3850	2980	4112	2238	992	581	525	38186
1985	735	2335	1518	1044	1663	2089	3282	2422	1119	515	420	535	17675
1986	589	891	1566	3327	16848	9881	4058	4222	2950	1130	591	662	46714
1987	623	489	602	918	1874	3294	1998	1663	707	464	366	355	13352
1988	402	548	2149	2511	1239	1494	1742	1787	1034	497	349	308	14060
1989	350	1239	927	1092	1211	7767	4147	2541	1346	548	386	513	22068
1990	866	671	527	1589	1151	2200	2038	1981	1389	541	344	339	13636
1991	339	388	386	414	531	3710	2343	2731	1800	645	346	317	13951
1992	463	482	581	733	3355	2584	2565	1496	626	570	327	312	14095
1993	439	443	1633	6328	4759	7247	5241	6017	4240	1553	681	484	39063
1994	566	477	942	915	1573	1760	1790	2027	905	399	313	354	12023
1995	431	728	1415	12001	4093	14337	7263	8974	6345	3852	1255	738	61433
1996	567	553	2147	3491	8444	5747	4884	6527	2791	1160	633	513	37458
1997	574	1530	9286	17210	3950	2963	3102	3365	1848	781	607	533	45750
1998	638	1201	1651	7394	11828	6932	6222	7248	7794	3748	1101	824	56582
1999	824	1696	2316	3338	6591	4910	4194	4989	3015	1064	652	600	34190
2000	622	832	765	3257	7711	5343	4277	4216	2081	813	572	581	31068
2001	672	629	757	1089	2133	3215	2422	2823	795	511	413	418	15878
2002	435	1147	3542	3802	2218	2989	3313	2996	1564	581	440	399	23425
2003	396	887	4771	4457	2114	3204	4246	5841	2817	834	614	478	30659
2004	465	630	3009	2590	5692	4310	3043	2614	1283	660	440	400	25135
2005	782	726	2228	3782	2859	5250	4043	8565	4146	1703	668	504	35257
2006	531	763	7962	6855	4458	7703	12217	8309	4301	1584	717	568	55970
2007	581	772	1601	1029	2874	2527	2012	1916	734	488	401	377	15313
2008	538	437	855	2595	2657	2194	2211	3001	1354	519	370	300	17030
2009	421	770	678	1114	3044	4572	2741	4847	1547	691	436	368	21231
2010	750	446	809	3406	2987	2949	4141	4400	4716	1341	542	442	26931
2011	1033	1125	5890	2865	2851	9228	6602	5871	6504	3090	998	616	46673
2012	803	674	551	1219	870	4046	4685	2643	1008	615	483	386	17983
2013	458	1503	5832	1712	1293	2014	2325	1628	917	520	415	380	18998
2014	401	396	412	409	1573	2580	2069	1325	603	414	371	326	10879
1922-2003 Average	**591**	**1158**	**2463**	**3624**	**4096**	**4274**	**4126**	**4247**	**2637**	**1092**	**557**	**475**	**29341**
1922-2014 Average	**594**	**1110**	**2492**	**3491**	**3947**	**4278**	**4134**	**4230**	**2617**	**1088**	**554**	**469**	**29003**

Table B-29. Delta Unimpaired Total Outflow Estimated Flow in TAF

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1922	352	485	1672	1536	4544	3493	4581	7671	5498	1379	495	336	32042
1923	413	809	3300	2548	1624	1794	4195	4136	2218	1070	407	370	22884
1924	423	393	489	594	1336	674	1098	1089	353	258	191	192	7090
1925	343	892	1192	1177	6907	2678	4726	4320	2206	831	414	323	26010
1926	370	514	731	942	4287	1986	4634	2327	860	378	243	232	17504
1927	308	2486	2447	2975	8879	4538	6034	4814	3399	1077	426	334	37717
1928	370	1666	1331	1743	2621	7556	4533	3308	1180	509	294	267	25379
1929	289	536	735	690	1362	1460	1788	2644	1467	462	202	223	11859
1930	228	265	2897	1885	2353	3588	3005	2484	1624	506	265	266	19364
1931	294	450	374	921	862	1319	1273	1186	461	188	157	167	7652
1932	279	380	2460	1877	2850	2960	3078	4590	3180	987	347	233	23220
1933	244	280	426	854	660	2222	2159	2600	2613	558	241	214	13071
1934	262	317	1319	1792	2014	2137	1712	1087	600	243	176	173	11830
1935	264	947	911	2663	2038	2982	7852	5344	3140	812	347	253	27553
1936	352	376	548	4295	7951	3493	4595	4152	2547	842	332	256	29738
1937	275	290	484	661	3870	4741	4663	5624	2638	755	294	235	24529
1938	362	2023	6203	2505	8515	11250	7549	8668	5808	2017	718	470	56088
1939	591	663	865	877	961	2251	2472	1527	655	314	221	258	11655
1940	393	323	723	5245	8218	8227	5588	4286	2011	626	334	322	36297
1941	407	642	4663	6186	7669	6755	6340	6775	3818	1624	635	460	45974
1942	484	713	4742	6122	7395	2980	5848	5632	4736	1700	616	439	41406
1943	457	1257	2349	6808	3907	7552	5082	4110	2469	1067	511	379	35948
1944	435	493	580	921	1958	2604	2158	3681	1890	811	337	267	16134
1945	367	1412	1821	1278	5831	2903	3303	4274	2843	1015	424	302	25774
1946	693	1565	6432	3427	1655	2834	3984	4041	1795	696	384	315	27821
1947	419	1046	1265	671	1951	3068	2496	2153	1169	393	273	250	15153
1948	714	607	514	2168	783	2065	5408	5155	3650	929	403	344	22740
1949	377	494	748	601	1138	4737	3764	3731	1570	443	297	258	18158
1950	294	400	439	2446	3631	3011	4375	4124	2241	665	319	301	22246
1951	1039	6116	8157	5085	4592	3452	3208	3582	1655	640	379	314	38218
1952	483	1091	4693	6204	5654	5591	7505	8608	5125	2207	762	509	48431
1953	454	530	2675	7269	1847	2635	3814	3841	3711	1426	537	446	29185
1954	458	909	869	2906	3727	4619	5505	3609	1507	642	414	379	25543
1955	395	859	1695	1701	1149	1458	2283	3567	1951	572	317	302	16248
1956	322	636	12885	10989	5411	3817	4069	5980	3839	1601	628	478	50656
1957	646	614	622	908	3363	4196	2711	4441	2629	748	406	438	21722
1958	962	923	1957	3325	11071	7010	9014	7791	4697	1733	781	545	49809
1959	503	540	598	2699	3560	2276	2488	1925	1046	443	308	528	16912
1960	374	353	464	1037	4266	3859	2794	2598	1323	432	290	284	18073
1961	337	808	1587	1064	2588	2312	2261	2347	1230	400	333	295	15562
1962	343	602	1384	1010	5715	3165	4390	3423	2647	866	374	293	24214
1963	3245	793	2361	2275	6140	2802	7432	5783	2886	1199	535	440	35891
1964	591	2012	969	2096	1174	1308	2120	2676	1622	507	305	264	15642
1965	361	1111	11821	8124	2813	2354	6051	4289	2997	1359	812	409	42501
1966	432	1746	1369	2655	2102	2967	3770	2735	888	433	315	301	19712
1967	312	1614	3951	5214	3240	5325	5569	7593	6197	2804	777	461	43056
1968	502	561	987	2157	4829	3160	2440	2324	1082	479	465	345	19331
1969	490	996	2396	11595	7572	5117	6950	8569	4955	1928	697	484	51750
1970	651	691	4245	14526	4055	4134	2096	3048	2038	768	445	371	37068

Table B-29. Delta Unimpaired Total Outflow Estimated Flow in TAF contd.

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1971	479	2429	4703	4075	2220	4641	3936	4638	3610	1215	528	450	32924
1972	523	714	1513	1634	2154	3772	2833	2828	1558	498	325	423	18775
1973	619	1547	2285	6204	5749	4681	3736	5309	2366	717	444	405	34063
1974	675	5664	4983	9216	2724	8373	6476	5304	3485	1405	626	473	49403
1975	508	631	984	1189	4339	6578	3718	6150	4427	1256	594	514	30888
1976	955	942	820	671	968	1472	1441	1469	532	327	431	381	10411
1977	359	386	353	497	469	548	663	908	685	273	240	331	5711
1978	296	487	2304	8462	5040	7297	5860	5522	4132	1759	623	759	42541
1979	380	546	550	1996	3163	3974	3188	5056	1823	651	369	317	22014
1980	684	1026	1694	9443	8709	5059	3759	4162	3136	1775	542	496	40485
1981	442	426	1061	2162	2089	3127	2604	2250	978	387	290	277	16093
1982	624	5313	7220	5303	7455	6737	11204	6735	3707	1845	766	864	57773
1983	1457	2691	5574	6784	9790	15899	6860	8736	8222	3989	1465	862	72330
1984	914	5142	9769	3907	3004	3774	2892	4003	2126	870	455	422	37277
1985	664	2314	1484	1009	1610	2048	3184	2299	991	387	305	441	16737
1986	510	851	1535	3307	16918	9854	3974	4100	2834	1004	473	572	45931
1987	541	418	544	866	1829	3234	1894	1541	582	341	248	250	12287
1988	317	489	2118	2490	1167	1404	1649	1674	911	361	230	203	13014
1989	262	1177	882	1035	1153	7721	4046	2425	1227	414	269	426	21039
1990	786	608	464	1554	1117	2116	1936	1884	1262	409	225	234	12594
1991	252	315	327	346	472	3688	2246	2617	1677	514	229	211	12894
1992	381	410	525	683	3351	2543	2467	1372	505	443	208	206	13095
1993	358	369	1620	6411	4808	7205	5147	5907	4120	1425	562	379	38311
1994	482	419	892	869	1540	1673	1693	1922	786	266	191	246	10978
1995	337	675	1363	12054	4018	14342	7170	8859	6215	3724	1133	623	60511
1996	470	464	2127	3474	8472	5683	4801	6417	2663	1023	502	402	36498
1997	488	1464	9292	17273	3883	2869	2987	3234	1718	648	483	420	44759
1998	544	1164	1600	7373	11967	6927	6139	7161	7667	3622	981	724	55868
1999	717	1631	2259	3288	6541	4838	4099	4854	2887	945	540	500	33099
2000	527	753	683	3206	7679	5240	4171	4090	1942	696	456	478	29921
2001	588	551	688	1039	2079	3129	2321	2674	657	393	300	315	14734
2002	336	1077	3515	3750	2140	2902	3193	2853	1414	454	326	290	22248
2003	294	825	4758	4399	2047	3121	4169	5703	2674	702	510	375	29578
2004	373	570	2983	2562	5680	4215	2947	2475	1152	535	325	295	24112
2005	701	676	2214	3776	2846	5206	3971	8488	4035	1577	553	407	34450
2006	447	702	8005	6853	4423	7720	12206	8228	4193	1465	619	469	55329
2007	487	714	1548	951	2825	2421	1937	1786	603	375	293	286	14225
2008	456	372	790	2579	2582	2088	2108	2906	1212	407	261	202	15964
2009	324	704	614	1058	3031	4506	2657	4722	1420	568	328	267	20199
2010	664	383	804	3507	2997	2968	4206	4370	4570	1226	437	346	26478
2011	918	1077	5841	2820	2804	9199	6636	5982	6421	2975	854	505	46030
2012	715	600	487	1141	783	3884	4520	2505	834	435	338	271	16514
2013	347	1419	5367	1668	1206	1920	2206	1514	774	350	276	276	17322
2014	396	396	396	396	396	396	396	396	396	396	396	396	10879
1922-2003 Average	**509**	**1099**	**2425**	**3600**	**4065**	**4218**	**4039**	**4133**	**2514**	**964**	**440**	**373**	**28380**
1922-2013 Average	**511**	**1051**	**2450**	**3468**	**3902**	**4198**	**4032**	**4111**	**2492**	**961**	**438**	**369**	**28050**

Table B-30. Delta Unimpaired Net Use in TAF (WY2014 data was assumed to be same as WY2013)

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1922	83	62	31	23	8	61	92	111	120	128	112	103	932
1923	76	48	-3	19	63	90	59	112	112	125	113	97	909
1924	83	71	61	54	58	78	102	117	123	122	113	100	1084
1925	71	61	26	39	13	66	61	95	122	124	110	93	882
1926	82	66	58	42	20	94	59	119	133	135	118	101	1028
1927	79	38	52	31	8	65	68	114	119	130	115	99	918
1928	74	55	41	42	50	39	89	118	124	129	119	103	983
1929	86	53	40	49	61	76	98	117	113	127	118	100	1037
1930	87	75	51	24	36	49	88	105	121	123	110	93	963
1931	81	68	67	36	52	81	109	116	119	138	122	101	1088
1932	84	60	-8	32	21	82	96	112	126	129	119	107	960
1933	88	74	53	23	68	66	103	104	122	137	120	101	1058
1934	84	74	36	53	27	93	108	117	120	130	120	103	1065
1935	84	54	42	18	58	35	49	116	130	130	121	103	938
1936	79	68	53	23	-3	69	84	113	120	134	122	104	966
1937	84	75	42	32	12	-13	97	118	122	131	122	103	924
1938	84	58	24	27	-41	2	82	118	126	130	120	104	834
1939	80	71	61	50	58	66	108	115	129	131	121	104	1093
1940	85	75	61	-12	-37	35	88	118	130	130	120	101	892
1941	84	70	-7	-14	-35	44	55	111	123	131	113	103	777
1942	80	65	21	6	31	60	47	107	128	131	120	103	899
1943	85	53	43	9	37	38	79	120	121	130	118	106	938
1944	85	70	57	45	16	85	80	115	119	130	122	108	1032
1945	82	49	39	49	27	39	107	110	129	136	120	105	991
1946	72	63	14	46	56	64	103	113	123	129	121	105	1008
1947	85	53	49	56	54	60	107	122	123	129	117	108	1064
1948	71	67	62	65	66	52	62	97	119	130	119	101	1011
1949	81	72	41	49	55	38	104	114	126	129	115	101	1025
1950	86	68	56	27	44	64	98	118	122	132	120	98	1032
1951	74	36	7	19	31	65	88	110	123	130	117	103	903
1952	79	55	5	-37	43	31	74	119	115	129	120	104	838
1953	89	59	6	28	75	78	73	106	116	135	114	103	982
1954	85	64	62	50	51	54	81	117	121	131	113	102	1032
1955	87	57	34	19	61	83	69	111	122	127	121	103	992
1956	87	64	-27	-74	60	89	76	109	126	128	116	100	853
1957	81	74	66	51	41	62	81	86	127	130	117	101	1019
1958	74	71	43	8	-40	-5	44	112	118	126	118	103	771
1959	88	73	63	38	29	90	105	115	128	133	118	82	1062
1960	88	75	60	43	44	74	92	111	131	132	120	105	1075
1961	87	46	58	23	65	57	94	109	129	132	117	100	1015
1962	87	55	57	58	-8	61	106	112	127	130	118	102	1004
1963	45	68	38	21	29	37	35	106	122	127	117	100	844
1964	76	43	52	26	76	82	102	111	114	128	116	101	1028
1965	78	54	10	20	70	74	61	117	118	127	113	99	941
1966	89	45	25	30	41	88	105	117	123	123	119	101	1007
1967	87	36	19	-57	59	31	35	116	115	130	121	102	793
1968	87	66	58	28	40	53	103	115	128	131	107	103	1020
1969	84	56	32	-14	-57	72	86	119	118	131	123	105	856
1970	79	68	27	-8	42	78	101	121	123	132	120	106	988

Table B-30. Delta Unimpaired Net Use in TAF contd.

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1971	82	25	9	34	70	66	91	103	122	130	118	104	954
1972	85	67	36	55	62	93	96	120	126	129	118	96	1083
1973	67	18	28	-53	-31	41	105	122	130	130	118	101	775
1974	74	35	19	25	70	37	73	119	124	125	120	107	928
1975	83	69	49	59	23	31	80	120	127	125	115	105	986
1976	70	71	67	68	66	86	95	123	126	129	106	99	1107
1977	88	69	63	55	68	78	105	95	126	129	116	96	1089
1978	87	61	34	-23	-3	12	62	120	125	129	119	101	824
1979	90	56	63	11	18	47	87	118	128	127	115	106	967
1980	76	62	26	10	-16	66	86	110	118	122	115	101	877
1981	89	74	51	26	67	42	97	116	131	130	119	102	1045
1982	74	33	26	-21	29	-33	53	120	115	126	116	86	723
1983	70	15	21	-56	-42	-76	54	113	124	126	118	101	569
1984	85	21	-4	55	41	83	97	119	124	130	117	106	975
1985	74	25	39	38	53	45	105	123	128	128	115	97	969
1986	83	42	35	22	-61	18	87	118	124	128	120	93	810
1987	88	74	60	52	43	57	109	122	124	124	118	105	1077
1988	86	58	30	21	72	89	92	112	122	136	119	105	1042
1989	88	61	44	57	57	43	106	118	122	134	118	87	1037
1990	80	63	62	34	34	84	103	96	128	132	119	105	1041
1991	87	73	59	68	58	22	97	114	123	131	117	107	1056
1992	81	73	55	49	2	41	98	124	122	127	120	106	996
1993	81	72	12	-82	-51	42	94	108	118	128	119	105	746
1994	85	57	51	45	30	92	94	104	128	131	122	106	1045
1995	85	47	40	-73	63	-28	85	103	116	125	119	103	784
1996	89	75	12	-1	-47	48	79	99	127	133	122	103	840
1997	78	58	0	-67	70	92	104	120	122	130	116	105	926
1998	84	37	37	1	-159	51	73	65	116	130	121	99	656
1999	81	54	54	29	20	53	83	115	124	125	115	102	955
2000	88	63	67	29	0	77	92	114	128	126	120	102	1006
2001	67	63	55	30	22	61	78	129	128	121	120	102	976
2002	91	54	4	31	59	56	101	118	126	130	118	106	994
2003	87	55	-7	34	45	59	58	113	128	134	115	106	927
2004	90	61	21	25	8	90	105	119	125	129	119	105	996
2005	66	48	18	10	15	46	78	111	118	133	122	102	865
2006	86	67	-5	22	48	6	45	115	128	135	118	104	869
2007	86	60	51	66	41	93	92	120	127	129	121	101	1085
2008	81	70	51	4	47	91	104	119	129	130	121	107	1053
2009	88	63	54	53	27	77	98	118	124	133	119	105	1059
2010	60	71	47	9	25	65	57	108	123	126	115	102	910
2011	78	54	9	35	26	5	97	105	108	121	115	105	859
2012	77	64	65	49	67	53	75	117	124	129	121	104	1045
2013	82	44	-4	39	74	83	101	114	123	129	114	96	996
2014	82	44	-4	39	74	83	101	114	123	129	114	96	996
1922-2003 Average	**82**	**58**	**37**	**22**	**29**	**55**	**85**	**113**	**123**	**129**	**118**	**102**	**953**
1922-2014 Average	**81**	**58**	**36**	**23**	**30**	**56**	**86**	**113**	**123**	**129**	**118**	**102**	**956**

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APPENDIX C   SWAT SIMULATED FLOW TABLES WY 1922-2014

Table C-1. UF 2 – Putah Creek near Winters Simulated Flow (TAF)

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1922	0.5	0.2	10.4	30.5	49.0	43.4	27.7	18.9	12.0	7.5	4.0	1.8	205.8
1923	0.9	6.4	54.7	53.3	33.5	25.9	18.2	13.6	8.2	4.9	2.7	1.3	223.5
1924	0.7	0.3	0.3	0.8	21.6	16.8	13.2	9.4	5.6	3.0	1.3	0.5	73.6
1925	0.4	3.7	35.5	34.6	140.6	68.0	46.7	30.6	20.2	13.2	7.7	4.0	405.2
1926	2.1	1.0	0.9	56.5	94.6	52.3	53.8	29.2	18.4	12.1	6.9	3.4	331.2
1927	1.6	38.0	92.4	63.3	113.6	73.9	61.7	28.0	17.5	11.4	6.5	3.2	511.1
1928	1.5	11.5	19.5	34.5	53.2	44.0	42.7	26.8	17.2	11.4	6.6	3.3	272.3
1929	1.6	3.1	9.0	15.6	25.0	21.5	14.5	9.8	5.7	3.2	1.5	0.6	111.2
1930	0.2	0.1	85.6	64.2	47.8	49.8	26.8	18.0	11.1	6.8	3.5	1.5	315.3
1931	0.7	0.3	0.3	14.5	19.4	19.3	14.5	9.6	5.4	2.9	1.3	0.5	88.7
1932	0.2	0.3	98.3	88.1	49.8	31.5	20.3	13.7	7.9	4.3	1.9	0.7	317.1
1933	0.2	0.1	4.4	31.0	36.5	33.2	23.7	16.5	10.5	6.6	3.6	1.6	167.9
1934	0.7	0.7	32.5	62.0	32.9	29.4	19.3	13.7	8.5	5.1	2.5	1.0	208.2
1935	0.4	4.1	11.6	94.5	48.4	75.3	39.7	25.4	16.1	10.6	6.2	3.1	335.4
1936	1.5	0.6	0.5	78.5	121.7	64.8	36.2	24.0	15.1	9.6	5.3	2.5	360.3
1937	1.1	0.4	0.2	2.3	88.0	69.9	46.8	27.6	17.2	11.0	6.1	2.9	273.5
1938	1.3	16.9	140.6	89.2	159.6	128.2	57.7	32.0	20.1	13.1	7.5	3.7	669.9
1939	1.8	0.9	1.5	5.3	9.1	12.1	10.7	8.4	5.7	3.5	1.8	0.8	61.7
1940	0.4	0.2	5.2	112.9	193.8	155.7	77.6	40.0	24.2	15.8	9.3	4.7	639.7
1941	2.3	1.8	137.8	204.7	160.4	142.6	102.2	42.6	25.4	16.8	10.2	5.4	852.2
1942	2.8	1.6	89.9	121.9	188.1	73.8	48.7	29.6	19.0	12.8	7.8	4.3	600.4
1943	2.4	4.0	19.7	154.9	78.0	52.9	29.3	20.4	12.8	8.0	4.4	2.1	388.8
1944	1.1	0.6	0.5	9.5	51.9	68.6	30.8	22.0	14.1	8.9	4.8	2.2	215.0
1945	1.0	7.4	17.7	38.2	83.7	40.4	27.5	18.6	11.8	7.5	4.1	1.9	259.6
1946	6.2	12.4	106.5	89.3	39.9	27.5	17.5	11.3	6.1	3.2	1.4	0.6	321.8
1947	0.2	5.5	19.9	18.2	24.9	31.1	22.0	15.6	10.0	6.4	3.5	1.6	158.9
1948	1.0	1.4	2.2	7.2	8.5	9.2	35.3	30.9	21.0	14.7	9.2	5.1	145.7
1949	2.6	1.1	5.5	8.0	15.3	62.1	37.4	26.0	16.7	11.0	6.3	3.0	195.0
1950	1.4	0.7	0.9	32.3	83.5	46.0	29.1	19.7	12.1	7.4	3.9	1.7	238.6
1951	0.9	39.5	122.5	87.0	57.8	38.0	23.9	16.5	10.3	6.3	3.4	1.6	407.8
1952	0.9	2.5	115.1	182.7	108.0	62.4	35.7	24.5	15.3	9.8	5.3	2.5	564.6
1953	1.2	0.7	110.6	187.1	61.2	43.3	27.3	19.0	12.0	7.5	4.1	2.0	475.9
1954	1.0	5.2	10.1	83.2	68.9	50.5	45.6	27.5	17.3	11.3	6.4	3.2	330.2
1955	1.5	5.0	38.7	30.7	22.6	18.5	13.1	12.0	8.4	5.7	3.7	2.0	161.8
1956	1.1	0.6	303.0	235.9	182.1	104.2	44.7	27.1	16.6	10.4	5.6	2.6	933.9
1957	1.3	1.3	1.5	5.9	43.6	53.0	32.8	24.9	17.6	11.4	6.4	3.2	202.8
1958	9.5	14.4	28.6	52.1	193.6	144.4	146.4	52.7	27.8	18.4	11.3	6.2	705.4
1959	3.3	1.6	0.9	57.1	96.5	58.8	31.0	21.0	12.9	7.9	4.1	2.0	296.9
1960	1.1	0.8	0.8	10.8	123.4	74.6	34.3	22.7	14.0	8.6	4.5	2.0	297.5
1961	0.9	0.9	35.3	52.7	49.8	37.0	26.2	18.0	11.4	7.1	3.7	1.7	244.5
1962	0.7	0.6	24.9	20.0	103.7	99.8	42.3	26.7	16.5	10.5	5.6	2.6	354.0
1963	74.4	35.7	49.2	127.5	106.6	67.8	77.8	43.2	25.7	17.2	10.6	5.7	641.5
1964	3.0	11.7	19.1	48.3	33.0	25.0	16.2	10.8	6.2	3.4	1.5	0.6	178.9
1965	0.3	18.0	200.4	240.6	69.0	39.0	33.0	21.2	13.5	8.7	5.0	2.6	651.3
1966	1.3	11.8	40.7	159.1	67.1	39.3	23.8	15.7	9.3	5.3	2.5	1.1	377.1
1967	0.5	13.9	101.2	177.0	101.5	78.6	51.4	32.9	21.7	15.1	9.5	5.3	608.5
1968	2.8	1.4	7.7	71.1	77.3	55.3	31.6	21.9	14.0	8.8	4.8	2.2	299.0
1969	1.1	0.8	46.7	229.5	186.1	97.0	42.5	26.3	16.2	10.2	5.6	2.7	664.7
1970	1.4	0.9	77.9	289.9	155.9	75.9	35.2	23.1	14.2	8.8	4.8	2.4	690.3

Table C-1. UF 2 – Putah Creek near Winters Simulated Flow (TAF) contd.

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1971	1.4	40.2	177.3	83.6	41.2	35.0	23.4	16.4	10.4	6.7	3.9	2.0	441.5
1972	1.2	0.8	11.6	28.1	28.2	23.6	16.0	11.4	6.9	4.0	2.0	0.8	134.6
1973	0.7	19.0	31.7	187.6	142.3	73.9	38.3	25.4	15.8	10.0	5.5	2.7	552.8
1974	1.5	106.2	100.5	121.5	61.1	95.3	59.2	30.8	19.6	13.1	7.8	4.2	620.9
1975	2.4	1.4	3.2	12.3	89.7	93.2	54.3	30.7	19.5	13.0	7.7	4.1	331.5
1976	2.3	1.8	1.8	2.8	2.4	4.6	4.4	3.7	2.7	1.9	1.1	0.5	29.9
1977	0.2	0.1	0.1	0.7	1.3	2.0	2.0	1.7	1.2	0.8	0.4	0.2	10.6
1978	0.1	5.3	59.8	276.8	167.6	96.5	42.5	26.5	16.2	10.1	5.4	2.5	709.3
1979	1.1	0.5	0.3	43.6	72.0	62.0	33.2	22.9	14.4	9.0	4.8	2.2	266.1
1980	1.5	8.7	46.0	150.2	160.3	100.9	43.7	27.0	16.6	10.4	5.6	2.6	573.3
1981	1.1	0.5	23.8	61.6	59.1	40.8	26.6	18.1	11.4	7.2	3.9	1.8	255.9
1982	0.9	30.0	138.4	151.6	99.0	124.0	128.0	53.9	28.5	18.9	11.5	6.2	790.8
1983	3.3	28.1	77.3	120.0	188.5	268.5	90.6	49.5	28.2	19.4	12.6	7.6	893.6
1984	4.8	42.0	157.1	97.0	46.0	31.0	20.9	14.3	9.2	6.3	4.1	2.7	435.3
1985	2.2	37.9	48.7	32.9	47.9	32.8	24.7	17.3	11.3	7.5	4.4	2.4	270.0
1986	1.4	1.1	17.2	55.7	293.9	194.2	67.6	35.2	21.5	14.1	8.4	4.7	715.1
1987	2.9	1.8	1.4	1.7	16.2	35.3	28.3	20.8	13.7	8.9	5.0	2.4	138.5
1988	1.1	0.8	36.7	102.6	48.6	30.6	19.5	12.9	7.3	4.0	1.9	0.8	266.9
1989	0.3	4.0	12.0	17.2	15.4	39.4	31.3	22.3	14.4	9.4	5.2	2.5	173.6
1990	2.5	4.3	6.1	25.9	25.2	23.1	16.1	11.6	9.9	8.3	5.6	3.4	141.9
1991	2.0	1.0	0.5	0.3	0.8	48.0	35.3	26.9	17.5	11.8	6.9	3.4	154.3
1992	1.6	0.8	0.6	4.1	42.8	46.3	30.2	21.4	13.7	8.6	4.6	2.1	176.7
1993	0.9	0.8	51.7	207.4	128.6	77.9	36.9	23.7	14.5	8.8	4.6	2.1	557.8
1994	1.0	0.5	13.7	15.5	32.8	30.5	20.7	14.5	8.9	5.3	2.7	1.2	147.2
1995	0.5	2.0	16.9	359.7	115.6	201.5	75.3	38.6	23.0	14.9	8.7	4.5	861.3
1996	2.2	0.9	46.8	87.1	154.0	81.8	39.9	26.5	17.4	11.3	6.3	3.2	477.5
1997	1.6	1.3	107.0	259.7	97.2	48.7	26.8	17.6	10.4	5.9	3.0	1.4	580.6
1998	0.8	5.8	21.9	92.6	234.5	97.3	47.2	29.7	20.1	14.3	9.2	5.6	579.0
1999	3.5	10.7	17.3	24.2	96.7	61.2	38.7	26.3	16.8	11.2	6.8	3.8	317.1
2000	2.3	2.0	4.1	10.2	70.8	76.3	38.9	26.3	16.6	10.9	6.5	3.5	268.3
2001	2.1	1.5	1.4	5.0	26.8	57.5	31.9	22.5	14.3	9.0	4.9	2.3	179.2
2002	1.1	9.0	88.1	103.8	43.4	30.4	19.2	12.3	6.8	3.7	1.7	0.7	320.3
2003	0.3	1.0	184.3	117.3	50.6	39.0	27.7	23.7	15.6	10.8	7.1	4.1	481.4
2004	2.3	1.3	56.4	88.5	107.6	75.3	35.7	23.8	14.8	9.4	5.3	2.7	422.9
2005	1.6	1.8	53.7	95.4	50.7	54.5	35.5	26.0	17.7	11.8	7.2	4.0	359.8
2006	2.3	1.4	164.9	163.1	76.5	105.1	85.2	46.0	27.5	18.7	12.0	7.2	710.0
2007	4.5	2.9	10.5	12.1	28.5	28.8	21.2	15.7	10.4	7.0	4.2	2.2	148.0
2008	1.2	0.6	1.2	99.8	79.3	45.9	27.1	18.2	11.0	6.4	3.1	1.3	294.9
2009	0.6	0.9	1.9	5.4	31.2	63.7	31.2	21.5	13.4	8.3	4.3	1.9	184.2
2010	2.6	3.8	5.1	82.9	78.7	56.2	41.4	26.9	17.4	11.8	7.0	3.6	337.3
2011	2.0	2.6	31.8	39.0	26.8	20.8	13.2	8.2	4.2	2.0	0.8	0.3	151.6
2012	0.1	0.1	0.0	4.6	8.8	63.9	58.2	33.7	22.3	15.2	9.2	4.8	220.8
2013	2.3	26.2	166.4	87.6	36.9	25.6	15.7	9.8	5.1	2.5	1.0	0.3	379.3
2014	0.1	0.0	0.0	0.0	23.1	39.2	27.6	19.5	12.6	8.1	4.4	2.0	136.6
Average	2.4	7.6	46.6	80.7	77.7	61.4	37.4	22.9	14.3	9.2	5.3	2.7	368.1
Minimum	74.4	106.2	303.0	359.7	293.9	268.5	146.4	53.9	28.5	19.4	12.6	7.6	933.9
Maximum	0.1	0.0	0.0	0.0	0.8	2.0	2.0	1.7	1.2	0.8	0.4	0.2	10.6

Table C-2. UF 3 – Cache Creek above Rumsey Simulated Flow (TAF)

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1922	0.5	1.1	23.7	33.9	88.6	79.3	64.1	41.6	25.0	14.6	6.4	2.3	381.1
1923	2.0	26.6	65.4	70.4	57.0	41.2	44.2	27.1	19.4	12.6	6.4	3.3	375.5
1924	2.2	2.0	3.7	15.9	42.3	35.5	27.1	18.7	9.4	4.2	1.5	0.4	162.9
1925	3.0	20.4	57.6	59.2	187.7	105.7	84.8	65.5	40.8	27.2	16.7	8.1	676.6
1926	3.6	2.4	9.2	96.9	103.9	73.9	83.1	45.9	27.2	17.3	8.2	3.1	474.7
1927	1.8	71.1	85.7	102.4	182.7	103.7	96.1	51.3	28.1	17.6	8.1	3.0	751.6
1928	1.1	23.9	39.8	47.1	75.0	83.9	74.3	54.5	32.2	21.3	10.5	4.1	467.9
1929	1.5	14.6	26.1	30.3	46.9	35.0	25.5	17.1	9.3	5.1	2.4	0.9	214.6
1930	0.3	0.1	60.6	65.8	78.2	76.7	54.8	34.9	22.4	12.6	5.6	2.1	414.1
1931	0.8	1.1	2.6	36.3	30.3	37.8	28.8	23.2	16.1	9.5	4.6	2.0	193.1
1932	1.0	3.4	69.2	76.1	71.7	50.4	29.4	20.0	11.2	6.5	3.3	1.4	343.6
1933	0.5	0.6	12.4	45.1	48.2	59.4	43.1	32.5	21.9	13.1	6.2	2.5	285.6
1934	1.4	3.5	46.8	50.7	53.4	49.2	34.1	25.9	16.2	9.2	4.4	1.8	296.4
1935	1.2	20.7	27.5	96.2	79.2	79.2	65.5	45.6	28.3	18.9	9.2	3.7	475.2
1936	1.7	1.6	5.3	97.6	150.5	95.3	78.7	43.8	27.4	16.7	8.3	3.7	530.7
1937	1.6	0.7	0.9	12.3	120.7	97.2	72.0	48.1	27.7	17.6	8.4	3.4	410.7
1938	2.0	58.9	202.2	132.4	200.0	156.3	101.2	67.4	34.2	21.3	10.1	3.9	989.8
1939	2.2	3.3	24.0	33.2	40.8	47.8	30.8	23.4	14.3	8.2	3.9	1.6	233.4
1940	0.6	0.3	10.8	97.6	225.2	171.3	101.5	73.1	38.5	23.8	12.1	4.9	759.6
1941	2.0	7.0	119.4	180.5	197.5	156.9	127.3	78.7	44.1	26.2	14.5	6.1	960.1
1942	2.5	5.1	94.2	115.3	191.5	104.6	88.2	56.4	34.2	23.0	12.1	5.1	732.2
1943	2.1	16.5	42.9	175.7	83.6	86.4	59.6	39.1	25.2	16.1	8.0	3.3	558.5
1944	1.3	1.0	4.3	34.7	66.1	79.2	50.8	35.8	24.0	14.8	7.4	3.1	322.4
1945	2.0	25.6	41.2	68.0	80.9	66.0	50.1	34.3	23.2	13.7	6.4	2.5	414.1
1946	13.0	25.9	127.2	107.3	77.7	57.9	35.5	24.9	14.5	7.6	3.2	1.1	496.0
1947	0.4	19.3	30.2	31.0	51.9	58.0	46.5	33.1	22.5	13.1	6.0	2.3	314.1
1948	5.1	11.2	13.5	27.5	29.1	45.2	74.3	61.3	40.5	26.6	15.6	7.0	356.8
1949	3.1	1.9	9.9	22.3	39.7	99.7	62.3	42.7	25.4	15.0	6.6	2.4	331.0
1950	0.8	1.6	4.6	57.5	98.9	71.7	56.4	37.7	24.7	15.0	7.0	2.7	378.5
1951	6.4	49.1	118.1	116.3	101.3	79.1	47.1	44.7	23.7	15.0	7.8	3.4	611.9
1952	1.8	22.4	116.0	152.6	119.6	103.8	65.5	37.7	22.7	12.4	5.5	2.1	662.2
1953	0.8	2.0	113.3	173.0	85.7	82.8	50.6	35.3	25.4	17.4	9.9	4.8	600.9
1954	2.4	28.7	17.1	116.8	89.2	88.6	73.7	45.7	27.0	17.0	8.2	3.6	517.9
1955	1.7	17.8	50.1	47.6	35.6	32.4	32.6	25.4	18.9	13.5	7.4	3.3	286.5
1956	1.4	3.1	234.7	251.3	231.0	112.9	77.9	45.9	25.2	14.6	6.4	2.3	1,006.7
1957	1.6	5.4	5.5	37.2	81.0	70.6	66.9	57.7	36.7	25.8	15.3	8.7	412.4
1958	35.5	23.1	41.1	81.2	267.9	188.8	165.4	85.6	47.5	26.8	14.7	6.1	983.8
1959	2.3	0.9	0.8	78.3	119.0	79.0	54.4	32.1	19.5	9.9	3.9	2.0	402.2
1960	1.8	1.2	1.4	21.9	147.3	100.6	71.8	46.8	28.6	19.3	10.0	4.3	454.9
1961	2.0	18.9	76.5	73.1	69.6	75.4	54.1	38.0	25.1	15.7	7.6	3.1	459.1
1962	1.2	28.7	54.2	45.4	140.1	119.6	72.2	44.2	24.9	14.1	5.9	2.1	552.4
1963	68.2	38.5	56.2	135.0	98.4	93.8	99.7	73.9	43.1	26.1	14.4	6.0	753.5
1964	3.3	39.0	34.8	66.3	42.7	38.3	27.2	19.5	11.0	5.8	2.5	0.8	291.0
1965	0.5	56.9	237.4	259.3	97.2	75.3	65.1	38.9	26.4	17.6	9.0	3.9	887.6
1966	1.6	42.1	47.2	134.2	105.2	75.5	45.4	28.1	17.2	9.0	3.8	1.4	510.5
1967	0.5	57.3	103.5	167.5	89.2	117.2	80.2	58.7	37.9	24.8	13.7	6.0	756.5
1968	3.1	3.8	29.8	106.4	87.2	91.1	60.5	36.2	22.2	11.9	5.1	1.9	459.2
1969	1.2	6.0	75.0	208.6	203.3	117.2	78.6	45.4	25.2	14.6	6.4	2.3	783.7
1970	1.3	3.5	79.3	293.6	159.0	107.6	67.2	35.9	20.7	10.2	3.9	1.2	783.4

Table C-2. UF 3 – Cache Creek above Rumsey Simulated Flow (TAF) contd.

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1971	0.6	87.3	145.1	126.6	78.0	77.6	48.2	34.5	24.1	14.8	7.0	2.7	646.6
1972	1.0	2.1	33.8	41.5	50.4	45.9	37.8	27.1	17.5	10.0	4.6	1.8	273.7
1973	3.9	38.2	61.1	172.7	180.4	115.3	75.8	42.9	24.1	13.2	5.4	1.9	734.8
1974	2.4	149.3	122.8	162.0	113.7	144.9	94.7	62.5	33.6	21.8	11.0	4.4	923.1
1975	1.8	1.6	19.2	30.2	138.8	154.1	95.2	69.8	36.2	22.8	11.4	4.5	585.6
1976	3.6	8.6	12.3	13.3	21.7	29.0	32.7	26.8	18.5	11.1	5.3	2.1	185.0
1977	0.9	1.1	1.3	11.1	11.9	19.7	17.5	14.6	9.8	5.7	2.6	1.3	97.5
1978	0.8	22.2	57.0	252.9	186.8	137.4	93.0	59.3	31.8	20.7	10.1	4.4	876.3
1979	1.8	1.1	1.2	60.4	94.2	88.3	67.5	47.3	28.1	18.8	9.5	4.0	422.1
1980	7.9	38.1	83.8	143.3	188.9	112.4	78.3	45.6	25.6	15.1	6.6	2.4	748.0
1981	0.9	0.6	29.5	63.4	61.3	66.7	48.5	31.9	20.7	11.3	4.9	1.8	341.7
1982	6.2	77.7	140.7	150.2	134.6	148.7	123.7	81.0	46.2	26.7	14.6	6.1	956.5
1983	4.8	72.2	93.2	171.3	221.1	296.0	127.1	95.7	56.5	30.9	18.1	8.0	1,195.0
1984	3.6	95.0	188.1	101.0	85.2	64.9	41.9	28.6	18.5	10.3	4.7	1.8	643.4
1985	1.3	71.7	65.5	55.1	74.0	56.9	43.6	30.7	20.7	11.6	5.1	2.1	438.4
1986	1.3	10.8	39.2	78.3	349.5	195.3	93.6	61.8	31.1	19.1	8.6	3.5	892.0
1987	1.6	1.2	3.5	18.0	58.6	78.6	56.0	37.2	23.4	13.1	5.6	2.0	298.8
1988	0.8	6.9	63.2	111.5	71.3	51.4	30.7	22.2	12.3	6.6	3.2	1.3	381.3
1989	0.5	24.4	32.1	44.8	35.1	78.4	55.2	40.2	25.4	15.6	7.2	3.2	362.1
1990	14.2	14.1	15.5	45.3	48.4	45.5	30.9	41.1	26.5	20.8	14.3	8.0	324.4
1991	4.1	2.3	1.9	2.0	19.0	103.6	66.9	49.5	28.4	18.0	8.4	3.2	307.1
1992	1.4	4.3	9.6	26.7	87.4	80.8	60.3	37.4	23.5	13.5	6.2	2.5	353.6
1993	1.8	5.8	74.3	188.5	142.1	106.0	73.0	47.5	35.6	25.9	16.0	7.8	724.4
1994	3.6	2.3	24.2	31.2	63.7	49.2	35.7	27.6	17.6	10.4	5.1	2.1	272.8
1995	1.0	17.2	37.1	368.2	110.3	270.9	106.8	88.6	49.9	29.0	17.2	7.7	1,103.8
1996	3.1	1.0	77.1	118.1	181.8	114.5	85.1	57.9	33.2	22.9	12.6	5.7	712.8
1997	2.4	9.6	121.2	239.2	100.0	83.0	47.4	28.2	17.1	9.0	4.2	2.0	663.3
1998	1.6	29.0	50.0	128.4	327.3	130.1	98.3	78.4	47.8	29.1	18.3	9.0	947.4
1999	4.2	32.7	38.4	47.8	129.1	104.6	86.1	56.6	30.3	19.2	8.9	3.4	561.2
2000	1.2	11.1	18.4	35.9	115.6	101.3	73.3	45.6	26.5	16.6	8.0	3.3	456.8
2001	1.7	3.6	8.8	27.3	59.1	81.0	51.9	32.0	19.8	10.3	4.2	1.5	301.2
2002	0.6	29.6	100.1	124.1	76.3	60.6	36.4	25.5	15.3	8.0	3.3	1.1	481.0
2003	0.3	11.6	210.7	122.0	92.8	92.9	66.8	59.2	39.4	26.5	15.6	6.9	744.7
2004	2.7	11.2	92.8	94.8	164.0	92.3	61.3	34.9	21.3	11.4	4.8	1.7	593.3
2005	3.1	9.2	77.6	87.7	73.7	86.6	69.0	61.8	38.8	26.4	16.0	7.6	557.4
2006	3.4	7.1	191.8	164.6	139.4	152.4	138.2	84.7	47.4	27.1	15.1	6.2	977.4
2007	2.4	3.8	25.7	30.6	74.9	60.2	44.5	30.2	19.4	10.9	5.0	1.9	309.3
2008	1.3	1.3	14.4	129.8	94.1	75.2	43.4	26.1	14.2	6.5	2.4	0.7	409.3
2009	0.8	8.0	12.3	18.0	56.8	69.9	47.9	38.2	24.1	14.9	7.5	3.1	301.7
2010	5.8	9.7	14.7	98.8	83.7	87.8	86.0	57.2	36.1	25.0	14.4	6.6	525.8
2011	6.4	19.0	58.7	63.6	41.2	28.6	16.9	8.2	3.1	1.0	0.2	0.0	246.9
2012	0.0	0.0	0.0	25.2	21.4	109.3	80.0	61.2	34.4	22.3	11.0	4.3	369.2
2013	1.7	60.2	198.8	93.1	62.6	42.7	26.6	15.2	7.1	3.3	1.3	0.4	513.0
2014	0.2	0.2	0.6	0.7	42.0	52.4	49.0	35.3	23.7	14.0	6.4	2.4	226.7
Average	3.4	19.7	58.3	93.6	104.6	90.3	64.4	43.7	26.2	16.0	8.1	3.4	531.9
Minimum	68.2	149.3	237.4	368.2	349.5	296.0	165.4	95.7	56.5	30.9	18.3	9.0	1,195.0
Maximum	0.0	0.0	0.0	0.7	11.9	19.7	16.9	8.2	3.1	1.0	0.2	0.0	97.5

Table C-3. UF 4 – Stony Creek at Black Butte Simulated Flow (TAF)

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1922	0.3	4.2	35.4	83.5	68.4	105.4	59.2	30.4	7.6	1.6	0.0	0.1	396.2
1923	10.6	26.7	52.5	77.2	39.4	22.6	38.3	16.1	1.5	1.5	0.1	1.5	288.0
1924	25.0	9.4	25.0	16.8	65.9	31.6	8.2	1.8	0.2	0.0	1.0	0.7	185.7
1925	8.3	55.3	58.0	36.6	151.4	72.9	61.6	28.9	7.4	1.7	0.1	1.6	483.7
1926	2.5	13.4	48.6	15.7	144.5	50.0	24.0	12.5	1.2	0.0	0.0	0.6	312.9
1927	4.1	11.5	179.7	72.1	149.2	118.9	51.0	11.1	3.7	2.3	0.1	0.0	603.8
1928	0.0	42.7	55.8	90.3	114.8	55.4	98.0	20.0	1.6	0.3	0.0	0.1	479.0
1929	1.1	32.3	48.3	35.6	68.4	34.9	19.8	11.4	4.4	5.2	0.4	0.0	261.7
1930	0.2	0.2	61.2	60.3	45.5	100.2	38.8	15.4	2.2	0.2	0.0	0.6	324.6
1931	1.8	8.9	23.9	80.6	50.8	37.8	22.2	2.9	8.0	11.8	1.3	0.3	250.2
1932	0.9	12.2	36.3	152.0	32.3	27.1	32.3	23.9	4.6	0.6	0.0	0.0	322.3
1933	0.1	1.7	34.4	59.2	44.3	48.2	49.8	20.4	4.4	0.1	0.0	0.0	262.8
1934	0.2	12.2	33.7	146.4	31.9	25.1	32.0	9.4	2.4	0.9	0.0	0.0	294.3
1935	1.3	50.8	52.1	74.1	49.6	94.3	57.1	29.8	3.3	0.1	0.0	0.3	412.6
1936	4.3	6.9	14.7	217.1	99.0	65.1	48.5	13.2	22.0	14.8	1.2	0.3	507.2
1937	0.1	0.4	2.2	32.0	76.2	127.0	100.6	44.3	22.8	23.4	2.4	0.0	431.6
1938	7.4	90.6	215.2	106.3	191.1	208.5	87.0	24.7	3.8	0.6	0.0	0.0	935.5
1939	10.8	12.7	145.1	75.7	54.4	54.1	37.8	10.9	7.3	1.3	0.0	0.3	410.5
1940	3.7	2.0	51.2	159.7	98.9	130.4	58.1	15.6	5.1	1.2	0.0	0.1	526.0
1941	0.8	29.3	56.1	221.2	174.6	151.5	80.0	27.8	6.8	2.8	0.7	0.2	751.7
1942	0.4	11.2	105.9	118.8	162.7	45.6	36.9	27.8	9.3	1.7	0.0	0.3	520.5
1943	0.7	10.5	75.5	143.0	106.9	65.4	37.8	22.3	4.7	1.3	0.1	0.0	468.4
1944	0.5	11.9	20.2	46.5	72.1	51.7	16.1	16.0	6.9	6.3	0.7	0.0	248.8
1945	0.2	38.3	66.1	75.7	147.8	37.5	44.3	10.9	8.9	2.5	0.1	0.0	432.2
1946	0.3	38.7	110.5	182.4	35.2	42.4	47.7	10.6	0.9	0.3	3.0	0.6	472.6
1947	6.0	10.7	59.1	21.2	57.2	83.6	32.8	6.0	4.5	3.9	0.3	0.0	285.2
1948	11.5	37.3	13.2	86.4	34.6	26.5	58.3	38.0	20.0	9.7	0.6	2.2	338.4
1949	9.6	22.4	42.4	42.2	11.3	136.8	64.2	31.4	10.3	1.6	0.2	0.1	372.4
1950	8.0	16.3	15.9	29.3	63.4	54.5	70.4	24.6	4.3	2.6	0.1	0.2	289.6
1951	1.7	45.1	108.6	93.6	136.9	48.6	20.1	24.1	4.7	0.1	0.0	0.0	483.4
1952	1.1	14.0	118.9	124.0	83.4	50.1	43.8	36.8	8.2	8.5	3.3	0.6	492.8
1953	1.7	35.8	167.5	221.8	64.3	40.4	25.3	18.3	17.0	7.5	0.5	1.5	601.5
1954	1.7	22.5	136.6	171.6	167.2	69.5	47.3	16.0	31.0	20.5	1.7	6.3	692.0
1955	6.5	26.1	148.5	56.3	32.7	39.9	28.5	35.2	7.7	0.9	0.0	0.1	382.6
1956	1.3	9.5	109.8	243.7	125.7	118.7	38.0	28.3	7.1	2.5	0.2	0.3	685.4
1957	1.4	15.1	48.2	59.0	55.4	122.7	50.5	17.3	3.2	0.2	0.0	0.0	373.0
1958	40.8	40.8	54.3	113.8	270.5	212.0	89.1	23.2	10.0	7.0	1.2	0.2	862.9
1959	3.1	9.7	17.7	106.7	109.7	82.0	52.9	11.4	1.4	0.1	0.0	1.0	395.8
1960	6.1	1.3	2.3	34.9	194.9	110.8	32.0	15.5	11.5	1.7	0.0	0.0	411.0
1961	1.4	10.0	124.0	40.2	155.3	67.3	38.5	14.5	4.0	0.8	0.6	1.6	458.4
1962	3.6	19.2	127.9	33.7	72.1	110.5	35.7	23.3	4.1	1.8	2.6	2.4	436.8
1963	21.5	53.6	106.7	35.0	84.2	50.9	92.0	37.6	5.4	0.4	0.0	0.0	487.2
1964	9.4	44.9	103.1	101.2	70.6	34.0	35.8	7.6	1.9	1.1	0.0	0.2	409.9
1965	0.1	87.8	137.9	260.6	59.3	29.6	59.1	30.0	3.2	0.1	4.9	6.1	678.8
1966	6.0	51.7	65.8	198.0	84.4	109.3	37.4	7.0	0.3	0.0	0.0	0.7	560.6
1967	0.9	23.9	181.9	65.1	110.0	41.3	46.9	31.1	30.6	12.5	0.8	0.2	545.2
1968	5.0	13.2	129.5	88.3	109.2	89.1	47.0	15.7	3.9	0.3	3.2	15.1	519.5
1969	2.2	30.6	127.7	190.4	141.5	108.4	58.4	32.9	28.2	8.9	0.6	0.0	729.7
1970	4.2	20.1	72.9	224.8	165.5	66.1	17.9	6.5	1.4	1.4	0.2	0.0	581.2

Table C-3. UF 4 – Stony Creek at Black Butte Simulated Flow (TAF) contd.

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1971	0.9	36.4	233.8	218.1	72.2	57.5	76.4	19.5	2.7	0.8	0.1	0.3	718.7
1972	2.9	24.9	55.4	89.0	117.2	99.3	61.8	13.5	4.5	1.7	0.1	0.3	470.7
1973	9.2	60.8	93.7	97.5	138.4	133.9	71.8	35.8	5.9	0.4	0.0	0.1	647.5
1974	4.5	73.0	150.9	151.0	100.6	95.8	73.2	27.1	3.3	3.3	2.7	0.2	685.6
1975	0.1	27.0	63.0	128.8	92.8	179.2	109.9	35.2	9.9	1.2	1.7	1.5	650.3
1976	9.5	55.5	60.5	79.2	27.7	68.4	28.4	11.0	0.8	1.0	13.3	15.6	371.1
1977	3.7	3.6	5.9	25.6	15.0	48.6	31.7	9.6	3.9	0.2	0.0	0.3	148.3
1978	3.4	8.0	43.3	179.9	146.6	104.0	47.4	17.4	2.0	0.2	0.0	1.2	553.3
1979	1.8	4.2	36.7	56.4	65.8	85.8	33.5	16.7	3.3	0.1	0.0	0.7	305.0
1980	4.5	47.1	55.1	128.7	109.0	133.9	28.2	10.0	2.8	0.9	0.0	0.0	520.3
1981	0.4	0.9	21.4	35.4	91.6	49.6	23.2	5.9	1.8	0.2	0.0	0.0	230.4
1982	3.5	48.4	122.4	150.6	62.2	58.7	82.1	26.5	2.4	4.2	0.9	0.1	562.1
1983	2.8	66.0	131.8	109.8	156.3	231.7	77.6	40.2	9.4	0.6	0.2	3.0	829.3
1984	2.7	40.6	139.8	113.1	28.5	24.5	16.9	8.1	0.8	0.0	0.0	0.0	375.0
1985	5.5	62.7	81.4	23.2	21.2	23.9	27.0	6.0	0.3	0.0	0.0	1.7	252.9
1986	3.5	10.0	67.9	48.2	238.9	243.1	56.2	8.8	0.8	0.0	0.0	0.2	677.6
1987	1.6	6.4	5.0	26.1	52.4	83.0	33.6	5.0	0.2	0.0	0.0	0.0	213.4
1988	0.4	13.4	128.5	146.4	37.7	7.5	2.5	10.5	4.8	2.8	0.1	0.0	354.6
1989	0.0	13.0	54.6	56.5	17.4	64.7	47.2	11.4	2.7	0.4	0.0	2.9	270.8
1990	12.4	33.0	11.7	53.9	51.3	26.5	5.6	0.9	16.7	5.0	0.3	0.2	217.6
1991	0.4	2.7	3.1	7.8	25.7	108.9	72.4	15.4	4.9	1.7	0.7	0.0	243.7
1992	0.0	4.2	5.7	41.3	80.3	82.1	31.3	9.1	0.7	2.6	0.9	0.0	258.4
1993	0.7	15.3	119.0	224.5	195.2	108.4	28.2	17.8	25.2	7.1	0.3	0.0	741.6
1994	0.7	3.1	33.0	31.5	80.1	50.5	8.0	9.7	4.7	0.2	0.0	0.0	221.5
1995	0.3	16.2	69.0	348.9	240.6	218.1	118.9	35.3	9.8	4.2	0.9	0.1	1,062.4
1996	0.0	0.1	3.5	35.7	168.9	139.8	33.6	20.3	15.1	2.0	0.0	0.0	419.0
1997	0.2	14.8	139.1	263.9	139.9	40.7	24.1	7.2	3.0	1.0	0.1	0.9	634.9
1998	5.0	24.9	114.3	165.1	331.6	213.2	93.8	26.5	32.1	10.0	1.2	0.6	1,018.4
1999	2.0	34.2	98.5	28.0	89.2	99.9	66.3	24.6	3.7	0.2	0.0	0.0	446.6
2000	0.0	25.1	48.8	36.5	113.3	88.8	25.4	15.4	6.6	1.6	0.0	0.4	362.0
2001	0.4	10.7	32.7	40.0	60.3	131.1	27.7	5.2	0.6	0.4	0.0	0.0	309.2
2002	0.5	30.8	147.7	121.5	29.8	17.5	6.4	2.0	1.1	0.1	0.0	0.0	357.3
2003	0.0	8.8	131.5	200.1	46.7	44.5	50.5	79.9	17.2	1.2	0.5	1.1	582.0
2004	0.6	15.4	119.1	154.3	101.2	102.0	18.8	3.2	0.5	0.0	0.0	0.0	515.2
2005	1.7	24.2	82.4	191.1	59.3	51.4	52.6	31.5	19.0	7.4	0.8	0.0	521.4
2006	0.0	10.8	109.5	260.4	70.8	114.0	100.4	35.0	7.9	1.2	0.0	0.0	709.9
2007	0.2	3.4	38.8	58.4	56.2	58.3	11.6	3.4	0.6	0.2	0.8	0.0	231.8
2008	2.0	6.0	16.0	139.8	144.7	41.4	7.2	2.0	1.1	0.1	0.0	0.0	360.2
2009	5.9	26.6	19.8	31.6	51.4	129.5	31.6	9.7	8.0	1.4	0.0	0.0	315.5
2010	3.5	9.1	17.3	100.0	143.8	64.2	52.0	36.7	11.2	2.6	0.1	0.2	440.7
2011	2.4	44.3	32.0	8.0	0.6	0.1	0.0	0.0	0.0	0.0	0.0	0.0	87.3
2012	0.0	0.0	0.0	9.6	43.6	26.2	70.7	19.2	1.5	0.0	0.0	0.0	170.9
2013	0.0	4.7	188.6	126.2	19.1	4.1	4.1	1.9	0.1	0.5	0.1	0.0	349.5
2014	0.3	0.2	2.2	0.7	18.3	105.4	37.9	10.7	0.7	0.5	0.1	0.0	177.0
Average	3.7	23.3	74.9	102.8	93.4	81.4	45.3	18.6	6.8	2.6	0.6	0.8	454.3
Minimum	40.8	90.6	233.8	348.9	331.6	243.1	118.9	79.9	32.1	23.4	13.3	15.6	1,062.4
Maximum	0.0	0.0	0.0	0.7	0.6	0.1	0.0	0.0	0.0	0.0	0.0	0.0	87.3

Table C-4. Sacramento Valley West Side Minor Streams (Thomes and Elder Creeks only) Simulated Flow (TAF)

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1922	1.7	1.6	27.4	24.8	56.5	41.8	21.9	13.4	8.7	6.4	4.2	2.6	211.1
1923	3.1	12.9	60.7	35.8	22.2	13.4	18.8	10.2	7.5	6.5	4.6	3.3	198.9
1924	3.6	2.9	4.0	7.4	29.9	11.4	8.7	6.8	4.6	3.1	2.0	1.2	85.6
1925	2.8	15.5	23.5	21.6	102.8	35.5	29.9	16.2	11.5	8.3	6.0	4.1	277.8
1926	3.1	2.7	6.9	37.3	64.9	20.4	39.8	13.2	8.2	6.0	4.0	2.5	209.0
1927	2.2	46.5	43.4	51.2	116.2	47.3	40.3	14.0	8.9	6.6	4.4	2.7	383.7
1928	1.9	18.4	28.6	30.9	38.4	59.9	36.8	14.5	8.7	6.4	4.2	2.5	251.2
1929	1.6	8.2	13.8	15.5	29.1	15.3	10.7	8.1	6.2	5.1	3.6	2.5	119.6
1930	1.8	1.2	52.3	35.0	39.0	38.3	20.0	13.0	8.5	6.1	4.0	2.5	221.7
1931	1.9	2.5	2.8	29.1	14.3	21.9	11.8	8.7	7.0	5.6	3.8	2.5	111.8
1932	2.1	3.5	60.8	37.2	21.8	14.5	10.5	9.9	7.7	6.1	4.4	3.0	181.5
1933	2.1	1.4	9.7	28.2	21.5	37.3	17.6	14.0	9.2	7.0	5.0	3.2	156.2
1934	2.3	4.0	41.3	33.1	25.5	24.3	14.5	10.4	7.5	5.8	4.0	2.6	175.3
1935	6.6	19.3	22.3	62.4	40.8	37.4	54.9	18.8	10.4	7.1	4.7	2.8	287.4
1936	2.2	2.2	10.2	90.6	83.3	31.1	32.0	12.4	9.6	7.4	5.3	3.6	290.1
1937	2.5	1.7	2.1	6.5	43.7	65.3	32.2	17.0	10.9	8.3	5.8	3.7	199.6
1938	4.3	48.9	84.5	68.8	144.9	137.0	43.8	16.9	9.6	6.7	4.3	2.6	572.3
1939	2.6	6.2	19.2	20.2	19.6	24.9	11.6	8.5	7.0	5.3	3.6	2.4	131.2
1940	2.1	1.6	24.6	82.8	108.6	85.0	30.0	17.2	10.4	7.4	5.1	3.2	377.9
1941	2.6	6.3	96.3	138.5	140.2	78.8	66.9	21.2	11.9	8.1	5.8	3.7	580.3
1942	2.5	4.8	90.3	78.0	107.0	29.4	46.5	21.3	11.8	8.0	5.7	3.7	409.0
1943	2.6	8.7	34.4	87.0	30.7	39.8	26.8	15.4	10.5	7.5	5.3	3.4	272.0
1944	2.4	2.7	4.2	25.6	33.7	30.8	14.4	11.6	8.5	6.6	4.9	3.3	148.7
1945	3.5	18.7	35.7	38.5	51.4	31.0	19.2	14.0	9.5	7.1	4.9	3.1	236.5
1946	12.2	21.0	118.2	52.8	25.0	19.9	14.1	9.3	6.6	4.7	3.1	2.0	288.9
1947	1.4	8.9	20.3	10.1	26.1	40.4	20.2	11.8	8.7	6.8	4.6	2.9	162.2
1948	8.2	8.6	9.1	40.4	14.8	24.2	59.1	22.8	14.9	9.9	6.7	4.5	223.2
1949	3.5	2.8	11.7	11.4	14.8	81.6	22.4	13.2	8.5	6.1	3.9	2.4	182.2
1950	1.6	2.3	3.2	24.5	39.0	37.6	24.0	14.9	9.2	6.9	4.8	3.0	171.2
1951	19.8	21.0	67.6	76.6	57.0	26.7	14.1	15.0	8.6	6.3	4.2	2.6	319.6
1952	2.2	15.4	90.7	79.7	64.7	57.7	20.7	13.3	8.3	7.0	5.0	3.1	367.8
1953	2.2	3.3	90.1	118.6	26.7	34.0	24.7	13.9	13.3	8.5	6.3	4.3	346.0
1954	3.1	10.5	13.7	107.8	68.4	60.4	49.5	17.7	10.4	7.6	5.2	3.7	358.0
1955	2.7	11.4	46.0	26.2	14.4	11.9	14.9	11.4	7.7	5.8	3.9	2.5	158.9
1956	1.7	5.0	123.6	147.0	109.5	32.6	17.3	14.7	9.0	6.8	4.6	2.9	474.8
1957	7.5	4.8	4.0	18.0	37.8	45.6	22.8	22.1	13.6	8.9	6.4	4.4	196.0
1958	21.4	19.1	41.4	84.5	210.6	97.0	74.0	19.8	12.4	8.5	6.0	3.9	598.7
1959	2.7	1.9	3.2	61.7	67.8	23.3	15.2	10.1	6.9	4.9	3.1	2.3	203.1
1960	2.2	1.5	1.9	13.2	87.9	50.9	19.8	17.7	11.2	7.9	5.7	3.7	223.6
1961	2.6	5.9	41.2	39.7	41.1	36.2	18.2	13.3	9.0	6.9	5.0	3.2	222.3
1962	2.3	11.2	27.3	15.1	63.0	47.1	16.7	10.6	7.2	5.3	3.6	2.3	211.6
1963	37.4	14.9	31.2	40.3	46.8	41.7	68.2	23.3	12.9	8.4	5.8	3.6	334.4
1964	3.1	31.0	18.1	43.2	16.7	13.8	9.6	7.7	5.9	4.4	2.9	2.0	158.2
1965	1.5	25.9	153.2	112.7	29.0	17.0	48.6	16.4	9.2	6.6	4.5	3.0	427.5
1966	1.9	20.5	23.6	70.1	39.3	31.3	15.1	10.1	7.0	5.2	3.4	2.1	229.7
1967	1.4	20.6	62.2	90.2	26.4	46.3	44.2	22.6	17.1	9.4	6.5	4.1	350.9
1968	3.1	3.7	28.0	63.1	66.2	37.4	16.9	10.6	7.2	5.2	3.4	2.7	247.5
1969	2.2	6.7	81.3	124.4	136.4	44.9	21.3	13.3	8.3	6.3	4.2	2.6	451.8
1970	2.8	3.8	73.5	196.6	61.5	43.4	15.9	9.7	6.6	4.8	3.0	1.9	423.5

Table C-4. UF 5 — Sacramento Valley West Side Minor Streams (Thomes and Elder Creeks only) Simulated Flow (TAF) contd.

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1971	1.6	47.8	93.3	66.3	19.9	52.3	20.2	13.6	8.8	6.8	4.6	2.8	337.9
1972	2.0	3.3	22.3	24.2	34.2	28.2	17.9	12.5	8.5	6.5	4.4	2.8	167.1
1973	4.3	29.4	38.6	94.2	105.2	55.1	21.1	11.9	7.5	5.3	3.3	2.0	377.9
1974	5.6	82.2	82.8	107.3	65.3	88.3	47.9	17.7	10.1	7.4	5.3	3.2	523.0
1975	2.1	2.5	14.9	27.0	83.7	125.3	31.7	19.1	10.7	7.3	5.1	3.1	332.6
1976	6.1	8.4	14.6	11.0	25.6	21.2	16.6	10.3	7.1	5.2	3.7	2.8	132.6
1977	2.1	1.6	1.6	6.0	4.4	7.5	7.3	7.6	6.1	4.5	3.0	2.3	54.1
1978	2.2	10.6	52.5	126.8	84.2	81.2	37.8	17.1	9.6	7.0	4.8	3.2	437.1
1979	2.3	1.7	2.1	22.1	52.2	35.3	17.5	15.6	9.5	7.1	5.0	3.1	173.5
1980	10.3	22.5	42.9	57.3	99.3	50.2	31.3	13.1	8.6	6.5	4.3	2.7	349.1
1981	2.1	1.6	16.9	44.1	40.1	47.1	20.9	13.5	8.8	6.3	4.2	2.6	208.1
1982	5.4	39.4	90.4	45.3	64.5	75.5	69.9	21.1	11.7	8.4	5.9	3.8	441.1
1983	4.9	28.1	77.4	96.9	138.0	199.9	79.7	36.4	16.0	9.6	6.6	4.8	698.4
1984	3.7	49.1	125.3	30.6	41.3	34.5	17.8	13.0	8.4	6.4	4.4	2.9	337.4
1985	2.6	43.6	28.7	16.6	16.8	15.3	14.5	10.8	7.5	5.7	3.8	3.0	169.0
1986	2.7	4.5	23.8	52.2	143.3	94.6	23.8	15.6	9.4	6.9	4.8	3.3	384.9
1987	2.8	1.9	2.7	18.0	38.1	57.6	20.7	12.8	8.1	6.0	3.9	2.3	174.8
1988	1.5	2.1	51.5	48.0	22.8	15.2	13.8	14.3	10.1	7.7	5.7	3.7	196.3
1989	2.5	17.5	15.1	17.2	12.4	79.7	26.2	18.6	10.8	7.6	5.3	4.1	216.9
1990	11.0	7.8	7.0	31.1	14.6	22.4	13.4	18.3	16.3	10.0	7.1	4.8	163.7
1991	3.3	2.6	2.4	2.8	8.4	60.6	26.4	16.2	9.9	7.4	5.3	3.3	148.6
1992	2.2	2.2	4.5	12.9	52.2	44.9	29.0	15.3	9.1	7.2	5.1	3.2	187.7
1993	2.4	4.8	49.2	69.9	69.8	71.8	42.3	38.5	22.8	12.9	8.2	5.5	398.1
1994	4.0	2.9	16.3	19.5	41.1	24.5	13.7	13.0	8.7	6.5	4.4	2.8	157.3
1995	1.9	4.0	15.8	213.5	52.7	179.9	59.5	32.2	16.1	10.5	7.1	4.6	597.9
1996	3.0	1.8	1.1	18.2	64.5	39.8	23.8	21.7	13.9	9.0	6.3	4.0	207.1
1997	2.7	7.9	118.4	119.3	36.8	31.5	15.8	11.0	7.8	6.2	4.4	3.2	365.1
1998	3.4	21.8	34.2	121.2	204.4	120.4	50.0	36.3	22.9	12.8	8.0	5.2	640.6
1999	3.5	24.7	25.1	27.5	69.2	66.5	43.3	19.7	11.4	7.8	5.4	3.3	307.4
2000	2.3	6.7	13.3	46.8	83.2	50.1	26.8	15.6	10.2	7.4	5.2	3.4	270.9
2001	2.5	3.6	6.6	15.1	33.2	40.3	16.4	11.1	7.4	5.7	3.8	2.4	148.0
2002	1.8	15.5	69.8	61.7	36.9	28.9	15.9	10.9	7.6	5.6	3.7	2.3	260.7
2003	1.5	4.0	112.7	60.5	37.8	47.8	61.0	38.2	15.9	9.5	6.5	4.1	399.4
2004	2.6	3.6	55.5	40.7	106.9	45.8	19.6	12.3	8.0	6.0	3.9	2.4	307.2
2005	3.0	6.6	52.9	42.6	31.7	57.8	33.7	46.2	18.0	11.7	7.9	5.5	317.4
2006	3.7	5.5	121.9	81.1	75.2	87.9	116.2	31.4	16.3	10.0	6.8	4.4	560.3
2007	2.9	2.8	22.1	15.5	37.2	25.5	17.8	13.6	8.7	6.5	4.7	3.0	160.4
2008	3.0	3.3	10.6	54.5	30.8	30.4	20.5	14.5	9.3	6.9	4.8	3.0	191.7
2009	3.5	5.3	6.3	8.7	38.8	47.2	19.7	23.8	11.3	8.0	5.6	3.5	181.7
2010	3.9	4.0	11.0	48.9	47.5	53.1	50.6	24.3	16.1	10.4	7.1	4.8	281.6
2011	10.1	13.7	10.8	10.7	20.0	89.4	68.6	37.6	23.9	14.8	9.1	6.2	314.9
2012	7.3	5.3	4.2	4.2	4.5	24.3	30.9	19.5	11.6	7.9	5.6	3.5	128.9
2013	2.3	13.1	63.9	22.5	13.3	14.3	17.5	11.7	7.9	6.3	4.2	2.6	179.7
2014	1.9	1.2	1.3	1.1	11.9	45.4	20.9	13.4	8.5	6.6	4.5	2.7	119.3
Average	4.0	11.8	38.9	51.8	54.7	48.3	29.4	16.5	10.2	7.2	4.9	3.2	280.9
Minimum	1.4	1.2	1.1	1.1	4.4	7.5	7.3	6.8	4.6	3.1	2.0	1.2	54.1
Maximum	37.4	82.2	153.2	213.5	210.6	199.9	116.2	46.2	23.9	14.8	9.1	6.2	698.4

Table C-5. UF 7 — Sacramento Valley Eastside Minor Streams Simulated Flow (TAF)

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1922	27.8	30.8	147.3	108.1	322.7	186.3	151.6	186.4	130.8	45.3	28.9	23.0	27.8
1923	32.1	78.7	285.8	164.6	94.1	66.5	171.0	71.6	44.9	23.8	15.5	21.0	32.1
1924	26.2	19.8	43.0	61.5	119.9	50.2	52.4	19.4	11.1	10.6	9.8	9.8	26.2
1925	37.0	53.1	117.4	77.8	301.0	81.0	144.2	57.5	36.3	21.4	16.2	15.8	37.0
1926	23.1	35.7	58.7	71.4	281.8	69.3	195.2	43.2	24.4	14.1	11.2	11.6	23.1
1927	24.5	172.4	88.3	176.3	377.7	133.1	198.2	110.6	55.6	35.1	22.8	20.2	24.5
1928	26.3	118.2	86.7	95.3	120.5	386.9	135.5	56.1	36.3	20.1	20.7	17.1	26.3
1929	18.5	48.4	79.4	57.7	104.5	86.6	81.8	51.5	39.2	19.7	16.8	13.1	18.5
1930	11.2	11.6	224.0	166.4	137.9	200.7	116.0	70.7	32.7	25.3	19.8	15.0	11.2
1931	12.6	34.6	14.7	94.2	67.0	70.3	33.5	23.0	12.9	5.6	4.0	6.4	12.6
1932	23.7	40.3	153.1	128.7	122.0	72.5	98.2	100.1	50.8	16.6	12.6	11.1	23.7
1933	14.6	14.3	33.8	67.1	45.0	119.5	64.2	80.1	33.6	11.6	10.1	9.1	14.6
1934	19.1	22.1	114.1	128.5	132.1	55.0	31.4	25.2	17.1	7.4	6.0	8.0	19.1
1935	15.1	70.1	58.1	171.4	82.7	148.1	255.6	103.0	35.1	19.4	14.0	12.7	15.1
1936	24.7	21.4	43.3	295.4	376.4	82.3	131.6	51.6	41.9	23.4	15.2	12.3	24.7
1937	11.5	15.4	32.2	61.6	193.1	228.8	165.8	111.6	45.8	23.3	16.3	12.2	11.5
1938	21.5	94.9	249.5	121.4	384.4	351.4	166.0	145.3	73.1	38.0	25.8	19.4	21.5
1939	29.6	32.9	60.7	72.8	78.7	107.2	58.1	35.2	13.2	7.9	7.1	10.0	29.6
1940	19.1	12.0	39.6	324.6	328.2	294.8	156.7	51.1	30.0	20.5	15.8	14.0	19.1
1941	22.7	54.9	280.6	328.1	293.8	195.1	204.6	114.9	52.6	35.8	24.6	19.3	22.7
1942	24.1	42.5	279.7	289.9	298.8	99.8	188.4	131.2	66.8	33.3	22.7	19.1	24.1
1943	19.7	93.4	147.8	315.9	159.8	262.1	111.1	67.1	49.8	25.9	15.2	12.6	19.7
1944	18.2	23.6	56.5	98.5	146.0	152.4	78.3	79.7	34.3	16.4	12.1	10.4	18.2
1945	15.4	113.8	108.8	64.0	301.8	119.5	88.4	71.8	36.4	21.2	14.6	11.2	15.4
1946	25.4	99.9	299.8	150.5	84.0	105.0	107.1	77.1	31.0	20.9	15.3	13.1	25.4
1947	17.9	71.9	79.4	34.3	120.5	140.1	76.3	27.8	25.1	11.0	8.5	8.2	17.9
1948	48.2	42.7	26.5	106.6	53.0	118.1	226.0	131.0	57.6	23.7	18.3	15.8	48.2
1949	16.3	30.4	62.1	44.4	72.3	227.2	98.9	81.8	22.8	15.3	12.2	9.3	16.3
1950	13.3	27.9	36.0	188.4	198.9	135.6	129.9	94.6	38.4	17.9	14.7	13.8	13.3
1951	40.0	259.1	304.3	240.4	170.6	153.0	93.6	89.5	36.2	27.1	18.1	13.1	40.0
1952	38.6	76.9	227.6	315.3	225.3	192.4	193.9	160.5	108.9	59.3	30.2	25.3	38.6
1953	24.2	35.1	156.0	318.3	59.3	129.6	129.5	121.0	78.4	26.4	19.9	17.5	24.2
1954	24.7	58.1	77.2	167.5	173.6	177.7	181.9	62.2	33.2	19.2	14.7	13.9	24.7
1955	15.7	41.9	139.6	120.8	62.1	76.1	89.6	90.7	28.7	18.3	13.3	13.2	15.7
1956	15.2	34.8	583.3	397.6	183.5	117.7	100.3	140.9	71.6	32.0	24.5	22.5	15.2
1957	35.7	39.0	48.8	80.1	163.2	182.0	88.1	116.0	32.1	18.5	14.1	15.1	35.7
1958	34.4	41.7	120.1	156.3	370.8	242.4	248.2	143.0	99.2	40.0	28.2	24.6	34.4
1959	26.4	30.1	37.1	169.4	184.4	92.7	70.8	40.1	16.8	12.2	11.1	18.8	26.4
1960	10.2	10.5	22.1	113.8	225.2	161.0	79.1	57.8	23.3	15.2	12.0	10.7	10.2
1961	13.2	70.6	70.6	47.7	150.6	121.5	68.5	53.5	25.7	14.7	10.0	9.5	13.2
1962	10.3	21.8	84.7	63.5	330.4	140.6	94.5	68.1	30.2	19.5	15.3	12.1	10.3
1963	223.1	43.2	174.6	126.2	247.4	120.4	260.7	117.0	41.0	26.9	20.9	17.6	223.1
1964	25.9	125.2	67.1	148.1	59.0	86.1	85.7	71.1	33.6	16.3	11.9	11.8	25.9
1965	14.2	86.1	540.0	336.0	86.4	94.2	184.9	100.0	48.4	28.9	27.1	19.4	14.2
1966	19.3	91.4	85.8	155.3	111.0	113.5	117.0	48.0	23.9	12.6	10.6	9.8	19.3
1967	10.4	110.7	226.2	304.6	142.9	188.1	170.7	166.7	93.9	36.7	26.7	25.3	10.4
1968	28.4	32.3	106.5	144.2	233.0	128.1	78.1	53.1	28.1	14.2	14.8	12.1	28.4
1969	24.4	78.1	155.9	574.1	260.9	138.4	164.2	148.7	78.5	37.7	27.7	24.5	24.4
1970	36.5	45.2	247.9	601.8	139.7	152.1	61.9	54.0	41.2	20.8	12.9	12.8	36.5

Table C-5. UF 7 — Sacramento Valley Eastside Minor Streams Simulated Flow (TAF) contd.

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1971	23.8	120.0	258.4	161.5	70.8	182.6	110.5	105.7	61.4	29.5	20.3	17.2	23.8
1972	22.1	40.2	111.8	99.4	128.7	101.5	105.1	52.2	26.0	16.2	11.5	14.3	22.1
1973	27.7	105.1	105.1	332.8	228.2	182.5	102.6	97.4	41.3	27.6	18.9	17.4	27.7
1974	30.0	271.9	233.1	317.8	121.6	330.8	204.6	99.4	54.6	49.6	28.0	20.0	30.0
1975	23.7	45.5	62.0	79.2	236.3	240.2	114.6	127.3	72.7	32.2	27.1	16.9	23.7
1976	44.9	49.6	51.2	32.4	57.5	73.3	49.3	21.2	11.5	8.8	14.1	11.6	44.9
1977	10.4	16.6	10.6	46.4	37.7	33.5	14.9	25.7	6.4	4.6	4.9	7.0	10.4
1978	9.0	34.9	143.3	371.0	173.7	241.5	170.7	110.8	60.8	27.2	22.0	23.5	9.0
1979	16.9	46.1	49.4	157.9	171.7	157.9	102.1	114.6	31.7	21.2	17.4	12.7	16.9
1980	39.3	66.0	94.1	397.7	422.3	161.4	100.9	69.5	46.0	27.6	17.8	12.7	39.3
1981	21.3	18.6	137.4	151.3	140.3	211.0	73.3	50.5	24.0	16.3	10.2	13.5	21.3
1982	84.9	478.6	336.2	162.4	297.5	268.0	416.1	174.2	65.4	63.4	43.8	44.1	84.9
1983	108.6	192.2	277.2	321.4	414.5	653.1	250.1	268.5	152.3	81.3	65.4	51.6	108.6
1984	51.0	323.8	482.3	168.9	176.4	228.8	130.0	90.1	59.6	26.9	21.8	24.9	51.0
1985	48.4	219.3	79.9	55.7	98.3	135.1	124.9	47.1	25.1	14.4	12.5	37.9	48.4
1986	21.7	61.9	80.1	237.6	767.7	334.5	105.6	98.2	48.8	36.2	23.6	61.2	21.7
1987	32.9	30.6	47.3	80.9	166.2	282.4	112.4	56.7	22.1	17.9	11.6	8.3	32.9
1988	12.1	36.0	235.7	155.4	87.5	120.6	83.4	61.3	36.9	13.6	9.8	5.9	12.1
1989	8.0	154.2	53.8	59.2	90.7	513.3	152.8	49.5	37.1	24.8	20.0	37.7	8.0
1990	99.2	40.0	29.7	152.6	61.2	165.5	55.4	76.4	56.8	13.4	11.1	9.9	99.2
1991	12.2	21.0	18.1	17.3	56.1	280.1	164.3	81.6	24.3	19.6	9.4	8.7	12.2
1992	20.1	31.5	63.8	53.8	267.5	174.0	83.5	33.2	25.5	22.7	8.1	5.4	20.1
1993	28.9	31.9	129.8	263.1	258.0	318.5	257.3	268.1	183.9	47.0	41.9	30.4	28.9
1994	55.2	41.8	130.5	101.3	151.0	151.7	88.6	62.2	20.9	12.4	8.8	8.8	55.2
1995	12.7	55.7	103.9	704.3	169.0	658.6	351.9	366.6	135.2	64.6	54.8	39.8	12.7
1996	37.4	35.3	208.1	209.7	394.8	243.1	239.0	197.2	62.1	34.6	21.7	28.0	37.4
1997	31.2	99.5	525.0	616.0	125.0	157.3	87.1	58.1	53.1	28.6	22.4	21.6	31.2
1998	40.5	117.9	132.6	442.6	506.7	275.2	231.7	358.4	230.7	82.5	64.7	55.9	40.5
1999	62.6	188.1	191.5	187.3	308.7	233.2	198.8	139.9	61.3	31.7	26.5	20.1	62.6
2000	31.3	95.8	57.9	220.3	400.3	257.8	172.7	75.5	53.8	32.2	19.4	20.6	31.3
2001	42.3	35.2	49.3	82.8	128.3	183.2	131.6	50.8	25.1	14.6	10.8	12.5	42.3
2002	13.4	121.1	187.4	203.8	121.8	154.0	155.6	62.7	32.9	21.3	17.0	11.9	13.4
2003	10.6	76.6	412.1	339.5	135.6	226.0	236.7	204.7	63.4	41.2	34.4	22.1	10.6
2004	17.6	50.2	217.0	135.1	371.3	197.4	142.0	70.6	47.5	23.3	15.1	13.1	17.6
2005	62.7	45.8	131.1	157.3	140.9	225.1	146.3	208.2	69.4	35.8	23.2	15.3	62.7
2006	20.6	92.3	511.6	325.2	227.9	396.6	470.2	286.8	112.7	64.4	58.1	40.8	20.6
2007	37.3	67.5	152.4	52.2	237.7	134.3	85.3	38.1	19.5	17.4	11.8	15.1	37.3
2008	30.3	22.4	64.1	150.3	132.2	128.9	120.9	115.0	26.4	17.4	14.7	11.1	30.3
2009	23.2	81.9	43.0	79.3	269.5	268.1	120.0	104.6	40.8	23.4	16.8	12.0	23.2
2010	34.1	37.1	79.1	243.4	175.7	165.7	224.7	208.3	93.4	40.0	26.9	24.3	34.1
2011	68.3	77.5	291.1	110.3	172.2	394.8	225.3	293.6	165.7	68.8	47.2	33.0	68.3
2012	53.0	52.6	30.6	101.1	69.6	207.6	166.0	43.8	22.9	12.5	10.3	8.9	53.0
2013	14.7	66.1	322.0	84.7	59.8	90.3	56.2	23.8	18.8	10.8	9.3	10.5	14.7
2014	5.1	10.4	5.7	6.1	84.0	144.7	70.9	9.3	8.8	6.3	4.5	5.2	5.1
Average	30.2	72.8	147.5	183.6	192.4	187.5	140.7	100.3	50.4	26.2	19.4	17.7	30.2
Minimum	5.1	10.4	5.7	6.1	37.7	33.5	14.9	9.3	6.4	4.6	4.0	5.2	5.1
Maximum	223.1	478.6	583.3	704.3	767.7	658.6	470.2	366.6	230.7	82.5	65.4	61.2	223.1

Table C-6. UF 8 — Feather River near Oroville Simulated Flow (TAF)

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1922	71.5	76.2	337.7	247.4	404.3	473.8	703.9	1,042.4	553.5	314.6	150.4	84.9	4,460.5
1923	117.8	185.1	422.6	318.4	298.2	441.6	672.8	376.8	259.2	133.3	78.2	82.8	3,386.7
1924	86.9	55.6	70.0	96.2	379.0	133.8	216.4	110.6	71.4	60.6	50.6	40.4	1,371.6
1925	93.0	161.5	182.8	234.9	731.9	530.0	624.3	416.2	235.4	111.1	75.5	71.2	3,467.7
1926	81.6	85.3	117.5	180.4	653.3	546.1	866.4	400.5	177.2	101.1	70.8	57.3	3,337.4
1927	95.0	540.3	294.6	394.5	767.7	720.3	830.4	556.3	361.1	179.4	96.8	67.5	4,904.1
1928	88.8	430.0	244.5	257.4	333.9	1,034.7	685.5	412.0	228.8	117.8	76.3	60.2	3,970.0
1929	55.6	119.5	107.3	102.8	199.4	305.5	343.4	287.5	244.5	111.8	69.5	57.0	2,003.9
1930	52.0	40.4	854.5	391.6	455.6	744.7	604.1	409.2	205.2	106.9	72.5	63.4	4,000.2
1931	60.0	89.8	56.9	190.6	170.3	381.5	210.8	163.1	118.5	66.9	53.7	43.3	1,605.4
1932	83.3	94.9	236.2	207.6	214.7	580.7	633.3	556.9	344.2	173.3	88.9	64.2	3,278.2
1933	61.2	66.1	76.4	128.3	157.0	488.8	513.6	422.5	248.5	120.3	76.0	61.3	2,420.1
1934	121.9	93.6	311.1	428.0	514.7	445.6	313.7	194.4	114.9	69.6	57.2	46.7	2,711.4
1935	61.5	211.1	190.5	433.5	330.2	439.3	1,184.1	743.3	418.8	223.4	116.0	74.9	4,426.6
1936	95.1	68.2	112.9	829.1	977.2	681.4	660.2	406.4	263.6	119.2	73.8	64.8	4,351.8
1937	54.3	43.7	46.7	64.0	251.1	533.3	770.0	729.2	418.4	211.5	105.5	70.2	3,298.0
1938	109.2	412.1	1,108.3	460.3	749.3	844.3	1,013.7	1,100.1	575.5	339.4	162.9	99.1	6,974.2
1939	109.7	100.0	127.5	123.0	112.9	394.2	331.4	242.4	118.3	70.7	58.5	48.0	1,836.6
1940	59.9	44.6	143.0	1,023.6	1,227.4	1,381.8	936.3	560.8	323.9	157.2	88.9	70.2	6,017.7
1941	100.5	236.5	712.5	756.8	1,082.3	1,039.6	918.6	741.2	405.2	218.2	110.7	77.0	6,399.1
1942	73.1	148.6	839.0	823.8	817.5	593.0	963.7	815.9	463.8	262.3	128.0	77.1	6,006.0
1943	68.6	228.4	321.8	913.4	661.5	1,011.6	770.6	514.7	344.4	154.3	83.4	63.0	5,135.8
1944	62.6	91.7	102.0	202.4	311.4	560.1	555.9	463.2	255.7	128.5	79.0	60.7	2,873.3
1945	88.7	439.1	370.8	244.9	930.9	483.0	547.7	500.5	278.1	139.9	81.0	61.8	4,166.3
1946	155.8	302.9	782.0	505.4	280.9	534.0	620.6	465.1	240.7	128.1	76.9	62.4	4,154.9
1947	63.3	279.7	307.3	109.2	564.1	709.4	482.6	238.4	163.2	82.5	63.1	51.8	3,114.5
1948	175.3	178.2	85.1	636.7	170.2	329.3	817.6	711.6	474.6	248.5	129.3	80.2	4,036.7
1949	66.7	142.1	133.4	83.0	136.1	447.3	673.6	510.1	285.1	142.7	84.9	65.2	2,770.4
1950	59.2	104.4	77.1	270.0	762.9	707.4	808.8	627.8	345.7	183.8	102.1	72.7	4,121.9
1951	248.4	780.0	1,125.7	687.9	713.6	692.8	543.4	490.4	248.2	129.5	79.0	61.0	5,799.8
1952	114.7	222.7	640.8	497.1	611.6	539.0	1,138.8	1,327.8	770.8	428.9	233.0	120.4	6,645.5
1953	86.8	111.4	406.1	1,289.6	463.7	558.0	659.4	541.0	353.0	184.2	103.6	66.8	4,823.6
1954	91.7	189.4	168.9	484.5	723.5	861.7	825.1	453.7	256.5	126.0	79.8	61.9	4,322.7
1955	57.8	181.7	368.2	200.9	153.0	327.3	372.6	474.8	274.6	138.5	78.0	62.7	2,690.2
1956	70.9	114.8	1,668.9	1,258.9	678.0	738.8	754.7	840.9	478.2	269.6	144.6	90.6	7,109.0
1957	118.0	129.7	83.4	155.0	553.1	741.4	544.9	538.7	272.4	136.7	82.2	78.6	3,433.9
1958	148.3	143.2	377.5	485.4	1,075.2	829.9	1,040.3	864.5	503.0	290.5	142.7	84.2	5,984.6
1959	78.2	81.7	96.4	570.3	505.2	568.5	395.2	270.6	132.4	79.1	63.4	78.7	2,919.6
1960	53.2	39.4	55.6	247.2	776.1	900.5	577.6	426.5	221.6	108.3	72.8	61.6	3,540.3
1961	61.1	204.0	283.0	245.4	537.1	539.1	436.9	353.2	212.2	103.8	69.8	57.6	3,103.2
1962	50.9	99.9	270.6	161.7	680.7	515.1	879.7	633.4	372.7	194.8	109.3	69.6	4,038.3
1963	1,002.6	261.9	622.4	419.8	1,019.8	550.5	938.2	582.1	298.5	157.9	91.2	72.5	6,017.3
1964	94.2	350.9	206.0	312.3	220.3	330.5	415.0	350.5	240.3	115.6	71.0	63.1	2,769.8
1965	57.9	242.4	1,721.3	1,263.8	581.7	720.5	806.8	521.9	332.8	167.9	127.8	73.3	6,618.0
1966	61.5	321.2	213.0	358.3	232.8	570.2	630.0	368.0	180.5	97.8	68.9	57.8	3,160.0
1967	50.5	410.5	738.2	906.1	733.8	791.4	564.1	871.9	585.7	339.8	169.6	96.3	6,257.9
1968	119.6	97.4	186.2	330.5	756.0	797.4	573.0	389.1	208.5	109.4	87.7	63.2	3,718.0
1969	122.4	218.1	294.2	1,227.8	624.4	657.3	1,016.6	1,058.0	581.5	338.7	172.4	93.5	6,404.8
1970	127.8	144.4	759.8	2,039.3	991.0	832.4	474.8	360.5	214.9	116.6	72.4	58.8	6,192.7

Table C-6. UF 8 — Feather River near Oroville Simulated Flow (TAF) contd.

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1971	92.4	459.0	575.0	391.3	327.5	817.0	783.6	602.7	426.1	248.0	121.1	81.7	4,925.4
1972	72.4	109.4	125.9	176.4	358.4	692.6	596.9	360.5	188.3	100.1	70.4	65.4	2,916.8
1973	130.1	272.3	231.3	717.0	675.2	561.9	728.0	658.5	358.0	197.9	106.0	85.2	4,721.4
1974	143.9	1,052.9	668.3	993.9	488.8	1,209.4	1,066.5	719.0	419.6	273.2	128.8	74.7	7,239.0
1975	83.8	111.7	155.8	148.1	550.0	710.0	474.9	749.9	434.4	256.0	149.3	83.4	3,907.3
1976	187.1	165.2	145.3	78.2	152.8	250.7	225.9	132.4	82.2	63.2	64.5	54.8	1,602.3
1977	45.4	62.4	38.5	56.3	56.4	65.8	99.6	117.5	61.7	51.8	43.3	45.8	744.6
1978	40.0	63.4	406.0	1,301.6	753.1	1,376.2	995.9	758.9	395.1	212.4	113.4	103.4	6,519.4
1979	65.8	87.2	80.7	290.4	420.1	652.3	557.2	556.7	300.6	152.7	91.5	68.2	3,323.3
1980	181.0	203.0	216.2	1,334.8	1,144.9	736.5	625.9	522.5	323.3	171.2	89.6	70.8	5,619.7
1981	65.7	67.0	326.2	360.3	545.7	702.3	576.8	398.8	200.6	108.2	71.1	73.7	3,496.5
1982	191.9	1,208.8	1,235.4	699.8	1,144.3	1,030.5	1,415.3	841.6	422.0	245.6	119.6	98.9	8,653.6
1983	245.1	363.2	438.2	819.1	1,334.0	1,769.5	1,030.9	1,167.5	908.0	462.4	264.5	146.7	8,949.1
1984	138.2	766.9	1,066.3	531.7	548.3	954.0	680.8	546.4	368.6	177.8	99.5	69.9	5,948.1
1985	101.4	416.4	229.1	133.0	281.6	346.5	618.7	346.5	186.6	99.8	70.2	97.5	2,927.2
1986	76.9	119.0	270.7	742.5	2,306.7	1,516.1	734.8	549.1	328.7	168.8	91.4	145.8	7,050.3
1987	99.7	67.8	77.2	125.6	353.3	574.0	393.3	251.4	121.5	81.0	62.9	51.3	2,259.1
1988	45.9	72.8	358.1	281.5	335.0	398.4	288.2	201.8	118.7	72.1	59.6	47.4	2,279.5
1989	39.4	314.9	157.4	174.6	215.9	1,341.7	771.3	440.2	259.1	120.3	81.5	89.7	4,005.9
1990	219.0	125.8	93.3	268.6	166.6	473.5	366.3	335.8	245.1	104.7	73.7	59.4	2,531.9
1991	57.7	53.5	59.4	46.5	82.9	588.0	498.1	338.5	190.1	107.8	73.3	58.2	2,154.0
1992	72.9	81.3	109.0	154.7	529.8	585.0	422.1	222.3	135.1	88.8	64.2	51.7	2,516.8
1993	89.2	77.1	246.1	515.5	452.8	1,057.9	1,092.1	1,094.9	722.8	377.6	199.8	101.2	6,027.0
1994	116.8	93.4	267.9	196.1	269.8	605.1	334.9	265.3	126.8	75.1	60.7	50.0	2,461.9
1995	50.7	122.8	252.6	1,792.3	828.9	1,884.5	1,278.5	1,302.6	800.1	447.4	243.7	120.2	9,124.3
1996	78.1	68.2	565.8	467.5	1,203.3	983.0	881.1	756.3	373.4	209.1	105.0	81.1	5,771.9
1997	78.4	219.8	1,271.1	2,085.9	652.5	800.7	540.4	391.7	247.8	120.2	75.9	68.2	6,552.7
1998	104.6	247.2	319.9	1,112.9	1,059.6	1,020.7	966.7	928.7	739.3	407.5	220.4	125.9	7,253.4
1999	98.2	364.5	434.8	507.7	748.9	760.7	686.0	616.0	393.7	216.3	115.6	70.7	5,012.9
2000	87.3	164.9	127.0	538.2	1,031.0	971.3	785.1	533.8	306.1	161.4	91.9	68.5	4,866.5
2001	110.0	84.0	106.3	154.7	229.4	512.1	338.5	198.4	103.0	75.9	61.1	49.6	2,022.8
2002	50.7	213.2	512.3	519.2	469.2	645.3	527.1	369.6	182.0	101.9	69.7	57.0	3,717.1
2003	48.9	255.8	1,021.8	1,127.8	564.4	730.3	698.8	663.4	313.4	160.0	106.9	69.5	5,761.0
2004	59.3	92.4	404.5	349.1	802.6	929.3	640.2	423.2	219.8	110.4	71.7	58.5	4,160.9
2005	155.3	148.2	590.4	429.7	491.5	972.0	871.3	1,101.4	595.0	326.2	162.8	89.7	5,933.5
2006	76.9	151.3	1,484.2	1,259.0	937.3	1,134.1	1,539.6	1,107.8	610.5	362.0	190.1	92.6	8,945.6
2007	74.1	122.2	296.0	163.8	597.6	551.2	417.9	298.1	165.6	82.2	62.1	54.0	2,884.8
2008	78.0	62.3	137.6	303.7	353.8	390.2	350.9	388.4	235.5	127.1	69.0	55.8	2,552.3
2009	99.4	207.5	100.9	220.3	624.7	904.1	523.5	695.9	327.8	152.7	82.3	62.3	4,001.2
2010	143.9	74.8	145.5	630.5	540.8	626.1	812.3	789.7	520.8	307.4	146.8	80.9	4,819.5
2011	254.7	251.9	947.1	502.1	556.0	1,195.4	930.4	893.1	627.3	309.3	155.2	88.2	6,710.7
2012	147.1	82.9	60.0	223.1	152.8	799.6	762.0	417.2	202.6	108.4	75.4	58.7	3,089.7
2013	70.6	450.1	1,356.1	515.1	369.2	446.6	319.4	172.0	111.8	74.8	57.3	56.1	3,999.2
2014	42.5	52.4	35.3	31.9	415.4	708.1	422.8	184.3	96.0	70.6	63.4	46.8	2,169.5
Average	105.4	207.2	395.7	508.3	574.2	715.7	672.4	546.7	320.1	172.7	99.7	72.1	4,390.1
Minimum	1,002.6	1,208.8	1,721.3	2,085.9	2,306.7	1,884.5	1,539.6	1,327.8	908.0	462.4	264.5	146.7	9,124.3
Maximum	39.4	39.4	35.3	31.9	56.4	65.8	99.6	110.6	61.7	51.8	43.3	40.4	744.6

Table C-7. UF 9 — Yuba River at Smartville Simulated Flow (TAF)

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1922	6.8	16.5	225.0	78.3	326.5	281.8	337.9	884.6	470.7	29.3	13.8	10.4	2,681.4
1923	17.1	156.6	478.9	143.3	64.4	124.9	372.7	290.8	211.0	29.8	13.8	50.7	1,954.1
1924	26.7	16.7	36.0	84.7	281.3	37.4	114.2	66.6	16.0	12.5	8.5	3.6	704.2
1925	122.6	136.3	185.6	140.5	581.5	203.5	411.3	400.0	189.6	20.0	13.9	13.8	2,418.4
1926	30.5	77.9	79.8	251.6	432.4	175.4	566.9	211.4	23.1	13.5	10.5	5.4	1,878.3
1927	58.4	609.3	81.9	272.2	529.3	246.0	463.7	535.2	423.7	40.6	13.9	10.8	3,284.7
1928	35.9	342.3	105.3	98.3	137.6	929.7	268.6	320.5	54.5	14.5	11.6	6.8	2,325.7
1929	3.5	39.8	60.1	33.5	106.5	157.7	216.9	318.5	218.7	20.7	13.0	9.1	1,197.9
1930	4.6	2.4	756.3	163.6	183.6	320.8	359.1	210.5	173.9	17.4	12.6	10.1	2,214.9
1931	6.8	75.8	19.6	140.9	117.6	263.6	179.5	154.3	60.2	15.2	12.1	8.7	1,054.3
1932	103.7	48.0	251.0	76.7	161.6	316.3	435.2	593.0	309.9	27.2	13.5	10.2	2,346.4
1933	5.7	9.0	13.2	39.6	20.9	291.2	313.7	349.1	213.0	18.8	13.0	9.6	1,296.7
1934	174.2	28.1	275.5	183.9	322.8	256.8	153.7	55.8	43.2	14.5	11.4	16.4	1,536.2
1935	47.7	229.5	124.3	214.6	217.3	177.7	834.7	459.4	187.4	17.2	12.7	8.8	2,531.3
1936	30.6	11.2	65.5	662.5	860.5	255.6	398.2	353.7	239.6	19.1	12.9	9.8	2,919.2
1937	6.8	4.3	12.5	14.5	205.6	405.1	433.8	696.5	211.9	20.9	13.4	9.8	2,035.1
1938	35.0	305.3	789.0	277.5	476.0	576.2	469.6	719.3	548.3	39.1	15.2	11.6	4,262.1
1939	44.0	44.6	69.9	101.0	35.7	301.3	283.0	193.3	23.0	13.8	10.9	6.1	1,126.5
1940	49.1	14.7	77.5	836.0	956.2	801.6	264.9	419.5	200.2	17.1	12.6	8.9	3,658.3
1941	21.3	144.8	654.5	410.1	605.6	325.9	358.7	549.8	388.4	60.8	15.2	12.1	3,547.3
1942	14.0	113.1	679.0	545.8	420.7	163.4	584.4	541.2	438.6	78.5	14.6	11.5	3,604.7
1943	7.9	283.9	329.7	701.5	205.6	584.2	426.6	411.8	218.7	26.2	13.5	10.5	3,220.0
1944	19.1	26.3	49.8	164.6	273.0	228.4	258.2	390.4	120.4	18.8	13.5	10.6	1,573.1
1945	189.4	296.4	264.0	118.7	644.7	145.1	306.7	402.1	184.4	18.9	13.0	9.8	2,593.2
1946	192.9	185.9	728.3	148.8	102.1	203.1	370.2	408.8	70.1	16.0	12.8	11.9	2,451.0
1947	7.8	202.6	172.5	21.4	310.1	508.2	220.6	171.6	113.8	15.2	11.8	7.2	1,762.9
1948	232.9	68.8	20.4	439.9	53.2	189.4	534.4	511.2	301.2	26.1	14.0	10.9	2,402.5
1949	7.1	89.0	73.6	18.5	44.2	357.5	509.8	347.4	43.5	15.3	12.1	8.5	1,526.5
1950	5.8	48.4	22.0	291.2	367.2	354.7	481.1	511.6	171.8	18.7	13.1	9.9	2,295.4
1951	193.1	974.7	832.8	344.3	242.3	228.4	386.9	408.5	100.5	16.2	12.5	8.6	3,748.8
1952	125.1	223.9	465.3	256.9	332.1	201.0	637.4	904.3	553.7	145.5	18.7	13.1	3,876.9
1953	10.7	33.8	235.3	673.4	74.5	274.3	516.9	376.4	335.3	112.6	15.6	12.2	2,671.0
1954	28.6	156.6	74.5	347.6	349.6	411.7	592.5	217.7	59.2	15.6	12.3	8.4	2,274.3
1955	5.8	133.1	307.3	72.5	60.3	141.4	223.4	456.0	133.5	18.0	12.9	10.9	1,575.0
1956	8.5	38.7	1,606.3	621.8	163.9	196.3	374.6	626.9	418.5	54.2	15.6	13.6	4,138.8
1957	111.8	21.1	36.0	104.9	600.7	442.8	320.2	600.3	104.0	16.9	12.7	19.7	2,391.2
1958	101.5	132.8	300.2	342.1	700.6	339.3	497.3	803.9	438.2	48.6	15.4	13.3	3,733.2
1959	11.3	20.3	47.9	366.8	224.9	255.5	296.5	147.5	31.8	14.4	11.9	71.3	1,499.9
1960	11.4	10.3	31.4	206.5	580.4	538.7	300.1	310.6	166.8	16.8	12.7	9.4	2,195.2
1961	6.3	133.6	111.5	182.5	204.9	282.9	208.9	281.7	102.7	16.6	12.7	9.4	1,553.6
1962	9.0	106.9	110.8	82.1	608.2	213.3	536.9	347.6	240.8	20.7	14.2	11.4	2,302.1
1963	1,097.8	97.9	389.1	661.0	423.9	219.8	497.4	514.9	195.4	20.8	13.6	11.6	4,143.1
1964	51.9	425.4	47.4	200.7	49.7	131.8	227.8	299.7	191.1	20.8	14.6	11.1	1,671.9
1965	16.1	182.4	1,540.4	386.3	160.9	228.1	464.4	360.9	347.1	42.6	69.5	16.1	3,814.8
1966	13.5	241.1	88.9	129.8	74.9	272.4	475.2	175.8	19.9	13.8	11.3	7.1	1,523.7
1967	4.5	400.9	422.2	585.5	128.5	344.3	165.1	744.8	621.7	139.1	16.1	12.7	3,585.4
1968	42.7	54.0	59.7	179.9	474.7	349.7	207.2	191.6	66.2	15.9	27.9	11.2	1,680.7
1969	77.3	246.9	217.7	1,035.8	248.5	212.9	550.5	776.5	354.2	41.1	14.4	11.5	3,787.3
1970	65.6	53.7	640.4	1,343.2	203.0	230.1	115.0	328.7	273.3	21.7	13.5	10.7	3,298.8

Table C-7. UF 9 — Yuba River at Smartville Simulated Flow (TAF) contd.

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1971	33.1	512.0	288.4	129.0	94.1	463.4	327.2	395.0	464.0	105.5	16.5	24.3	2,852.4
1972	11.3	55.3	66.0	67.1	275.8	366.8	335.7	307.9	68.5	15.3	12.3	28.5	1,610.5
1973	105.1	268.8	207.9	519.0	389.6	176.9	364.2	694.5	162.4	18.0	13.1	21.4	2,940.9
1974	106.9	908.4	396.9	463.2	187.7	652.0	398.9	554.9	466.4	180.8	18.2	12.4	4,346.5
1975	38.1	38.5	71.5	104.1	328.8	336.8	200.1	746.2	441.9	26.0	22.2	12.9	2,367.2
1976	153.3	94.6	66.5	29.1	150.3	51.1	119.1	137.3	30.0	14.4	39.5	24.9	910.3
1977	12.7	25.6	10.0	19.5	31.1	27.3	69.6	149.3	45.5	16.2	12.6	14.9	434.2
1978	10.0	60.3	359.8	673.7	234.5	612.5	469.6	586.3	492.9	80.3	15.5	68.0	3,663.6
1979	13.5	25.8	23.1	223.1	238.7	346.0	414.7	606.4	102.2	18.1	13.2	10.8	2,035.6
1980	150.4	158.5	185.5	864.2	670.5	207.1	389.0	395.9	328.7	121.5	16.2	12.3	3,499.8
1981	12.1	34.6	91.8	179.3	213.6	337.2	306.7	217.0	29.8	14.6	11.9	13.7	1,462.3
1982	157.0	1,022.7	992.5	129.5	580.5	404.7	739.4	597.9	414.5	114.4	16.6	46.1	5,215.8
1983	294.0	445.8	317.8	356.5	542.6	743.3	328.6	722.1	801.1	316.2	28.9	58.7	4,955.5
1984	140.2	737.9	564.8	99.0	255.7	378.1	288.8	467.5	311.3	25.9	15.0	12.1	3,296.3
1985	35.7	335.8	65.3	33.8	112.1	174.6	428.6	195.8	42.9	15.3	12.5	31.0	1,483.3
1986	19.0	95.7	178.3	487.8	1,393.8	695.3	241.7	352.6	291.4	20.5	13.4	101.2	3,890.6
1987	33.9	21.2	32.7	107.1	288.6	291.0	293.0	133.1	18.7	14.0	11.9	8.3	1,253.4
1988	5.9	43.0	283.7	197.6	139.8	167.4	271.4	198.6	67.7	18.1	13.3	10.7	1,417.2
1989	7.8	345.6	53.9	70.8	121.7	1,027.8	537.9	340.7	134.7	17.4	18.7	52.3	2,729.2
1990	240.9	136.5	23.2	266.0	61.8	257.4	292.4	418.1	76.0	17.9	13.1	11.7	1,815.1
1991	11.2	12.0	26.5	20.9	80.3	510.0	290.1	368.1	215.3	24.0	17.5	12.4	1,588.4
1992	92.0	57.9	96.4	89.3	390.5	284.6	297.3	74.8	74.7	21.8	13.2	10.3	1,502.6
1993	117.0	27.3	220.9	512.7	263.2	619.0	477.9	714.0	447.1	47.4	16.5	12.4	3,475.3
1994	33.2	81.7	163.3	105.9	166.7	205.2	214.9	175.7	25.1	14.5	12.0	8.5	1,206.6
1995	11.3	95.8	243.0	1,121.4	182.1	1,048.8	558.5	772.5	608.8	401.6	31.4	13.8	5,088.9
1996	11.9	10.0	554.8	372.7	724.1	398.5	581.0	734.6	110.7	18.5	13.3	15.0	3,545.1
1997	20.0	257.9	1,357.5	1,173.8	107.5	275.4	212.7	387.6	165.2	19.1	13.9	13.0	4,003.5
1998	61.9	227.2	161.5	729.9	510.3	417.0	409.8	557.9	541.3	290.0	19.6	21.0	3,947.4
1999	21.3	374.6	159.3	456.9	487.0	169.3	270.9	459.8	353.4	38.5	17.1	12.4	2,820.5
2000	53.7	171.5	44.3	501.9	649.1	259.7	437.2	446.9	119.2	17.4	13.0	18.8	2,732.8
2001	78.4	42.4	76.8	77.2	106.7	340.7	269.1	222.2	20.4	14.7	12.2	9.7	1,270.5
2002	28.8	181.1	414.7	191.9	261.1	388.8	343.0	329.9	99.2	17.3	13.1	10.5	2,279.4
2003	7.7	236.9	662.9	341.6	162.1	397.8	356.3	520.5	150.9	18.0	18.8	12.8	2,886.2
2004	13.4	48.7	409.4	144.5	396.9	380.3	309.8	241.7	36.5	15.2	12.6	9.6	2,018.6
2005	121.8	67.8	266.2	250.8	220.2	458.9	267.5	704.2	306.5	33.2	14.3	11.8	2,723.1
2006	18.3	115.6	1,300.7	310.0	401.6	379.9	776.4	681.3	368.4	27.4	14.3	11.8	4,405.6
2007	9.5	72.1	262.7	81.5	476.9	220.2	272.5	186.1	33.1	14.9	12.3	9.5	1,651.3
2008	60.8	40.6	129.2	187.5	158.9	216.9	215.4	331.0	44.1	16.5	12.9	10.2	1,423.8
2009	54.7	142.1	31.9	115.9	403.4	418.2	271.0	561.6	54.6	15.3	12.5	9.6	2,090.6
2010	90.3	29.3	97.1	318.2	230.9	244.6	390.9	416.8	343.2	35.1	15.1	12.1	2,223.7
2011	319.2	157.2	731.6	116.9	136.0	479.1	480.4	524.5	735.5	309.8	20.4	13.5	4,024.1
2012	68.7	17.4	13.9	201.3	52.9	540.0	577.4	324.3	90.8	17.0	13.0	10.7	1,927.3
2013	17.9	370.0	754.5	59.9	49.0	231.4	217.6	95.0	58.1	16.1	12.7	20.7	1,902.9
2014	10.2	18.7	11.1	27.5	411.4	384.8	273.3	82.5	17.4	13.3	11.7	10.7	1,272.5
Average	69.0	167.1	287.5	293.8	304.2	340.7	366.8	413.8	219.7	44.5	15.3	16.1	2,538.3
Minimum	1,097.8	1,022.7	1,606.3	1,343.2	1,393.8	1,048.8	834.7	904.3	801.1	401.6	69.5	101.2	5,215.8
Maximum	3.5	2.4	10.0	14.5	20.9	27.3	69.6	55.8	16.0	12.5	8.5	3.6	434.2

Table C-8. UF 10 — Bear River near Wheatland Simulated Flow (TAF)

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1922	2.4	4.0	28.3	31.4	69.8	78.4	69.7	33.9	6.9	3.5	3.0	2.6	334.0
1923	4.5	25.4	119.6	43.2	36.6	16.5	45.7	6.5	4.2	2.0	0.6	0.7	305.5
1924	3.6	2.8	8.2	12.2	36.5	4.5	4.6	1.0	0.0	0.0	0.0	0.0	73.6
1925	4.4	12.8	33.9	26.3	106.9	15.5	33.0	7.0	3.2	0.5	0.1	0.5	244.1
1926	1.7	5.6	11.0	36.4	90.1	11.4	49.3	4.8	1.3	0.2	0.0	0.1	211.9
1927	2.1	76.3	22.7	46.6	125.0	49.3	64.9	12.0	5.9	2.9	2.1	2.8	412.5
1928	3.7	34.6	25.5	29.4	35.9	135.2	28.2	6.5	3.1	1.6	0.6	0.7	305.0
1929	1.9	5.1	15.8	15.8	35.7	26.8	21.8	4.2	2.5	1.0	0.0	0.0	130.6
1930	0.0	0.0	80.6	24.1	39.7	56.6	15.5	6.1	1.7	0.2	0.0	0.1	224.7
1931	0.6	5.1	5.9	29.1	26.6	24.5	3.7	1.2	0.6	0.3	0.0	0.0	97.7
1932	2.6	6.2	24.6	27.4	54.4	69.7	34.5	13.1	3.9	1.2	0.5	0.5	238.6
1933	1.4	2.2	3.2	4.3	4.8	71.7	24.0	14.5	2.3	0.2	0.0	0.0	128.6
1934	6.3	3.9	39.6	45.8	44.7	11.6	4.5	2.4	1.0	0.1	0.0	0.0	160.0
1935	0.7	26.2	13.4	36.7	53.9	40.3	88.9	10.3	3.7	2.1	1.0	1.2	278.4
1936	3.3	4.8	10.7	114.7	146.5	37.6	40.1	8.8	6.3	2.6	1.4	1.9	378.8
1937	2.6	3.7	4.6	4.9	29.9	106.4	91.6	15.1	5.5	2.5	1.4	1.9	270.0
1938	3.4	29.3	99.1	43.8	65.7	113.4	112.4	38.9	10.3	7.0	5.2	5.2	533.8
1939	8.8	11.8	15.2	13.0	24.0	53.8	12.4	4.6	2.2	0.3	0.0	0.0	146.3
1940	0.9	1.3	5.6	124.0	133.2	113.0	32.0	8.8	4.3	2.3	1.4	2.3	429.2
1941	3.7	17.9	95.5	82.4	109.7	54.7	48.0	19.7	7.9	4.6	3.6	4.0	451.6
1942	5.0	13.0	82.3	100.2	86.3	43.7	71.6	32.9	8.9	4.4	3.1	3.6	455.1
1943	4.5	42.4	54.4	130.4	57.4	103.5	22.8	10.9	7.6	3.8	2.3	2.2	442.4
1944	3.7	5.8	10.6	24.4	57.9	57.9	20.9	6.0	3.4	0.8	0.1	0.0	191.5
1945	4.0	48.9	39.7	21.1	114.0	29.0	31.2	8.2	3.9	0.8	0.1	0.1	300.9
1946	10.3	29.7	107.3	39.5	33.3	34.9	25.9	5.1	3.0	0.8	0.2	0.4	290.3
1947	1.4	18.7	30.3	9.1	49.4	53.8	14.5	3.0	1.9	0.4	0.0	0.0	182.6
1948	10.2	9.1	4.2	45.7	12.0	30.6	84.3	32.0	5.6	2.0	0.9	1.0	237.5
1949	2.1	6.8	5.6	4.6	12.8	84.2	66.3	7.6	2.8	0.7	0.4	0.6	194.5
1950	1.5	5.6	4.0	48.1	96.0	62.5	49.4	10.5	4.1	1.6	1.0	1.3	285.6
1951	10.4	166.4	122.4	66.0	69.5	60.0	19.6	23.4	5.8	3.3	2.3	2.6	551.7
1952	10.0	35.7	92.7	49.7	89.4	63.7	99.7	54.5	12.4	7.2	5.8	6.0	526.9
1953	6.6	10.9	28.6	118.6	32.9	44.2	46.4	21.1	9.1	3.1	2.2	2.2	325.9
1954	3.5	15.5	17.7	48.0	66.7	62.6	45.7	8.2	4.1	1.6	0.8	1.4	275.8
1955	2.0	9.9	49.6	25.1	25.9	33.4	24.3	16.8	2.3	0.7	0.1	0.1	190.2
1956	0.5	2.2	262.5	102.3	43.5	57.2	34.4	32.4	6.3	3.9	3.1	3.2	551.4
1957	8.9	8.5	9.6	14.4	83.4	74.6	23.4	42.7	5.3	2.1	1.4	1.6	275.8
1958	6.7	12.1	47.4	51.5	127.4	71.0	97.7	27.8	10.3	6.1	4.4	4.5	466.8
1959	5.6	8.0	8.9	62.1	46.5	40.9	10.6	5.4	2.0	0.3	0.0	1.7	192.0
1960	1.4	1.4	3.3	44.2	124.3	64.0	12.0	6.7	2.0	0.5	0.1	0.2	260.2
1961	0.5	17.5	25.8	19.9	40.4	34.8	10.0	8.9	2.1	0.1	0.0	0.0	160.0
1962	0.1	5.3	16.8	15.0	149.8	48.6	38.0	6.9	2.8	0.8	0.4	0.4	284.9
1963	134.8	14.6	54.4	96.2	65.7	24.2	92.2	26.2	5.6	3.3	1.7	2.0	520.9
1964	4.3	49.9	16.5	27.4	40.9	25.1	16.7	5.7	2.8	0.6	0.0	0.2	190.1
1965	0.2	19.3	239.2	103.9	44.4	31.7	52.1	10.3	5.6	3.0	2.5	2.8	515.1
1966	3.2	26.3	15.6	29.7	41.9	45.7	22.4	4.3	1.8	0.4	0.0	0.1	191.5
1967	0.3	39.2	74.7	96.4	49.3	68.1	36.0	52.3	8.5	3.7	2.4	2.6	433.4
1968	5.2	7.0	13.1	42.9	83.4	53.8	16.3	5.6	2.6	0.6	0.5	0.8	231.8
1969	3.1	23.7	30.5	190.3	58.1	67.4	77.8	38.4	9.0	5.1	3.2	3.6	510.3
1970	8.6	11.4	93.7	195.9	49.6	49.3	17.3	8.9	4.6	2.4	1.2	1.6	444.6

Table C-8. UF 10 — Bear River near Wheatland Simulated Flow (TAF) contd.

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1971	3.5	64.9	60.3	44.2	53.0	74.3	32.3	10.8	5.0	2.4	0.9	1.2	352.7
1972	2.8	7.1	10.0	31.3	65.5	44.3	20.6	4.8	1.8	0.4	0.1	0.2	188.9
1973	4.7	36.7	31.1	104.0	91.4	54.9	47.7	10.5	4.6	2.4	1.5	2.1	391.6
1974	6.8	115.6	75.2	80.7	53.3	114.0	66.4	26.1	7.8	9.0	4.5	4.0	563.6
1975	6.8	11.2	13.3	30.3	80.6	77.2	41.0	41.2	5.5	3.6	2.3	2.6	315.7
1976	10.7	13.7	12.8	8.1	25.0	15.4	6.3	1.6	0.1	0.0	0.3	0.6	94.4
1977	0.3	0.6	0.4	1.4	6.8	3.5	1.0	1.2	0.5	0.0	0.0	0.0	15.6
1978	0.1	1.6	48.5	130.6	48.4	101.7	63.5	25.0	5.6	3.7	1.9	4.6	435.4
1979	3.6	7.2	7.7	46.6	52.3	77.6	42.7	16.6	3.7	2.0	1.1	1.2	262.3
1980	6.1	17.3	27.4	151.6	130.6	52.9	33.0	12.1	6.7	4.0	2.2	2.6	446.5
1981	3.4	5.3	11.9	33.9	41.1	54.0	14.3	4.0	1.6	0.3	0.0	0.0	169.7
1982	6.6	103.8	138.2	41.2	122.2	84.9	118.3	28.1	11.7	8.2	5.9	7.9	677.1
1983	27.9	81.1	75.0	72.5	110.8	156.0	79.1	65.1	19.4	11.9	9.6	10.2	718.6
1984	15.4	114.2	109.3	59.3	61.9	60.5	22.8	12.4	6.7	3.5	2.7	2.8	471.7
1985	6.5	44.2	23.6	20.8	35.7	38.3	19.7	4.3	1.8	0.5	0.3	0.8	196.4
1986	1.2	14.5	33.9	71.5	250.0	105.3	20.1	10.6	5.1	3.3	2.0	7.0	524.4
1987	6.2	5.5	8.0	15.6	57.9	49.7	8.1	3.0	1.0	0.2	0.1	0.0	155.4
1988	0.2	3.0	29.3	40.9	34.4	19.3	7.3	3.7	1.3	0.1	0.0	0.0	139.6
1989	0.0	34.3	9.7	24.3	31.6	152.7	26.2	6.7	3.7	1.5	0.8	1.8	293.3
1990	10.2	14.3	8.4	49.2	27.9	42.8	6.6	11.7	7.6	1.0	0.2	0.3	180.2
1991	0.5	1.5	2.9	2.6	8.0	69.7	49.9	8.2	2.3	1.0	0.2	0.1	146.9
1992	2.1	5.1	11.6	16.5	75.7	41.3	8.1	2.8	0.7	0.8	0.1	0.0	164.8
1993	3.7	3.2	27.5	73.6	72.6	113.6	58.8	23.9	12.3	4.9	3.7	3.4	401.2
1994	5.3	13.0	27.4	23.0	41.6	34.1	6.2	5.0	1.5	0.2	0.0	0.1	157.4
1995	0.7	18.8	46.4	168.6	51.2	158.4	78.1	62.6	15.0	8.9	6.7	6.7	622.0
1996	7.9	8.8	55.8	51.2	136.8	75.4	50.9	41.4	9.2	5.4	4.0	4.8	451.6
1997	6.6	34.4	179.3	210.6	54.9	51.0	24.6	10.5	7.2	4.0	2.9	3.5	589.4
1998	6.9	24.5	35.0	118.4	100.8	83.2	61.5	55.9	17.4	7.7	5.7	6.7	523.7
1999	8.8	35.1	37.6	84.5	92.1	57.8	43.4	24.9	6.8	3.8	3.4	2.9	401.1
2000	4.2	16.2	11.0	87.3	105.1	71.0	36.6	14.6	5.5	3.5	2.2	3.2	360.5
2001	7.9	8.6	12.4	13.6	29.4	60.4	17.9	4.1	1.1	0.4	0.1	0.1	155.9
2002	0.4	14.1	48.1	44.9	57.1	69.9	30.1	7.7	3.3	1.2	0.7	0.9	278.4
2003	1.8	15.2	76.0	57.8	31.9	42.7	46.3	27.5	4.0	1.8	1.5	1.6	308.0
2004	2.0	6.3	44.5	29.6	72.6	56.5	10.2	4.9	2.3	0.7	0.3	0.4	230.5
2005	8.4	17.1	36.4	47.5	65.5	70.5	34.6	43.6	8.4	3.8	2.4	2.9	340.9
2006	4.2	8.7	191.1	68.0	69.6	69.5	132.7	38.3	11.2	7.1	6.5	6.4	613.3
2007	8.5	12.8	25.0	25.0	77.9	42.8	15.4	7.4	2.6	1.0	0.6	0.6	219.4
2008	4.4	5.7	13.1	19.0	39.2	68.5	14.0	3.9	1.6	0.2	0.0	0.0	169.8
2009	0.7	9.8	3.3	28.5	51.2	63.9	16.9	25.6	3.4	0.9	0.3	0.4	204.9
2010	3.5	3.7	14.2	40.9	52.3	49.8	45.5	18.8	5.8	2.1	1.2	1.4	239.2
2011	19.7	19.5	116.1	45.4	34.4	102.1	95.3	37.3	15.7	7.1	5.4	4.9	502.8
2012	10.7	9.3	8.5	21.3	20.7	114.0	62.3	10.2	4.4	2.2	0.9	1.0	265.6
2013	2.8	43.5	115.1	35.5	23.0	21.0	11.3	3.5	1.4	1.0	0.3	0.5	259.0
2014	0.8	1.0	1.8	1.5	80.0	46.1	15.3	2.5	0.5	0.6	0.1	0.2	150.5
Average	6.1	21.3	44.1	53.6	63.9	60.5	39.2	16.4	5.0	2.4	1.6	1.9	316.0
Minimum	134.8	166.4	262.5	210.6	250.0	158.4	132.7	65.1	19.4	11.9	9.6	10.2	718.6
Maximum	0.0	0.0	0.4	1.4	4.8	3.5	1.0	1.0	0.0	0.0	0.0	0.0	15.6

Table C-9. UF 11 — American River at Folsom Lake Simulated Flow (TAF)

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1922	3.7	4.3	220.4	216.6	382.2	324.8	384.1	865.5	459.4	113.3	26.9	11.7	3,012.9
1923	10.4	155.6	551.0	296.6	148.4	187.9	530.9	386.4	252.6	81.4	26.6	37.0	2,664.8
1924	44.8	24.9	25.0	63.0	179.1	64.1	156.5	96.3	30.9	18.6	6.7	2.3	712.2
1925	52.2	177.5	117.5	131.4	672.7	287.3	518.3	443.0	231.4	62.6	23.8	12.6	2,730.3
1926	24.3	34.5	86.8	122.5	543.5	252.0	495.1	212.1	51.1	23.4	10.2	2.5	1,857.9
1927	30.3	368.3	230.6	259.8	459.3	297.2	522.4	626.9	420.4	124.5	26.7	10.9	3,377.1
1928	26.4	198.9	134.0	112.6	164.7	808.7	352.4	403.7	197.7	38.2	17.1	5.6	2,460.0
1929	1.5	25.1	52.3	56.6	124.9	204.8	209.6	300.8	287.2	71.5	23.5	9.3	1,367.0
1930	2.7	1.5	426.3	165.9	150.8	402.2	407.4	275.3	194.6	43.9	19.5	7.8	2,097.9
1931	6.7	56.1	27.8	130.9	115.2	189.0	213.5	184.9	106.9	34.8	17.5	5.7	1,089.0
1932	36.1	58.8	216.5	172.0	213.1	282.5	418.7	621.3	392.6	104.9	25.9	10.8	2,553.2
1933	2.9	3.4	18.0	24.4	29.0	224.3	308.6	358.5	295.0	61.5	22.9	9.6	1,358.2
1934	88.9	103.3	237.9	231.7	214.9	264.7	232.9	104.0	80.0	29.6	16.6	7.0	1,611.3
1935	18.7	159.4	108.2	273.4	153.8	234.9	743.7	523.9	341.9	64.6	22.6	9.6	2,654.8
1936	23.3	22.2	31.4	545.6	772.6	390.2	559.0	497.8	382.0	73.8	23.8	11.8	3,333.4
1937	6.5	6.1	13.0	20.0	301.1	499.1	464.5	736.8	351.1	73.1	24.7	10.8	2,506.8
1938	15.2	125.1	757.4	198.6	487.9	590.3	555.9	795.7	629.3	155.8	31.8	15.6	4,358.6
1939	26.7	42.3	60.4	89.3	57.7	280.6	318.1	199.8	75.1	26.3	13.0	8.9	1,198.2
1940	37.3	24.2	40.6	674.0	703.0	831.7	456.9	483.6	259.5	47.6	19.6	6.8	3,584.8
1941	4.2	101.5	364.0	399.1	408.6	419.8	382.6	640.5	452.4	165.1	32.3	15.6	3,385.9
1942	6.8	90.1	397.6	499.5	451.1	209.6	525.7	605.6	512.2	203.1	35.1	15.3	3,551.6
1943	5.8	263.5	228.5	687.3	297.6	727.8	445.9	433.2	370.2	78.2	25.8	11.9	3,575.8
1944	4.9	9.3	28.3	75.6	197.1	289.6	323.7	387.6	194.1	40.2	21.1	9.0	1,580.5
1945	87.6	349.7	159.2	87.8	563.1	198.9	380.9	565.1	305.6	65.2	24.6	11.3	2,798.9
1946	114.5	236.4	553.7	269.1	77.8	249.9	397.5	493.1	218.3	39.0	20.6	8.9	2,678.9
1947	12.3	129.3	125.6	37.5	186.7	408.0	389.7	228.2	128.3	31.0	15.2	4.4	1,696.3
1948	145.1	111.7	29.0	205.8	44.1	174.2	562.9	622.9	390.2	104.9	26.3	11.5	2,428.7
1949	4.1	51.7	40.3	27.1	19.0	416.1	550.1	426.2	130.3	30.7	16.2	6.7	1,718.4
1950	4.0	36.9	27.1	211.9	338.4	339.8	621.1	576.9	284.5	49.9	21.2	8.7	2,520.6
1951	92.3	1,331.5	914.8	380.7	237.0	268.1	409.5	495.3	231.2	45.6	20.0	7.2	4,433.2
1952	86.0	163.3	321.3	378.3	321.6	316.5	708.5	986.9	621.2	243.4	47.4	21.5	4,215.9
1953	12.2	23.6	134.9	453.5	125.4	252.3	523.2	444.3	368.7	178.5	35.1	16.8	2,568.4
1954	10.5	87.2	85.9	177.1	275.3	465.4	602.5	397.1	116.4	31.5	16.8	5.9	2,271.6
1955	2.0	54.8	313.5	156.4	58.7	122.0	259.5	440.8	275.1	49.1	21.0	8.4	1,761.4
1956	4.7	7.3	1,302.5	594.7	180.7	226.7	448.4	843.2	495.8	190.2	38.1	18.6	4,350.8
1957	42.1	51.2	29.0	48.9	314.6	516.2	352.4	627.9	380.7	71.0	23.6	9.8	2,467.4
1958	42.7	74.5	192.5	227.3	559.9	487.3	697.0	964.7	535.5	185.8	37.3	20.5	4,024.9
1959	13.7	9.9	18.2	239.2	191.0	203.9	342.3	249.4	72.3	27.0	14.7	55.3	1,436.9
1960	32.6	17.0	11.1	99.7	404.9	464.1	439.7	343.7	223.9	43.6	19.0	7.3	2,106.6
1961	4.1	68.1	99.0	50.4	179.7	194.3	303.7	305.8	172.8	36.6	19.5	16.2	1,450.2
1962	12.0	20.6	109.2	42.1	399.6	267.7	684.9	449.3	256.3	52.1	22.8	10.0	2,326.7
1963	962.8	88.5	312.3	447.8	545.9	148.2	514.5	596.3	403.1	131.1	30.0	18.3	4,198.7
1964	58.5	273.2	104.0	105.4	50.7	140.9	284.6	359.2	284.0	63.1	23.8	11.1	1,758.4
1965	13.3	164.1	1,510.1	447.3	154.3	254.9	498.8	484.7	399.3	156.7	81.6	34.9	4,200.0
1966	20.9	149.0	110.0	116.4	90.0	226.2	467.2	266.0	49.4	23.9	11.3	3.6	1,534.0
1967	1.1	192.9	464.5	344.8	260.3	338.6	305.8	931.7	683.9	275.9	42.5	20.5	3,862.5
1968	50.4	47.8	75.0	122.0	271.7	376.7	287.6	253.6	109.6	30.7	21.3	15.0	1,661.5
1969	32.3	256.1	160.6	907.2	347.2	307.6	642.8	847.6	474.5	116.5	27.9	13.3	4,133.7
1970	71.8	112.8	396.8	1,034.0	290.9	261.5	151.2	412.4	380.7	90.8	25.4	10.8	3,239.2

Table C-9. UF 11 — American River at Folsom Lake Simulated Flow (TAF) contd.

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1971	7.5	340.5	387.7	105.5	93.6	414.9	422.7	362.1	465.4	222.5	38.8	17.5	2,878.6
1972	13.2	49.9	120.7	61.4	151.1	417.0	354.7	335.4	153.3	32.4	15.9	20.9	1,725.9
1973	61.9	220.7	177.1	651.4	349.0	284.1	397.8	687.5	291.7	51.7	20.7	11.6	3,205.3
1974	75.2	573.8	445.5	500.0	199.6	534.0	522.7	704.8	552.6	333.6	45.5	18.5	4,505.8
1975	23.5	58.0	83.5	151.8	306.0	342.9	241.8	770.5	528.2	98.9	31.6	21.1	2,657.7
1976	121.6	133.5	58.3	26.5	53.6	74.2	127.5	177.3	44.9	25.5	37.1	41.3	921.2
1977	25.8	27.4	16.6	22.5	24.0	25.3	46.1	99.5	75.1	29.0	16.9	7.1	415.3
1978	7.5	33.6	233.5	654.5	275.6	558.2	570.2	641.9	614.5	186.8	34.7	109.3	3,920.5
1979	31.0	28.8	34.7	295.6	195.8	362.4	383.5	632.6	268.1	49.7	22.8	9.9	2,314.9
1980	64.4	118.9	161.0	913.7	530.0	296.3	375.3	577.7	397.2	280.9	49.6	19.1	3,784.1
1981	9.7	13.1	74.0	114.0	177.3	304.1	317.8	316.5	101.9	27.8	13.7	4.2	1,474.2
1982	48.5	698.9	838.0	313.0	632.5	461.0	794.7	825.1	605.8	347.8	89.1	81.7	5,736.2
1983	304.5	423.6	464.3	393.5	501.0	747.4	387.5	993.7	999.0	454.9	94.9	40.5	5,804.8
1984	93.4	637.7	605.6	235.2	215.2	329.2	343.3	575.1	444.1	104.6	26.7	12.2	3,622.1
1985	28.4	227.5	116.4	41.3	126.8	184.9	472.4	288.7	74.6	26.9	13.8	24.0	1,625.7
1986	34.2	93.1	222.3	460.1	1,400.5	895.1	354.2	368.0	320.9	67.0	22.8	38.0	4,276.1
1987	37.4	20.8	14.6	61.7	225.2	315.5	259.5	182.6	38.1	23.1	10.7	2.9	1,192.2
1988	1.0	32.3	148.5	212.9	104.0	197.2	237.0	197.4	99.7	32.7	18.2	6.7	1,287.7
1989	2.0	135.7	91.3	62.6	85.1	933.0	653.9	385.3	203.9	43.6	22.0	52.3	2,670.7
1990	175.9	155.4	87.5	194.1	112.4	247.8	210.3	208.2	207.0	39.9	20.1	9.2	1,667.8
1991	8.2	13.4	17.1	13.8	80.2	446.9	292.2	295.2	307.4	114.2	27.5	14.6	1,630.8
1992	59.4	80.0	87.4	120.8	325.4	309.2	266.4	140.3	47.0	70.9	24.4	11.1	1,542.5
1993	41.3	92.9	308.7	604.4	353.6	719.6	463.6	502.6	479.1	177.2	34.1	14.5	3,791.5
1994	22.4	42.8	228.7	104.5	188.1	196.3	182.7	197.9	53.9	25.0	12.1	3.3	1,257.8
1995	11.5	171.5	328.5	1,006.6	303.4	1,031.7	564.5	742.7	587.1	428.8	103.0	24.6	5,304.1
1996	10.8	2.9	399.3	394.9	698.0	496.7	601.4	789.6	278.0	65.6	23.1	10.0	3,770.4
1997	7.0	334.7	1,187.3	1,575.1	235.3	233.5	246.4	392.2	273.1	60.7	22.3	9.5	4,577.0
1998	36.2	106.6	222.2	648.3	642.8	618.0	535.8	539.9	537.5	342.3	64.1	41.2	4,334.8
1999	30.3	147.3	256.7	566.5	639.1	336.3	268.4	450.5	368.8	103.8	26.8	13.2	3,207.8
2000	21.3	129.7	89.9	488.4	754.5	408.6	366.0	463.5	189.6	38.8	16.9	22.5	2,989.8
2001	54.0	61.0	72.0	84.7	91.4	301.9	322.2	258.1	48.4	22.4	9.7	2.7	1,328.4
2002	6.0	154.3	361.3	311.8	289.4	487.1	375.7	307.2	153.3	34.7	16.7	5.7	2,503.3
2003	1.4	218.8	366.6	269.0	165.9	272.2	385.6	572.3	307.0	51.7	22.8	13.8	2,647.0
2004	7.6	12.4	283.4	229.5	286.5	374.1	326.2	231.7	59.8	25.2	12.3	3.4	1,852.1
2005	92.8	107.0	242.3	394.7	218.2	451.8	374.3	750.3	529.2	186.9	33.9	15.7	3,397.2
2006	7.2	33.9	1,128.3	501.5	322.1	432.7	916.0	829.4	488.1	149.6	29.9	13.1	4,851.8
2007	4.7	39.7	171.8	131.9	342.3	278.4	262.2	258.4	55.1	24.9	12.0	3.3	1,584.6
2008	24.3	40.9	97.2	208.7	167.0	218.8	175.6	262.7	98.9	30.1	16.4	5.2	1,345.8
2009	26.6	144.6	51.3	107.6	253.1	439.8	295.1	606.5	171.7	33.7	17.1	5.7	2,152.8
2010	91.5	42.2	88.9	209.9	224.7	308.9	398.0	420.7	417.3	120.2	28.0	13.2	2,363.5
2011	263.4	206.5	618.3	204.9	114.5	381.7	535.3	704.8	776.6	484.3	120.0	26.9	4,437.4
2012	58.9	23.7	12.3	117.8	54.4	313.5	545.6	413.2	160.8	35.6	18.2	7.6	1,761.5
2013	3.9	77.5	542.2	81.0	35.8	199.1	290.8	276.3	118.0	53.2	21.7	9.4	1,709.1
2014	7.9	5.7	8.7	8.7	359.8	309.2	330.0	273.5	87.9	49.6	21.2	9.0	1,471.2
Average	48.2	134.2	253.0	285.1	286.2	358.9	410.2	471.0	297.2	100.1	27.9	15.8	2,687.8
Minimum	962.8	1,331.5	1,510.1	1,575.1	1,400.5	1,031.7	916.0	993.7	999.0	484.3	120.0	109.3	5,804.8
Maximum	1.0	1.5	8.7	8.7	19.0	25.3	46.1	96.3	30.9	18.6	6.7	2.3	415.3

Table C-10. UF 13 — Cosumnes River at Michigan Bar Simulated Flow (TAF)

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1922	0.0	0.3	15.9	30.7	72.7	91.1	86.7	95.2	19.2	4.8	0.9	0.0	417.5
1923	0.1	18.5	114.3	50.5	23.4	34.0	106.9	52.6	10.5	3.5	0.8	0.1	415.3
1924	3.8	2.8	1.4	3.6	12.5	7.8	17.7	9.8	2.8	0.5	0.0	0.0	62.8
1925	2.4	20.6	24.7	20.3	151.2	37.6	76.2	35.6	8.7	2.5	0.5	0.0	380.3
1926	1.2	2.7	5.8	6.4	79.0	34.1	76.8	9.8	2.6	0.7	0.0	0.0	219.0
1927	0.4	59.6	47.9	41.6	124.5	47.7	93.0	31.3	7.8	2.5	0.4	0.0	456.6
1928	0.0	20.4	19.1	16.5	32.2	171.7	80.3	13.7	3.8	0.8	0.0	0.0	358.5
1929	0.0	1.8	5.3	6.9	22.4	33.3	59.1	41.6	11.0	6.6	1.6	0.1	189.7
1930	0.0	0.1	24.9	36.1	33.8	72.9	55.5	24.2	9.1	2.4	0.3	0.0	259.3
1931	0.3	5.7	6.5	8.7	24.8	33.7	27.6	12.7	4.7	2.6	0.7	0.0	128.0
1932	0.1	6.7	66.4	53.7	59.0	47.2	53.2	72.8	12.9	3.5	0.6	0.0	376.0
1933	0.0	0.0	1.7	6.1	7.3	54.6	52.2	43.0	10.8	2.9	0.4	0.0	179.2
1934	5.5	9.9	28.7	38.1	62.6	38.5	13.9	6.3	2.5	1.7	0.4	0.0	208.2
1935	1.1	14.7	12.9	60.3	29.1	36.8	169.9	59.4	12.2	3.2	0.5	0.0	400.2
1936	0.4	3.1	2.3	83.3	208.7	59.0	79.3	57.7	19.6	5.5	1.0	0.1	520.0
1937	0.4	0.4	1.8	11.2	84.5	105.3	89.1	96.0	13.0	4.5	0.9	0.1	407.1
1938	0.3	5.6	73.0	37.1	113.6	143.8	100.6	108.0	39.6	6.3	1.5	0.2	629.6
1939	0.6	5.5	5.6	9.7	13.4	39.9	37.8	9.3	6.1	1.9	0.2	0.0	130.1
1940	3.6	4.1	2.6	110.9	143.3	135.0	86.1	20.4	5.4	1.3	0.1	0.0	512.8
1941	0.1	5.4	68.4	85.8	100.4	69.4	75.1	57.2	11.6	3.6	0.8	0.0	477.7
1942	0.1	4.4	49.4	90.9	94.6	32.9	90.5	84.6	36.3	7.2	1.6	0.1	492.7
1943	0.0	46.6	51.1	138.6	57.4	160.5	59.7	37.1	11.3	3.3	0.6	0.0	566.1
1944	0.0	0.9	2.5	10.7	40.5	43.3	44.1	58.9	10.4	3.1	0.5	0.0	215.0
1945	5.3	52.6	22.0	12.1	124.3	43.5	62.9	48.5	11.4	3.9	0.8	0.0	387.4
1946	9.1	34.2	112.9	43.5	15.7	52.2	69.8	47.9	9.5	2.5	0.3	0.0	397.6
1947	0.8	11.4	18.1	10.2	26.2	78.9	51.3	13.5	3.8	1.7	0.3	0.0	216.3
1948	8.9	13.9	4.7	9.2	8.3	55.9	111.7	75.7	19.4	4.6	0.8	0.0	313.2
1949	0.0	1.6	5.6	8.0	9.7	89.8	85.8	35.8	8.0	2.0	0.2	0.0	246.7
1950	0.1	2.3	4.5	29.9	56.3	69.7	100.5	56.2	12.3	3.5	0.6	0.0	335.9
1951	6.6	202.0	157.6	67.5	56.7	68.8	53.5	49.2	8.3	2.0	0.2	0.0	672.4
1952	1.8	15.3	75.7	102.5	67.8	72.2	121.2	111.8	33.0	6.4	1.5	0.3	609.5
1953	0.4	0.7	21.9	77.4	12.3	37.1	75.2	56.7	21.4	6.1	1.3	0.1	310.5
1954	0.0	3.7	9.5	14.0	35.5	74.5	94.1	23.8	5.7	2.1	0.4	0.0	263.4
1955	0.0	1.4	35.8	31.6	16.7	31.7	36.7	65.7	12.5	3.6	0.6	0.0	236.4
1956	0.1	0.3	213.7	137.5	30.5	44.0	60.8	107.4	25.4	5.5	1.1	0.1	626.4
1957	0.9	6.5	3.5	3.2	37.5	101.7	52.9	69.7	13.0	3.6	0.6	0.0	293.0
1958	0.4	2.7	9.5	36.3	120.9	93.3	144.4	106.7	22.1	5.7	1.2	0.2	543.5
1959	0.3	0.6	1.1	20.7	45.9	38.4	44.0	12.8	4.1	1.0	0.0	1.0	169.8
1960	4.1	1.5	0.4	7.5	76.0	76.4	44.2	31.8	7.4	1.8	0.2	0.0	251.2
1961	0.1	3.2	12.5	3.4	20.4	38.6	42.7	23.3	6.9	1.7	0.2	0.0	153.1
1962	1.2	1.1	7.0	3.4	90.7	54.6	86.7	44.1	10.6	3.0	0.6	0.0	302.9
1963	59.5	11.1	21.1	34.7	115.9	35.9	100.2	91.8	21.5	5.3	1.0	0.1	498.3
1964	2.2	25.0	10.9	17.2	10.4	28.5	54.4	40.0	10.7	3.7	0.7	0.0	203.6
1965	0.1	16.1	218.7	75.1	28.8	54.0	101.1	80.2	20.1	5.2	1.2	1.5	602.0
1966	1.0	17.3	20.0	20.6	20.5	45.2	69.7	11.5	3.3	0.6	0.0	0.0	209.6
1967	0.0	13.8	75.5	65.4	39.9	72.2	67.2	146.3	58.7	9.8	2.3	0.3	551.4
1968	1.9	2.6	10.7	10.1	55.6	63.5	42.7	13.1	4.2	1.1	0.1	0.4	205.9
1969	0.5	19.1	21.2	170.1	75.8	67.6	115.1	101.1	24.2	5.5	1.1	0.1	601.4
1970	1.8	8.1	47.1	178.8	46.6	49.7	24.0	52.4	11.5	3.9	0.8	0.0	424.9

Table C-10. UF 13 — Cosumnes River at Michigan Bar Simulated Flow (TAF) contd.

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1971	0.0	37.8	94.2	18.3	16.8	74.7	57.7	50.5	12.8	4.6	1.3	0.1	368.7
1972	0.5	2.7	21.3	12.1	40.9	58.0	50.8	26.6	6.4	1.7	0.2	0.0	221.3
1973	1.9	15.5	12.1	110.7	92.9	57.0	67.6	72.4	10.6	2.8	0.4	0.0	443.9
1974	0.9	58.2	72.7	64.3	32.8	119.8	88.5	78.4	16.9	8.2	4.1	0.9	545.8
1975	0.2	4.5	10.2	10.9	54.3	79.4	48.8	114.2	31.8	6.1	1.3	1.0	362.7
1976	5.6	12.6	6.2	2.1	2.2	10.4	20.5	13.1	3.9	0.8	0.3	2.7	80.4
1977	2.5	1.2	1.5	1.6	0.8	4.6	7.2	8.8	4.7	1.5	0.2	0.0	34.8
1978	0.3	0.7	27.2	139.5	52.8	128.8	88.6	87.4	22.8	5.1	1.0	3.9	558.3
1979	4.8	1.6	4.4	30.4	51.7	80.5	69.9	82.7	11.7	3.3	0.7	0.2	341.6
1980	0.4	10.7	14.1	157.1	109.2	54.8	54.3	59.6	23.0	6.7	1.9	0.2	492.1
1981	0.1	0.6	2.6	15.4	26.4	67.0	57.4	17.5	6.9	1.8	0.2	0.0	196.0
1982	1.4	91.7	116.7	51.7	133.7	125.0	150.4	99.7	15.1	4.9	1.4	2.0	793.8
1983	27.3	71.2	90.9	80.8	111.2	180.8	76.2	128.4	101.3	12.2	3.5	1.5	885.3
1984	3.1	104.4	119.4	40.2	51.1	84.2	49.7	66.5	13.4	4.2	0.8	0.0	536.8
1985	0.6	35.6	18.6	5.5	11.8	36.4	76.1	21.1	4.9	1.2	0.1	0.8	212.6
1986	2.9	6.1	19.5	57.3	278.7	138.0	40.0	58.9	14.1	3.9	0.7	0.1	620.2
1987	2.2	2.1	0.9	3.1	15.4	47.9	39.2	11.5	3.4	0.8	0.0	0.0	126.6
1988	0.0	1.5	7.7	15.1	11.8	37.3	29.9	11.8	4.2	1.5	0.3	0.0	120.9
1989	0.0	2.6	8.6	4.1	1.9	157.3	83.7	20.0	5.4	1.6	0.2	0.5	285.8
1990	9.5	10.8	7.9	6.7	7.4	55.3	33.0	13.3	10.1	3.7	0.7	0.0	158.2
1991	0.2	0.9	1.2	0.9	3.7	54.6	54.1	48.4	10.8	3.9	1.4	0.2	180.3
1992	0.2	5.4	4.5	8.0	52.4	56.0	41.4	10.4	2.6	1.4	1.4	0.2	184.1
1993	0.2	5.5	22.7	84.8	62.4	130.6	90.7	90.5	24.7	5.6	1.0	0.0	518.7
1994	0.1	2.5	8.0	5.4	16.6	40.0	28.6	15.9	5.8	1.3	0.1	0.0	124.3
1995	0.7	11.4	20.4	153.5	38.9	198.6	113.5	123.5	69.0	11.3	2.9	0.4	744.2
1996	0.0	0.0	23.5	67.9	122.3	86.8	76.3	88.7	12.0	3.5	0.9	0.0	481.9
1997	0.2	20.1	169.9	239.6	39.6	46.3	39.8	34.7	8.3	3.2	0.7	0.0	602.4
1998	0.4	6.1	17.9	113.4	149.5	100.7	91.8	107.1	50.4	8.1	1.7	0.3	647.3
1999	1.6	4.9	18.5	74.2	125.0	68.6	60.8	53.1	11.3	3.2	0.5	0.0	421.9
2000	0.1	7.6	10.9	88.9	137.1	62.7	47.2	47.5	9.2	2.5	0.3	0.7	414.7
2001	2.2	7.1	4.4	7.6	33.3	55.4	52.4	27.8	5.2	1.0	0.0	0.0	196.5
2002	0.1	11.8	71.5	43.8	44.4	83.2	50.0	19.5	7.2	1.8	0.2	0.0	333.6
2003	0.0	17.2	76.3	32.4	23.5	53.2	92.0	58.1	8.2	1.9	0.2	0.3	363.3
2004	0.2	0.6	48.9	35.5	77.8	72.6	17.0	6.7	1.7	0.4	0.0	0.0	261.4
2005	17.3	22.2	70.8	123.2	66.5	129.9	56.9	44.9	9.8	3.8	0.8	0.0	546.1
2006	0.1	1.2	167.3	146.1	56.1	145.1	224.8	26.5	7.7	2.1	0.3	0.0	777.2
2007	0.1	4.5	25.0	22.3	78.2	56.2	21.9	12.6	3.8	0.7	0.0	0.0	225.4
2008	0.3	2.6	6.5	51.4	45.3	47.6	22.0	8.6	3.1	1.3	0.1	0.0	188.9
2009	0.7	12.6	7.2	17.9	70.0	103.4	44.3	39.2	6.0	1.3	0.1	0.0	302.7
2010	4.4	5.9	13.6	52.5	66.1	81.7	81.6	31.0	11.4	3.3	0.5	0.0	351.9
2011	20.6	33.7	156.4	43.9	44.3	175.7	101.0	53.8	18.5	6.4	1.8	0.2	656.3
2012	2.6	3.7	1.6	9.8	13.3	100.9	63.3	12.5	3.7	1.5	0.2	0.0	213.2
2013	0.1	24.2	129.1	18.1	8.4	28.0	17.6	5.5	1.9	1.3	0.9	0.1	235.1
2014	0.8	0.9	1.9	1.1	94.8	61.3	21.4	7.3	2.3	0.5	0.0	0.0	192.5
Average	2.6	15.0	37.7	47.5	58.2	72.1	67.1	49.1	13.7	3.4	0.7	0.2	367.5
Minimum	59.5	202.0	218.7	239.6	278.7	198.6	224.8	146.3	101.3	12.2	4.1	3.9	885.3
Maximum	0.0	0.0	0.4	0.9	0.8	4.6	7.2	5.5	1.7	0.4	0.0	0.0	34.8

Table C-11. UF 14 — Mokelumne River at Pardee Reservoir Simulated Flow (TAF)

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1922	2.1	4.3	19.7	16.4	48.0	81.3	113.8	217.1	246.7	16.8	2.8	1.5	770.7
1923	8.4	24.3	92.1	33.7	26.0	52.1	105.5	218.2	176.9	31.6	3.3	17.0	789.0
1924	15.8	6.1	7.9	9.5	24.7	11.0	36.7	90.4	3.5	0.7	0.0	3.6	209.9
1925	23.5	36.5	25.7	17.0	145.3	38.0	88.1	161.3	151.1	9.3	4.1	5.4	705.0
1926	14.4	8.4	10.8	15.5	62.3	76.5	216.1	24.4	4.1	1.7	0.4	0.1	434.6
1927	10.4	206.2	30.2	26.1	179.5	97.1	202.9	71.0	10.4	1.4	0.2	0.9	836.5
1928	27.2	37.8	12.1	9.7	41.5	267.5	86.5	168.9	10.3	2.1	0.7	0.3	664.5
1929	0.4	6.0	5.9	5.4	12.5	30.0	73.8	220.4	46.8	3.1	0.6	0.3	405.1
1930	1.3	0.7	24.1	18.3	53.5	82.5	76.8	79.6	200.6	4.1	2.0	3.6	547.1
1931	4.6	14.2	3.3	24.4	35.9	32.2	62.6	126.8	15.0	1.9	0.3	0.4	321.8
1932	4.6	9.3	44.1	19.6	36.3	72.6	118.4	208.5	195.0	5.3	1.4	0.7	715.7
1933	0.9	2.8	5.3	9.7	5.4	91.1	86.6	117.0	118.6	3.8	0.9	2.1	444.0
1934	10.4	11.0	32.4	20.0	58.7	115.6	102.4	27.1	13.0	2.3	1.0	1.7	395.6
1935	15.5	23.4	12.4	17.9	26.5	47.2	247.4	168.2	195.3	6.0	2.8	1.7	764.4
1936	12.0	5.3	5.6	51.1	191.4	82.3	144.8	227.2	227.6	31.7	3.2	5.9	988.0
1937	7.8	7.0	15.0	13.0	66.9	96.3	128.7	382.2	62.8	4.6	2.1	1.1	787.4
1938	10.7	13.8	138.5	28.9	71.4	117.5	141.0	325.0	367.0	43.3	4.9	6.0	1,268.1
1939	25.3	14.2	20.9	16.0	15.9	66.8	113.1	80.5	17.3	2.0	0.6	11.9	384.5
1940	17.3	4.5	6.1	117.5	151.4	148.9	86.0	247.0	98.4	3.5	1.4	2.0	884.0
1941	7.0	12.4	73.3	39.5	122.3	89.2	83.3	214.6	229.7	17.9	3.0	4.0	896.1
1942	7.4	30.8	50.5	81.4	68.9	57.2	118.0	172.2	330.7	49.0	2.9	3.3	972.2
1943	6.4	71.0	57.2	81.6	65.1	198.6	148.9	231.9	151.0	13.8	3.1	2.8	1,031.5
1944	7.8	9.8	11.4	16.8	39.0	58.8	68.8	207.6	80.9	5.4	1.7	1.3	509.4
1945	36.4	69.0	29.3	8.7	123.8	35.7	132.2	213.7	189.5	8.7	2.8	2.3	851.9
1946	70.8	40.1	84.4	19.4	15.8	66.1	173.6	228.0	87.8	6.1	2.3	3.4	797.7
1947	15.4	32.0	23.6	7.5	48.4	96.8	93.7	153.4	14.4	2.1	0.6	0.6	488.6
1948	33.5	14.1	4.3	14.0	8.7	50.1	107.2	166.4	211.4	9.0	1.4	0.8	620.8
1949	3.6	5.5	7.0	6.3	7.1	46.4	190.1	203.3	39.4	3.8	2.8	2.1	517.5
1950	2.6	13.8	7.2	18.1	60.9	89.6	155.2	205.0	137.4	4.7	1.9	3.9	700.3
1951	30.6	288.0	157.3	63.2	48.4	75.1	108.2	196.0	181.2	5.8	2.1	2.5	1,158.3
1952	17.3	24.3	66.8	47.3	51.2	57.8	206.8	357.7	283.9	32.3	6.1	7.9	1,159.4
1953	7.8	12.6	28.7	69.8	27.4	63.5	132.2	89.6	182.1	60.9	5.1	3.5	683.1
1954	5.7	14.5	10.5	26.2	50.5	89.7	178.9	176.9	11.8	2.2	1.2	0.6	568.7
1955	0.6	9.8	33.3	20.8	23.3	42.4	45.4	181.5	129.2	3.6	1.6	1.5	493.1
1956	1.6	3.3	176.9	91.5	18.8	52.7	127.3	294.1	330.8	64.5	4.8	9.0	1,175.4
1957	15.7	15.0	11.6	14.2	64.3	101.4	87.2	180.1	132.5	4.8	2.0	2.8	631.9
1958	7.4	8.1	16.2	39.1	118.6	89.0	151.7	355.1	226.8	25.5	10.0	8.9	1,056.5
1959	6.4	9.0	8.8	39.0	40.4	68.9	113.0	79.3	25.3	4.1	1.5	22.1	417.7
1960	4.0	1.5	2.2	8.8	61.3	109.9	96.9	137.4	48.2	3.4	2.4	1.7	477.7
1961	4.1	8.9	6.4	8.8	23.8	40.4	78.9	127.1	40.3	3.6	2.2	19.9	364.3
1962	3.7	5.1	5.5	4.5	79.5	47.8	216.0	118.3	149.9	5.7	2.0	1.1	639.0
1963	76.8	13.0	18.7	76.3	117.4	46.7	98.5	242.1	243.1	23.4	3.5	15.7	975.3
1964	27.9	40.5	9.2	14.2	16.4	44.3	81.1	151.8	94.6	4.9	2.0	1.7	488.6
1965	4.0	21.8	199.7	39.6	42.1	63.0	152.1	208.4	291.3	92.7	41.1	11.0	1,166.6
1966	6.9	46.4	21.3	18.7	16.4	82.9	194.9	107.0	5.3	1.8	1.9	1.0	504.6
1967	1.6	23.6	53.3	55.3	34.9	94.1	42.4	336.0	345.1	140.1	8.9	10.4	1,145.7
1968	18.1	18.1	14.5	25.5	69.9	78.3	82.7	109.9	22.3	1.9	6.5	2.3	450.0
1969	4.1	33.3	24.5	179.0	36.7	57.9	173.6	345.8	309.8	53.6	4.0	8.6	1,231.0
1970	21.6	26.7	89.8	173.9	53.8	70.2	40.3	208.4	217.8	6.6	2.1	2.7	913.8

Table C-11. UF 14 — Mokelumne River at Pardee Reservoir Simulated Flow (TAF) contd.

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1971	5.2	53.9	55.9	19.0	38.7	82.7	87.9	118.0	249.6	35.1	3.0	3.2	752.3
1972	7.0	26.4	31.4	10.9	37.3	118.5	71.6	156.8	35.8	2.1	0.6	13.9	512.2
1973	12.3	18.3	12.8	61.4	63.1	37.5	141.0	346.9	76.4	3.7	6.5	3.3	783.2
1974	15.6	80.1	57.5	44.2	30.4	126.6	119.4	237.0	280.9	44.3	6.2	2.4	1,044.6
1975	9.1	12.1	12.8	18.6	45.7	84.1	44.4	290.1	268.3	6.8	11.5	5.7	809.3
1976	29.9	15.6	7.8	6.3	18.5	17.4	32.7	120.0	5.4	5.1	20.1	10.7	289.5
1977	8.2	3.1	1.6	2.6	8.6	7.4	46.8	29.2	16.9	3.1	0.5	4.1	132.2
1978	2.0	4.8	33.4	80.0	44.9	181.7	134.9	233.0	294.3	21.5	2.6	50.0	1,083.2
1979	3.3	6.7	10.7	35.3	36.0	93.7	119.7	292.5	105.5	6.8	2.1	1.6	714.0
1980	15.3	20.5	25.9	149.2	125.3	61.0	111.1	175.9	234.4	112.6	5.0	7.8	1,044.0
1981	9.1	8.9	12.7	33.5	39.9	76.5	113.8	155.4	12.5	1.8	0.6	2.7	467.5
1982	14.5	95.6	88.9	26.6	133.3	128.8	157.5	286.3	340.0	119.4	7.5	46.9	1,445.3
1983	84.4	83.3	60.7	68.9	93.6	160.0	92.8	317.5	426.4	195.9	20.5	28.1	1,632.1
1984	30.8	141.3	118.1	37.0	64.2	119.1	69.8	267.8	176.4	8.9	3.9	6.4	1,043.9
1985	20.2	53.5	14.3	10.4	32.2	48.2	151.1	157.2	16.7	2.0	1.9	14.5	522.2
1986	10.0	16.3	24.0	60.5	260.8	173.3	79.3	221.8	274.1	10.2	3.8	8.5	1,142.7
1987	14.6	8.2	8.1	10.7	28.0	57.6	153.4	56.4	4.8	1.6	0.5	0.6	344.7
1988	4.8	9.8	7.8	9.9	30.6	56.0	74.4	79.3	8.5	2.6	0.9	0.7	285.3
1989	0.9	7.9	7.1	1.9	8.4	185.3	183.5	157.5	34.9	2.7	2.2	25.7	618.1
1990	25.2	12.8	4.7	12.0	10.5	84.1	131.4	77.4	20.7	2.8	2.4	4.8	388.9
1991	3.8	2.7	2.3	1.7	16.2	56.9	67.5	128.4	118.1	5.2	2.2	3.0	408.0
1992	10.0	13.1	6.8	5.8	59.1	75.9	138.2	61.0	9.2	9.2	1.9	1.5	391.5
1993	9.0	7.7	20.0	46.4	43.0	169.2	151.0	292.6	239.3	13.7	2.5	1.9	996.1
1994	14.2	8.6	12.2	14.2	24.4	70.5	94.9	83.7	6.3	1.2	0.2	2.1	332.4
1995	9.2	15.8	13.6	87.9	59.8	207.9	162.7	209.5	297.0	299.0	7.7	5.0	1,375.0
1996	7.7	12.2	47.1	45.7	142.7	109.3	129.5	292.0	192.2	6.3	3.1	4.3	992.0
1997	6.8	38.2	138.2	247.1	29.3	101.7	114.7	317.0	125.3	5.7	3.4	4.3	1,131.6
1998	12.4	18.5	17.8	79.6	86.4	139.9	128.4	282.3	363.0	46.4	4.7	25.3	1,204.8
1999	13.5	25.9	23.1	89.8	97.5	52.2	95.2	250.2	196.5	6.7	4.7	3.7	859.0
2000	13.7	28.5	9.3	110.8	104.4	55.9	132.9	281.6	55.9	3.1	1.3	13.3	810.7
2001	13.4	7.0	7.5	22.0	25.4	96.2	113.7	157.3	3.7	1.3	0.6	2.1	450.3
2002	8.5	53.5	69.0	32.3	55.8	106.7	122.6	163.8	25.4	2.1	1.1	1.0	641.7
2003	1.1	69.8	81.3	32.8	36.1	89.2	101.1	227.1	49.2	4.4	4.5	2.8	699.5
2004	1.0	5.5	82.7	29.4	98.6	164.7	103.5	46.5	5.1	1.5	0.5	0.5	539.6
2005	49.6	36.6	119.0	120.4	107.7	192.9	107.7	199.7	79.2	5.7	2.5	4.7	1,025.9
2006	10.9	24.4	359.6	130.0	130.0	153.3	283.3	182.2	59.9	5.5	4.6	4.2	1,347.8
2007	10.9	35.0	52.0	25.3	116.7	116.0	60.8	32.9	4.0	1.2	0.4	2.2	457.5
2008	10.4	8.2	18.2	61.3	62.0	82.6	73.7	76.9	8.8	1.6	0.6	0.1	404.4
2009	14.3	46.7	11.9	83.3	97.8	159.4	95.4	109.2	9.1	1.7	1.0	1.3	631.2
2010	48.0	8.0	31.3	83.8	100.8	101.2	128.7	100.4	92.6	8.7	1.9	1.5	706.7
2011	115.0	48.5	242.5	95.9	65.8	251.6	139.8	136.5	141.9	48.5	4.4	7.8	1,298.2
2012	29.8	10.4	8.6	56.7	23.8	154.8	107.4	26.1	8.9	1.1	0.9	1.3	429.8
2013	4.7	87.3	161.1	28.8	14.2	67.3	40.8	29.3	8.0	2.2	0.9	2.8	447.5
2014	1.5	7.3	2.8	4.2	149.8	88.4	53.6	25.1	2.8	2.6	2.5	3.7	344.3
Average	15.2	28.6	42.5	43.2	61.3	91.8	115.8	179.0	127.8	20.5	3.5	6.1	735.3
Minimum	115.0	288.0	359.6	247.1	260.8	267.5	283.3	382.2	426.4	299.0	41.1	50.0	1,632.1
Maximum	0.4	0.7	1.6	1.7	5.4	7.4	32.7	24.4	2.8	0.7	0.0	0.1	132.2

Table C-12. UF 15 — Calaveras River at Jenny Lind Simulated Flow (TAF)

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1922	0.1	0.7	22.3	27.4	85.6	41.9	14.0	3.8	0.5	0.0	0.0	0.0	196.3
1923	0.8	12.0	65.1	54.1	18.1	1.5	48.7	2.7	0.7	0.0	0.0	0.7	204.5
1924	1.8	0.3	2.0	8.3	9.3	3.6	3.7	0.5	0.0	0.0	0.0	0.0	29.5
1925	2.9	7.4	17.0	16.2	82.3	17.8	42.7	6.4	1.6	0.1	0.0	0.2	194.4
1926	1.3	1.6	5.0	6.0	52.6	4.6	26.6	1.6	0.1	0.0	0.0	0.0	99.5
1927	1.7	16.3	21.6	36.3	64.4	15.6	30.5	1.3	1.0	0.1	0.0	0.0	189.0
1928	1.0	11.5	15.7	17.7	22.6	58.9	25.1	1.0	0.2	0.0	0.0	0.0	153.6
1929	0.0	4.5	9.2	9.5	18.8	18.0	22.6	1.6	6.3	1.2	0.0	0.0	91.7
1930	0.0	0.0	10.1	23.4	28.5	43.0	6.3	7.2	0.5	0.0	0.0	0.0	118.9
1931	0.3	4.6	1.1	13.3	14.6	9.7	1.4	1.0	1.7	0.4	0.0	0.0	48.2
1932	0.3	5.3	55.9	48.5	56.4	8.1	5.7	11.6	1.4	0.0	0.0	0.0	193.2
1933	0.0	0.1	4.5	18.0	16.9	23.4	4.0	26.7	1.2	0.0	0.0	0.0	94.8
1934	1.6	2.2	28.6	29.2	36.2	10.9	0.6	1.6	1.6	0.1	0.0	0.1	112.5
1935	1.4	7.6	12.3	49.9	15.8	33.2	68.7	9.1	0.4	0.0	0.0	0.0	198.5
1936	1.2	1.5	2.5	58.0	154.2	15.0	25.2	0.9	6.1	0.5	0.0	0.1	265.1
1937	0.0	0.7	8.8	19.0	95.4	60.9	17.1	1.8	0.6	0.3	0.0	0.0	204.5
1938	0.7	2.0	24.2	28.5	121.2	80.7	19.0	7.6	0.3	0.0	0.0	0.0	284.0
1939	1.7	3.1	3.3	8.8	18.0	16.7	4.0	4.7	1.5	0.0	0.0	0.1	62.0
1940	2.6	1.1	2.5	79.5	67.6	50.3	21.0	1.6	0.1	0.0	0.0	0.0	226.3
1941	0.5	2.1	37.5	53.4	51.2	34.5	41.4	2.5	0.4	0.0	0.0	0.1	223.6
1942	0.2	2.1	33.5	84.2	49.3	14.7	41.2	38.6	3.5	0.1	0.0	0.0	267.5
1943	0.1	31.3	35.2	89.0	39.9	70.3	13.5	4.6	1.5	0.1	0.0	0.0	285.4
1944	0.5	1.2	4.2	17.3	37.7	31.0	19.6	4.4	0.8	0.0	0.0	0.0	116.8
1945	1.0	23.7	24.6	12.8	82.9	39.2	11.8	1.7	6.9	0.4	0.0	0.0	205.1
1946	1.5	15.8	88.1	29.4	17.4	27.4	14.6	1.3	1.1	0.0	0.0	0.0	196.6
1947	1.1	12.7	23.7	10.9	24.6	27.3	14.7	0.6	1.2	0.1	0.0	0.0	117.0
1948	3.8	5.5	2.8	7.9	15.1	56.8	58.5	19.2	4.5	0.3	0.0	0.0	174.4
1949	0.3	0.5	9.5	17.5	27.7	65.4	5.1	0.5	0.3	0.0	0.0	0.0	126.8
1950	0.2	3.7	5.6	63.8	51.1	30.3	33.5	2.7	0.2	0.0	0.0	0.1	191.1
1951	4.1	73.7	112.4	76.9	33.6	31.5	3.3	16.2	0.5	0.0	0.0	0.0	352.4
1952	1.8	9.9	68.1	115.6	49.2	57.8	9.4	2.0	0.1	0.2	0.0	0.1	314.2
1953	0.0	2.6	30.8	62.2	3.6	21.9	20.5	12.0	7.8	0.3	0.0	0.0	161.6
1954	1.1	4.3	9.7	24.9	34.9	39.2	17.8	6.5	1.4	0.2	0.0	0.0	140.0
1955	0.0	2.4	26.7	52.8	22.3	9.1	25.9	15.2	0.4	0.0	0.0	0.0	154.9
1956	0.0	2.6	179.9	105.0	27.0	9.1	12.4	45.6	1.2	0.0	0.0	0.1	382.8
1957	1.9	2.6	5.4	12.4	26.7	53.7	13.6	44.8	4.3	0.1	0.0	0.0	165.6
1958	1.4	2.0	12.7	42.8	85.1	63.3	95.0	2.0	1.1	0.1	0.0	0.0	305.5
1959	0.0	0.6	1.1	23.4	50.9	6.0	2.8	1.6	0.1	0.0	0.0	1.5	87.9
1960	0.7	0.0	0.7	12.0	57.9	14.0	11.7	6.9	0.4	0.0	0.0	0.0	104.4
1961	0.1	6.8	7.1	2.0	9.6	19.0	9.5	9.3	0.7	0.0	0.0	0.0	64.0
1962	0.0	1.5	8.3	4.7	87.7	41.0	4.4	2.5	0.2	0.0	0.0	0.0	150.3
1963	12.7	1.6	13.7	24.8	57.9	26.3	74.2	26.2	2.7	0.3	0.0	0.0	240.5
1964	2.2	15.3	3.9	29.6	6.9	17.0	10.6	7.1	2.3	0.2	0.0	0.0	95.3
1965	0.9	16.6	134.9	66.0	10.1	15.3	54.9	2.6	0.2	0.0	0.5	0.2	302.1
1966	0.3	13.2	23.4	30.0	24.0	5.7	6.4	1.1	0.1	0.0	0.0	0.0	104.1
1967	0.0	8.3	50.4	78.8	23.6	40.6	100.3	19.5	3.3	0.2	0.0	0.0	325.1
1968	1.7	2.2	11.8	22.3	44.5	26.9	6.2	1.1	0.4	0.0	0.1	0.1	117.3
1969	0.6	11.3	31.2	126.0	81.9	36.8	24.2	1.8	0.0	0.0	0.0	0.0	313.8
1970	2.5	5.8	29.3	115.0	27.0	28.6	8.7	2.7	1.6	0.3	0.0	0.0	221.7

Table C-12. UF 15 — Calaveras River at Jenny Lind Simulated Flow (TAF) contd.

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1971	0.3	12.6	87.8	28.2	2.0	27.1	7.0	6.4	0.6	0.6	0.0	0.0	172.7
1972	0.7	5.1	57.2	19.8	23.6	5.2	13.4	1.6	0.1	0.0	0.0	0.3	127.0
1973	1.5	11.8	21.8	100.0	75.4	45.5	10.5	1.4	0.0	0.0	0.0	0.0	267.9
1974	3.0	24.1	64.8	49.5	17.0	45.2	37.5	4.4	0.3	1.3	0.2	0.0	247.3
1975	1.0	3.9	8.7	17.6	62.5	64.1	26.3	3.5	0.2	0.1	0.5	0.4	188.9
1976	3.5	4.7	2.9	1.4	11.5	7.7	6.7	1.2	0.0	0.0	0.8	0.9	41.4
1977	0.3	1.4	0.5	3.2	2.2	3.5	1.0	6.4	0.7	0.0	0.0	0.1	19.4
1978	0.1	2.8	32.6	109.8	47.4	53.6	66.1	7.8	0.3	0.3	0.0	1.5	322.4
1979	0.3	1.7	8.9	53.6	57.4	56.0	12.8	10.3	0.6	0.0	0.0	0.0	201.5
1980	2.2	10.0	13.7	125.6	63.0	29.3	9.9	5.5	0.7	0.4	0.0	0.0	260.2
1981	0.1	0.3	3.5	26.4	22.7	32.7	12.7	2.5	0.8	0.0	0.0	0.0	101.8
1982	2.6	22.8	52.1	120.2	82.9	75.6	68.1	1.9	0.1	0.3	0.0	1.1	427.8
1983	9.1	43.2	73.1	84.5	72.4	107.6	43.2	25.4	0.9	0.0	0.0	0.3	459.7
1984	1.1	61.0	117.0	21.9	34.4	25.7	10.2	3.8	0.7	0.1	0.0	0.0	276.0
1985	2.6	21.2	12.7	11.3	27.8	30.8	7.9	0.4	0.2	0.0	0.0	0.6	115.5
1986	1.1	9.1	20.8	41.5	176.9	67.7	6.1	3.4	0.2	0.0	0.0	0.5	327.2
1987	1.3	0.1	1.1	8.9	22.5	36.9	3.4	0.4	0.2	0.0	0.0	0.0	74.8
1988	0.1	2.3	10.5	22.6	4.0	11.4	14.1	4.1	0.6	0.1	0.0	0.0	69.8
1989	0.0	7.3	10.7	11.7	19.1	63.9	12.2	2.4	0.3	0.0	0.0	1.4	129.0
1990	5.8	5.9	2.7	20.2	24.4	26.5	7.9	18.4	11.7	0.4	0.0	0.0	123.8
1991	0.1	0.6	1.6	0.9	2.3	62.7	10.8	8.6	2.0	1.3	0.0	0.0	91.0
1992	3.4	2.9	5.4	8.1	60.0	29.4	3.3	0.4	0.1	0.9	0.0	0.0	114.0
1993	0.6	1.9	34.3	107.5	62.8	38.6	19.2	2.6	10.3	0.5	0.0	0.0	278.2
1994	0.8	0.9	6.8	7.6	30.6	9.0	12.6	12.5	1.0	0.0	0.0	0.0	81.7
1995	2.1	11.2	32.6	153.3	23.3	99.5	43.8	61.6	3.2	0.6	0.0	0.0	431.1
1996	0.0	0.0	16.4	82.8	94.2	37.1	29.6	27.3	2.5	0.8	0.0	0.0	290.7
1997	0.2	10.3	141.7	158.0	20.9	4.1	1.5	1.0	1.6	0.2	0.0	0.0	339.5
1998	1.5	5.6	18.8	112.7	134.8	40.5	48.8	46.0	10.7	0.6	0.0	0.2	420.1
1999	0.2	4.5	12.2	52.6	103.0	25.4	27.8	3.3	0.4	0.0	0.0	0.0	229.3
2000	0.3	5.0	4.1	82.1	108.4	31.2	10.5	23.5	2.0	0.1	0.0	0.8	267.9
2001	2.6	3.5	6.6	19.3	43.8	24.0	29.2	3.4	0.1	0.0	0.0	0.0	132.5
2002	0.2	5.4	56.6	39.3	29.9	38.3	6.6	12.1	2.5	0.1	0.0	0.0	190.9
2003	0.0	5.3	58.4	22.5	18.1	21.9	60.9	22.1	0.6	0.0	0.3	0.0	210.1
2004	0.0	2.9	64.2	31.2	39.4	15.9	1.9	0.1	0.1	0.0	0.0	0.0	155.7
2005	9.7	9.2	36.7	78.4	34.8	61.9	23.1	26.7	2.3	0.3	0.0	0.0	283.2
2006	0.1	0.6	71.5	64.6	19.8	60.8	106.1	14.7	2.3	0.1	0.0	0.0	340.6
2007	0.9	1.8	11.1	6.4	46.8	23.5	17.2	7.9	0.3	0.0	0.0	0.0	115.9
2008	0.5	1.3	6.1	44.0	32.9	13.5	3.7	4.5	1.9	0.1	0.0	0.0	108.5
2009	0.6	3.4	3.9	11.6	33.0	46.4	16.1	25.5	0.6	0.0	0.0	0.0	141.2
2010	3.2	0.8	9.5	37.4	29.7	28.3	27.8	9.2	2.8	0.1	0.0	0.0	148.8
2011	4.6	14.4	60.8	26.7	34.2	89.2	14.0	6.8	6.8	1.1	0.0	0.0	258.8
2012	2.2	0.9	0.4	7.6	4.9	34.3	29.8	2.6	0.6	0.0	0.0	0.0	83.1
2013	0.5	6.4	47.6	11.0	1.8	4.8	7.3	0.6	0.1	0.3	0.0	0.2	80.7
2014	0.4	0.8	1.0	0.2	20.6	20.5	11.9	1.7	0.1	0.0	0.0	0.0	57.4
Average	1.4	7.7	28.5	43.1	43.2	33.9	22.5	8.9	1.6	0.2	0.0	0.1	191.2
Minimum	12.7	73.7	179.9	158.0	176.9	107.6	106.1	61.6	11.7	1.3	0.8	1.5	459.7
Maximum	0.0	0.0	0.4	0.2	1.8	1.5	0.6	0.1	0.0	0.0	0.0	0.0	19.4

Table C-13. UF 16 — Stanislaus River at Melones Reservoir Simulated Flow (TAF)

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1922	1.9	1.8	15.7	24.6	41.1	80.4	172.0	396.8	271.0	46.5	5.0	1.7	1,058.6
1923	5.2	40.0	91.5	37.5	37.9	95.3	258.4	253.6	151.9	124.1	9.8	11.1	1,116.3
1924	28.7	6.8	3.9	12.7	61.3	31.0	99.9	167.3	22.5	3.8	0.9	1.4	440.1
1925	20.1	65.8	29.9	23.1	206.7	135.1	212.6	205.0	256.3	98.4	11.6	4.3	1,269.0
1926	9.9	10.7	29.2	24.0	96.2	158.0	305.0	105.4	24.7	6.3	2.0	0.9	772.4
1927	5.6	123.9	43.5	22.6	120.6	141.0	337.4	247.9	150.3	17.8	3.4	2.2	1,216.2
1928	27.0	63.0	15.9	10.0	50.9	307.0	172.7	292.3	71.4	9.7	2.7	1.1	1,023.6
1929	1.2	8.6	18.7	5.1	19.7	67.9	120.6	292.9	155.4	17.7	3.8	2.0	713.4
1930	3.3	1.8	33.5	24.8	110.7	206.5	185.3	127.0	257.5	16.2	3.2	1.7	971.5
1931	8.7	17.9	13.3	65.4	58.1	81.7	112.2	163.0	58.5	9.1	2.8	1.9	592.6
1932	3.8	10.2	35.0	17.9	77.1	155.9	240.7	367.3	240.3	33.6	4.2	1.7	1,187.7
1933	2.6	2.0	2.3	3.2	19.9	150.9	158.8	179.2	193.2	15.2	3.2	1.7	732.4
1934	5.0	8.7	33.8	25.5	82.2	164.9	147.3	68.8	41.4	7.6	2.4	2.1	589.8
1935	14.4	34.1	26.7	21.2	36.6	82.5	443.7	245.1	248.8	37.8	5.4	2.9	1,199.0
1936	10.9	7.3	5.6	54.8	213.8	129.5	273.1	334.2	254.5	54.0	6.0	3.2	1,346.9
1937	3.8	4.8	13.2	6.2	142.7	122.2	177.7	579.6	158.4	28.6	5.6	2.3	1,244.9
1938	5.5	23.2	230.7	29.5	90.1	152.2	248.9	509.8	443.1	117.6	9.7	3.8	1,864.0
1939	23.1	18.8	20.4	15.8	26.0	107.5	201.2	151.7	64.2	8.9	4.9	27.6	670.3
1940	42.7	13.9	16.4	143.5	167.8	254.9	196.6	295.4	145.1	12.8	3.4	2.9	1,295.5
1941	5.3	19.7	100.3	35.1	141.2	188.6	196.1	322.0	264.7	147.3	9.5	4.6	1,434.4
1942	3.7	25.3	81.7	98.4	75.0	96.6	224.3	370.5	432.4	180.6	8.6	3.8	1,600.9
1943	4.8	57.9	63.3	127.6	100.6	217.8	307.2	342.9	212.6	80.6	8.2	3.3	1,526.9
1944	5.8	7.4	14.8	23.9	38.2	105.9	154.2	257.8	121.1	39.1	5.8	3.2	777.2
1945	7.7	85.4	35.9	15.0	193.6	62.2	272.7	306.7	272.7	55.0	6.2	4.6	1,317.7
1946	38.4	59.7	123.9	26.2	19.9	98.9	329.3	302.5	216.0	29.3	6.4	5.0	1,255.4
1947	19.1	74.3	57.6	17.8	89.7	158.9	190.2	197.2	57.5	8.6	4.0	3.5	878.3
1948	37.5	20.0	7.1	37.3	18.8	73.4	209.0	291.0	238.0	53.6	6.5	3.7	996.0
1949	4.3	5.2	4.9	4.1	11.2	80.9	296.7	252.1	73.7	8.8	4.7	4.9	751.6
1950	5.5	24.9	14.4	90.9	153.2	157.7	345.9	250.0	92.3	14.0	5.4	4.5	1,158.7
1951	39.0	312.3	298.5	117.2	128.3	157.4	201.5	275.4	199.2	55.9	7.1	4.2	1,795.9
1952	12.5	25.5	70.7	63.7	75.0	131.1	454.3	636.7	247.3	121.6	17.6	6.8	1,862.8
1953	7.5	17.3	20.7	91.4	51.2	153.3	271.4	156.3	173.7	84.1	7.8	5.1	1,039.6
1954	6.5	25.5	17.0	36.7	114.3	185.0	308.8	185.9	58.2	15.7	6.3	4.4	964.3
1955	4.5	11.9	52.2	49.6	74.4	88.4	133.9	259.0	133.8	15.1	6.7	4.6	834.1
1956	5.4	5.4	258.0	119.9	63.7	218.9	298.2	572.5	307.5	102.6	16.5	7.8	1,976.4
1957	13.4	17.5	17.1	74.8	131.9	180.7	146.7	278.1	176.2	28.3	6.4	4.9	1,075.9
1958	17.0	16.5	28.5	76.7	214.2	137.4	293.8	591.1	220.1	54.9	10.0	10.5	1,670.6
1959	8.4	8.3	11.6	75.0	107.4	154.0	156.5	91.2	49.9	8.5	6.1	40.0	717.0
1960	27.4	8.7	6.6	25.1	185.8	163.6	152.4	146.8	51.9	8.1	6.5	6.4	789.3
1961	16.5	28.5	22.2	25.5	43.7	83.6	141.6	157.6	97.0	12.9	9.2	11.6	649.8
1962	10.1	11.5	13.5	16.8	128.6	87.7	368.8	147.0	182.9	31.8	7.5	5.7	1,011.8
1963	90.9	23.5	40.2	56.0	236.0	89.6	186.2	386.1	249.7	83.1	9.3	8.8	1,459.3
1964	37.3	70.6	15.4	16.0	35.4	81.6	187.6	225.9	145.5	20.4	7.5	6.4	849.7
1965	17.1	53.0	232.8	57.7	77.3	143.8	254.3	379.2	329.5	136.4	35.8	8.5	1,725.4
1966	7.7	79.5	21.5	14.5	27.0	122.7	303.0	176.8	27.7	8.1	6.8	5.9	801.1
1967	7.5	52.4	116.6	49.8	63.5	175.4	117.8	579.3	424.5	188.9	11.3	10.6	1,797.5
1968	15.7	17.3	16.0	35.0	107.9	136.4	141.5	138.5	82.5	10.6	9.6	9.4	720.4
1969	14.2	79.6	30.2	261.1	54.7	122.3	337.5	676.2	358.5	143.6	17.4	10.8	2,106.1
1970	34.8	40.8	129.4	256.9	87.3	137.5	157.8	320.8	294.3	42.2	7.7	7.0	1,516.5

Table C-13. UF 16 — Stanislaus River at Melones Reservoir Simulated Flow (TAF) contd.

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1971	7.4	82.1	61.3	22.3	73.3	122.7	179.9	196.4	303.6	81.7	11.6	10.0	1,152.4
1972	13.0	25.6	27.8	15.8	74.2	217.2	125.2	190.0	96.2	10.2	7.0	14.8	816.9
1973	18.0	37.3	46.5	79.2	87.9	71.9	293.6	532.2	167.6	15.2	9.2	8.1	1,366.6
1974	30.9	124.6	86.7	56.6	38.1	205.8	243.5	400.3	311.0	75.4	12.5	7.4	1,592.7
1975	16.8	23.8	38.5	45.2	96.6	118.9	100.5	491.4	284.7	26.6	21.3	14.1	1,278.3
1976	37.3	31.3	13.2	11.3	37.2	55.3	70.9	178.4	33.9	14.2	28.4	34.6	546.0
1977	15.4	12.7	9.6	10.5	39.4	29.9	95.1	63.6	79.9	11.5	7.6	8.3	383.4
1978	10.0	22.5	79.8	124.1	91.2	295.3	265.1	460.8	346.8	69.8	10.9	55.2	1,831.5
1979	14.7	9.5	10.5	67.7	58.8	167.8	212.1	456.5	132.6	17.5	9.3	7.5	1,164.6
1980	24.7	47.0	29.5	220.5	187.8	96.0	274.1	279.5	277.8	213.1	16.4	9.3	1,675.9
1981	9.2	9.7	16.1	59.5	68.1	110.9	224.9	191.0	63.1	11.4	7.6	8.1	779.8
1982	30.6	161.2	117.8	23.6	225.4	223.2	367.7	439.3	373.9	241.5	25.7	53.0	2,282.7
1983	123.7	102.9	74.3	66.2	129.2	255.0	174.6	640.8	545.5	281.1	55.9	33.5	2,482.6
1984	27.2	207.6	114.7	37.8	73.7	186.4	217.8	360.6	231.4	44.8	9.9	8.5	1,520.6
1985	21.3	62.5	17.9	15.8	61.6	92.9	277.0	162.4	79.4	15.7	11.9	29.4	847.8
1986	29.6	28.8	36.3	92.1	417.0	384.4	247.7	321.3	315.9	68.3	13.1	11.8	1,966.3
1987	24.3	12.1	10.7	13.9	65.8	130.8	222.7	116.4	22.2	10.0	8.6	8.4	645.8
1988	14.0	22.3	13.4	28.2	91.5	110.0	139.6	155.4	62.0	15.4	10.8	8.8	671.3
1989	9.5	24.5	21.2	15.2	46.3	244.1	324.0	193.9	81.2	15.2	10.3	42.7	1,028.0
1990	63.2	39.0	19.3	40.8	38.6	174.3	198.7	159.6	119.8	20.8	10.6	10.3	894.9
1991	11.2	10.6	11.2	10.1	33.9	123.9	136.2	217.7	197.8	37.8	11.0	10.7	811.9
1992	21.7	26.2	22.2	17.2	105.9	151.0	195.6	162.1	24.4	74.1	11.0	9.9	821.3
1993	17.6	19.2	30.0	56.6	73.3	275.8	292.0	518.2	339.8	97.5	11.5	8.5	1,740.1
1994	15.5	13.7	14.4	28.1	48.4	121.6	162.7	166.1	42.6	10.0	8.6	11.4	643.3
1995	27.5	22.2	20.8	133.1	103.1	309.1	303.5	471.1	452.7	457.3	81.5	11.4	2,393.4
1996	9.0	8.9	71.3	46.4	217.2	179.3	295.3	429.8	312.2	50.3	10.7	9.6	1,640.1
1997	11.1	74.9	153.6	359.9	70.6	199.5	269.3	409.0	299.8	47.1	10.8	10.0	1,915.4
1998	16.7	24.7	29.3	87.6	82.1	167.1	253.4	342.3	646.7	324.5	38.2	26.9	2,039.5
1999	14.7	23.4	36.4	112.0	101.2	71.7	202.8	450.9	281.2	38.4	11.3	10.2	1,354.3
2000	15.7	35.1	13.7	154.7	139.2	111.6	318.7	438.5	115.8	16.1	10.1	18.7	1,388.0
2001	21.3	14.8	15.7	68.3	41.5	150.7	200.0	229.3	16.4	17.8	10.8	11.3	798.0
2002	13.1	69.2	109.0	56.8	90.4	179.0	191.3	234.7	89.1	12.4	9.8	10.1	1,065.0
2003	10.3	101.0	122.6	54.1	74.1	120.8	176.4	372.3	98.3	16.6	23.8	11.8	1,182.3
2004	9.9	23.2	153.1	49.2	92.6	286.6	179.1	78.6	15.8	9.9	9.5	9.6	917.2
2005	69.3	51.7	75.9	116.6	84.1	231.1	226.6	520.4	161.2	27.0	10.0	12.2	1,586.0
2006	15.9	21.0	197.6	122.1	149.0	163.0	379.5	618.0	117.4	12.6	10.5	10.3	1,816.9
2007	17.0	33.1	49.7	32.9	122.0	188.6	121.8	71.7	12.3	9.9	10.0	13.0	682.1
2008	16.1	19.9	34.1	64.7	73.2	125.4	199.1	182.8	28.6	13.7	10.1	9.6	777.4
2009	21.3	84.3	26.0	136.8	99.8	206.0	222.3	242.7	23.8	12.3	13.8	11.0	1,100.2
2010	90.0	18.1	42.7	80.8	83.9	143.8	280.2	233.9	155.2	15.9	9.7	9.4	1,163.5
2011	151.0	75.8	184.2	75.3	61.0	203.5	264.8	376.7	373.3	111.9	11.2	16.9	1,905.4
2012	35.3	14.4	13.8	58.2	34.6	114.5	230.6	121.7	28.1	10.5	11.5	10.1	683.2
2013	12.1	60.8	154.6	44.0	41.9	102.8	133.5	139.6	39.9	14.0	9.6	10.9	763.5
2014	11.8	15.1	14.9	26.4	124.7	118.6	6.7	0.0	0.0	0.0	0.0	0.0	318.2
Average	20.9	39.8	54.2	60.2	93.1	150.0	222.6	293.3	180.6	55.4	11.0	10.3	1,191.4
Minimum	151.0	312.3	298.5	359.9	417.0	384.4	454.3	676.2	646.7	457.3	81.5	55.2	2,482.6
Maximum	1.2	1.8	2.3	3.2	11.2	29.9	6.7	0.0	0.0	0.0	0.0	0.0	318.2

Table C-14. UF 18 — Tuolumne River at Don Pedro Reservoir Simulated Flow (TAF)

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1922	4.5	6.7	150.4	76.9	251.8	218.2	238.9	596.1	397.8	31.4	6.3	2.1	1,981.1
1923	19.3	89.1	268.3	170.2	91.3	139.9	250.5	382.0	237.0	110.0	9.7	22.9	1,790.4
1924	40.8	13.3	12.8	52.2	80.3	59.2	156.4	154.9	11.5	3.3	1.1	1.9	587.6
1925	48.6	115.7	94.0	67.5	351.7	228.6	321.4	367.1	279.6	48.6	16.4	9.1	1,948.3
1926	28.3	28.5	49.2	84.2	242.1	161.3	378.5	222.3	55.3	10.9	4.9	1.5	1,267.1
1927	7.3	223.2	68.1	137.7	289.4	163.0	378.1	406.9	293.3	17.7	5.6	5.3	1,995.6
1928	107.8	153.1	82.2	83.1	113.1	483.5	223.5	412.4	107.8	9.4	3.3	1.7	1,781.0
1929	1.8	36.0	59.2	38.4	67.4	194.2	184.1	351.3	200.4	15.0	4.7	4.4	1,156.9
1930	7.1	3.4	64.7	108.5	188.2	275.0	218.2	168.1	219.5	11.0	5.1	6.8	1,275.7
1931	19.9	50.4	21.7	112.9	81.6	125.7	171.6	225.8	45.6	8.6	7.0	7.6	878.4
1932	9.4	31.0	246.7	110.8	254.6	237.5	236.2	468.5	558.1	104.2	7.5	3.5	2,267.9
1933	6.1	9.2	20.7	71.5	66.8	245.2	235.7	270.6	323.7	17.0	5.6	4.5	1,276.7
1934	23.1	38.8	216.4	125.4	171.6	266.7	173.1	85.4	55.4	9.2	6.0	6.4	1,177.5
1935	48.1	121.9	102.0	187.7	127.7	194.8	513.4	395.5	489.8	42.3	9.5	7.4	2,240.0
1936	35.2	21.1	31.6	223.2	498.5	311.2	434.2	391.8	292.7	41.8	9.6	6.8	2,297.6
1937	16.3	14.9	133.9	39.8	426.0	302.9	259.9	625.0	309.0	35.7	8.4	3.6	2,175.3
1938	14.3	46.3	575.6	164.5	301.6	384.0	418.3	608.8	616.2	178.0	11.9	10.8	3,330.3
1939	82.7	39.5	49.6	62.2	78.3	311.9	288.4	149.2	44.0	9.3	5.5	41.4	1,162.0
1940	85.4	25.1	40.2	414.8	286.1	399.9	297.9	513.7	193.3	11.9	4.6	4.6	2,277.5
1941	18.4	33.6	279.1	152.9	295.5	218.0	252.5	518.1	482.3	219.0	14.0	6.7	2,490.2
1942	8.1	78.1	254.1	236.1	126.2	161.1	325.1	404.6	582.0	205.1	10.9	6.4	2,397.7
1943	10.6	183.5	178.1	321.7	176.6	400.2	319.7	433.9	288.2	139.9	10.9	5.0	2,468.2
1944	15.9	28.5	38.1	100.8	137.6	212.6	181.0	399.3	206.1	59.6	8.4	5.2	1,393.1
1945	76.0	206.3	110.2	49.7	328.5	167.8	355.6	349.8	410.1	77.6	10.3	9.5	2,151.5
1946	165.2	126.6	360.8	97.6	80.8	183.5	357.3	357.2	248.6	28.8	10.7	10.7	2,027.7
1947	53.8	180.2	142.6	40.3	139.5	220.5	190.3	296.2	59.3	10.2	5.4	7.0	1,345.1
1948	102.1	43.8	13.6	62.0	48.0	179.8	385.5	376.9	294.8	37.5	8.0	4.8	1,556.8
1949	10.7	20.2	31.2	30.7	73.8	210.2	499.2	340.0	181.7	13.0	9.3	8.2	1,428.1
1950	8.0	67.3	32.8	132.7	236.9	217.9	438.9	403.9	141.1	16.4	9.9	7.9	1,713.7
1951	133.9	730.8	561.3	135.4	140.5	179.7	215.7	382.3	273.2	38.8	10.3	8.5	2,810.2
1952	24.1	101.5	216.4	254.5	173.2	238.1	492.3	653.0	463.0	269.5	26.2	12.4	2,924.1
1953	12.2	30.4	130.8	226.0	64.1	143.1	265.4	180.7	340.4	127.1	15.1	10.5	1,546.0
1954	11.0	62.3	60.9	111.3	226.4	254.6	433.1	377.6	86.2	12.7	7.7	5.8	1,649.4
1955	5.9	50.8	173.6	82.5	95.5	122.2	121.7	414.2	279.9	26.4	10.0	7.0	1,389.7
1956	9.1	20.3	968.6	297.9	74.8	187.1	306.8	581.4	550.0	214.8	15.3	10.5	3,236.5
1957	39.9	50.2	38.8	80.3	236.9	227.7	195.5	386.3	265.2	15.6	8.3	8.0	1,552.8
1958	28.8	35.1	160.8	171.0	301.5	294.1	484.2	631.0	356.1	94.2	20.1	26.0	2,602.7
1959	11.6	16.4	26.3	178.9	184.6	159.6	255.7	139.0	81.8	11.0	9.0	146.8	1,220.6
1960	24.2	10.8	11.0	76.9	244.0	306.5	264.9	250.0	97.9	15.1	11.1	10.0	1,322.3
1961	20.2	78.8	87.2	58.1	68.1	139.9	194.2	157.7	136.7	16.8	24.0	21.3	1,003.0
1962	14.5	36.0	66.6	65.8	391.2	195.9	504.7	237.5	330.7	31.8	12.1	18.5	1,905.5
1963	121.8	22.6	112.3	408.2	418.7	139.5	288.4	493.4	361.7	154.6	14.3	17.3	2,553.0
1964	53.6	200.9	51.8	79.5	61.8	129.6	199.0	289.3	181.1	19.8	13.2	12.4	1,292.0
1965	32.6	136.6	730.9	244.0	153.5	142.3	363.6	338.3	421.5	270.3	97.8	15.3	2,946.6
1966	14.3	221.2	121.6	74.8	69.3	190.0	324.6	286.8	41.8	11.3	9.3	11.1	1,375.9
1967	11.1	155.5	295.6	220.5	124.2	258.5	224.6	730.0	627.7	377.0	22.9	22.7	3,070.2
1968	24.3	39.1	57.0	142.8	217.3	180.8	148.9	190.8	104.3	13.8	17.4	12.1	1,148.8
1969	48.4	184.2	97.2	743.5	197.0	276.5	392.9	736.4	581.5	346.3	26.0	11.8	3,641.7
1970	87.7	92.3	177.1	503.6	144.4	178.2	100.1	486.9	411.7	47.0	10.8	8.5	2,248.2

Table C-14. UF 18 — Tuolumne River at Don Pedro Reservoir Simulated Flow (TAF) contd.

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1971	10.1	199.5	167.9	123.0	112.9	197.4	153.5	239.4	439.5	122.7	20.4	17.7	1,804.1
1972	14.3	69.0	111.6	75.4	168.9	256.1	163.0	285.4	148.6	13.0	9.5	27.8	1,342.6
1973	27.0	88.3	115.4	219.5	236.1	145.8	319.1	614.4	262.8	16.8	20.5	10.8	2,076.6
1974	76.9	238.5	286.7	161.6	68.3	330.7	257.0	470.8	384.3	89.3	18.6	9.7	2,392.5
1975	38.2	49.0	99.3	124.5	244.9	280.9	183.5	560.7	402.1	30.0	28.3	19.7	2,061.0
1976	111.3	77.4	37.0	26.6	64.5	112.8	100.1	221.7	27.0	27.6	42.5	39.3	887.7
1977	22.8	21.1	13.4	28.7	60.6	37.8	117.6	97.5	112.5	13.5	10.0	10.9	546.5
1978	13.8	62.8	275.1	310.3	239.1	512.2	352.3	448.6	550.5	207.0	18.2	111.2	3,101.1
1979	14.0	27.6	44.6	218.6	186.5	326.4	269.1	558.1	294.1	20.6	12.9	10.5	1,983.0
1980	52.7	96.4	116.7	591.7	365.9	149.6	333.6	368.4	459.2	385.8	25.5	16.2	2,961.7
1981	16.8	22.5	88.4	148.0	137.2	188.5	315.8	261.0	119.2	14.4	10.0	12.4	1,334.3
1982	70.3	343.4	291.7	166.9	384.7	326.2	514.6	532.3	497.8	311.6	32.0	107.9	3,579.5
1983	215.3	229.9	202.5	270.3	323.5	435.3	237.0	733.5	796.2	400.4	74.4	36.5	3,954.7
1984	53.0	304.2	377.6	108.7	141.7	190.7	193.9	575.2	292.8	42.0	15.1	13.6	2,308.5
1985	53.7	164.8	50.2	49.6	143.7	159.1	405.1	203.6	87.0	16.5	14.5	37.2	1,385.1
1986	59.6	84.6	170.8	242.2	714.9	522.3	194.1	420.1	371.7	41.6	14.4	22.1	2,858.6
1987	31.0	14.8	21.9	52.5	132.9	194.2	319.2	152.1	39.9	14.4	11.8	11.9	996.7
1988	40.6	50.5	53.1	136.5	130.0	142.6	197.3	234.6	85.1	16.2	14.0	13.6	1,114.0
1989	12.7	59.9	55.5	59.5	106.0	443.1	405.2	237.8	167.9	15.7	16.6	69.9	1,649.8
1990	121.1	78.7	38.3	93.6	86.0	222.4	215.0	145.5	141.3	30.3	16.7	14.6	1,203.5
1991	23.7	22.1	18.4	23.3	78.0	333.9	203.2	261.6	346.5	49.5	14.7	16.4	1,391.5
1992	66.6	75.0	58.8	71.7	219.3	216.7	263.3	172.7	37.3	59.0	16.6	15.6	1,272.6
1993	59.8	44.9	144.3	348.5	184.5	568.8	320.2	511.3	425.4	124.5	14.8	11.3	2,758.2
1994	31.1	33.6	57.4	69.9	142.6	203.0	192.6	226.3	53.2	13.0	11.7	17.8	1,052.1
1995	65.3	81.7	93.7	486.7	222.4	543.9	411.2	491.4	598.4	531.3	73.1	14.1	3,613.1
1996	12.5	14.4	221.0	228.9	428.7	369.4	334.7	466.0	363.8	55.6	17.1	12.7	2,524.8
1997	22.2	220.3	518.7	840.1	91.4	268.9	203.2	535.7	306.6	77.0	15.9	15.8	3,115.9
1998	24.5	72.5	79.0	346.6	349.7	445.1	356.6	318.8	603.1	394.8	20.2	39.6	3,050.5
1999	23.8	80.9	94.9	284.3	289.6	141.7	276.6	395.0	316.8	31.8	17.6	16.8	1,969.8
2000	33.8	83.4	24.9	376.1	377.8	255.2	362.8	445.6	179.0	17.3	15.0	28.2	2,199.2
2001	52.0	37.0	49.7	107.8	100.4	384.5	288.7	310.6	21.9	22.2	13.5	17.2	1,405.6
2002	31.6	139.5	234.3	114.8	179.7	236.2	284.0	321.9	163.7	16.3	13.4	16.2	1,751.7
2003	15.2	228.8	211.3	179.3	74.6	223.5	254.8	524.5	203.4	23.4	31.0	16.5	1,986.4
2004	13.3	47.3	278.8	116.7	181.1	425.3	218.0	220.2	72.3	15.1	13.9	13.5	1,615.6
2005	159.7	86.0	215.9	340.7	211.7	358.5	235.9	633.4	430.8	229.5	17.3	18.8	2,938.1
2006	27.2	39.9	553.3	252.6	232.3	251.0	553.3	638.7	486.8	50.3	14.7	12.7	3,112.6
2007	25.6	57.9	91.5	64.3	210.4	281.4	183.3	129.9	16.8	13.5	14.8	17.9	1,107.2
2008	27.3	24.4	72.8	192.5	218.1	187.3	190.9	291.0	127.2	18.2	13.7	12.7	1,376.0
2009	59.2	134.5	64.8	244.9	212.1	288.6	247.4	536.6	99.8	17.2	17.4	14.8	1,937.4
2010	168.1	32.4	101.4	199.4	197.7	246.7	302.3	279.1	456.9	74.6	14.6	13.0	2,086.2
2011	223.5	123.1	463.4	190.9	130.9	465.6	397.4	429.3	629.3	193.4	18.0	31.1	3,295.9
2012	65.9	26.0	20.3	117.5	61.5	218.0	369.7	152.2	32.4	14.5	16.3	14.5	1,108.8
2013	17.8	170.7	340.7	99.0	53.9	188.1	210.1	202.6	55.9	17.0	13.8	17.7	1,387.4
2014	18.2	25.9	24.6	48.0	206.7	189.0	193.8	112.8	19.9	25.8	16.3	18.1	899.0
Average	44.4	91.4	156.2	174.9	192.5	250.4	285.6	371.9	272.5	81.2	15.9	17.8	1,954.6
Minimum	223.5	730.8	968.6	840.1	714.9	568.8	553.3	736.4	796.2	531.3	97.8	146.8	3,954.7
Maximum	1.8	3.4	11.0	23.3	48.0	37.8	100.1	85.4	11.5	3.3	1.1	1.5	546.5

Table C-15. UF 19 — Merced River at Exchequer Reservoir Simulated Flow (TAF)

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1922	1.8	1.7	69.2	39.8	98.7	108.3	139.6	352.8	246.7	73.4	4.4	0.5	1,136.7
1923	5.1	41.6	93.7	68.0	39.6	70.5	160.1	229.3	72.6	129.7	11.7	4.8	926.8
1924	10.9	4.4	2.9	14.3	21.0	24.2	60.0	70.0	21.1	1.5	0.0	0.0	230.3
1925	13.7	47.5	28.3	29.2	127.3	103.5	186.1	202.8	146.2	56.8	5.4	2.1	948.9
1926	9.8	8.0	16.9	12.7	105.0	82.0	195.0	89.8	83.7	9.3	1.6	0.0	613.9
1927	1.4	110.9	33.8	49.2	114.1	70.1	185.8	261.8	152.5	28.6	3.3	1.7	1,013.2
1928	27.2	78.3	21.6	21.8	49.0	184.2	110.9	233.8	77.8	13.9	2.3	0.1	821.0
1929	0.0	13.7	21.3	15.0	33.0	78.2	86.6	179.0	102.7	22.6	2.6	2.4	557.1
1930	3.3	0.7	23.1	41.9	82.3	134.8	122.1	66.9	146.5	11.9	1.2	0.3	635.1
1931	5.5	20.9	6.0	30.0	36.4	50.5	64.9	88.9	44.5	10.0	1.5	0.9	360.0
1932	2.3	7.4	97.5	39.7	105.7	168.3	131.5	250.8	324.0	97.5	6.1	0.6	1,231.6
1933	0.4	1.0	8.6	12.8	40.7	118.5	136.3	93.3	211.8	25.0	2.6	0.1	651.0
1934	1.0	17.2	82.5	54.9	67.3	149.7	83.2	71.6	33.7	10.1	0.9	1.0	573.2
1935	12.6	65.6	46.7	95.0	62.3	80.7	266.4	239.7	275.5	42.5	5.6	2.4	1,194.9
1936	10.9	6.5	7.8	84.1	200.0	161.5	265.5	181.9	155.2	46.7	3.9	0.8	1,124.9
1937	4.1	7.1	50.0	14.9	177.2	157.8	154.3	400.7	165.8	70.0	4.2	0.3	1,206.3
1938	3.2	9.3	262.5	67.5	122.7	211.5	220.5	364.4	365.3	164.6	18.3	3.2	1,813.2
1939	19.2	20.3	8.0	19.2	30.8	141.7	133.0	55.8	86.0	7.9	0.8	9.8	532.4
1940	38.5	6.8	5.3	170.2	107.7	171.5	210.5	297.2	149.6	13.8	1.3	0.1	1,172.5
1941	5.2	12.3	101.5	75.6	137.7	119.5	131.3	396.3	256.8	153.9	14.8	3.2	1,408.0
1942	1.0	21.6	90.3	92.8	62.3	76.4	169.9	253.3	354.7	161.8	7.7	0.9	1,292.6
1943	3.0	64.3	57.4	103.9	95.2	190.8	222.8	286.6	138.5	138.1	9.2	1.0	1,310.8
1944	1.8	9.3	15.2	38.6	46.2	101.7	90.3	221.9	82.6	84.7	4.8	0.3	697.4
1945	4.2	116.8	32.5	11.4	118.7	59.7	202.6	234.1	206.9	77.7	4.8	1.8	1,071.3
1946	24.6	73.0	118.8	31.4	22.1	81.1	249.7	197.3	150.9	78.5	6.8	1.5	1,035.7
1947	18.7	70.6	65.7	12.5	47.7	96.7	119.8	175.1	51.5	10.3	3.1	0.6	672.2
1948	26.3	14.4	2.6	11.0	8.9	74.4	192.8	186.1	146.4	75.2	5.0	0.4	743.5
1949	2.7	5.5	7.2	6.8	28.4	114.5	268.1	145.5	135.6	13.7	2.3	1.1	731.4
1950	0.9	19.3	10.5	33.2	110.1	74.2	259.6	173.2	98.8	35.8	2.5	0.6	818.6
1951	19.2	311.7	218.1	41.1	69.6	83.2	142.4	241.7	197.4	67.9	5.4	0.4	1,398.2
1952	4.2	27.9	74.8	97.4	89.2	98.8	296.0	391.4	225.6	169.5	32.1	3.3	1,510.1
1953	2.6	5.6	46.7	77.0	36.6	67.1	128.6	87.2	160.5	97.7	5.2	1.1	715.8
1954	1.4	16.0	15.4	39.1	88.0	119.1	257.5	174.2	54.8	33.6	3.0	0.1	802.2
1955	0.0	21.6	65.7	38.0	32.6	49.1	62.6	227.4	146.7	28.9	4.9	0.4	677.8
1956	0.2	3.1	388.0	133.4	30.4	98.0	209.0	376.0	382.0	202.8	21.6	6.1	1,850.7
1957	10.4	9.5	5.0	22.4	74.1	83.4	95.1	181.1	202.6	18.6	1.8	0.6	704.6
1958	5.5	8.3	68.5	60.8	120.5	126.0	269.6	406.3	171.5	114.1	13.2	7.8	1,372.0
1959	4.4	3.7	2.3	67.6	67.9	92.9	126.2	72.3	76.7	6.8	1.0	47.9	569.7
1960	12.1	3.6	1.1	31.4	80.9	163.9	141.9	92.4	107.0	6.1	1.0	0.4	641.7
1961	8.3	31.4	32.0	14.1	28.5	50.8	102.0	55.3	117.6	11.8	4.9	2.9	459.6
1962	2.7	11.2	35.1	5.5	184.1	81.4	327.9	116.1	173.1	48.8	5.8	1.7	993.5
1963	20.7	6.1	26.0	23.6	288.5	59.5	112.6	322.5	190.5	131.0	15.8	4.7	1,201.5
1964	13.8	80.1	14.2	11.1	22.0	47.3	109.5	113.6	93.2	38.2	4.5	3.2	550.8
1965	4.3	58.5	206.1	90.5	75.1	76.6	184.0	251.4	287.4	191.7	49.6	5.0	1,480.2
1966	2.3	109.9	28.4	22.7	27.5	72.9	232.1	131.6	52.5	10.0	1.2	0.6	691.8
1967	1.5	38.5	133.7	63.5	69.9	129.6	99.7	468.8	391.9	235.3	11.9	5.4	1,649.7
1968	6.9	7.3	16.8	29.2	91.8	78.3	92.1	86.7	89.8	9.4	2.0	1.3	511.7
1969	7.9	55.4	44.4	275.1	81.9	131.2	272.1	532.2	364.3	242.9	59.2	5.2	2,071.8
1970	20.4	32.3	46.9	174.5	57.2	100.2	67.1	313.1	210.5	40.2	3.0	0.1	1,065.6

Table C-15. UF 19 — Merced River at Exchequer Reservoir Simulated Flow (TAF) contd.

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1971	0.2	47.2	78.1	36.6	56.1	96.8	105.3	138.6	208.4	82.3	9.3	4.7	863.5
1972	2.0	19.5	38.7	17.5	67.9	143.9	74.9	157.3	124.5	20.3	2.1	7.1	675.5
1973	6.3	36.0	28.7	75.6	107.6	72.6	173.5	367.1	158.9	17.6	5.2	1.0	1,050.0
1974	17.7	77.4	89.9	65.3	29.7	149.1	158.6	275.3	231.4	47.7	6.3	0.7	1,149.1
1975	8.8	16.7	38.1	40.6	92.0	133.0	86.0	319.5	238.4	39.0	7.9	5.8	1,025.8
1976	25.1	32.8	5.9	2.8	24.7	50.8	32.6	85.8	28.3	10.2	6.9	12.0	317.9
1977	7.8	3.2	1.7	9.9	13.1	9.5	38.4	28.2	73.5	6.1	0.5	0.1	191.9
1978	0.5	19.9	100.9	143.8	115.3	230.6	235.3	303.8	336.2	148.6	30.8	30.0	1,695.6
1979	6.6	7.1	13.8	77.2	69.7	161.7	144.4	351.2	165.0	31.9	5.5	0.5	1,034.7
1980	6.4	30.9	19.8	246.1	154.7	88.7	204.6	271.1	257.7	239.8	40.7	3.7	1,564.3
1981	1.5	3.7	23.7	35.0	72.0	84.1	157.3	131.0	105.7	7.7	0.9	0.4	623.0
1982	18.8	114.5	63.5	80.1	159.1	134.0	259.8	405.1	268.5	181.5	36.5	22.6	1,744.1
1983	46.2	99.6	84.2	93.7	124.6	204.7	145.8	413.3	547.2	145.5	71.2	22.3	1,998.3
1984	19.7	108.6	134.0	45.0	60.5	107.8	106.0	315.4	150.2	63.2	5.8	1.0	1,117.1
1985	12.8	53.9	20.6	9.5	52.7	65.7	193.8	73.3	90.8	7.2	3.1	2.8	586.2
1986	12.2	30.1	51.2	89.9	286.8	243.3	161.9	239.3	280.0	63.1	10.1	1.8	1,469.7
1987	5.4	2.2	1.8	11.2	47.3	61.4	149.2	84.9	27.1	4.7	0.5	0.4	396.2
1988	8.9	24.8	14.3	44.3	53.4	80.6	86.6	125.2	64.8	9.0	1.8	0.3	514.0
1989	0.3	13.7	15.4	13.0	45.9	185.3	234.6	88.1	82.3	21.1	3.4	13.4	716.6
1990	41.9	18.7	7.4	50.2	36.9	105.5	84.5	54.1	98.9	22.1	3.0	0.5	523.6
1991	2.1	3.4	3.7	2.3	13.1	122.9	110.5	170.2	199.7	55.4	4.3	1.9	689.7
1992	13.6	20.8	16.6	25.3	91.4	102.7	135.1	124.0	35.0	29.7	4.7	1.1	600.2
1993	4.3	18.3	43.1	132.7	87.0	323.4	157.6	311.8	244.1	147.8	21.5	2.3	1,494.0
1994	4.5	5.8	18.4	12.5	57.2	86.2	89.0	95.0	59.2	6.6	0.6	0.8	435.7
1995	23.7	24.5	26.8	183.8	105.7	251.5	170.9	278.2	399.1	350.5	71.5	6.5	1,892.7
1996	1.1	0.1	61.6	72.4	183.1	183.1	172.2	298.7	239.6	59.8	4.8	0.8	1,277.4
1997	1.4	83.0	177.6	270.5	49.3	178.6	149.6	356.5	194.4	102.9	16.7	4.3	1,584.7
1998	3.4	19.3	39.2	125.7	140.7	223.9	163.9	194.1	338.4	285.7	31.0	8.7	1,574.0
1999	4.0	14.2	37.9	90.3	105.8	65.9	151.5	199.1	173.1	47.1	3.6	1.1	893.4
2000	2.8	20.3	6.9	125.1	145.9	148.6	218.2	225.1	154.4	11.5	1.5	4.3	1,064.5
2001	13.5	10.4	6.0	26.2	37.2	167.4	124.0	201.9	32.1	7.6	1.3	0.3	627.8
2002	2.5	42.8	62.6	62.5	68.4	90.6	188.2	133.6	170.3	19.0	1.8	0.9	843.2
2003	1.1	86.3	70.6	54.1	38.0	109.2	111.9	284.4	208.1	15.5	13.9	2.2	995.2
2004	0.5	6.6	81.5	42.1	71.7	251.7	119.8	94.4	107.3	10.1	1.3	0.0	787.0
2005	55.0	29.8	60.8	148.0	84.7	167.8	127.9	409.2	277.8	197.9	9.8	3.4	1,572.1
2006	3.6	6.4	148.3	123.6	49.3	153.8	229.3	488.6	317.1	67.8	3.8	0.2	1,591.7
2007	4.8	9.6	26.9	16.9	60.8	137.6	71.1	86.0	23.7	3.5	0.4	1.7	443.0
2008	2.4	4.6	22.3	75.6	89.5	94.4	102.5	173.2	102.5	9.2	1.0	0.0	677.1
2009	9.0	42.7	17.7	77.3	85.0	126.0	156.5	318.0	51.5	39.6	3.3	1.6	928.2
2010	54.3	12.9	38.6	75.8	71.6	127.9	152.8	146.3	277.0	102.1	5.1	0.4	1,064.8
2011	53.0	45.8	263.6	62.3	43.8	150.3	244.4	235.3	329.7	226.1	28.5	9.9	1,692.6
2012	18.7	6.3	1.5	21.0	24.2	74.4	194.5	93.6	37.9	4.3	0.4	0.2	477.1
2013	0.3	18.2	117.0	31.0	28.4	92.6	137.9	120.8	74.1	10.1	0.8	0.3	631.5
2014	2.2	2.4	2.0	2.1	32.9	68.7	72.9	67.7	23.5	4.0	2.3	0.5	281.1
Average	10.1	32.4	54.2	60.9	79.0	118.0	156.3	214.8	169.8	68.3	9.4	3.5	976.6
Minimum	55.0	311.7	388.0	275.1	288.5	323.4	327.9	532.2	547.2	350.5	71.5	47.9	2,071.8
Maximum	0.0	0.1	1.1	2.1	8.9	9.5	32.6	28.2	21.1	1.5	0.0	0.0	191.9

Table C-16. UF 20 — Chowchilla River at Buchanan Reservoir Simulated Flow (TAF)

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1922	0.2	0.2	11.6	11.4	33.2	27.4	14.1	3.2	1.3	0.4	0.0	0.0	103.0
1923	0.1	5.1	14.0	17.0	11.3	6.5	22.3	2.1	0.8	0.2	0.0	0.1	79.4
1924	1.1	0.7	0.5	1.2	2.7	8.3	3.9	1.4	0.3	0.0	0.0	0.0	20.1
1925	0.5	8.9	6.3	4.9	30.3	10.0	14.1	2.4	1.1	0.3	0.0	0.0	78.9
1926	0.6	1.2	2.3	4.4	30.6	4.7	19.1	1.8	0.5	0.1	0.0	0.0	65.3
1927	0.1	11.0	8.6	11.0	36.6	12.7	19.9	1.6	0.7	0.2	0.0	0.0	102.4
1928	0.5	6.7	7.2	6.0	15.6	35.6	15.6	1.5	0.5	0.1	0.0	0.0	89.2
1929	0.0	2.1	3.5	5.2	11.1	18.1	15.3	2.1	0.9	0.7	0.1	0.0	59.2
1930	0.3	0.1	0.9	4.9	15.3	22.0	7.3	3.3	0.9	0.1	0.0	0.0	55.0
1931	0.5	2.5	1.6	6.7	8.7	5.1	1.9	1.8	1.1	0.3	0.0	0.0	30.2
1932	0.2	1.3	27.6	15.6	32.8	17.9	10.1	4.0	1.0	0.2	0.0	0.0	110.6
1933	0.1	0.0	0.6	5.6	8.4	19.8	4.3	3.5	1.1	0.3	0.0	0.0	43.6
1934	0.0	0.4	5.9	9.4	14.0	4.4	1.1	0.6	0.4	0.2	0.0	0.0	36.4
1935	0.5	5.8	8.9	22.5	10.7	23.8	30.4	4.6	0.9	0.1	0.0	0.0	108.2
1936	0.4	1.1	1.3	15.3	65.1	11.4	16.7	1.7	0.6	0.3	0.0	0.0	113.8
1937	0.0	0.8	7.3	7.7	60.4	38.5	15.5	2.2	0.6	0.1	0.0	0.0	133.2
1938	0.0	0.6	24.1	21.5	65.1	72.7	16.8	6.1	1.1	0.5	0.1	0.0	208.6
1939	0.8	2.4	4.1	8.5	12.8	21.1	8.2	1.2	0.9	0.2	0.0	0.3	60.4
1940	2.2	1.1	1.9	46.3	29.2	21.4	10.7	1.9	0.6	0.1	0.0	0.0	115.3
1941	0.1	1.3	26.1	23.6	39.2	24.1	20.6	3.5	0.8	0.1	0.0	0.0	139.4
1942	0.0	0.8	23.4	24.4	27.0	18.7	18.7	7.7	1.7	0.4	0.0	0.0	122.8
1943	0.1	12.9	11.1	49.0	25.4	45.6	7.8	3.4	1.2	0.3	0.0	0.0	157.0
1944	0.0	0.9	3.1	10.3	21.1	17.0	5.7	2.0	0.8	0.1	0.0	0.0	61.1
1945	0.1	16.1	8.1	3.4	55.8	32.5	8.2	1.3	0.8	0.3	0.0	0.0	126.5
1946	0.6	4.2	26.2	12.7	11.6	23.1	12.4	1.2	0.9	0.2	0.0	0.0	93.1
1947	0.7	15.6	15.1	6.6	15.3	11.9	6.0	1.2	0.5	0.2	0.0	0.0	73.1
1948	0.6	1.7	1.4	3.7	7.0	32.3	30.1	4.0	1.5	0.5	0.0	0.0	82.8
1949	0.1	0.5	1.0	3.5	11.4	36.8	9.0	1.6	0.9	0.2	0.0	0.0	65.0
1950	0.0	2.0	2.5	11.9	23.6	19.2	14.1	1.9	0.5	0.0	0.0	0.0	75.9
1951	0.6	40.6	33.2	17.5	17.9	18.7	3.7	3.9	0.8	0.1	0.0	0.0	137.1
1952	0.2	2.7	20.5	37.0	22.9	45.1	25.5	5.3	1.0	0.4	0.1	0.0	160.6
1953	0.2	1.4	14.9	24.6	9.1	13.6	4.6	3.3	1.7	0.6	0.0	0.0	73.9
1954	0.0	1.5	3.3	14.7	28.8	29.3	7.8	3.0	0.8	0.3	0.0	0.0	89.4
1955	0.0	1.5	9.4	13.1	10.8	10.2	5.7	5.1	0.9	0.1	0.0	0.0	56.8
1956	0.0	0.5	82.0	36.4	20.2	9.9	7.9	5.5	1.1	0.2	0.0	0.0	163.6
1957	0.2	0.8	1.2	4.6	17.4	20.9	3.4	6.9	2.0	0.5	0.0	0.0	57.9
1958	0.7	1.2	7.0	13.0	35.6	49.4	38.8	3.1	1.1	0.4	0.0	0.1	150.3
1959	0.4	0.3	0.9	9.1	27.4	6.7	2.7	1.8	0.5	0.0	0.0	2.8	52.7
1960	1.7	0.4	0.1	2.6	27.7	14.4	6.9	2.9	0.7	0.0	0.0	0.0	57.7
1961	0.5	3.8	6.9	2.3	5.1	9.8	2.5	1.4	0.7	0.1	0.0	0.0	33.1
1962	0.1	1.1	6.9	1.7	56.4	23.5	3.1	1.2	0.6	0.1	0.0	0.0	94.6
1963	1.2	1.0	2.5	14.3	39.1	14.7	23.2	5.0	1.2	0.3	0.0	0.0	102.6
1964	0.7	10.9	4.6	3.6	2.7	11.0	4.9	2.1	0.9	0.3	0.0	0.1	41.7
1965	0.5	10.5	32.2	21.1	11.4	13.2	19.0	2.0	0.7	0.1	0.0	0.0	110.8
1966	0.1	18.2	11.3	9.2	13.6	7.5	1.9	1.1	0.4	0.0	0.0	0.0	63.3
1967	0.0	3.4	36.2	15.1	11.7	39.6	36.4	6.3	1.5	0.5	0.0	0.0	150.6
1968	0.3	1.0	5.3	9.2	19.8	15.9	3.6	1.0	0.5	0.1	0.0	0.0	56.8
1969	0.2	4.1	19.3	92.4	57.5	41.0	28.3	5.7	1.7	0.8	0.2	0.0	251.2
1970	1.4	3.9	10.7	49.2	18.0	22.7	4.4	1.8	0.5	0.3	0.0	0.0	113.0

Table C-16. UF 20 — Chowchilla River at Buchanan Reservoir Simulated Flow (TAF) contd.

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1971	0.0	6.2	21.8	13.8	7.0	14.0	4.2	3.0	1.1	0.3	0.0	0.1	71.5
1972	0.3	2.2	8.7	6.3	11.5	4.6	6.6	1.5	0.5	0.1	0.0	0.3	42.8
1973	0.6	8.3	7.1	24.3	33.6	30.8	6.6	1.5	0.6	0.2	0.0	0.0	113.6
1974	1.0	12.7	15.4	20.0	10.2	36.1	20.9	2.3	0.7	0.1	0.0	0.0	119.4
1975	0.3	2.2	10.0	10.0	31.6	33.6	18.2	3.9	0.8	0.1	0.0	0.1	110.7
1976	0.7	2.1	1.2	1.1	9.3	8.7	3.0	1.2	0.2	0.0	0.0	0.5	27.9
1977	1.1	0.7	0.6	1.5	1.4	2.5	1.3	0.9	0.9	0.4	0.0	0.0	11.4
1978	0.1	1.4	15.5	39.3	38.9	32.5	25.4	5.0	0.8	0.2	0.0	1.3	160.4
1979	0.8	1.1	3.6	24.0	30.9	35.8	9.8	2.6	0.6	0.0	0.0	0.0	109.3
1980	0.2	2.3	4.5	51.2	51.5	30.7	6.7	3.1	1.0	0.3	0.0	0.1	151.6
1981	0.1	0.6	3.1	9.5	13.2	19.0	4.0	1.1	0.3	0.0	0.0	0.0	51.0
1982	0.4	11.3	15.4	30.6	46.6	48.1	44.9	4.4	1.1	1.0	0.4	0.4	204.7
1983	3.3	25.9	45.7	30.8	52.5	64.5	25.5	11.9	2.2	0.8	0.3	0.3	263.9
1984	1.9	18.4	36.8	15.9	19.4	12.6	4.7	1.6	0.5	0.1	0.0	0.0	112.0
1985	0.7	9.1	8.2	3.1	17.3	17.6	4.8	1.0	0.2	0.0	0.0	0.1	62.2
1986	0.5	6.6	10.9	10.3	92.3	41.7	7.0	2.7	0.6	0.0	0.0	0.2	173.0
1987	1.1	0.5	0.9	3.4	14.6	18.4	2.8	0.8	0.4	0.1	0.0	0.0	42.9
1988	0.1	2.5	2.8	10.5	3.4	9.2	5.8	2.4	0.9	0.2	0.0	0.0	37.7
1989	0.0	5.2	5.9	3.8	10.0	31.0	4.0	1.7	0.9	0.1	0.0	0.5	63.1
1990	2.1	3.1	2.1	6.9	9.2	7.9	2.0	1.7	1.4	0.5	0.0	0.0	36.7
1991	0.0	0.2	0.6	0.6	2.1	62.2	6.5	1.4	0.6	0.1	0.0	0.0	74.4
1992	0.5	1.8	1.9	3.7	20.0	10.4	3.0	0.9	0.1	0.0	0.1	0.0	42.4
1993	0.1	1.0	10.1	44.1	34.5	28.4	9.3	1.5	1.3	0.7	0.0	0.0	131.2
1994	0.1	0.6	2.6	2.0	15.9	4.5	4.7	3.1	1.0	0.2	0.0	0.0	34.7
1995	1.6	4.2	5.6	45.4	15.4	96.1	15.3	14.6	1.9	0.8	0.2	0.0	201.1
1996	0.0	0.1	8.9	15.3	35.9	30.1	11.6	3.7	1.3	0.4	0.0	0.0	107.3
1997	0.1	17.4	46.5	71.7	25.2	10.1	4.3	1.3	0.4	0.1	0.0	0.0	177.0
1998	0.2	1.5	7.7	32.0	59.6	33.5	24.9	11.8	3.1	0.9	0.1	0.1	175.3
1999	0.3	1.0	4.6	18.4	33.8	13.1	13.4	1.9	0.5	0.1	0.0	0.0	87.0
2000	0.0	1.3	1.5	26.8	49.2	19.9	5.6	2.2	0.8	0.2	0.0	0.2	107.6
2001	0.6	1.5	1.5	9.3	20.3	22.6	7.9	2.0	0.4	0.0	0.0	0.0	66.1
2002	0.0	7.3	30.3	10.8	10.5	12.2	2.0	1.3	1.0	0.2	0.0	0.0	75.6
2003	0.1	14.1	23.3	7.6	7.2	12.3	15.1	8.1	1.0	0.1	0.2	0.1	89.2
2004	0.0	0.6	12.8	13.1	20.4	8.6	1.3	0.3	0.0	0.0	0.0	0.0	57.1
2005	12.8	6.2	22.6	50.1	25.6	34.3	9.2	10.3	1.5	0.4	0.0	0.0	173.0
2006	0.1	0.2	23.8	37.5	9.9	38.6	51.3	3.6	1.3	0.3	0.0	0.0	166.5
2007	0.1	0.6	4.3	4.6	19.3	6.1	1.5	0.9	0.2	0.0	0.0	0.0	37.5
2008	0.1	0.3	4.7	41.2	25.2	5.7	1.2	0.2	0.4	0.2	0.0	0.0	79.3
2009	0.3	3.4	7.3	16.7	24.9	16.8	3.6	3.2	1.0	0.4	0.0	0.0	77.5
2010	6.2	1.5	18.0	22.4	23.2	21.9	18.8	3.5	1.3	0.3	0.0	0.0	117.1
2011	3.4	8.8	57.7	26.1	31.4	64.2	19.1	8.2	4.8	1.5	0.4	0.0	225.6
2012	1.0	0.9	1.0	9.3	6.1	15.2	13.8	2.0	0.5	0.1	0.0	0.0	49.7
2013	0.1	2.6	47.2	6.7	2.7	2.7	1.5	0.8	0.3	0.0	0.0	0.0	64.6
2014	0.2	0.5	1.1	0.8	4.5	7.6	4.9	1.6	0.4	0.0	0.0	0.0	21.6
Average	0.7	4.5	12.2	17.2	23.8	23.0	11.5	3.1	0.9	0.3	0.0	0.1	97.1
Minimum	12.8	40.6	82.0	92.4	92.3	96.1	51.3	14.6	4.8	1.5	0.4	2.8	263.9
Maximum	0.0	0.0	0.1	0.6	1.4	2.5	1.1	0.2	0.0	0.0	0.0	0.0	11.4

Table C-17. UF 21 — Fresno River near Daulton Simulated Flow (TAF)

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1922	0.2	0.2	3.8	8.6	30.7	26.0	22.1	8.2	1.9	0.4	0.0	0.0	0.2
1923	0.1	5.1	10.7	12.9	10.0	11.6	30.0	2.9	0.8	0.3	0.0	0.5	0.1
1924	1.7	0.8	0.5	0.4	2.1	6.2	4.2	1.2	0.3	0.0	0.0	0.0	1.7
1925	0.9	12.2	4.1	5.1	36.2	10.8	15.0	2.2	1.1	0.3	0.0	0.0	0.9
1926	1.1	1.0	2.1	5.3	39.8	5.7	30.5	2.1	0.4	0.1	0.0	0.0	1.1
1927	0.1	11.2	10.3	11.3	49.8	16.0	27.3	2.2	0.7	0.2	0.0	0.1	0.1
1928	0.7	7.5	4.6	4.9	14.4	35.0	20.6	1.4	0.4	0.1	0.0	0.0	0.7
1929	0.0	2.6	2.7	2.5	9.7	20.9	18.9	2.9	1.5	0.7	0.1	0.1	0.0
1930	0.5	0.2	1.0	2.3	19.1	21.2	8.9	2.9	0.6	0.2	0.0	0.0	0.5
1931	1.1	2.2	1.2	3.4	8.4	5.6	2.1	2.3	1.3	0.3	0.0	0.0	1.1
1932	0.2	0.5	12.2	5.6	30.4	40.3	27.5	8.8	1.7	0.3	0.0	0.0	0.2
1933	0.0	0.0	0.6	0.9	5.1	32.5	5.4	3.4	0.8	0.2	0.0	0.0	0.0
1934	0.0	0.7	6.5	14.4	16.2	5.0	0.7	0.4	0.7	0.3	0.0	0.0	0.0
1935	1.3	7.9	7.8	20.4	14.3	24.1	53.5	8.2	0.8	0.1	0.0	0.0	1.3
1936	0.4	1.2	1.1	18.5	79.1	18.0	20.1	2.7	1.5	0.3	0.0	0.0	0.4
1937	0.1	1.1	8.1	4.3	67.1	47.3	17.8	4.6	0.8	0.2	0.0	0.0	0.1
1938	0.0	1.1	44.3	24.4	88.9	94.2	23.7	13.1	3.6	1.4	0.3	0.5	0.0
1939	4.3	6.5	6.8	7.9	7.4	20.8	10.9	1.6	0.8	0.2	0.0	0.6	4.3
1940	3.3	0.7	1.4	55.0	33.4	30.4	16.9	2.4	0.4	0.0	0.0	0.0	3.3
1941	0.4	1.5	29.5	27.9	39.1	24.8	17.8	4.1	0.9	0.2	0.0	0.0	0.4
1942	0.0	1.2	34.3	30.8	27.7	19.2	31.5	10.9	2.0	0.3	0.0	0.0	0.0
1943	0.0	18.7	11.7	78.3	33.7	54.9	15.3	6.5	1.8	0.4	0.0	0.0	0.0
1944	0.2	1.1	3.3	8.3	22.7	25.4	9.9	3.3	0.6	0.2	0.0	0.0	0.2
1945	0.1	19.9	4.0	2.1	67.0	33.8	10.2	2.3	1.2	0.3	0.0	0.0	0.1
1946	1.2	4.6	32.8	13.5	7.6	24.3	16.2	1.8	1.1	0.2	0.0	0.1	1.2
1947	1.5	20.7	19.5	6.0	15.7	9.6	4.5	0.6	0.7	0.2	0.0	0.1	1.5
1948	1.3	1.3	0.9	2.8	2.4	35.4	44.1	7.1	1.8	0.3	0.0	0.0	1.3
1949	0.1	0.3	0.4	1.3	5.0	46.0	14.1	3.3	0.8	0.2	0.0	0.0	0.1
1950	0.0	2.9	1.7	6.7	30.8	18.6	16.6	2.2	0.3	0.0	0.0	0.0	0.0
1951	1.1	54.9	46.5	19.3	19.6	17.5	6.7	4.5	0.5	0.2	0.0	0.0	1.1
1952	0.2	3.0	20.4	30.2	23.5	44.9	48.3	12.7	3.6	0.8	0.1	0.3	0.2
1953	0.6	2.7	8.7	28.4	11.3	16.7	7.7	3.8	1.6	0.3	0.0	0.0	0.6
1954	0.1	1.7	1.5	17.1	35.7	35.4	11.2	3.2	0.8	0.3	0.0	0.0	0.1
1955	0.0	2.8	9.1	10.3	9.7	10.6	9.4	6.7	0.6	0.1	0.0	0.0	0.0
1956	0.0	0.1	114.2	51.3	26.4	12.7	13.9	11.7	1.3	0.3	0.0	0.0	0.0
1957	0.6	1.0	0.7	5.5	18.3	21.4	3.7	8.9	1.9	0.3	0.0	0.1	0.6
1958	0.8	1.2	7.0	14.9	43.3	64.6	56.5	11.3	3.5	0.5	0.1	0.4	0.8
1959	0.8	1.2	2.5	14.1	34.8	13.0	3.6	2.0	0.3	0.0	0.0	6.2	0.8
1960	1.8	0.3	0.1	3.0	29.7	17.2	8.1	2.8	0.4	0.0	0.0	0.0	1.8
1961	0.9	3.6	7.3	2.5	5.5	12.0	3.6	1.7	0.7	0.1	0.0	0.0	0.9
1962	0.3	1.3	5.9	1.0	69.6	26.6	6.6	3.0	0.8	0.1	0.0	0.0	0.3
1963	1.9	0.8	1.6	17.7	50.1	15.0	31.3	7.9	1.0	0.2	0.0	0.1	1.9
1964	1.2	14.6	3.6	0.7	0.9	6.4	6.3	2.2	0.9	0.3	0.0	0.2	1.2
1965	0.8	11.0	30.1	23.0	19.4	22.2	24.1	5.6	0.8	0.1	0.0	0.0	0.8
1966	0.2	23.1	6.7	4.7	12.3	8.5	2.4	1.0	0.3	0.0	0.0	0.0	0.2
1967	0.0	4.1	63.7	12.6	14.1	62.5	49.0	13.9	5.2	0.5	0.0	0.1	0.0
1968	0.5	0.8	4.2	6.5	16.3	14.0	3.1	0.8	0.6	0.2	0.0	0.0	0.5
1969	0.3	4.4	15.9	134.2	63.3	44.4	54.5	15.6	8.6	1.8	0.4	0.5	0.3
1970	5.0	6.8	15.0	60.7	22.4	27.3	7.5	2.6	0.6	0.5	0.1	0.0	5.0

Table C-17. UF 21 — Fresno River near Daulton Simulated Flow (TAF) contd.

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1971	0.0	9.2	20.8	6.9	12.0	19.8	7.8	4.1	1.1	0.3	0.0	0.1	0.0
1972	0.5	2.4	6.9	2.4	9.9	5.3	10.8	1.5	0.6	0.3	0.0	0.9	0.5
1973	0.8	9.1	5.2	31.2	37.2	30.5	10.2	3.4	1.0	0.2	0.0	0.0	0.8
1974	1.3	19.5	19.3	18.9	10.7	55.6	28.2	4.2	0.5	0.1	0.0	0.0	1.3
1975	0.2	2.0	10.5	7.1	26.0	47.2	23.0	7.6	0.8	0.1	0.0	0.2	0.2
1976	1.6	1.9	0.9	0.7	7.9	6.0	2.7	0.9	0.2	0.0	0.0	1.4	1.6
1977	1.2	0.6	0.5	1.0	1.5	2.1	0.8	1.6	1.1	0.4	0.0	0.0	1.2
1978	0.1	2.0	17.3	51.4	46.4	48.8	30.6	9.4	1.1	0.4	0.1	2.6	0.1
1979	0.7	1.3	4.4	26.5	30.4	45.3	16.1	5.7	0.6	0.1	0.0	0.0	0.7
1980	0.6	2.7	2.9	65.2	78.2	38.6	13.2	6.8	1.9	0.3	0.0	0.1	0.6
1981	0.2	1.0	4.2	10.1	16.9	25.0	6.2	1.0	0.4	0.1	0.0	0.1	0.2
1982	0.7	12.1	11.8	15.7	53.0	60.9	68.4	10.3	3.9	2.7	0.3	1.6	0.7
1983	6.8	33.4	55.9	31.5	61.2	69.4	26.5	19.5	6.4	3.0	1.4	1.8	6.8
1984	6.3	26.1	43.6	19.7	22.5	18.1	5.7	1.7	0.4	0.2	0.0	0.0	6.3
1985	1.0	8.2	5.7	2.2	14.6	20.0	5.8	0.7	0.3	0.1	0.0	0.3	1.0
1986	0.8	7.3	12.7	13.8	123.5	55.2	9.8	4.4	0.8	0.1	0.0	0.4	0.8
1987	1.7	0.8	2.8	6.8	19.4	19.3	2.7	0.7	0.4	0.1	0.0	0.2	1.7
1988	0.5	4.1	2.9	8.9	7.4	13.2	8.2	2.7	0.7	0.2	0.1	0.0	0.5
1989	0.0	3.3	3.2	2.3	7.7	31.1	4.0	2.5	0.7	0.1	0.0	1.2	0.0
1990	2.6	3.4	2.1	7.6	5.0	11.3	1.7	1.9	1.7	0.4	0.0	0.0	2.6
1991	0.0	0.2	0.7	0.8	1.8	72.1	9.8	2.1	0.6	0.2	0.1	0.0	0.0
1992	0.6	2.3	2.0	5.1	22.6	14.2	4.0	0.6	0.1	0.2	0.2	0.0	0.6
1993	0.2	1.7	8.0	48.8	34.8	44.1	17.2	5.7	3.4	0.5	0.0	0.0	0.2
1994	0.1	0.8	3.4	3.6	15.9	5.2	6.6	4.5	0.8	0.1	0.0	0.0	0.1
1995	2.8	2.9	3.4	53.7	18.1	120.1	19.5	21.8	3.9	0.9	0.1	0.1	2.8
1996	0.2	0.9	14.5	12.5	49.5	42.2	19.0	6.5	1.4	0.4	0.1	0.0	0.2
1997	0.1	23.5	47.2	88.8	25.1	13.0	9.0	4.9	1.0	0.2	0.0	0.1	0.1
1998	0.2	1.6	7.6	28.6	58.5	33.6	24.1	17.8	8.4	1.2	0.2	0.5	0.2
1999	1.5	2.8	4.7	19.4	31.0	10.9	13.6	2.2	0.5	0.1	0.0	0.0	1.5
2000	0.0	1.7	1.0	30.3	55.1	19.4	6.6	2.3	0.6	0.2	0.0	0.5	0.0
2001	0.7	1.6	0.8	7.4	25.0	27.2	10.2	2.5	0.3	0.1	0.0	0.0	0.7
2002	0.1	6.6	35.6	13.1	9.1	17.3	2.8	1.8	0.9	0.1	0.0	0.1	0.1
2003	0.1	16.9	24.8	8.6	8.4	13.5	16.3	10.6	0.7	0.1	0.3	0.2	0.1
2004	0.0	1.2	17.7	16.9	19.2	11.5	1.2	0.2	0.0	0.0	0.0	0.0	0.0
2005	13.4	5.7	23.3	51.9	24.3	34.8	10.9	11.5	1.4	0.3	0.0	0.0	13.4
2006	0.1	0.3	27.6	46.3	9.6	39.4	57.5	5.4	1.6	0.3	0.0	0.0	0.1
2007	0.4	1.6	4.9	4.6	17.4	7.1	1.9	0.8	0.2	0.0	0.0	0.0	0.4
2008	0.0	0.4	5.0	44.5	27.1	7.8	0.9	0.3	0.7	0.2	0.0	0.0	0.0
2009	0.4	4.8	6.1	17.1	24.1	17.7	4.6	4.1	1.0	0.3	0.0	0.0	0.4
2010	12.3	1.4	18.2	24.0	25.4	26.1	26.0	5.6	1.2	0.2	0.0	0.0	12.3
2011	6.0	9.1	60.5	30.3	21.4	74.9	27.2	11.1	5.8	2.0	0.6	0.3	6.0
2012	2.8	2.7	2.3	13.8	7.7	15.9	16.0	2.2	0.4	0.1	0.0	0.0	2.8
2013	0.2	2.9	43.0	7.0	3.0	5.3	2.1	0.7	0.2	0.0	0.0	0.0	0.2
2014	0.4	1.0	0.9	0.6	5.3	10.3	6.4	1.7	0.3	0.0	0.0	0.0	0.4
Average	1.2	5.6	13.2	18.8	26.6	27.6	16.0	4.9	1.3	0.3	0.0	0.2	1.2
Minimum	0.0	0.0	0.1	0.4	0.9	2.1	0.7	0.2	0.0	0.0	0.0	0.0	0.0
Maximum	13.4	54.9	114.2	134.2	123.5	120.1	68.4	21.8	8.6	3.0	1.4	6.2	13.4

Table C-18. UF 22 — San Joaquin River at Millerton Reservoir Simulated Flow (TAF)

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1922	6.7	4.0	63.9	52.3	87.6	81.3	230.8	641.6	499.5	281.6	50.6	13.2	2,013.2
1923	4.7	34.5	64.2	63.9	52.0	116.3	244.3	350.0	240.8	274.0	59.3	20.6	1,524.5
1924	25.8	25.1	13.6	12.4	28.4	65.7	119.6	230.9	91.8	37.3	12.5	1.9	665.0
1925	11.0	79.6	64.4	29.3	169.0	181.4	237.8	376.6	417.8	195.1	43.6	15.0	1,820.5
1926	13.2	19.4	32.9	34.6	125.3	150.9	314.1	360.0	268.5	71.3	22.4	4.3	1,416.9
1927	1.0	106.9	94.6	40.8	150.8	148.2	347.7	456.7	363.2	168.9	40.2	10.7	1,929.7
1928	25.4	110.3	51.6	36.7	80.3	236.3	196.6	399.1	235.6	64.0	21.8	4.5	1,462.3
1929	0.9	10.8	29.0	24.3	37.9	131.2	184.1	392.3	256.2	132.6	30.2	7.4	1,236.9
1930	5.8	3.5	4.5	31.4	98.1	154.2	224.8	210.1	346.3	87.9	24.5	5.2	1,196.3
1931	8.6	20.2	15.1	29.1	47.0	88.5	167.6	306.0	131.2	47.3	15.5	5.0	881.0
1932	5.2	14.4	86.6	50.3	112.6	201.9	283.1	436.7	566.2	387.2	65.9	18.7	2,228.6
1933	5.3	4.1	8.3	40.5	35.3	146.5	268.6	265.6	376.0	112.1	29.2	6.7	1,298.1
1934	2.0	10.8	103.5	71.4	83.4	199.2	216.0	263.7	111.2	66.4	22.7	5.8	1,156.1
1935	13.4	82.1	73.7	97.3	90.2	111.8	399.3	408.7	633.5	217.6	46.6	14.5	2,188.9
1936	11.5	17.2	14.5	83.0	233.3	204.2	420.0	513.2	441.1	203.2	52.2	15.9	2,209.1
1937	7.9	20.4	110.1	47.8	213.6	216.2	241.4	681.5	402.4	256.6	49.8	12.9	2,260.6
1938	3.5	6.9	338.1	88.7	195.2	257.3	276.0	593.9	740.6	423.1	120.5	28.1	3,072.0
1939	25.6	33.2	24.6	44.7	38.1	138.3	291.1	226.2	185.0	60.5	20.0	7.9	1,095.2
1940	56.0	37.6	22.1	187.7	177.9	255.2	268.2	574.3	414.5	120.1	28.3	6.4	2,148.5
1941	6.1	19.5	117.2	102.0	156.7	164.3	199.4	581.4	540.0	409.9	94.1	30.7	2,421.3
1942	9.8	16.1	167.4	93.3	105.0	119.2	318.1	405.3	611.7	348.9	60.1	16.5	2,271.3
1943	4.7	62.7	65.2	178.5	130.1	317.7	358.4	504.1	370.2	258.8	61.7	17.7	2,329.5
1944	6.2	9.3	21.3	44.1	96.2	123.5	193.0	451.7	229.6	190.6	47.8	13.8	1,426.9
1945	11.1	138.8	52.1	29.1	236.8	106.0	267.2	460.3	434.6	256.3	49.7	15.4	2,057.4
1946	33.3	87.3	127.7	60.2	37.5	159.2	379.6	369.4	288.4	105.7	35.4	12.7	1,696.3
1947	27.2	116.4	113.7	51.1	76.1	148.7	203.2	366.9	151.9	55.2	19.4	6.6	1,336.4
1948	18.5	30.2	15.2	16.2	31.0	76.8	294.3	397.2	300.2	183.8	37.4	8.7	1,409.4
1949	4.9	13.5	25.0	19.9	36.2	132.3	352.9	332.8	284.9	75.0	23.1	8.2	1,308.6
1950	5.6	15.7	38.1	49.0	115.3	161.9	382.5	369.7	266.8	79.7	26.0	7.4	1,517.7
1951	18.9	362.2	265.4	69.7	85.0	118.5	258.1	401.7	485.9	197.3	39.7	10.5	2,312.8
1952	4.9	27.8	103.0	135.8	87.2	124.5	433.4	708.1	543.4	385.7	127.5	41.6	2,722.9
1953	22.3	14.8	47.8	75.4	52.5	106.4	245.8	230.6	323.6	236.0	48.6	13.8	1,417.6
1954	5.0	16.1	22.7	67.8	157.3	231.4	363.7	452.4	190.8	86.9	27.9	7.1	1,629.0
1955	3.0	21.3	72.5	56.0	54.5	98.6	156.9	373.4	408.7	117.9	46.6	14.4	1,424.0
1956	5.2	6.4	369.1	200.0	88.2	130.3	366.4	588.6	575.3	413.7	143.9	48.6	2,935.8
1957	27.0	21.4	15.2	46.7	91.6	160.0	156.5	341.8	401.0	117.1	28.2	7.5	1,413.9
1958	11.2	19.7	70.6	60.6	161.1	217.7	367.6	812.9	425.5	293.8	67.6	30.7	2,539.1
1959	26.9	11.6	7.4	46.7	114.7	155.1	278.6	206.0	166.1	50.9	15.3	61.5	1,140.9
1960	51.9	21.7	8.8	21.4	121.5	181.6	299.2	291.5	204.3	51.0	17.9	6.0	1,276.8
1961	7.3	32.1	47.5	22.7	52.1	100.5	220.1	219.7	223.6	63.9	21.1	12.5	1,023.1
1962	13.3	14.8	36.3	23.0	303.0	119.7	501.3	350.5	419.4	244.6	51.7	15.9	2,093.5
1963	23.7	20.4	12.6	207.3	359.7	127.9	222.3	535.4	410.8	351.8	119.5	33.2	2,424.6
1964	28.5	96.1	58.5	37.8	27.3	71.8	219.9	333.0	233.6	85.0	27.9	11.1	1,230.7
1965	7.0	70.5	189.4	146.0	80.5	119.7	290.3	543.4	511.5	383.0	108.4	36.1	2,485.9
1966	13.2	101.7	76.6	35.7	38.5	120.9	350.9	350.3	149.7	54.9	18.6	5.9	1,316.8
1967	6.1	31.7	239.0	67.4	98.4	279.1	184.3	711.5	713.9	644.0	135.9	35.5	3,146.8
1968	27.9	15.7	37.1	36.2	85.2	146.0	185.6	256.3	224.2	53.0	18.7	7.8	1,093.5
1969	14.6	60.9	94.1	366.9	193.9	144.2	460.7	969.5	701.6	520.0	209.2	46.1	3,782.0
1970	31.1	38.2	50.9	155.5	114.0	170.3	154.2	497.1	451.4	152.2	34.5	9.4	1,859.0

Table C-18. UF 22 — San Joaquin River at Millerton Reservoir Simulated Flow (TAF) contd.

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1971	3.7	51.4	111.3	42.4	65.8	139.0	230.0	256.7	413.6	254.8	53.6	20.0	1,642.3
1972	13.6	26.0	76.8	27.9	58.2	244.4	165.8	296.3	289.0	76.4	23.5	17.4	1,315.4
1973	20.4	39.5	28.8	88.4	136.9	112.8	241.1	727.4	406.2	160.7	36.4	13.1	2,011.5
1974	12.8	125.6	104.1	103.7	72.6	236.3	286.2	511.0	514.8	142.1	40.4	14.6	2,164.5
1975	8.8	24.5	59.2	47.8	145.9	214.8	143.8	585.1	520.7	150.9	38.5	19.7	1,959.8
1976	52.5	57.8	22.1	11.6	59.8	98.8	110.0	287.5	105.0	46.0	24.3	38.4	913.7
1977	43.6	18.8	8.5	23.3	25.1	49.0	105.6	125.6	199.7	54.7	17.7	5.8	677.5
1978	5.7	14.9	117.1	211.9	203.9	368.2	317.3	579.9	713.8	413.4	184.5	100.3	3,230.8
1979	35.8	16.7	26.2	86.2	101.1	231.3	268.9	601.6	392.7	156.5	47.7	14.8	1,979.6
1980	12.7	48.6	50.8	292.2	310.7	187.1	309.8	449.7	538.9	512.1	207.4	38.4	2,958.3
1981	15.7	12.4	23.5	44.4	85.8	178.8	265.8	359.1	261.0	60.5	18.4	5.5	1,331.0
1982	17.4	164.7	100.1	127.3	204.5	292.4	461.1	573.5	561.3	434.1	178.0	82.7	3,197.0
1983	138.2	175.1	154.9	106.6	193.3	295.9	196.5	619.3	956.1	557.3	242.5	80.3	3,716.0
1984	56.3	128.6	172.2	74.1	106.5	192.0	220.7	551.1	371.3	125.8	36.6	13.3	2,048.4
1985	14.0	78.1	56.6	21.1	55.4	129.8	343.1	248.6	199.8	66.4	25.0	14.1	1,251.9
1986	34.5	56.3	89.7	108.8	548.6	364.6	248.7	443.0	587.3	264.1	66.5	24.5	2,836.5
1987	21.0	13.1	8.8	16.7	91.0	128.1	271.0	255.3	127.0	49.0	17.3	7.0	1,005.3
1988	9.2	63.4	48.3	80.8	79.8	146.3	203.1	294.8	213.3	81.8	29.1	11.3	1,261.3
1989	7.9	20.9	44.7	26.6	50.3	298.8	415.4	273.5	169.1	74.6	27.4	21.5	1,430.7
1990	64.0	54.6	28.0	54.5	57.2	181.1	226.7	224.6	186.8	84.9	30.5	10.6	1,203.5
1991	10.6	11.7	11.7	10.5	41.7	290.1	171.5	331.3	424.6	167.2	41.8	15.2	1,527.7
1992	16.6	36.4	32.9	45.7	104.1	148.9	299.5	318.5	120.4	66.3	34.6	11.6	1,235.4
1993	12.9	40.1	75.4	159.7	154.2	323.3	314.1	591.1	513.3	376.7	90.6	24.9	2,676.3
1994	11.2	17.4	35.9	31.1	88.9	151.5	203.5	277.3	193.8	53.2	17.3	5.8	1,086.9
1995	54.7	57.3	45.5	218.2	128.2	538.4	295.8	572.6	609.7	674.7	279.6	53.4	3,528.1
1996	18.6	6.5	56.7	96.6	258.7	258.7	359.9	575.2	527.1	196.4	49.3	16.3	2,420.0
1997	7.4	135.7	217.2	391.4	91.6	237.1	284.7	661.9	485.1	242.0	61.8	22.4	2,838.1
1998	14.0	17.8	57.5	131.2	222.6	218.9	264.6	376.7	629.5	720.5	239.9	53.7	2,947.0
1999	31.4	24.3	52.8	98.7	137.4	118.6	232.5	394.6	392.7	186.1	39.2	13.1	1,721.4
2000	10.6	21.4	23.8	115.5	261.7	177.7	358.8	502.4	378.1	96.4	26.7	13.5	1,986.5
2001	18.4	35.7	18.2	49.3	89.3	185.1	265.2	538.3	193.7	50.3	22.4	7.5	1,473.4
2002	7.9	59.6	130.4	106.4	86.9	156.7	258.1	301.4	379.9	87.0	25.1	8.4	1,607.8
2003	8.5	149.7	135.6	73.7	70.0	102.9	151.0	519.9	580.8	85.0	35.3	18.5	1,931.1
2004	9.7	12.6	110.5	91.6	92.4	261.0	162.9	270.8	309.1	115.5	37.3	12.8	1,486.2
2005	67.3	81.0	96.5	239.2	163.8	261.4	195.4	699.1	583.8	376.4	75.2	25.1	2,864.0
2006	13.6	17.6	260.1	283.3	140.7	207.6	385.3	684.0	666.2	264.3	61.5	18.1	3,002.4
2007	10.9	19.7	44.4	44.4	128.3	218.6	175.2	203.9	104.8	46.4	16.6	9.2	1,022.6
2008	13.1	15.4	36.2	125.5	106.7	151.7	190.1	378.5	272.2	96.5	31.9	9.3	1,427.1
2009	16.0	90.0	69.1	154.9	151.7	185.4	224.4	542.5	168.5	100.0	35.2	13.3	1,751.0
2010	108.8	55.5	72.0	96.8	120.7	169.0	223.7	314.6	638.7	283.6	57.5	17.2	2,158.1
2011	64.6	95.7	269.8	139.7	118.1	201.4	340.6	438.4	645.3	522.4	145.3	36.3	3,017.5
2012	27.7	34.6	21.0	68.3	57.1	90.8	320.0	268.8	87.0	35.9	12.8	6.6	1,030.7
2013	6.3	15.6	214.6	255.2	136.9	268.2	319.3	299.6	211.0	60.9	20.5	7.7	1,815.8
2014	6.6	9.4	12.4	17.0	39.7	123.7	188.8	193.2	82.0	31.4	14.4	8.5	727.1
Average	20.1	47.4	77.6	88.5	119.2	179.1	266.8	426.0	375.2	197.6	57.4	19.1	1,873.8
Minimum	138.2	362.2	369.1	391.4	548.6	538.4	501.3	969.5	956.1	720.5	279.6	100.3	3,782.0
Maximum	0.9	3.5	4.5	10.5	25.1	49.0	105.6	125.6	82.0	31.4	12.5	1.9	665.0

APPENDIX D   COMPARISON BETWEEN MONTHLY NATURAL FLOW AND UNIMPAIRED FLOWS FOR WY 1922-2014

Note on comparison tables:

- Major rim watersheds with CDEC unimpaired flow data consist of Sacramento River at Shasta Reservoir, Feather River at Lake Oroville, Yuba River, American River, Cosumnes River, Mokelumne River, Stanislaus River, Merced River, Tuolumne River, and San Joaquin River at Millerton, their total inflows are about 80 percent of total rim inflow.

- Smaller and minor streams unimpaired flows are maintained and updated by DWR's Bay Delta Office. Exact corresponding comparisons were made by identifying unimpaired flow equation and components where possible.

- Valley floor or Tulare basin subwatersheds UF1, UF12, UF17, UF23 and UF24 were not compared.
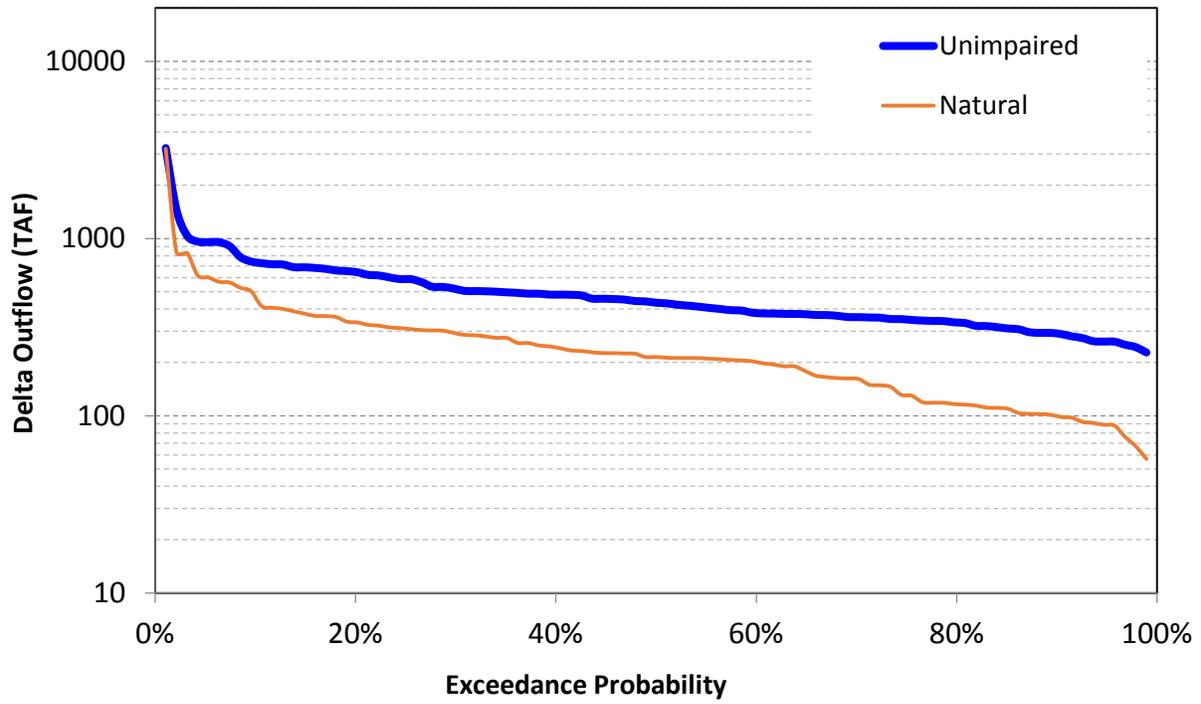
Figure D-1. October Net Delta Outflow
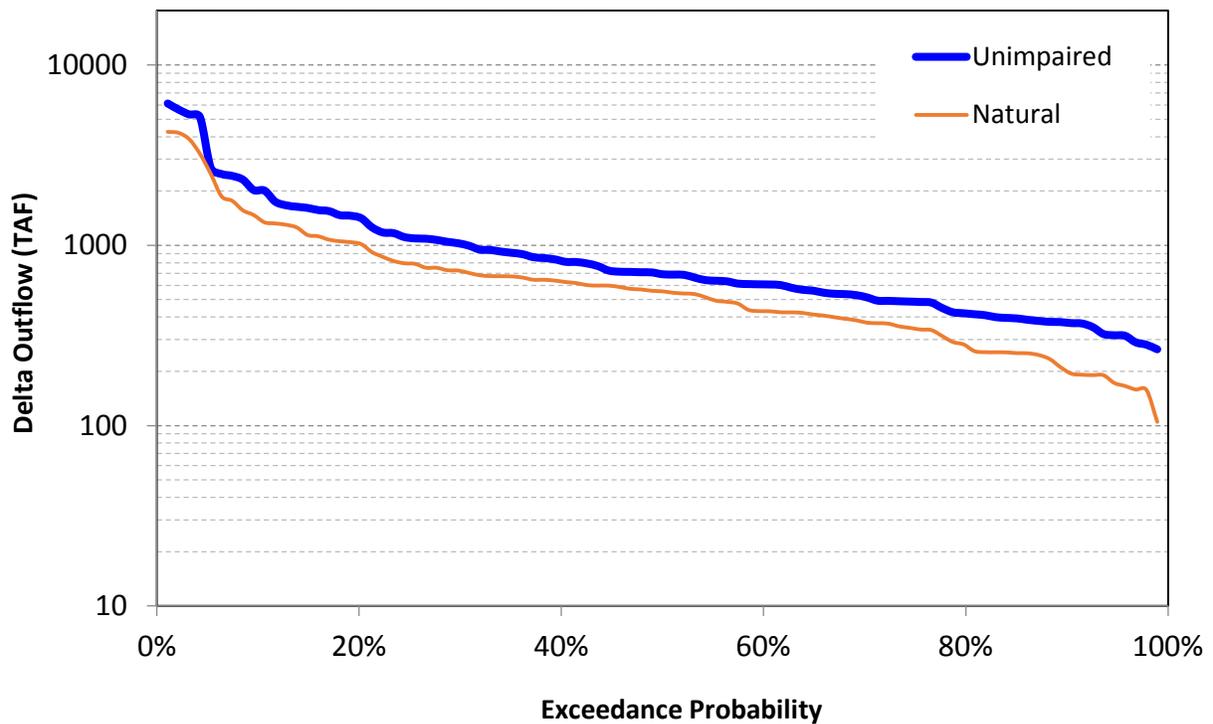
Figure D-2. November Net Delta Outflow
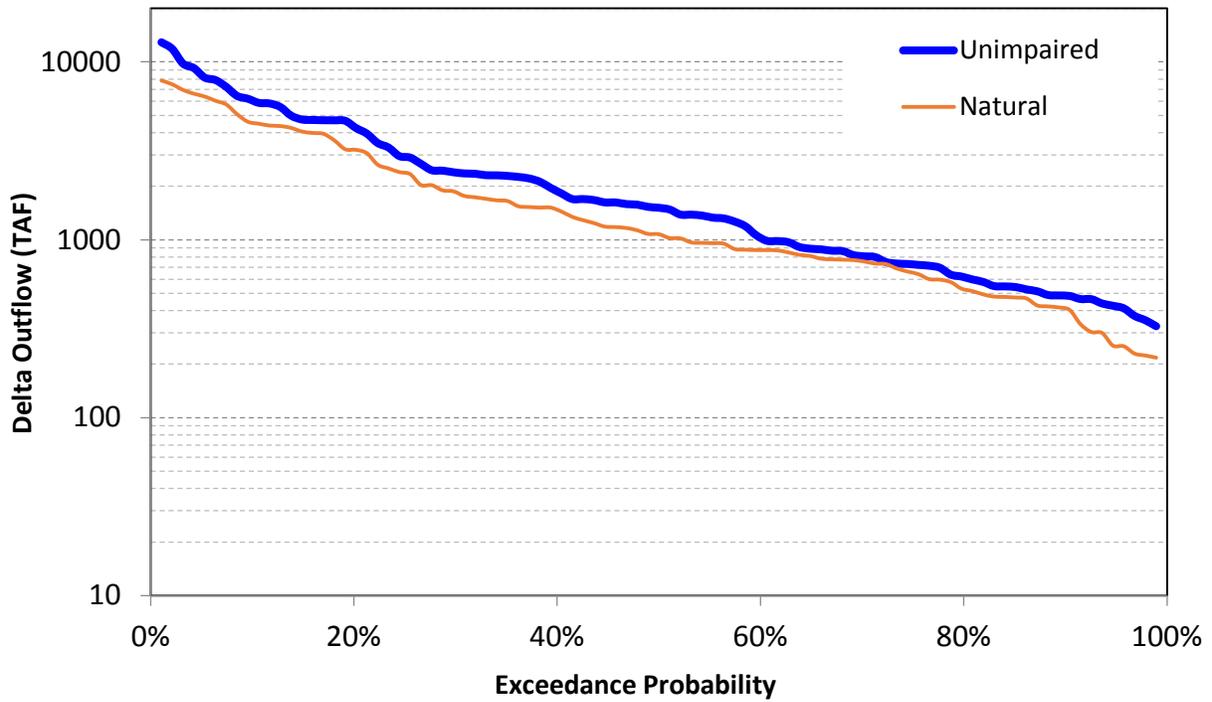
Figure D-3. December Net Delta Outflow
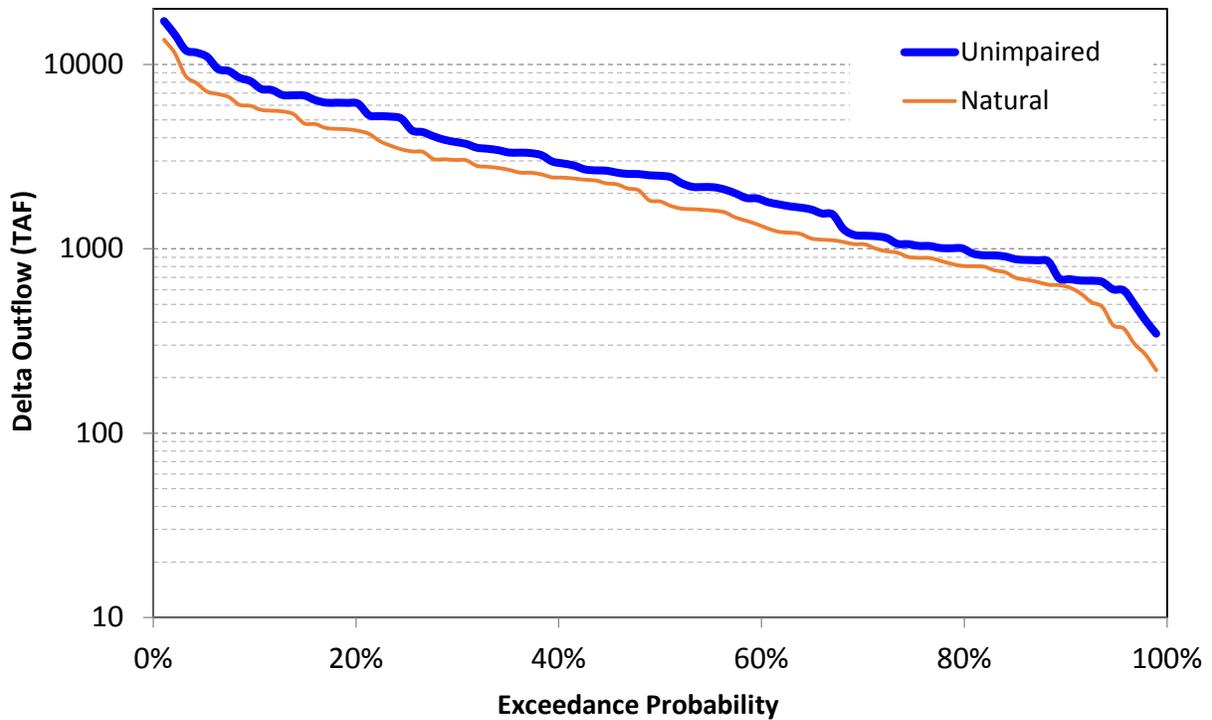
Figure D-4. January Net Delta Outflow
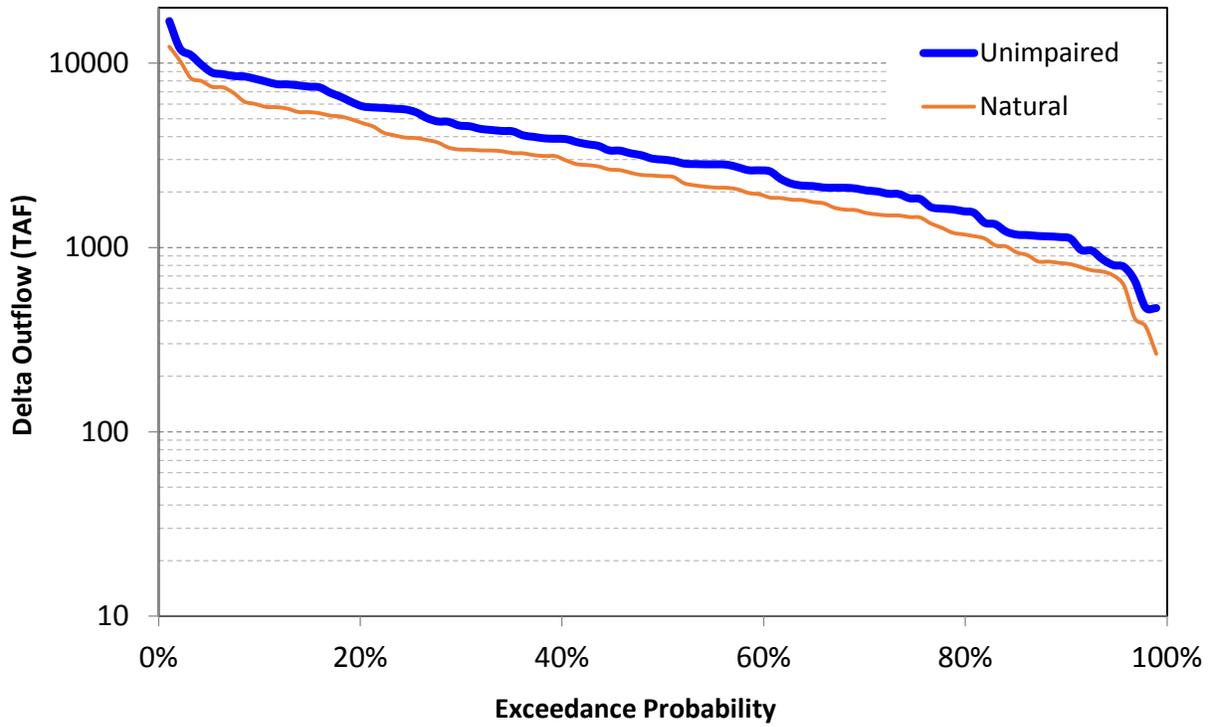
Figure D-5. February Net Delta Outflow
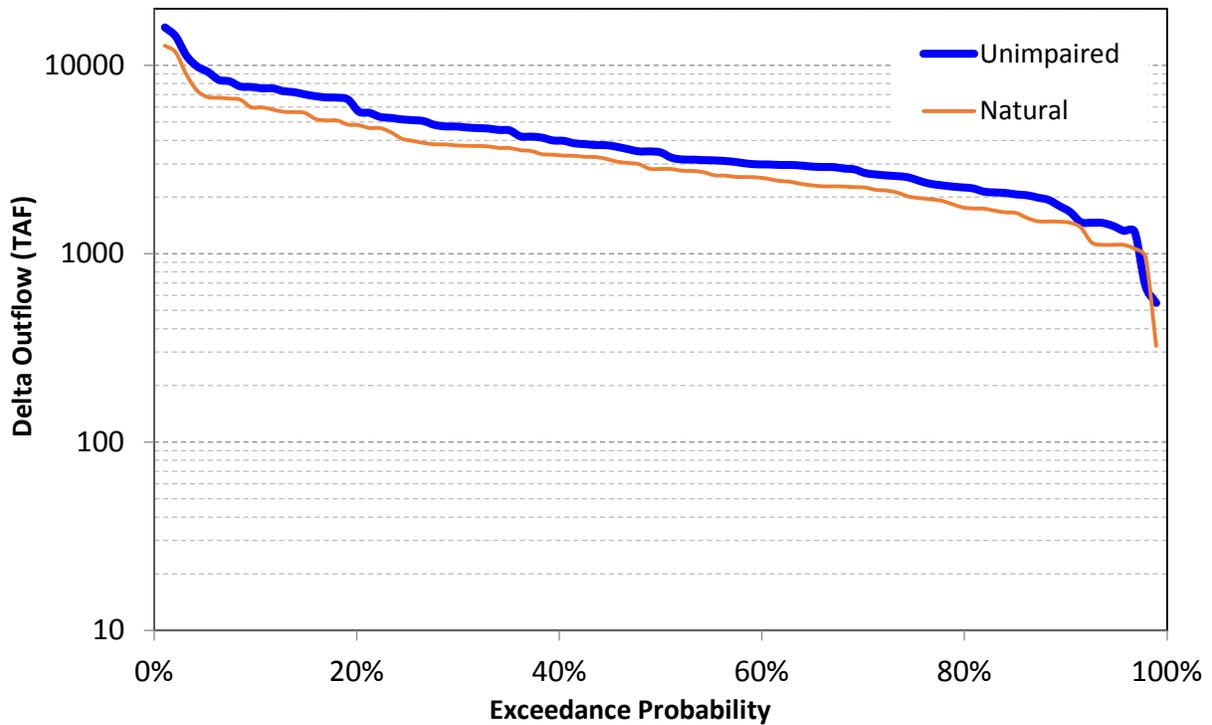
Figure D-6. March Net Delta Outflow
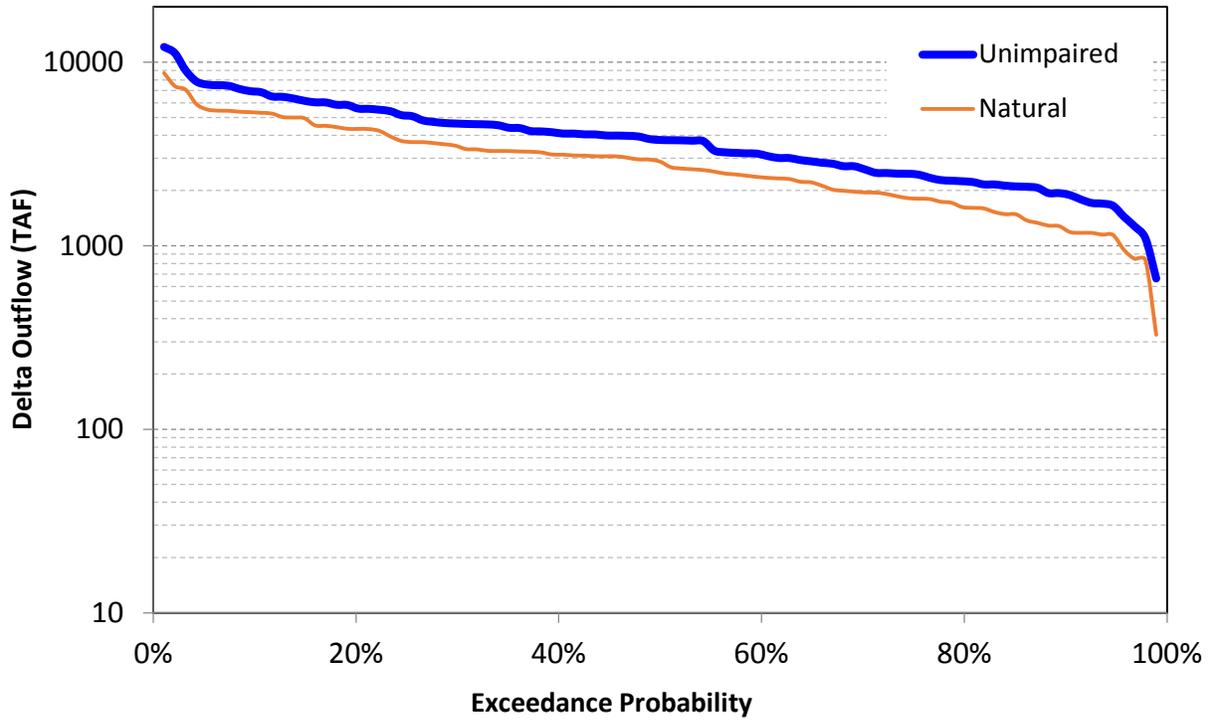
Figure D-7. April Net Delta Outflow
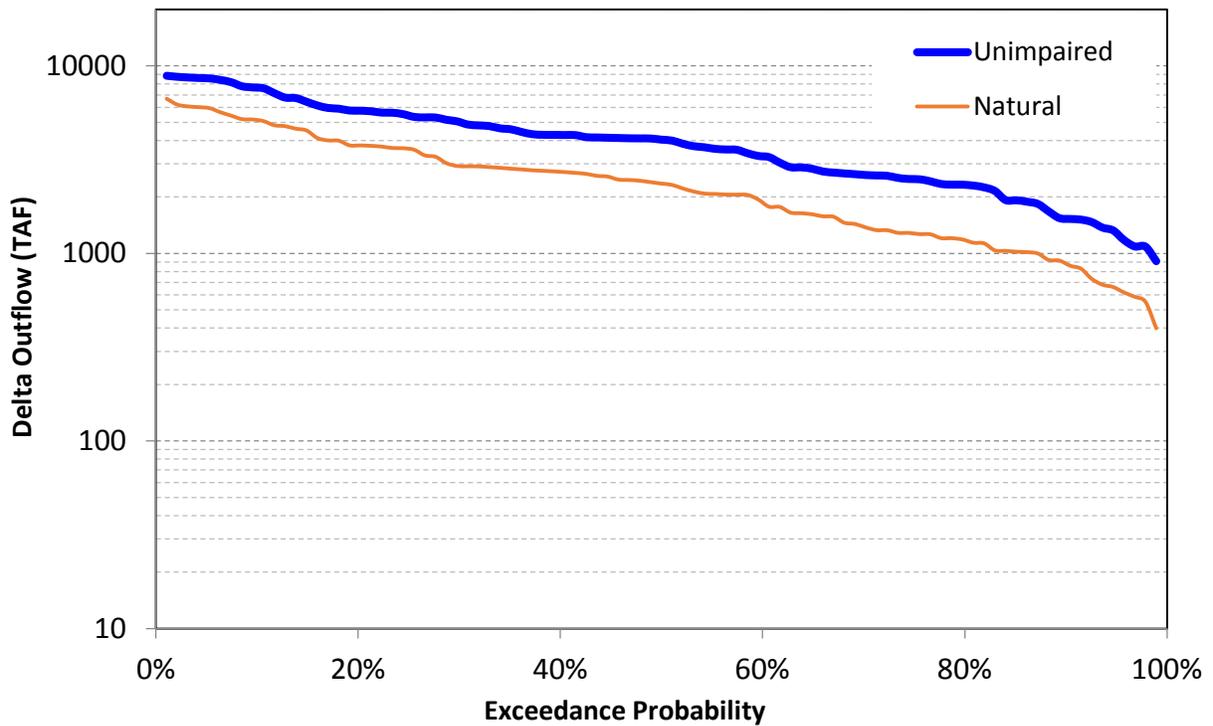
Figure D-8. May Net Delta Outflow
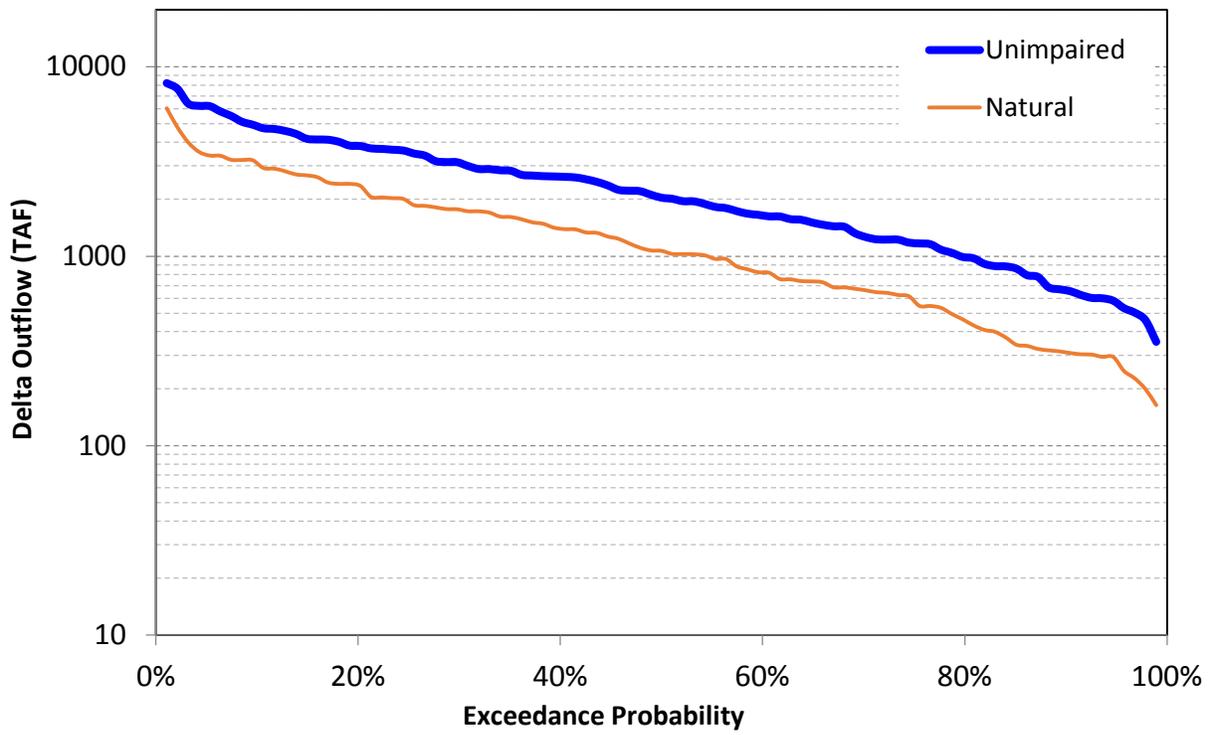
Figure D-9. June Net Delta Outflow
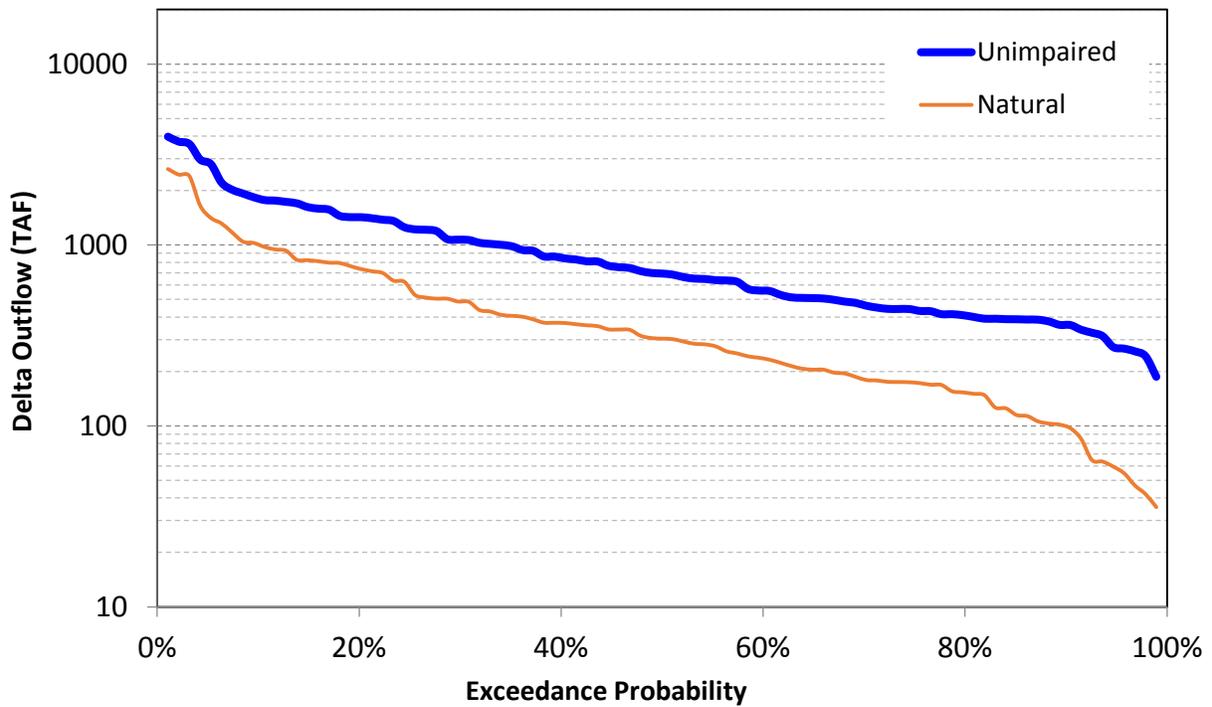
Figure D-10. July Net Delta Outflow
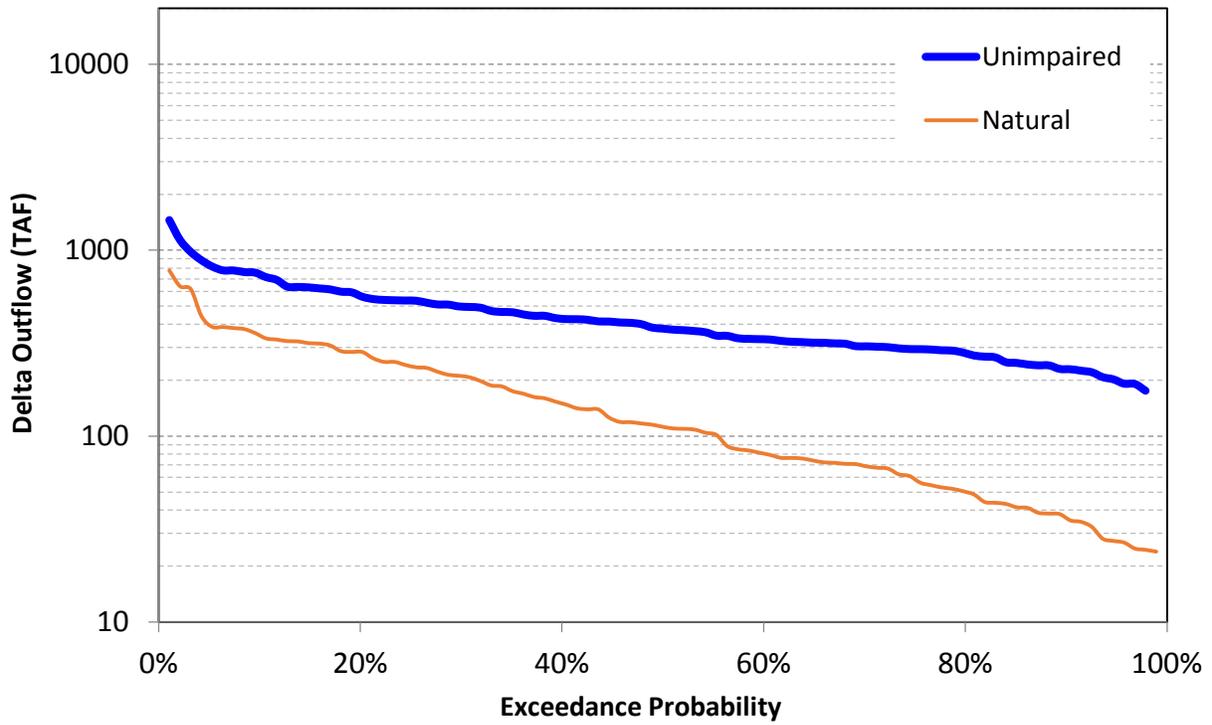
Figure D-11. August Net Delta Outflow
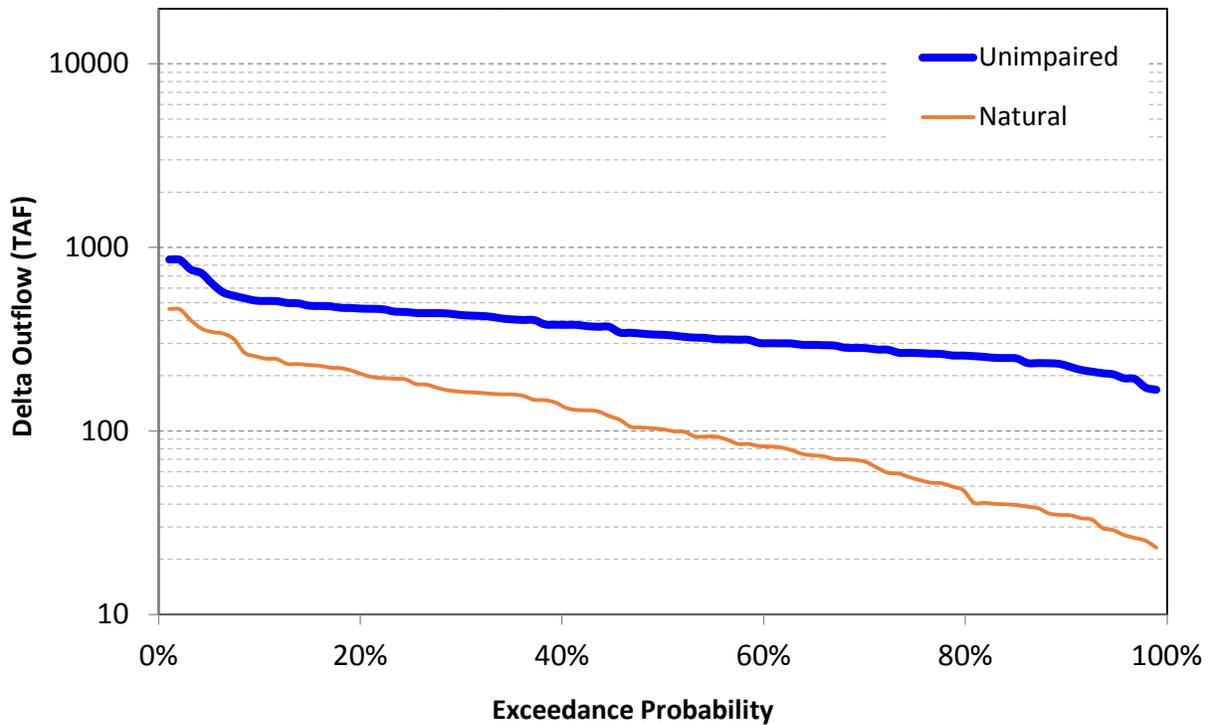
Figure D-12. September Net Delta Outflow
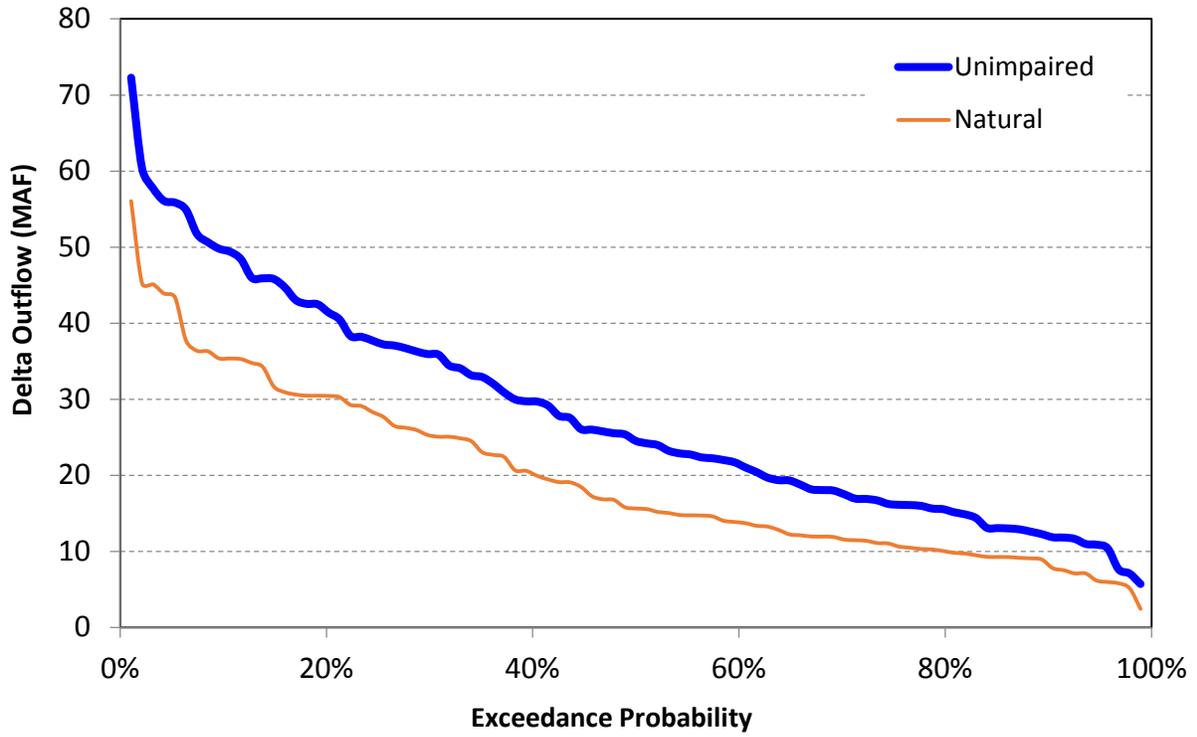
Figure D-13. Annual Net Delta Outflow

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Table D-1. UF 2 – Putah Creek near Winters Simulated minus Unimpaired (TAF)

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1922	1	0	-25	22	-83	8	13	15	11	7	4	2	-24
1923	1	-7	-86	-1	11	17	-14	9	7	5	3	1	-55
1924	1	0	0	-3	-10	15	12	9	6	3	1	0	35
1925	0	-4	10	25	-74	40	16	8	14	12	8	4	57
1926	2	1	0	20	-72	37	-67	22	17	12	7	3	-17
1927	2	-25	54	6	-122	35	-36	19	14	10	6	3	-33
1928	2	-13	-4	7	-14	-56	-5	20	16	11	7	3	-28
1929	2	2	-4	11	-7	12	11	9	6	3	1	1	45
1930	0	0	-27	-12	-5	-13	16	13	10	6	3	2	-8
1931	1	-1	-1	-1	15	9	12	9	4	3	1	1	54
1932	0	0	-11	47	17	25	16	10	6	3	2	1	116
1933	0	0	2	-7	24	6	15	12	9	6	4	2	73
1934	1	1	-11	28	-9	12	14	12	7	5	3	1	63
1935	0	-3	7	-27	30	-39	-30	13	13	10	6	3	-17
1936	1	1	-1	16	-93	38	6	18	12	9	5	2	14
1937	1	0	-1	-5	-60	-20	23	22	14	10	6	3	-6
1938	1	-7	5	44	-199	-88	6	18	16	12	6	3	-183
1939	1	0	-2	-2	0	-3	8	7	5	4	2	1	20
1940	0	0	3	-25	-118	7	22	29	20	15	8	4	-35
1941	1	0	-41	-32	-55	-21	-60	15	16	13	8	4	-152
1942	2	0	-44	-19	-66	18	-38	5	10	10	6	3	-115
1943	1	-2	-1	-28	41	11	13	12	10	7	3	1	69
1944	1	0	-1	-2	-10	-14	21	16	12	8	5	2	37
1945	1	-1	0	26	-24	2	13	13	10	7	4	2	54
1946	5	-3	-55	50	24	15	6	8	5	2	1	1	60
1947	0	-2	6	15	-15	-14	6	14	8	6	4	2	30
1948	0	-1	0	-9	5	-14	-28	13	17	15	9	5	13
1949	2	0	-1	-2	-22	-58	25	22	16	11	6	3	3
1950	1	1	-1	-17	-8	26	14	16	11	7	4	2	57
1951	-2	-9	-19	-1	13	-4	14	8	9	6	3	2	20
1952	1	-5	-4	-60	10	-24	14	16	12	9	4	3	-23
1953	1	0	-28	-3	42	0	10	9	9	6	4	2	53
1954	1	0	6	6	-13	-5	-6	19	16	11	6	3	46
1955	2	-5	13	18	15	9	-6	5	7	6	4	2	69
1956	1	1	-11	7	-55	56	29	16	14	9	5	2	73
1957	1	-1	-1	-7	-26	24	20	7	14	10	5	2	49
1958	-5	10	-3	-32	-153	-9	-38	33	20	14	8	4	-150
1959	3	2	-2	11	-16	44	24	16	8	4	2	-1	95
1960	1	1	-1	-13	-11	22	20	14	9	4	2	1	48
1961	1	-3	10	17	12	3	13	13	5	3	2	2	78
1962	1	-4	6	11	-65	15	31	22	13	7	5	3	43
1963	-8	33	0	-14	-4	3	-51	15	17	11	8	5	15
1964	1	-17	15	-10	24	13	10	5	0	-3	-2	-2	34
1965	-4	4	-16	27	43	26	-16	10	8	3	1	3	89
1966	0	-12	5	31	5	19	12	10	5	2	-1	-3	73
1967	0	-25	1	-82	54	-19	-59	2	5	10	5	4	-103
1968	2	-1	-5	-34	3	3	20	16	10	6	4	2	26
1969	1	-2	-25	-60	-42	20	14	13	12	6	5	3	-55
1970	1	0	-39	-126	53	9	20	10	7	4	4	2	-55

Table D-1. UF 2 – Putah Creek near Winters Simulated minus Unimpaired (TAF) contd.

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1971	1	-15	6	12	27	-15	5	6	3	0	1	1	34
1972	1	0	-11	15	0	13	5	3	3	1	1	1	32
1973	-1	-12	5	-54	-36	-8	15	13	10	6	5	3	-54
1974	-1	-17	31	-33	6	-105	-17	14	11	8	8	3	-91
1975	1	1	-7	3	-68	-67	25	17	13	8	7	3	-64
1976	0	2	0	1	-4	-2	-3	-2	-1	2	1	0	-6
1977	0	0	0	-1	-2	-4	-2	-1	-2	-1	-1	-1	-14
1978	-1	-8	16	-7	21	-15	7	15	13	8	5	1	55
1979	1	0	0	-3	-25	21	16	13	10	8	5	2	49
1980	-3	2	-15	-16	-78	27	20	17	11	5	6	3	-22
1981	1	0	-2	-18	31	4	15	11	4	7	3	2	58
1982	0	-55	-9	8	-6	-16	-124	31	22	16	12	6	-116
1983	0	-24	-12	-88	-106	-153	6	3	15	13	11	7	-327
1984	5	-50	-91	51	12	-5	8	4	4	3	2	2	-55
1985	2	-6	30	23	-6	1	13	12	6	6	2	2	85
1986	1	-5	1	-1	-199	6	45	25	20	14	8	5	-80
1987	3	2	1	-6	-19	-14	21	18	12	9	5	1	33
1988	0	1	1	36	40	27	20	10	5	3	2	1	144
1989	0	-3	4	10	11	-44	22	19	13	7	5	1	48
1990	-1	3	6	1	2	15	14	1	6	7	6	3	64
1991	2	-3	0	-1	-4	-124	22	22	17	10	7	2	-50
1992	2	1	-1	1	-16	10	24	19	10	7	3	1	60
1993	-2	1	2	-70	-28	31	18	16	9	9	5	2	-7
1994	1	-1	-2	8	3	21	19	13	9	5	-7	1	70
1995	1	-3	1	-107	67	-181	26	-1	13	15	9	4	-156
1996	1	1	-16	-18	-44	-32	-3	-1	11	8	6	3	-84
1997	2	-4	-62	-115	59	30	18	12	10	6	3	1	-41
1998	1	-20	-19	-64	-225	19	-16	-13	-1	9	8	6	-314
1999	2	-13	3	-2	-63	-21	-20	13	11	10	7	4	-69
2000	2	0	4	-28	-101	0	21	16	13	11	6	4	-52
2001	2	1	0	-15	-52	7	24	17	14	9	3	2	13
2002	1	-7	-31	-11	24	10	12	7	4	3	1	0	11
2003	0	-4	-51	36	19	-7	-16	-7	13	11	7	4	5
2004	2	1	-65	21	-112	20	23	19	13	9	5	3	-60
2005	0	-1	-30	-6	0	-36	6	-15	10	10	7	4	-52
2006	2	0	-51	37	5	-89	-111	17	16	15	11	7	-141
2007	4	0	-3	11	-25	15	15	12	7	4	4	2	47
2008	1	1	-3	-19	9	33	23	15	10	6	3	1	80
2009	1	0	-1	5	-34	15	27	13	13	8	4	0	49
2010	-1	4	0	-54	23	6	-15	11	10	9	5	2	2
2011	-1	-1	-39	10	-52	-201	-21	-8	-9	-3	-2	-1	-328
2012	0	-3	0	-15	2	-28	17	24	18	10	5	2	33
2013	1	-10	0	67	30	15	9	5	0	-2	-3	-2	110
2014	0	0	0	-1	-5	21	11	16	8	5	4	1	61
Average	**1**	**-4**	**-8**	**-6**	**-21**	**-6**	**3**	**12**	**10**	**7**	**4**	**2**	**-6**

Table D-2. UF 3 – Cache Creek above Rumsey Simulated minus Unimpaired (TAF)

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1922	-4	-3	15	23	41	38	26	15	8	5	0	-1	162
1923	-1	23	37	35	25	18	11	9	7	6	2	1	175
1924	0	0	3	13	35	33	25	18	9	4	1	0	142
1925	2	15	38	45	80	63	26	11	4	4	3	-2	289
1926	-3	-4	1	82	43	39	39	11	3	1	-1	-2	210
1927	-2	44	33	-9	-97	-72	-18	-13	-10	-5	-7	-6	-162
1928	-6	14	25	10	24	-9	-2	7	2	2	-1	-3	63
1929	-3	11	17	21	31	23	15	10	4	3	1	1	134
1930	0	0	35	37	42	36	25	13	8	5	2	0	202
1931	0	0	2	27	26	31	25	21	15	10	5	2	163
1932	1	3	18	49	53	37	19	10	6	5	3	1	207
1933	1	1	11	36	39	39	34	25	18	12	6	2	225
1934	1	3	31	35	34	33	24	19	12	7	4	2	206
1935	1	16	23	46	51	18	-2	1	1	2	-1	-2	154
1936	-2	-1	1	37	5	9	12	1	-6	-3	-5	-4	43
1937	-3	-2	-2	8	69	32	24	16	6	3	-1	-3	147
1938	-2	24	83	60	-178	-268	-89	-14	-9	-5	-7	-7	-410
1939	-6	-4	15	22	26	31	20	15	10	6	4	2	141
1940	1	0	11	39	46	-1	-14	12	1	2	-1	-4	92
1941	-4	1	16	-54	-92	-122	-98	-30	-9	-5	-6	-7	-409
1942	-6	-3	27	-8	-54	-34	-29	-28	-18	-7	-8	-8	-174
1943	-7	5	7	34	-10	1	-2	-10	-8	-5	-5	-6	-7
1944	-5	-4	-2	21	39	27	24	14	9	7	3	1	134
1945	1	20	25	53	17	25	16	9	7	5	1	1	180
1946	9	12	4	28	26	10	-4	-3	-3	-2	-3	-2	71
1947	-2	16	23	28	37	27	28	21	15	9	4	1	208
1948	4	10	13	17	25	29	18	28	19	14	9	3	189
1949	1	0	4	13	19	12	21	14	7	4	1	-1	95
1950	-1	0	3	34	54	36	24	15	11	8	3	1	187
1951	1	28	45	7	-6	-6	-4	-5	-4	-2	-2	-4	49
1952	-3	11	3	-25	-84	-50	-19	-16	-13	-10	-9	-7	-223
1953	-5	-3	28	-18	-1	6	-6	-15	-10	-4	-4	-4	-36
1954	-4	19	7	43	25	24	3	2	-3	-1	-4	-4	106
1955	-4	9	28	25	16	12	6	2	7	6	3	1	112
1956	0	2	52	-55	-111	-60	12	-5	-10	-6	-8	-7	-195
1957	-4	-1	1	22	28	11	31	14	12	11	6	3	132
1958	7	11	-3	-29	-163	-186	-110	-33	-11	-6	-8	-10	-540
1959	-9	-7	-6	49	44	33	21	7	2	0	-2	-1	132
1960	0	-1	-1	13	72	45	37	18	9	8	3	0	203
1961	0	15	56	53	29	31	18	9	6	4	1	-2	219
1962	-2	23	38	34	56	39	25	9	2	-1	-3	-4	216
1963	42	29	33	87	25	31	-29	-4	-2	-3	-5	-7	197
1964	-7	22	22	32	21	17	11	6	2	1	0	0	128
1965	0	47	51	10	-22	13	-14	-16	-8	-3	-6	-6	47
1966	-6	25	19	34	30	14	2	-3	-3	-6	-6	-6	96
1967	-4	42	41	10	0	23	-34	-27	-14	-10	-8	-8	12
1968	-7	-4	16	32	-12	13	11	0	-1	-3	-6	-7	32
1969	-5	0	34	19	-71	-140	-46	-12	-10	-8	-9	-10	-257
1970	-7	-4	23	-53	-57	-16	4	-6	-8	-9	-9	-8	-150

Table D-2. UF 3 – Cache Creek above Rumsey Simulated minus Unimpaired (TAF) contd.

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1971	-5	65	50	21	18	5	-11	-10	-9	-10	-8	-8	97
1972	-5	-3	21	21	23	20	16	10	7	5	3	1	119
1973	3	26	39	7	-42	-68	-6	-5	-5	-5	-5	-7	-67
1974	-4	75	18	-58	-30	-92	-80	-9	-6	-6	-7	-8	-208
1975	-7	-5	7	17	26	-34	-28	11	2	-1	-5	-5	-22
1976	-5	1	7	7	17	19	23	23	17	10	3	2	123
1977	1	1	1	10	12	20	18	15	10	6	3	1	96
1978	1	19	39	61	26	-54	-25	-4	-7	-9	-7	-9	31
1979	-6	-6	-5	32	30	27	25	7	3	1	-4	-2	102
1980	2	26	40	-23	-56	-55	-23	8	-4	-7	-8	-8	-108
1981	-6	-3	15	13	20	23	18	8	2	-3	-1	0	85
1982	2	34	24	-7	-6	-8	-119	-21	-4	-8	-7	-10	-132
1983	-9	40	15	-56	-100	-366	-193	-53	-12	-12	-10	-13	-769
1984	-12	9	-142	-49	-9	-16	-10	-7	-2	0	1	0	-239
1985	-2	37	27	25	35	17	10	12	12	11	4	2	188
1986	0	6	23	37	-72	-115	-3	11	0	1	0	-3	-115
1987	-2	-1	1	7	34	37	35	23	15	11	5	2	166
1988	1	7	38	29	41	27	11	5	-1	1	3	0	163
1989	0	20	26	34	28	14	25	23	21	10	6	0	209
1990	10	11	12	26	28	29	21	32	21	20	14	8	232
1991	3	2	2	1	17	38	42	35	20	16	7	2	185
1992	1	2	6	21	37	38	32	14	9	5	3	3	172
1993	-3	3	25	-76	-149	-70	-1	-8	-7	-3	0	0	-290
1994	-1	-3	10	12	21	22	12	9	-9	10	4	0	87
1995	1	15	29	-116	-48	-205	-103	11	22	-10	-9	-12	-425
1996	-7	1	50	10	-104	-93	24	12	-13	-21	-3	-1	-144
1997	-7	6	30	-164	-145	63	33	9	-3	-14	-31	-10	-234
1998	-3	-25	-27	-267	-481	-105	-21	-20	-3	15	10	9	-919
1999	-22	4	-12	-20	-180	-82	-8	23	13	12	6	-7	-273
2000	-2	-1	11	-48	-211	-57	27	14	10	13	5	-6	-246
2001	0	1	2	-12	-86	-41	30	6	12	-1	0	-4	-94
2002	-4	-16	-126	-68	34	13	12	1	-1	2	-1	0	-156
2003	-1	-4	-144	-79	30	0	-83	-23	25	12	12	5	-252
2004	-10	-1	-136	-53	-225	1	24	14	-8	-16	-12	-13	-436
2005	-8	1	-36	-90	-16	-91	-16	-22	12	10	9	7	-238
2006	-2	-13	-106	-89	17	-204	-205	39	20	11	5	0	-527
2007	1	-6	-25	17	-71	7	25	15	14	-2	-7	1	-31
2008	-7	-2	-11	-112	-89	34	29	13	-1	2	-9	-8	-162
2009	-6	-4	1	8	-65	-34	34	4	19	4	7	-2	-34
2010	1	10	8	-94	5	17	7	35	26	21	12	4	54
2011	-9	2	-119	2	-78	-370	-51	-22	-32	-31	-24	-9	-741
2012	-5	-4	-1	-15	9	-26	-13	53	31	-4	-9	-3	14
2013	1	15	-91	52	49	18	14	13	7	-16	-17	-4	42
2014	-8	0	0	1	-6	2	14	34	23	-2	-7	-5	47
Average	**-2**	**9**	**6**	**1**	**-15**	**-18**	**-3**	**5**	**3**	**1**	**-1**	**-3**	**-17**

Table D-3. UF 4 – Stony Creek at Black Butte Simulated minus Unimpaired (TAF)

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1922	-1	3	26	77	5	76	13	-9	-5	2	0	0	188
1923	9	16	8	39	20	9	7	4	-2	2	0	2	114
1924	26	9	24	12	54	30	7	2	0	0	1	1	165
1925	9	53	36	14	-41	36	-1	-50	-9	0	0	1	46
1926	1	11	47	-5	17	26	-46	1	0	0	0	1	52
1927	3	-25	108	22	-95	50	0	-16	-4	2	0	0	46
1928	-1	37	36	49	35	-39	42	3	0	0	0	0	163
1929	0	30	40	30	45	25	10	4	3	5	0	0	194
1930	0	0	32	31	4	38	15	2	-2	0	0	1	123
1931	2	7	23	65	41	22	17	0	8	13	1	0	200
1932	1	11	-10	114	11	-8	13	3	-2	1	0	0	134
1933	0	2	34	51	38	18	28	3	-7	0	0	0	167
1934	0	12	7	117	-3	0	23	5	1	1	0	0	162
1935	1	42	47	15	16	30	-26	-1	-4	-1	0	0	120
1936	5	6	12	148	-38	21	11	-1	14	16	1	0	196
1937	0	0	0	32	8	58	38	18	18	25	3	0	202
1938	7	53	96	62	-10	-26	-8	-53	-23	-4	0	0	93
1939	11	10	145	73	47	36	30	7	8	1	0	0	367
1940	4	2	49	56	-120	20	-1	-4	1	1	0	0	8
1941	0	28	-73	-16	-74	-70	-95	-49	-18	-1	1	-1	-368
1942	-1	8	23	-28	-22	0	-71	-25	-11	0	0	-1	-129
1943	1	0	41	-10	62	1	11	1	-1	0	0	0	107
1944	0	12	19	36	44	1	-12	-16	0	7	1	0	90
1945	-1	31	43	56	81	12	15	-2	5	3	0	0	243
1946	-2	21	-30	120	15	23	31	3	-1	0	3	1	185
1947	6	3	49	21	25	36	16	4	4	4	0	0	169
1948	11	38	11	64	28	9	-13	0	4	8	1	2	163
1949	10	22	39	38	-9	12	11	9	6	1	0	0	140
1950	9	16	14	-4	9	17	36	0	-4	1	0	-1	92
1951	-3	12	20	-2	53	3	-3	-12	-4	-4	0	0	59
1952	0	9	30	-15	-50	-41	-30	-23	-8	5	4	0	-120
1953	1	36	74	3	30	-2	-18	-27	0	3	1	1	101
1954	2	18	136	89	95	7	-25	-10	23	17	2	6	360
1955	6	15	129	45	22	27	8	14	5	-1	0	0	270
1956	0	8	-26	21	-13	62	-4	-24	-8	-1	0	-1	14
1957	-4	13	49	46	-24	86	9	-27	-13	-5	0	-2	129
1958	16	27	16	3	-192	70	-45	-43	-10	2	1	-3	-157
1959	2	7	15	59	21	46	36	6	-1	0	0	0	193
1960	6	1	2	23	69	39	12	0	7	2	0	0	163
1961	2	5	90	11	92	31	16	-2	0	1	1	2	248
1962	4	16	112	25	-23	43	-6	9	-1	2	3	3	186
1963	-2	50	72	15	-78	-5	-48	-4	-6	-3	0	0	-9
1964	7	25	102	78	57	25	29	2	0	1	0	0	327
1965	0	68	-130	77	15	5	-46	7	-1	0	3	6	5
1966	6	19	48	96	26	71	0	-10	-5	0	0	1	253
1967	1	1	105	-113	50	-10	-20	-29	-8	8	1	0	-13
1968	4	11	123	12	-26	48	31	8	1	0	3	16	232
1969	2	28	77	-56	-59	-14	-22	-12	15	8	1	0	-32
1970	3	18	-2	-167	87	5	0	-3	-3	1	0	0	-59

Table D-3. UF 4 – Stony Creek at Black Butte Simulated minus Unimpaired (TAF) contd.

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1971	1	2	126	94	39	-26	42	-5	-8	-1	0	0	264
1972	3	22	43	57	88	55	46	3	3	2	0	0	321
1973	7	25	40	-103	-81	24	23	8	1	0	0	0	-55
1974	2	-5	38	-89	53	-64	-21	-1	-8	2	3	0	-90
1975	0	25	51	117	-50	-35	50	-7	-4	1	2	2	152
1976	6	53	57	80	17	55	18	8	0	1	13	17	326
1977	4	2	4	24	14	46	34	8	4	0	0	0	141
1978	4	5	-3	-128	-34	-35	-7	-10	-11	-2	0	1	-220
1979	1	2	37	30	15	21	6	-6	-1	0	0	1	106
1980	0	27	14	-55	-141	48	-5	-6	-4	1	0	0	-122
1981	0	-1	8	-44	47	10	4	-2	-1	0	0	0	20
1982	-1	-25	-20	51	-49	-30	-76	-28	-13	-1	1	-1	-191
1983	-4	34	18	-118	-118	-214	-47	-64	-30	-8	-2	1	-552
1984	1	-57	-155	50	-18	-14	-4	-1	1	0	0	0	-197
1985	5	13	48	12	-4	3	3	4	0	0	0	2	85
1986	3	4	42	-19	-187	88	24	-4	1	0	0	0	-47
1987	2	6	3	19	29	41	26	3	0	0	0	0	129
1988	0	12	78	48	9	-7	-6	6	5	3	0	0	149
1989	0	1	51	44	8	-26	24	7	3	0	0	3	115
1990	11	32	11	37	44	11	2	-4	12	5	0	0	162
1991	0	1	1	6	24	33	43	10	5	2	1	0	128
1992	0	5	-2	35	4	22	-18	5	1	3	1	0	55
1993	0	14	84	-4	2	7	-18	-8	9	8	0	0	94
1994	1	3	28	25	57	36	4	6	5	0	0	0	165
1995	0	14	62	-187	148	-135	40	-37	-11	-1	1	0	-105
1996	0	-1	-37	-88	-31	1	-12	-19	4	1	0	0	-181
1997	0	7	10	-13	92	12	10	1	3	1	0	1	124
1998	4	10	76	-42	-199	53	-14	-74	-44	-5	-1	0	-235
1999	1	23	75	0	-13	-6	-3	-6	-6	0	-1	0	65
2000	0	21	46	6	76	45	-15	-7	0	1	0	0	174
2001	0	9	31	26	26	33	11	-3	0	0	0	0	134
2002	1	12	32	-20	-3	-10	-9	-5	1	0	0	0	-1
2003	0	3	-27	71	11	-4	9	27	9	0	1	1	100
2004	1	11	6	85	-98	19	-7	-11	-3	0	0	0	3
2005	0	20	5	84	-51	-77	-4	-48	-3	2	1	0	-72
2006	0	6	-85	135	-7	-29	-140	-27	-7	-1	0	0	-156
2007	0	0	17	50	20	33	2	-1	1	0	1	0	124
2008	2	6	10	31	39	-13	-18	-20	-2	0	0	0	35
2009	6	25	18	27	19	83	23	-5	6	1	0	0	203
2010	3	10	13	-15	63	12	-40	-5	-10	1	0	0	30
2011	-4	40	-40	-48	-36	-163	-88	-34	-48	-9	0	0	-429
2012	-2	-4	-2	-6	37	-16	31	10	1	0	0	0	49
2013	0	-10	42	92	4	-12	-8	0	0	1	0	0	109
2014	0	-1	1	-1	6	61	25	10	1	1	0	0	104
Average	**2**	**13**	**30**	**20**	**2**	**10**	**-1**	**-7**	**-2**	**1**	**1**	**1**	**70**

Table D-4. UF5 — Sacramento Valley West Side Minor Streams (Thomes and Elder Creeks only) Simulated minus Unimpaired (TAF)

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1922	2	0	5	-3	24	15	-45	-30	3	5	4	3	-18
1923	2	7	27	3	5	1	-22	-3	1	5	5	3	33
1924	3	2	1	1	10	6	4	4	5	3	2	1	44
1925	0	2	-1	-1	-12	-3	-30	-30	3	5	5	3	-60
1926	1	-1	-2	25	-7	-6	6	4	5	6	4	2	39
1927	2	20	-8	6	-11	-25	-26	-20	-2	5	4	3	-52
1928	2	-9	11	-5	-20	-29	-12	-3	2	5	4	2	-53
1929	2	7	2	5	15	6	0	-3	3	5	4	2	48
1930	2	0	11	15	2	1	-3	4	5	6	4	3	49
1931	2	2	0	14	2	2	3	5	6	6	4	3	48
1932	2	0	48	19	5	-23	-10	-9	2	5	4	3	47
1933	2	1	8	24	17	12	-15	-10	-3	6	5	3	51
1934	2	4	30	15	5	4	3	4	7	6	4	3	85
1935	6	8	12	41	13	9	-15	-7	6	6	5	3	88
1936	2	1	6	21	10	-4	4	0	3	7	5	4	58
1937	3	1	1	3	34	31	-18	-16	3	7	6	4	58
1938	3	0	-6	40	63	-5	-69	-66	-13	2	3	2	-47
1939	2	3	8	13	10	-1	-1	-1	5	5	4	2	50
1940	2	1	11	16	-19	-6	-21	-1	6	6	5	3	2
1941	2	2	21	44	7	-53	-42	-38	-11	2	5	3	-58
1942	1	1	15	5	15	1	-4	-17	-5	4	4	4	24
1943	3	-3	1	8	-12	-4	1	2	5	6	5	3	17
1944	2	0	1	18	22	10	-1	-5	3	5	5	3	65
1945	4	8	16	26	4	15	-9	-2	4	7	5	3	80
1946	11	5	26	2	11	-6	-20	-8	2	4	3	2	31
1947	1	3	11	7	1	5	5	7	4	7	5	3	60
1948	2	5	6	4	7	13	6	-12	1	8	7	3	50
1949	3	-2	3	7	4	15	-35	-10	3	5	4	2	-1
1950	1	1	2	4	13	-5	-14	-2	5	6	5	3	18
1951	5	0	19	22	-11	3	-6	-5	4	5	4	3	43
1952	1	7	32	35	-21	-7	-66	-35	-5	2	4	3	-50
1953	2	1	50	-8	-8	8	-17	-16	-4	3	5	4	19
1954	2	1	5	44	-5	-2	-18	-2	3	6	4	3	40
1955	2	-1	24	12	4	0	-3	-15	2	5	4	2	36
1956	1	-1	-38	14	31	-19	-47	-39	-7	3	4	2	-95
1957	5	2	2	12	-16	-1	-3	-8	5	7	6	3	15
1958	-2	1	4	14	-44	18	-23	-37	-5	3	4	3	-63
1959	2	0	0	21	37	-11	-8	1	4	4	3	1	55
1960	2	1	1	7	3	-11	-1	2	4	7	5	4	24
1961	2	2	18	21	-8	6	-8	-3	2	6	5	3	46
1962	2	9	17	9	28	15	-31	-3	2	4	3	2	57
1963	16	7	1	14	-44	10	-14	-20	3	6	5	3	-14
1964	1	7	11	27	1	4	-1	1	3	4	3	2	63
1965	1	10	-64	10	-11	-7	-35	-17	1	4	3	2	-102
1966	1	-4	14	17	14	-20	-41	-8	3	4	3	2	-16
1967	1	-2	5	11	-19	13	8	-46	-12	5	5	3	-29
1968	1	1	18	3	-23	5	-4	0	4	4	3	2	14
1969	1	2	58	-14	63	-41	-107	-71	-8	3	3	2	-111
1970	2	1	9	-36	21	1	3	-2	2	4	3	2	9

Table D-4. UF 5 — Sacramento Valley West Side Minor Streams (Thomes and Elder Creeks only) Simulated minus Unimpaired (TAF) contd.

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1971	1	25	35	-36	-20	-18	-23	-18	-2	4	4	2	-47
1972	1	0	15	-2	8	-30	-1	2	5	6	4	2	11
1973	0	8	-11	9	37	0	-34	-18	2	4	3	1	1
1974	3	12	-4	-76	37	-16	-24	-14	0	3	4	3	-72
1975	1	1	6	14	15	-10	-22	-43	-7	4	4	2	-35
1976	3	1	8	8	14	5	2	1	5	5	3	2	57
1977	2	1	1	5	3	2	3	4	5	4	3	2	34
1978	2	3	8	-19	1	-14	-10	-15	-4	3	4	1	-40
1979	2	0	1	8	28	-15	-10	-7	5	6	5	3	26
1980	5	3	29	-70	-13	3	-3	-5	2	4	4	2	-38
1981	1	0	-2	5	-9	13	-1	5	6	6	4	2	31
1982	2	-24	-13	1	-29	23	-15	-18	1	5	5	3	-60
1983	0	5	8	-10	8	4	-3	-72	-26	0	4	3	-80
1984	2	-16	-15	-11	17	2	-1	0	4	5	4	3	-6
1985	1	-7	3	5	-2	-1	-17	2	5	5	4	2	0
1986	2	2	11	11	-113	-8	-4	2	5	6	4	2	-80
1987	1	0	0	10	10	10	1	5	7	6	4	2	55
1988	1	0	-7	4	-4	-3	-1	3	5	7	5	4	15
1989	2	0	7	1	-1	-7	-6	9	8	7	5	3	28
1990	6	5	5	12	6	3	7	5	6	9	7	5	75
1991	3	2	2	0	3	16	-6	-1	6	6	5	3	40
1992	2	0	1	5	-1	-12	-8	6	6	5	5	3	12
1993	1	1	28	-6	-6	-44	-7	-4	-6	8	7	5	-23
1994	3	2	11	11	28	2	4	4	7	6	4	3	84
1995	2	2	10	6	-36	-3	-11	-27	-4	6	6	4	-45
1996	2	1	-35	-44	-53	-46	-20	-24	3	7	6	4	-199
1997	1	0	19	-33	-2	11	5	6	5	5	4	3	25
1998	2	10	11	13	-54	2	-26	-70	-35	2	4	3	-137
1999	1	11	11	15	15	-7	-22	-6	4	5	4	3	33
2000	1	2	9	24	-37	-24	-45	-8	3	4	4	2	-64
2001	0	1	3	-2	-12	-68	-8	0	5	5	4	2	-70
2002	1	3	-7	-48	13	7	-3	2	5	5	3	2	-17
2003	1	2	-24	-32	13	8	21	-11	6	6	5	3	-1
2004	2	-1	-8	-10	-29	-20	-4	1	4	5	4	2	-54
2005	1	4	-8	-16	-38	-31	-15	-58	-5	6	6	4	-151
2006	2	2	5	9	33	8	-40	-13	5	6	5	3	26
2007	1	-2	5	8	-5	0	8	8	7	6	5	3	45
2008	2	2	6	-10	-34	-3	-4	-6	5	6	5	3	-28
2009	3	0	3	6	-5	-7	5	10	7	7	6	3	38
2010	1	2	7	-36	-19	12	-30	-14	1	7	6	4	-59
2011	5	9	-24	-18	7	0	10	12	-8	8	7	5	13
2012	4	1	1	-10	-2	-11	-15	9	9	7	6	3	3
2013	2	-2	-15	-1	3	2	2	7	7	6	4	3	17
2014	1	0	-1	-1	-1	1	2	10	8	7	4	3	33
Average	**2**	**2**	**6**	**3**	**0**	**-3**	**-13**	**-10**	**1**	**5**	**4**	**3**	**0**

Table D-5. UF 7 — Sacramento Valley Eastside Minor Streams Simulated minus Unimpaired (TAF)

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1922	-11	-6	38	25	95	19	-36	-73	-18	-6	-7	-9	11
1923	-5	10	59	42	24	-3	21	-3	0	-7	-14	-12	111
1924	-4	-6	14	29	39	0	12	-6	-10	-10	-11	-10	38
1925	12	15	60	36	56	-11	-10	-16	-2	-4	-6	-6	126
1926	-2	1	14	8	91	-9	-25	-11	-2	-7	-10	-8	41
1927	-2	26	3	38	6	-45	-8	-17	2	1	-5	-6	-6
1928	-3	22	23	25	-10	8	-16	-26	-8	-9	-7	-8	-9
1929	-9	11	36	24	39	27	23	-2	4	-3	-3	-7	140
1930	-11	-9	32	40	4	15	-15	-21	-10	-4	-4	-9	7
1931	-11	9	-10	45	27	0	-4	-8	-9	-11	-12	-10	5
1932	1	14	13	54	61	-30	-23	-26	-2	-10	-9	-9	33
1933	-6	-9	6	26	6	16	-16	1	-15	-11	-10	-10	-23
1934	-4	0	16	40	26	-31	-27	-12	-9	-12	-11	-9	-31
1935	-7	18	14	12	-10	-17	-77	-75	-32	-14	-10	-9	-207
1936	-1	-4	9	84	73	-37	-18	-33	-15	-10	-9	-11	29
1937	-11	-8	5	30	83	38	-22	-24	-12	-6	-6	-9	58
1938	-10	-42	-146	-8	-35	-110	-106	-188	-135	-58	-26	-25	-886
1939	-6	-3	17	34	37	12	-9	-9	-16	-14	-13	-11	18
1940	-6	-11	-7	74	-167	-115	-71	-43	-24	-14	-12	-15	-412
1941	-9	14	-11	-12	-177	-129	-144	-79	-32	-16	-13	-14	-624
1942	-10	-2	-40	-41	-124	-5	-78	-73	-54	-24	-17	-16	-484
1943	-15	46	58	9	-4	-64	-105	-61	-29	-21	-21	-19	-227
1944	-16	-12	18	46	41	28	-5	-12	-16	-15	-14	-14	29
1945	-14	47	0	2	53	-13	-16	-35	-27	-16	-13	-15	-46
1946	-16	25	-70	5	11	8	-12	-19	-16	-13	-13	-13	-123
1947	-10	18	0	0	14	24	-38	-18	-13	-15	-15	-14	-66
1948	1	-9	-6	-2	15	-61	-88	-77	-85	-24	-14	-12	-363
1949	-14	-5	19	9	21	-11	-10	3	-16	-10	-11	-13	-36
1950	-11	1	7	77	-19	13	-39	-22	-18	-14	-10	-9	-45
1951	-7	109	60	18	-56	24	-22	-26	-16	-6	-10	-14	55
1952	5	11	-74	47	-100	-67	-70	-106	-9	-1	-10	-8	-381
1953	-8	1	-43	-93	-21	13	-31	-41	-32	-28	-17	-14	-313
1954	-10	4	32	11	-57	-42	-101	-54	-26	-20	-18	-17	-298
1955	-15	-18	39	42	9	10	-10	-14	-18	-12	-11	-11	-10
1956	-11	-2	27	-135	-164	-34	-40	-51	-23	-17	-11	-9	-470
1957	-1	5	14	28	6	2	-8	-37	-29	-17	-15	-28	-79
1958	-30	-12	0	-58	-197	-110	-92	-83	-35	-21	-14	-11	-662
1959	-10	-8	-3	18	-38	2	-8	-18	-21	-17	-15	-9	-126
1960	-19	-16	-9	54	42	2	-10	-16	-23	-13	-13	-13	-34
1961	-13	3	-39	-21	-25	-13	-24	-27	-26	-14	-14	-13	-229
1962	-15	-17	-29	2	34	2	-27	-28	-24	-9	-9	-10	-131
1963	6	-5	-8	3	38	-19	-124	-47	-23	-12	-11	-11	-213
1964	-8	45	27	31	5	33	12	4	-11	-12	-12	-13	101
1965	-12	0	38	-83	-23	-6	-86	-19	-18	-11	-10	-11	-239
1966	-12	19	29	28	13	10	-13	-30	-13	-16	-13	-14	-12
1967	-15	2	40	7	1	-46	-73	-103	-49	-19	-8	-5	-269
1968	-7	-5	48	-28	-15	-22	-11	-15	-13	-16	-17	-13	-113
1969	-9	22	-54	-66	-90	-23	-55	-87	-18	-10	-7	-6	-404
1970	-2	1	-41	-230	-51	-82	-16	-22	-19	-16	-18	-16	-512

Table D-5. UF 7 — Sacramento Valley Eastside Minor Streams Simulated minus Unimpaired (TAF) contd.

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1971	-9	-42	7	-33	-14	-54	-38	-41	-35	-22	-18	-15	-315
1972	-12	3	45	34	38	-40	-22	-22	-19	-15	-16	-15	-41
1973	-12	14	9	6	-59	-27	-38	-47	-20	-8	-11	-13	-206
1974	-8	-89	-53	-223	-19	-171	-86	-63	-44	-13	-15	-16	-802
1975	-14	3	2	19	-29	-87	-50	-79	-46	-22	-15	-17	-334
1976	0	5	5	-5	3	4	-15	-28	-18	-17	-13	-13	-92
1977	-17	-10	-17	12	11	0	-15	-8	-18	-15	-14	-16	-108
1978	-15	4	54	-46	-57	-124	-66	-24	-19	-18	-9	-5	-326
1979	-10	16	17	88	-21	-4	-2	-8	-13	-7	-11	-11	34
1980	-7	-2	-54	-18	-10	-28	-4	-39	-15	-12	-12	-14	-215
1981	-11	-11	68	8	43	74	-4	-6	-9	-10	-13	-9	122
1982	40	143	29	-50	36	5	-19	8	-15	9	6	8	201
1983	46	83	69	53	27	37	24	8	-63	-43	-2	1	241
1984	5	137	6	6	50	67	24	-15	-10	-17	-15	-9	229
1985	8	115	10	7	23	61	31	-7	-7	-11	-11	8	228
1986	-11	10	16	88	27	-12	-7	-5	-15	-7	-8	23	98
1987	-1	-5	7	20	62	64	33	-2	-6	-4	-8	-13	147
1988	-10	9	130	32	30	55	18	8	-2	-8	-10	-13	238
1989	-16	101	8	-1	35	119	11	-21	-11	-3	-5	9	225
1990	53	1	-6	68	2	75	-3	23	13	-10	-9	-12	196
1991	-10	-4	-10	-12	22	107	73	19	-12	-3	-10	-8	153
1992	0	6	29	9	107	73	5	-9	2	3	-8	-11	208
1993	2	2	60	-10	44	55	59	71	21	-31	-5	-5	264
1994	22	10	68	52	71	78	31	-2	-15	-12	-11	-11	281
1995	-14	22	21	150	-4	96	55	25	-64	-57	-7	-4	219
1996	-2	-3	94	63	68	50	60	-22	-40	-23	-19	-8	217
1997	-6	41	84	-62	-13	45	-25	-45	-17	-19	-17	-16	-51
1998	-2	49	43	81	57	24	15	68	-27	-67	-7	4	238
1999	13	80	64	64	39	21	40	-13	-47	-29	-20	-19	192
2000	-12	38	7	100	81	39	25	-45	-27	-18	-19	-16	153
2001	5	-1	11	30	27	67	51	-24	-13	-16	-15	-13	108
2002	-16	64	44	55	43	35	34	-26	-29	-15	-13	-14	163
2003	-18	35	135	87	14	36	-14	-43	-71	-24	-11	-14	112
2004	-11	16	100	34	116	44	39	-24	-17	-17	-16	-13	253
2005	28	14	57	62	76	105	45	29	-15	-12	-8	-11	370
2006	-11	46	148	60	41	61	52	51	-8	-7	10	2	445
2007	6	28	88	9	136	60	30	-13	-12	-8	-9	-5	308
2008	6	0	30	59	52	66	55	38	-10	-6	-6	-7	276
2009	1	52	15	41	130	103	57	4	-3	-3	-5	-7	385
2010	8	11	42	94	62	57	82	82	-17	-18	-4	-3	396
2011	21	27	74	15	38	57	-33	48	-44	-53	-14	-11	124
2012	10	11	-8	42	28	30	-1	-62	-36	-23	-18	-17	-45
2013	-16	-10	21	5	-5	-4	-35	-41	-25	-19	-17	-16	-164
2014	-20	-15	-20	-20	30	17	5	-32	-17	-14	-15	-13	-114
Average	**-4**	**14**	**19**	**15**	**11**	**5**	**-14**	**-23**	**-21**	**-15**	**-11**	**-10**	**-34**

Table D-6. UF 8 — Feather River near Oroville Simulated minus Unimpaired (TAF)

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1922	-10	-24	144	55	-18	41	-229	-528	-168	105	31	-4	-604
1923	23	56	76	9	92	80	22	-105	29	8	-6	8	291
1924	3	-23	-22	-11	81	12	48	10	8	-2	-12	-15	76
1925	15	24	43	80	-22	152	90	-6	43	-2	-17	-9	392
1926	-8	-30	-21	24	34	138	4	76	38	7	-7	-17	240
1927	14	92	-4	25	-502	-62	-101	-194	-21	15	-11	-19	-766
1928	6	139	58	28	-31	-375	-41	-28	66	0	-10	-12	-202
1929	-18	27	-11	2	14	47	75	-62	67	21	3	-5	160
1930	-7	-17	-35	66	36	127	-46	-43	-4	-8	-12	-7	48
1931	-12	-12	-26	43	24	101	9	20	30	-2	-4	-9	162
1932	5	13	-28	-29	5	27	27	-124	18	44	5	-9	-46
1933	-9	-7	-8	-19	68	228	171	25	-47	14	5	0	421
1934	55	26	106	150	201	74	50	38	16	-5	-7	-7	695
1935	-1	71	51	157	90	92	-196	-219	18	74	20	-2	157
1936	15	-10	11	166	33	80	-59	-115	-14	-11	-20	-16	61
1937	-15	-25	-31	-28	-1	28	65	-55	99	80	16	-1	132
1938	32	75	-22	114	1	-526	-486	-600	-252	46	5	-18	-1630
1939	-4	-22	-13	-21	-17	66	-33	48	9	-11	-9	-15	-20
1940	-9	-21	20	349	7	-118	-41	63	98	25	-12	-18	343
1941	0	85	52	71	-18	91	80	-319	-46	-1	-34	-43	-83
1942	-33	10	22	-68	-243	110	-106	-107	-173	9	-24	-43	-646
1943	-39	14	-83	-73	77	-168	-121	-14	23	-18	-41	-41	-484
1944	-31	-16	-16	43	64	160	78	-145	-18	-82	-18	-18	1
1945	7	222	76	31	151	91	21	-117	2	-3	-26	-24	431
1946	35	81	-69	22	31	74	-52	-104	13	-7	-29	-24	-30
1947	-18	76	93	-8	205	194	64	26	-2	-11	-18	-19	583
1948	35	56	-12	233	30	57	-116	-126	-58	68	22	-6	183
1949	-14	30	-4	-18	-10	-6	36	6	106	43	5	0	175
1950	0	24	0	-63	195	150	-25	-70	28	46	4	-7	281
1951	70	13	36	20	-54	171	-58	-56	18	-5	-22	-25	109
1952	7	32	-3	-35	-218	-138	-691	-362	-49	93	57	-8	-1316
1953	-20	1	131	30	112	115	-79	-252	-267	-70	-39	-53	-392
1954	-16	-5	1	163	219	96	-195	-105	15	-19	-28	-34	93
1955	-31	34	148	14	-6	50	26	-62	44	24	-7	-14	218
1956	-3	4	-291	-111	-70	22	-143	-219	-35	9	3	-29	-865
1957	-24	-6	-41	0	-96	33	98	-96	-18	1	-22	-19	-190
1958	-6	-33	36	94	-360	-22	-106	-411	-160	25	-17	-27	-986
1959	-26	-37	-35	153	46	141	-41	-30	-27	-39	-27	-10	68
1960	-27	-33	-48	94	88	143	76	47	3	-5	-8	-13	318
1961	-11	57	83	85	141	178	49	-50	-20	-9	-24	-14	466
1962	-19	5	101	29	-16	90	12	54	55	56	17	-6	380
1963	147	76	136	31	-62	143	-329	-321	-18	-6	-13	-32	-249
1964	-18	40	50	46	28	90	-1	-53	15	-8	-11	4	182
1965	-11	90	-276	65	72	216	-198	-207	-25	-6	-18	3	-294
1966	-32	97	50	92	34	134	-32	-33	29	-8	-17	-10	304
1967	-11	137	257	158	174	-88	-45	-393	-305	61	35	-5	-25
1968	3	-23	19	11	-41	214	107	10	22	-21	-27	-16	259
1969	8	58	-14	-407	-108	57	-180	-283	22	131	57	-5	-664
1970	12	14	-64	-431	337	155	114	-62	-46	-34	-32	-39	-76

Table D-6. UF 8 — Feather River near Oroville Simulated minus Unimpaired (TAF) contd.

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1971	-7	111	24	-99	-48	-192	-101	-438	-268	6	8	-29	-1033
1972	-43	-31	-91	-87	11	-16	70	-66	-16	-12	-11	-23	-316
1973	7	62	-108	-28	78	-67	41	-124	72	60	-1	-12	-19
1974	4	11	-45	-495	45	-350	-65	-163	-85	30	2	-14	-1124
1975	-30	-11	1	-34	14	-154	-136	-409	-228	54	22	-36	-947
1976	36	-15	0	-51	-29	-14	4	-51	-31	-35	-47	-14	-247
1977	-18	-9	-30	-34	-38	-26	0	-8	-31	-22	-19	-16	-250
1978	-17	-19	86	188	135	256	204	17	-43	18	21	-10	834
1979	3	-36	-20	55	119	159	52	-113	79	19	-5	-10	301
1980	32	59	20	-113	-13	86	46	-43	41	13	17	-59	87
1981	-28	-24	93	97	183	296	191	118	82	19	-5	-4	1019
1982	45	-32	-91	45	-2	147	-274	-157	-20	25	-6	-25	-344
1983	32	13	-195	107	138	-259	7	-259	-214	94	67	1	-469
1984	-18	20	-332	-63	54	243	168	36	91	23	1	-41	181
1985	-29	92	34	-25	42	18	59	56	55	-2	-13	-2	286
1986	-16	-21	72	225	-370	27	151	103	105	36	-9	-12	290
1987	-22	-36	-43	-46	41	-9	94	61	14	1	-11	-13	32
1988	-18	-13	5	-8	150	147	50	-19	-20	-21	-15	-8	231
1989	-19	72	37	33	11	-175	89	132	97	40	3	-2	319
1990	67	-6	25	18	-5	76	49	119	33	9	3	-27	361
1991	17	-13	-2	-23	-14	49	101	-25	4	4	0	0	97
1992	12	10	20	54	144	242	52	50	38	2	-2	-4	619
1993	16	10	15	-157	-113	-303	142	190	202	211	92	8	314
1994	17	-2	114	44	43	275	64	15	19	-2	-5	-12	571
1995	-10	19	49	272	223	-398	-59	-380	-70	94	91	15	-155
1996	-26	-39	215	7	-76	126	-1	-262	36	39	-6	-23	-11
1997	-27	-3	-235	-454	122	269	44	66	61	4	-25	-24	-202
1998	1	55	87	143	-57	40	80	-153	-238	38	59	0	54
1999	-31	26	15	-60	-203	-50	3	-79	74	70	-1	-29	-265
2000	-10	14	4	106	53	210	87	46	98	30	-2	-14	622
2001	-1	-12	-16	17	18	116	0	-99	-4	-10	-10	-16	-18
2002	-12	42	147	27	165	199	21	28	21	7	-5	-7	633
2003	-4	121	360	385	194	162	60	-176	-34	25	-10	-15	1068
2004	-14	-13	5	26	20	206	121	18	28	1	-21	-17	361
2005	31	39	357	130	165	288	274	-15	202	155	51	-9	1667
2006	-8	7	131	236	213	1	-167	-98	189	169	63	-2	733
2007	-24	-16	13	-17	131	110	108	73	56	-32	-31	-26	344
2008	-13	-12	22	75	115	27	-7	-29	91	39	3	4	314
2009	35	80	-12	48	149	127	114	89	152	67	4	1	854
2010	51	0	32	283	226	188	194	107	-28	126	53	1	1234
2011	118	99	160	141	183	84	-235	-90	-279	-42	8	-16	132
2012	23	-35	-25	36	-3	120	68	18	52	-5	-14	-4	230
2013	-3	168	406	244	135	31	-31	-3	-26	-17	-20	-14	870
2014	-34	-27	-39	-46	158	246	132	57	17	-2	-5	-10	448
Average	**1**	**23**	**20**	**28**	**36**	**57**	**-6**	**-81**	**-5**	**21**	**-1**	**-14**	**79**

Table D-7. UF 9 — Yuba River at Smartville Simulated minus Unimpaired (TAF)

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1922	-19	-16	92	-50	-21	-5	-113	-64	-221	-77	-23	-12	-530
1923	-11	86	141	-34	-54	-45	-93	-194	-29	-57	-21	18	-293
1924	-9	-9	-22	37	130	-28	-33	-18	-3	5	-1	-11	38
1925	79	71	49	17	-34	-47	-28	-31	45	-20	-12	-9	80
1926	3	33	18	165	-17	-60	62	-21	-51	-8	-7	-14	104
1927	23	241	-127	22	-263	-198	-164	-52	20	-30	-10	-11	-550
1928	10	163	-39	-88	-30	48	-220	-88	-37	-19	-6	-11	-317
1929	-17	0	7	-11	13	-1	7	16	81	-4	12	-22	81
1930	-9	-11	397	-30	-42	-29	-18	-77	46	-11	-7	-10	200
1931	1	21	1	67	46	92	24	46	18	6	2	-4	319
1932	68	8	62	-77	-49	10	49	7	-18	-21	-14	-4	23
1933	-11	-8	-15	-4	-16	124	69	34	-45	-18	0	-6	103
1934	137	-1	154	40	144	0	-32	-36	2	-2	4	2	412
1935	26	143	41	42	48	-37	88	-139	-103	-28	-9	-8	64
1936	1	-22	18	258	255	-100	-137	-138	-8	-37	-9	-12	69
1937	-11	-12	-19	-19	-44	88	-20	69	-5	-23	-6	-4	-5
1938	9	171	223	112	11	-186	-162	-190	-28	-78	-22	-13	-152
1939	6	2	17	36	-23	61	-6	50	-27	0	7	-3	119
1940	23	-7	38	369	294	7	-254	-21	53	-14	-7	-11	472
1941	-6	63	340	-1	48	-128	-94	-144	102	-62	-13	-12	93
1942	-11	33	248	1	-129	-89	-3	-61	-27	-37	-27	-21	-123
1943	-22	123	17	52	-121	-99	-114	17	11	-32	-22	-11	-201
1944	-11	-7	4	86	106	-5	20	-65	-52	-20	-9	-8	37
1945	150	163	92	3	121	-71	-40	-84	-28	-33	-14	-11	249
1946	139	52	171	-124	-53	-72	-70	-73	-86	-33	-13	-7	-168
1947	-24	89	56	-35	98	162	-62	-23	14	-13	-10	-11	240
1948	157	11	-23	191	-20	44	-22	-43	-49	-42	-21	-6	178
1949	-16	43	5	-26	-36	81	52	-92	-71	-17	-8	-11	-94
1950	-9	13	-18	28	3	14	-23	-3	-70	-30	-12	-21	-129
1951	107	210	-36	-97	-157	-78	-7	7	-20	-15	-22	-17	-125
1952	73	101	109	-91	-178	-172	-111	-106	-78	-89	-28	-19	-587
1953	-34	-1	88	43	-75	36	88	-60	-105	-30	-37	-34	-122
1954	-5	78	5	161	80	-10	49	-124	-42	-20	-7	-11	154
1955	-11	81	173	-34	-27	6	21	28	-59	-19	-4	-5	150
1956	-9	-5	271	-209	-158	-108	7	-5	85	-36	-9	-15	-192
1957	57	-29	-11	30	234	14	40	54	-127	-29	-12	-1	219
1958	51	62	133	129	-48	-134	-129	-67	-35	-55	-18	-20	-129
1959	-10	-18	11	133	-21	44	38	-37	-42	-12	-1	44	131
1960	0	-7	10	114	140	73	-40	18	19	-16	-3	-2	304
1961	-9	72	37	129	31	81	-28	5	-14	-7	-5	-3	290
1962	-9	76	28	19	119	-25	35	-46	15	-25	-12	-3	172
1963	549	10	106	388	-210	-5	-105	-139	-26	-37	-19	-14	498
1964	14	175	-34	50	-63	-3	-40	-47	22	-21	-6	-6	41
1965	-2	103	62	-327	-93	10	-78	-113	52	-33	22	-12	-408
1966	-12	128	5	-5	-31	21	31	-122	-39	-7	0	-4	-36
1967	-11	237	103	140	-143	-107	-149	22	-37	-51	-30	-8	-34
1968	13	19	-14	21	-10	43	-54	-48	-18	-6	7	4	-43
1969	42	136	68	-20	-150	-85	-21	-61	-66	-5	-52	-6	-220
1970	29	9	197	-55	-78	-78	-68	24	122	-14	-2	2	90

Table D-7. UF 9 — Yuba River at Smartville Simulated minus Unimpaired (TAF) contd.

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1971	30	282	-75	-170	-119	28	-60	-202	49	10	-29	-1	-259
1972	-20	4	-44	-74	37	-24	12	-10	-99	-21	-4	-4	-247
1973	49	93	-54	-40	2	-146	8	130	2	-11	-7	-8	19
1974	62	268	-32	-284	-5	-87	-128	5	140	56	-13	-7	-26
1975	23	-4	16	11	15	-92	-90	82	-40	-76	-32	-29	-217
1976	68	7	1	-23	65	-80	-19	-9	-5	4	21	8	38
1977	12	-15	-8	-9	-1	-10	6	57	1	-8	0	2	26
1978	0	32	149	57	-72	31	-3	40	121	-11	-15	22	352
1979	-4	-6	-16	73	47	0	82	32	-40	-11	-8	-22	127
1980	101	70	42	-159	12	-127	18	-37	75	25	-11	-7	1
1981	-10	6	28	62	28	80	31	18	-20	-4	-1	13	232
1982	103	318	127	-258	-141	-99	-212	-91	73	3	-11	13	-176
1983	148	216	-72	15	-72	-250	-129	-57	16	13	-35	20	-186
1984	76	153	-302	-218	-11	19	8	30	108	-18	0	-8	-161
1985	-1	133	-37	-30	-25	-3	62	-55	-22	0	-2	12	32
1986	-19	34	50	169	-82	-158	-97	27	121	-18	-5	50	72
1987	-6	-4	3	49	107	47	67	7	-8	-3	-2	1	258
1988	-1	22	117	24	35	7	90	57	9	2	4	6	372
1989	0	178	-22	-21	-27	82	-18	28	45	-46	-1	26	224
1990	159	67	-17	104	-45	3	23	190	-52	-19	1	1	415
1991	-4	-8	3	-1	42	141	1	41	53	-9	9	-2	268
1992	66	23	54	41	113	62	52	-23	49	6	8	3	456
1993	86	5	90	14	-54	-1	10	96	78	-39	-14	-9	262
1994	1	52	79	45	49	15	9	-8	-22	-3	6	-2	221
1995	-7	44	75	215	-156	-38	-46	-126	2	128	-16	-12	64
1996	-8	-8	303	72	-169	-40	72	-93	-96	-24	-21	-6	-19
1997	-4	120	325	-413	-201	36	-98	106	48	-3	5	-3	-83
1998	29	141	61	136	-101	-74	-60	-79	-102	63	-26	-15	-27
1999	-18	235	-46	62	-80	-216	-60	-47	38	-32	-2	-10	-175
2000	15	115	2	202	52	-163	13	43	6	-19	-4	-2	260
2001	53	-4	26	22	3	100	43	-3	-10	4	2	-2	235
2002	12	98	188	-54	51	73	-13	13	-6	-7	0	-1	353
2003	-5	149	310	-15	-25	78	-20	-83	-81	-8	-33	-10	258
2004	-10	11	188	-18	51	19	-4	-17	-43	-12	-5	-5	154
2005	70	27	135	53	38	56	-75	-144	2	-34	-13	-10	104
2006	-8	65	330	-237	-60	-145	-115	-86	112	-44	-15	-7	-209
2007	-11	23	123	-8	185	-43	42	-8	-14	-5	-1	-6	278
2008	21	12	67	47	6	15	-34	-14	-31	-4	-1	2	84
2009	29	78	-10	17	140	3	-7	13	-39	-11	-1	-2	210
2010	60	7	42	152	75	19	28	-27	-115	-39	-8	-8	187
2011	218	52	122	-97	-63	-173	-162	-81	24	35	-49	-17	-190
2012	15	-20	-14	102	-6	68	59	13	9	-12	-3	0	212
2013	-6	164	173	-81	-58	38	11	-18	13	-4	7	1	239
2014	-13	-6	-12	1	187	105	56	-29	-11	-1	1	-1	278
Average	**30**	**66**	**61**	**12**	**-8**	**-19**	**-27**	**-27**	**-7**	**-16**	**-9**	**-5**	**51**

Table D-8. UF 10 — Bear River near Wheatland Simulated minus Unimpaired (TAF)

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1922	2	1	-2	9	-95	-32	9	-8	-8	1	1	2	119
1923	-2	12	12	-19	2	-16	-32	-18	-12	-4	-4	-3	-84
1924	-2	0	2	4	23	-4	-1	-5	-4	-3	-1	-2	6
1925	-1	7	17	10	10	-27	-19	-14	-8	-6	-6	-3	-40
1926	-3	0	3	23	-10	-10	-22	-17	-3	-3	-2	-2	-45
1927	-2	37	4	-10	-93	-5	-46	-8	-4	-3	-2	0	-131
1928	1	17	-1	16	8	-3	-29	-3	-6	-3	0	-3	-7
1929	-4	-5	0	5	3	6	9	-3	-1	-1	-1	0	10
1930	-2	-1	45	-20	21	-12	-4	-2	-3	-3	-3	-2	14
1931	-3	-4	-7	18	13	11	0	-1	1	0	0	0	28
1932	1	-3	-34	-12	-14	47	17	0	-2	-2	-1	-3	-5
1933	-3	-3	-9	-9	-11	38	11	-1	-1	-2	-1	0	11
1934	4	1	10	17	17	-2	3	-2	-2	-2	-1	-2	41
1935	-2	13	-7	-14	16	-29	-23	-10	-6	-3	-2	-3	-71
1936	-10	2	-7	28	-38	-6	-5	-4	-2	0	-1	-1	-42
1937	-1	0	-11	-8	-63	10	36	-3	-1	-2	-1	-1	-47
1938	-3	12	46	11	-102	-51	43	12	1	2	2	3	-23
1939	3	4	3	1	6	18	-1	0	-1	-1	-1	0	31
1940	-1	-1	0	52	10	-10	-11	-3	1	0	0	1	39
1941	2	9	27	-22	6	-18	-25	-2	-1	1	1	3	-19
1942	-1	4	16	8	-30	-3	-10	-13	-7	-1	0	0	-37
1943	1	22	17	-1	-3	-28	-10	-7	-1	0	-1	0	-10
1944	0	2	0	7	7	4	-1	-6	-2	-1	-1	-2	8
1945	1	24	16	9	6	-22	4	-4	-4	-3	-2	-4	20
1946	1	9	-7	-5	8	-12	-3	-4	-1	-2	-2	-3	-20
1947	-5	3	8	0	16	4	-2	-1	-1	-2	-1	-1	19
1948	1	1	-6	28	0	-4	16	-3	-7	-2	-2	-2	21
1949	-3	0	-14	-9	-11	-18	47	-6	-1	-1	-1	1	-17
1950	-1	1	-5	-10	21	14	10	-3	-1	-2	0	-1	22
1951	4	62	-24	-66	-3	-13	2	0	2	1	0	1	-32
1952	6	16	27	-102	-50	-47	42	29	7	2	4	2	-65
1953	4	5	1	26	21	8	12	-4	0	1	0	-1	75
1954	0	6	0	1	13	-7	9	-3	-1	0	-1	-1	16
1955	-2	2	18	-18	7	14	2	1	-1	0	0	-1	22
1956	-1	-4	44	-67	-19	19	21	8	1	2	2	0	6
1957	2	2	0	1	39	17	1	-7	-2	-1	0	0	52
1958	-1	4	25	10	3	-38	-41	8	4	6	4	4	-11
1959	5	2	5	36	-9	22	5	5	2	0	0	2	73
1960	0	-1	-3	25	40	24	-3	-1	1	0	0	-1	84
1961	-1	8	14	13	17	10	-4	1	-1	-1	0	-2	56
1962	0	2	2	-1	23	2	19	1	3	0	0	0	53
1963	53	5	17	68	-14	-18	-20	-1	-1	2	2	0	93
1964	-1	21	0	-26	25	8	3	-14	3	-1	-2	0	16
1965	-5	4	34	-49	23	12	-14	-2	0	0	0	3	6
1966	2	9	-8	-10	13	17	4	-6	0	-1	0	-1	20
1967	0	7	9	-15	11	-5	-45	13	-5	4	2	3	-21
1968	0	3	-2	14	10	23	7	2	3	1	1	1	62
1969	-1	10	-10	-47	-62	2	33	20	4	5	3	4	-38
1970	2	7	33	3	5	9	9	6	5	2	1	2	84

Table D-8. UF 10 — Bear River near Wheatland Simulated minus Unimpaired (TAF) contd.

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1971	-7	23	-65	-10	27	5	2	-7	-2	2	1	1	-29
1972	2	2	-24	11	23	17	-1	-3	1	0	0	0	29
1973	4	4	-6	-43	-15	-24	21	0	4	2	2	2	-50
1974	2	39	-16	-37	17	-17	-6	10	-4	0	5	4	-4
1975	7	8	5	12	-7	-11	-4	21	5	4	2	3	45
1976	6	-2	3	3	15	5	3	2	0	0	0	0	35
1977	0	0	0	-8	2	0	1	0	0	0	0	0	-4
1978	0	-1	18	-27	-8	22	12	8	1	4	2	1	30
1979	4	-1	3	5	-8	14	19	-3	4	2	1	1	40
1980	2	6	-4	-1	-11	-7	10	-3	1	4	2	3	2
1981	3	4	4	10	28	11	6	4	2	0	0	0	73
1982	3	33	-8	-59	16	-11	-54	4	6	8	6	8	-47
1983	17	31	-16	9	-35	-48	11	21	10	9	10	10	28
1984	13	57	-28	22	18	24	-1	-5	-4	-3	-1	-1	90
1985	-2	23	10	10	6	2	-2	-5	-3	-4	0	-1	36
1986	1	5	10	29	-57	-15	2	-4	1	-3	1	7	-23
1987	5	6	4	11	32	14	1	-1	-1	-1	0	-1	70
1988	0	3	11	-4	28	10	-1	-2	-2	0	0	0	43
1989	0	21	-10	-2	13	4	-5	-14	-3	-6	1	-2	-4
1990	8	7	3	21	1	17	-2	8	-7	-2	0	0	53
1991	1	2	2	2	6	-13	29	-7	-9	-5	-3	0	5
1992	2	3	9	11	11	14	-2	0	1	-1	0	-1	48
1993	4	3	3	-69	-4	51	26	12	0	-2	1	2	29
1994	3	13	15	17	16	19	-1	-1	0	-1	0	0	80
1995	-2	12	-6	-41	23	-49	25	8	-6	-8	1	0	-44
1996	8	-8	39	-14	22	13	2	0	-12	-5	-2	2	47
1997	4	22	4	-30	32	36	15	-6	-4	-3	-3	-3	65
1998	5	25	-5	-18	-96	21	-2	6	-12	-7	-1	3	-82
1999	3	28	2	10	-56	-10	2	-2	-7	1	1	2	-27
2000	2	12	5	34	-45	-6	7	-8	-4	3	0	0	0
2001	-2	4	8	7	-1	37	4	-3	-2	-2	0	-3	47
2002	-1	9	-11	-4	16	4	6	-6	-9	1	-2	-3	0
2003	-3	14	21	17	9	8	-6	-19	-10	-2	2	1	33
2004	2	3	11	-12	0	24	6	0	2	-2	0	-2	33
2005	3	14	6	-14	30	-2	-4	-14	-17	-4	2	2	3
2006	4	9	48	-12	-7	-66	-34	0	-2	2	7	4	-48
2007	2	10	7	17	24	18	6	-4	-1	0	1	-1	77
2008	4	5	-7	-16	-5	50	3	4	-3	-2	0	0	32
2009	-2	8	-9	24	6	6	1	-7	-4	-2	0	-1	20
2010	-7	4	15	26	30	34	18	-15	-29	-10	1	1	69
2011	11	1	-9	-2	-25	-101	26	4	-11	-8	3	5	-107
2012	8	8	9	8	16	17	-14	-8	-12	-5	1	0	26
2013	-1	29	-13	15	11	9	6	-5	-9	-6	-2	0	35
2014	1	1	2	2	45	11	-11	0	-2	-1	-3	0	44
Average	**2**	**9**	**4**	**-2**	**0**	**0**	**1**	**-1**	**-2**	**-1**	**0**	**0**	**10**

Table D-9. UF 11 — American River at Folsom Lake Simulated minus Unimpaired (TAF)

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1922	-10	-35	89	104	22	0	-96	-161	-218	20	13	6	-266
1923	-9	100	153	22	-34	-37	-33	-230	-31	-15	9	20	-86
1924	22	4	-2	21	67	6	34	-8	5	15	6	0	169
1925	39	120	32	44	74	-24	-82	-170	-41	3	13	6	13
1926	4	2	33	74	283	52	16	0	-15	11	10	1	471
1927	17	188	89	37	-315	-150	-206	10	-11	50	13	2	-275
1928	9	86	35	4	26	-180	-184	8	100	18	13	3	-61
1929	-10	-2	14	15	26	57	-1	-57	107	41	22	8	220
1930	-9	-10	264	22	0	74	50	-10	35	17	13	0	446
1931	-10	22	7	74	40	49	41	49	60	27	15	2	374
1932	20	28	52	11	-106	-15	16	-38	-33	12	9	2	-42
1933	-8	-11	-5	-19	-18	89	70	4	-47	19	13	0	89
1934	67	70	130	73	43	9	37	-2	31	18	10	1	487
1935	8	100	54	117	6	22	-74	-144	-18	-5	6	-1	72
1936	2	-8	-3	137	-3	-42	-77	-89	24	-10	6	-2	-63
1937	-4	-8	-10	-24	-35	104	-38	49	117	21	10	-1	179
1938	-5	72	321	69	-51	-216	-176	-215	31	22	1	-5	-152
1939	-3	2	16	39	-12	59	-8	24	18	12	8	-3	153
1940	10	5	12	206	92	-15	-171	-28	61	8	7	-7	178
1941	-11	58	115	54	-64	-29	-62	-79	170	81	10	-1	241
1942	-11	41	73	-83	-103	-76	-100	-111	-44	48	3	-2	-366
1943	-11	109	-50	-4	-76	-202	-144	-13	106	-9	0	-6	-299
1944	-14	-15	-2	17	53	56	108	-84	0	-6	7	0	119
1945	77	229	35	-9	3	-60	-36	15	23	-5	10	1	283
1946	79	94	9	-39	-77	-92	-115	-56	15	-10	7	-4	-188
1947	-6	41	39	-13	14	103	88	-34	32	12	6	-3	279
1948	98	68	1	36	-30	27	31	-11	-56	17	8	0	189
1949	-10	16	-13	-21	-68	65	34	-105	-37	2	2	-3	-138
1950	-8	11	3	-90	4	-2	33	-22	-40	-32	3	-3	-144
1951	52	347	-139	-195	-188	-163	-22	40	75	1	2	-6	-198
1952	56	65	4	-162	-223	-185	-109	-149	-49	3	-9	-3	-760
1953	-8	-6	36	-1	-29	34	54	-41	-143	14	5	0	-85
1954	-6	33	21	54	65	16	60	33	2	-1	3	-6	275
1955	-10	26	199	23	-44	-32	20	-45	54	8	2	-5	197
1956	-9	-21	56	-357	-146	-79	41	89	65	66	4	-2	-294
1957	10	20	-19	-9	31	73	47	61	92	18	5	2	331
1958	21	37	95	64	-28	-65	-149	-92	-1	55	-1	0	-65
1959	-1	-13	-6	90	-13	4	59	44	-14	11	8	41	211
1960	21	4	-9	37	56	33	80	61	103	24	14	3	427
1961	-5	18	60	19	57	38	67	33	56	31	20	11	405
1962	2	7	59	-5	-18	20	131	29	-4	12	19	7	258
1963	628	44	134	189	-166	-85	-137	-165	122	68	13	2	647
1964	26	72	21	-51	-57	15	-7	-36	97	27	10	9	126
1965	3	100	1	-327	-128	17	-120	-26	84	61	30	20	-284
1966	-5	75	30	-5	-23	-11	55	-10	1	21	11	4	142
1967	-6	116	187	-76	-6	-201	-133	34	-67	35	9	5	-104
1968	32	3	-9	-21	-178	84	-4	3	18	20	4	12	-38
1969	18	156	33	-183	-147	-60	-32	-95	5	1	3	-9	-311
1970	44	63	61	-281	-43	-80	-57	118	182	51	15	4	76

Table D-9. UF 11 — American River at Folsom Lake Simulated minus Unimpaired (TAF) contd.

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1971	-2	162	46	-191	-118	10	9	-192	46	116	14	7	-93
1972	-1	-4	-13	-48	-43	-39	22	-46	-6	7	11	14	-148
1973	37	127	-50	54	-46	-71	-21	51	93	18	8	-3	197
1974	44	143	97	-319	13	-51	-126	166	85	170	12	1	234
1975	-3	28	37	53	54	-105	-61	8	25	-6	1	7	37
1976	40	50	-7	-18	-13	-46	-14	25	23	22	26	32	121
1977	10	17	13	0	-3	-16	-29	0	21	29	17	7	66
1978	8	15	52	104	-18	-10	48	47	238	99	28	86	697
1979	29	6	3	114	-22	2	19	-20	98	16	18	8	273
1980	33	52	67	-294	-187	-107	-32	91	98	154	30	6	-87
1981	-10	-5	32	22	41	36	26	101	57	28	14	4	346
1982	6	168	0	-216	-264	-227	-336	-17	218	212	48	21	-388
1983	136	146	-101	-61	-195	-420	-218	11	57	73	5	-10	-577
1984	45	-84	-341	-144	-72	-51	24	82	207	55	5	-5	-279
1985	-7	40	15	-28	-14	-15	38	6	-4	13	9	0	51
1986	13	24	68	102	-466	-72	-47	-51	11	16	-2	26	-377
1987	9	8	2	12	92	107	48	5	7	15	7	-1	312
1988	-8	18	59	52	11	57	72	69	49	32	18	7	435
1989	-4	51	29	-4	-24	67	101	70	59	27	19	33	423
1990	140	116	58	93	11	7	-60	28	98	34	19	6	550
1991	4	6	5	3	56	116	16	-32	138	89	28	7	436
1992	42	48	63	96	94	99	28	49	30	57	24	11	642
1993	27	73	180	84	-7	60	-53	-165	93	81	14	4	392
1994	5	26	182	61	94	34	-7	13	11	22	10	-4	447
1995	1	109	176	81	-1	-141	-191	-245	-143	87	22	-2	-245
1996	1	-6	216	55	-126	-76	43	-21	21	-2	2	-4	103
1997	-8	192	163	-413	-103	-62	-113	58	121	28	11	-1	-127
1998	18	57	131	134	-84	31	-46	-159	-250	77	19	8	-63
1999	10	61	110	199	-59	-100	-146	-194	-6	21	2	-6	-108
2000	3	95	49	172	77	-22	-72	-3	30	-6	5	4	332
2001	35	40	38	31	-14	74	69	3	16	10	7	-4	306
2002	4	100	181	85	71	131	-49	-66	0	13	8	0	478
2003	1	154	172	28	5	3	-30	-62	41	13	6	9	342
2004	-12	-4	137	97	18	-9	11	-8	-7	15	12	2	252
2005	41	64	118	123	-5	-72	-92	-224	77	75	11	3	119
2006	-7	0	249	-119	-162	-225	-338	-86	123	61	5	0	-497
2007	5	-7	71	47	85	-3	11	35	9	22	12	-1	287
2008	7	26	50	89	30	34	-76	-63	13	18	16	5	150
2009	21	100	16	5	13	-9	-37	0	64	11	14	1	200
2010	67	32	36	66	64	55	-5	-100	-120	42	15	6	158
2011	159	103	-62	-65	-121	-502	-199	21	14	175	71	2	-404
2012	13	0	-10	18	-9	-117	-16	121	82	16	12	8	114
2013	-15	-56	-3	-75	-73	-18	50	121	52	39	14	3	39
2014	2	-5	-2	-12	123	77	96	131	54	40	18	4	526
Average	**23**	**52**	**50**	**-3**	**-30**	**-28**	**-31**	**-22**	**32**	**33**	**12**	**4**	**92**

Table D-10. UF 13 — Cosumnes River at Michigan Bar Simulated minus Unimpaired (TAF)

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1922	0	-1	2	13	-31	22	3	-2	-14	1	0	0	-8
1923	-1	6	10	-26	-22	-6	8	12	-5	0	0	-1	-23
1924	2	1	-2	-1	1	3	9	7	3	0	0	0	22
1925	2	15	10	6	15	-7	-23	-12	-6	0	0	-1	-1
1926	0	1	2	2	27	11	28	-2	1	0	0	0	71
1927	0	45	34	7	-9	-24	-29	-11	-9	0	0	0	4
1928	-1	12	6	4	7	26	0	-8	-1	0	0	0	43
1929	-1	0	1	0	4	13	30	21	1	5	1	0	74
1930	0	0	19	16	15	16	20	4	3	2	0	0	94
1931	0	3	5	3	14	22	20	9	4	2	1	0	82
1932	0	5	34	26	-32	0	10	22	-5	1	0	0	62
1933	0	-1	0	1	1	36	29	9	-9	1	0	0	66
1934	5	8	11	7	32	16	4	2	0	1	0	0	86
1935	1	10	7	27	5	-7	-4	-2	-6	0	0	0	31
1936	-1	1	-1	25	-25	-14	-7	18	-1	2	0	0	-3
1937	0	-1	-1	2	-8	-9	-2	29	-3	1	0	0	8
1938	-1	2	43	18	-35	-57	-24	2	1	-1	-1	-1	-54
1939	-2	1	1	3	2	13	14	1	4	2	0	0	38
1940	2	3	0	34	14	-24	-8	-8	-2	0	0	0	11
1941	-1	3	41	36	21	-14	-6	2	-5	0	0	0	76
1942	-1	1	26	-19	-12	-14	5	-1	0	-1	-1	-1	-18
1943	-2	26	13	1	-24	-88	-14	3	-4	-2	-1	-1	-94
1944	-2	-2	-2	0	6	-4	11	20	-2	1	0	0	27
1945	5	30	3	-3	4	-13	4	9	-9	1	0	0	31
1946	7	20	5	-13	-12	-13	5	11	-1	0	0	0	7
1947	-1	1	6	2	3	36	19	3	0	1	0	0	71
1948	6	10	2	0	-1	23	16	0	-11	0	0	0	44
1949	-1	-1	-1	0	-7	5	23	-7	-3	0	0	0	9
1950	-1	-1	2	-11	-13	13	9	9	-3	1	0	-1	5
1951	3	54	-24	-67	-30	-26	6	2	-3	-2	-2	-1	-90
1952	-2	6	17	-38	-49	-59	-19	-5	-10	-6	-2	-2	-172
1953	-2	-4	7	19	-7	5	26	13	-9	0	0	-1	46
1954	-2	-1	3	-2	1	9	29	-2	-1	0	0	0	34
1955	-1	-1	16	-12	-7	5	4	26	2	2	0	0	34
1956	0	-2	3	-64	-36	-9	13	31	4	0	-1	-1	-63
1957	-2	3	-1	-5	-1	15	20	20	-2	1	0	-1	46
1958	-1	-1	2	10	9	-59	-81	15	-14	-2	-2	-1	-125
1959	-1	-2	-2	4	5	12	24	3	2	-1	-1	0	43
1960	4	1	-1	0	29	25	14	13	4	0	-1	0	87
1961	0	0	8	1	13	25	30	11	3	-1	-1	0	90
1962	1	0	4	1	12	6	23	15	0	1	0	0	62
1963	38	8	9	15	-9	-7	-33	8	0	0	-1	-1	26
1964	0	9	2	-11	-4	12	27	11	2	1	-1	-1	47
1965	-1	9	-3	-101	-25	15	1	32	0	0	-2	0	-75
1966	-1	7	0	-4	-6	10	30	-2	0	-3	-3	0	28
1967	0	9	34	-18	-14	-32	-61	14	2	-5	-2	-2	-74
1968	-1	-1	2	-9	0	18	15	-1	-1	-2	-2	0	18
1969	0	13	4	-64	-50	-18	-2	19	-2	-1	-1	-2	-105
1970	-1	3	16	-34	-19	-28	-4	26	1	0	-1	-1	-41

Table D-10. UF 13 — Cosumnes River at Michigan Bar Simulated minus Unimpaired (TAF) contd.

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1971	-2	19	23	-57	-16	12	3	7	-7	-1	0	-1	-20
1972	-1	-2	-4	-4	8	8	13	4	0	-2	-2	-1	18
1973	0	8	-6	-15	-14	-34	9	25	-1	-1	-2	-2	-31
1974	-2	28	-2	-51	-2	-11	-16	27	1	-1	1	-1	-28
1975	-2	0	3	-2	-5	-25	-23	29	1	-1	-2	-1	-27
1976	0	6	0	-3	-5	-1	9	6	2	0	-1	2	15
1977	2	0	0	-1	-2	1	4	5	4	1	0	0	15
1978	0	0	11	31	-10	22	-22	31	1	0	0	2	65
1979	5	-1	0	-2	-7	-12	-2	12	2	3	1	0	0
1980	-1	5	2	-54	-84	-48	2	19	8	2	2	0	-147
1981	0	-1	-2	-1	13	15	29	4	7	2	0	0	67
1982	0	53	29	-93	-34	-65	-88	12	-9	-3	-2	-2	-203
1983	15	21	-58	-65	-83	-148	-59	-10	35	-11	-3	-3	-368
1984	-1	2	-81	-27	-7	17	10	40	2	1	-1	0	-45
1985	-2	15	2	-5	-16	0	33	7	1	1	0	-1	36
1986	2	-2	-1	9	-72	-61	-6	34	5	1	0	-1	-90
1987	1	1	-2	-1	1	26	32	7	2	-1	-1	0	65
1988	0	0	5	0	5	26	19	4	-1	-1	-2	-1	56
1989	0	0	5	-3	-10	52	45	5	1	0	-1	0	93
1990	6	6	4	-2	-5	22	14	4	1	1	0	0	51
1991	0	0	1	0	2	5	22	24	1	2	1	0	59
1992	0	4	2	4	13	15	22	6	1	-1	0	0	68
1993	0	5	9	-45	-40	-15	-10	43	2	5	1	0	-43
1994	0	2	3	1	1	24	18	5	3	0	-1	0	57
1995	1	7	4	-44	-19	-77	-8	-22	17	-4	-2	-1	-147
1996	0	-1	13	15	-3	-24	10	26	-7	-4	-3	-2	23
1997	0	5	-1	-185	-33	15	15	20	1	0	-1	0	-165
1998	-1	2	9	9	-67	-45	-27	-5	-19	-11	-5	-4	-165
1999	-2	-2	4	17	-34	-18	-8	7	-8	-2	-4	-2	-52
2000	-1	4	6	37	-15	-14	7	15	-1	-3	-3	-2	32
2001	-1	4	0	-1	12	23	20	8	2	0	-1	-1	66
2002	-1	8	51	7	9	24	13	-2	0	0	-1	-1	108
2003	-1	13	59	12	7	28	24	-10	-6	-2	-1	0	122
2004	-1	-2	34	16	31	21	-8	-6	-2	-1	-1	-1	81
2005	14	17	52	46	13	6	-28	-54	-23	-5	-2	-2	34
2006	-2	-2	72	31	-6	-14	-88	-72	-18	-6	-4	-3	-111
2007	-4	-1	16	12	39	16	-2	-3	-1	-1	-1	-1	69
2008	-2	1	2	30	18	21	-1	-10	-2	0	-2	-2	54
2009	-1	10	4	7	37	27	11	-9	0	-1	-1	-1	85
2010	2	4	8	29	37	36	17	-35	-27	-2	-1	-1	67
2011	15	23	35	-17	-11	-60	-29	-27	-39	-11	-3	-3	-127
2012	-1	0	-2	0	7	47	-11	-12	-2	-1	-1	-1	22
2013	-1	19	60	-3	-7	7	-3	-1	-1	0	0	-1	69
2014	0	-1	0	-1	75	33	3	2	2	0	0	0	113
Average	**1**	**6**	**8**	**-6**	**-6**	**-3**	**2**	**6**	**-2**	**-1**	**-1**	**-1**	**3**

Table D-11. UF 14 — Mokelumne River at Pardee Reservoir Simulated minus Unimpaired (TAF)

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1922	0	2	8	-5	-12	24	6	-117	-37	-23	0	0	-155
1923	5	14	32	-13	-9	6	-24	-13	66	1	2	13	80
1924	8	1	2	1	8	-8	-19	21	1	1	0	4	20
1925	17	16	2	-6	37	-46	-81	-85	22	-11	2	2	-130
1926	10	2	-4	1	23	27	80	-70	-12	1	0	0	59
1927	8	175	-7	-15	74	15	43	-140	-179	-30	-3	-1	-60
1928	23	12	-7	-13	6	79	-53	-3	-19	-3	1	0	24
1929	-1	4	0	-3	-1	1	8	73	-15	-2	-1	0	62
1930	1	0	4	0	22	17	-39	-36	117	-2	1	3	87
1931	3	9	0	19	21	2	-10	63	4	2	0	0	112
1932	3	5	25	-3	-23	4	9	-21	-1	-24	-2	-2	-29
1933	1	1	2	5	-3	63	23	-9	-44	-12	-3	-3	20
1934	5	5	13	-4	29	43	24	-13	-8	1	1	2	99
1935	15	11	0	-6	-6	6	69	-61	43	-10	1	0	61
1936	8	1	1	12	53	-20	-42	-19	83	10	-1	4	91
1937	5	4	8	6	6	23	2	103	-54	-11	0	-1	92
1938	8	8	14	2	-6	-40	-39	-9	102	-8	-3	2	30
1939	18	2	8	3	1	12	-12	5	1	0	0	10	48
1940	9	1	-3	37	57	-8	-82	7	9	-5	-1	0	22
1941	4	7	42	2	53	-6	-23	-70	63	-13	-3	1	55
1942	4	20	-15	-15	-7	-2	-36	-48	90	-2	-5	0	-16
1943	4	36	4	-25	-11	7	-35	24	38	-11	-3	0	27
1944	3	6	3	3	17	13	3	19	1	-6	-1	1	63
1945	35	36	-5	-19	12	-20	10	5	41	-14	-2	0	78
1946	66	2	1	-41	-17	-9	20	21	8	-4	1	2	49
1947	11	13	3	-6	20	40	3	24	-15	1	0	1	95
1948	19	2	-4	-14	-8	21	3	-40	27	-16	-1	-1	-13
1949	1	2	-2	-2	-2	0	44	-1	-39	0	0	1	0
1950	1	10	2	-18	1	20	-18	-23	-12	-16	-1	1	-53
1951	21	18	-107	-30	-35	-13	-14	40	123	-4	-1	0	-2
1952	14	11	14	-30	-42	-38	-16	-16	16	-62	-11	-3	-163
1953	2	5	14	5	-7	13	2	-50	1	19	-1	-1	2
1954	1	6	0	11	15	6	22	11	-30	-6	1	1	38
1955	0	5	14	1	0	5	-17	13	39	-5	0	1	56
1956	1	-1	-62	-94	-59	-32	-12	37	125	34	-9	2	-71
1957	9	6	0	1	10	16	-4	1	1	-8	-3	2	31
1958	3	-1	-1	15	34	-8	-36	12	4	-30	-2	4	-7
1959	2	3	2	9	4	14	11	-9	-8	-2	1	16	43
1960	1	0	0	2	13	38	-14	19	6	0	2	0	64
1961	4	5	-2	2	5	12	5	25	7	0	2	18	85
1962	2	3	-4	-4	15	-1	36	-45	10	-11	-2	0	0
1963	58	6	1	40	-59	-1	-30	-21	98	1	-3	12	101
1964	22	0	-10	-3	-2	17	-6	15	28	-5	2	1	60
1965	1	7	-95	-111	-26	6	-4	3	123	46	14	7	-29
1966	-1	18	0	-4	-11	19	56	-20	-9	-1	2	-1	48
1967	0	8	-18	5	-24	-25	-60	42	54	22	-4	6	6
1968	12	14	6	10	1	20	-3	-4	-14	-2	3	2	43
1969	0	-1	2	-16	-59	-30	-34	-39	82	-6	-2	6	-96
1970	5	14	25	-64	-27	-11	-38	17	93	-14	0	3	4

Table D-11. UF 14 — Mokelumne River at Pardee Reservoir Simulated minus Unimpaired (TAF) contd.

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1971	-9	27	10	-38	-12	9	-23	-58	59	-3	3	3	-31
1972	1	14	4	-11	6	14	-10	-3	-34	-8	-2	11	-17
1973	5	5	-29	-12	-1	-27	13	63	-28	-7	4	2	-12
1974	9	-5	-11	-61	-9	9	-17	-9	135	6	-3	-1	43
1975	7	6	3	0	6	1	-27	33	34	-35	3	2	33
1976	7	-9	-6	-4	5	-11	-12	48	-3	3	16	8	44
1977	6	1	-1	-1	2	-1	13	-13	-8	3	0	4	3
1978	1	1	5	4	-12	58	-12	-4	81	-30	-3	37	125
1979	2	2	2	-10	-8	3	-1	31	12	-4	0	1	29
1980	6	3	7	-103	-37	-36	-16	-30	58	46	-1	6	-96
1981	7	7	6	17	14	31	4	31	-20	2	1	2	100
1982	8	17	-42	-64	-68	-22	-138	-19	168	63	-2	31	-66
1983	19	22	-41	-26	-47	-94	-47	0	49	-7	-8	12	-168
1984	23	-15	-74	-48	8	35	-17	50	78	-7	-10	6	30
1985	15	23	-1	-6	3	6	20	16	-17	-2	0	12	70
1986	8	5	-1	-7	-70	-72	-61	10	134	-12	-1	6	-62
1987	13	8	5	2	7	17	73	-23	-7	-1	-1	0	93
1988	3	4	-3	-7	11	15	7	11	-15	0	1	1	29
1989	1	-1	-2	-8	-16	41	31	28	-29	-3	2	22	65
1990	13	-3	-7	-5	-5	27	35	5	-13	-1	1	5	51
1991	4	2	0	-1	14	15	3	-4	38	-4	1	3	71
1992	6	6	-1	-3	24	25	33	7	2	1	2	2	103
1993	7	4	4	-43	-20	15	-1	17	48	-32	-4	-1	-5
1994	10	5	6	6	8	33	17	-9	-12	-1	-1	0	63
1995	5	1	-7	-46	-14	-41	-28	-122	-17	110	-19	-7	-184
1996	-4	8	21	-7	-17	-22	-22	29	82	-15	-5	-2	47
1997	1	2	-3	-190	-55	16	-6	154	57	-2	-3	0	-27
1998	8	9	5	6	-39	-19	-24	67	15	-96	-12	16	-63
1999	1	12	-7	33	-25	-31	-17	10	43	-20	-8	-1	-10
2000	9	18	0	51	2	-44	-7	69	-18	-13	-6	7	70
2001	5	-2	-1	9	7	33	21	15	-10	-3	-2	-2	70
2002	8	39	37	-14	18	39	-15	0	-39	-8	-3	-1	61
2003	-1	50	61	-10	0	29	2	4	-96	-14	2	0	28
2004	-1	-1	51	12	52	50	-19	-85	-29	1	1	1	34
2005	43	25	94	50	41	75	-17	-105	-120	-51	-9	-1	26
2006	3	14	220	-15	36	15	-28	-176	-144	-30	-4	-4	-112
2007	8	21	34	5	73	36	-27	-66	-16	-1	0	2	69
2008	10	8	13	43	32	32	-12	-61	-53	2	1	0	15
2009	11	32	3	50	59	63	-12	-139	-44	-7	0	1	17
2010	39	5	20	57	70	42	25	-70	-143	-22	0	0	24
2011	81	21	115	24	14	80	-60	-86	-178	-100	-13	1	-101
2012	18	2	2	32	8	94	-39	-84	-14	-4	-2	-1	12
2013	1	72	73	-5	-11	16	-57	-49	-12	0	1	2	29
2014	1	5	1	0	117	42	-23	-47	-9	2	3	4	95
Average	**9**	**11**	**5**	**-8**	**3**	**9**	**-9**	**-10**	**11**	**-6**	**-1**	**3**	**17**

Table D-12. UF 15 — Calaveras River at Jenny Lind Simulated minus Unimpaired (TAF)

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1922	0	1	7	10	-30	-3	-16	-5	-2	0	0	0	-39
1923	1	6	-4	17	-9	-10	25	-6	-2	-1	0	1	17
1924	1	-1	0	5	5	1	0	-2	0	0	0	0	9
1925	3	4	8	9	-7	4	0	0	-1	0	0	0	20
1926	1	0	3	2	9	-1	10	0	0	0	0	0	27
1927	2	-3	16	20	-22	-3	-13	-4	-1	0	0	0	-7
1928	1	8	6	11	0	-14	2	-2	-1	0	0	0	12
1929	0	3	5	4	5	8	13	-1	5	1	0	0	43
1930	0	0	9	10	14	3	3	5	0	0	0	0	44
1931	0	4	1	8	8	6	0	1	2	0	0	0	31
1932	0	5	13	24	-11	-1	1	7	0	0	0	0	39
1933	0	0	4	7	9	14	1	22	0	0	0	0	55
1934	1	2	13	13	10	4	0	1	0	0	0	0	46
1935	1	6	7	12	7	-1	5	-1	-2	-2	0	0	33
1936	1	1	1	22	-55	-7	-3	-4	2	-1	0	0	-42
1937	0	1	6	4	-11	-26	-8	-6	-2	-1	0	0	-44
1938	1	1	3	13	-49	-52	-13	-8	-5	-2	0	0	-110
1939	1	1	0	4	7	7	0	2	1	0	0	0	23
1940	2	1	1	27	8	-13	-21	-4	-2	-1	0	0	0
1941	0	0	17	25	0	-18	-11	-6	-3	-1	0	0	4
1942	0	1	16	10	5	-6	10	16	-3	-2	0	0	46
1943	0	19	13	19	-6	-45	-7	-4	-2	-1	0	0	-13
1944	-1	0	2	10	14	-7	12	0	0	0	0	0	30
1945	1	11	14	7	9	-5	-4	-3	4	0	0	0	34
1946	1	11	36	9	7	6	-3	-3	-1	0	0	0	64
1947	1	6	16	7	13	9	8	0	0	0	0	0	59
1948	4	4	1	5	10	28	17	9	1	0	0	0	79
1949	0	0	6	12	15	10	-4	-2	-1	0	0	0	37
1950	0	2	4	26	6	10	9	-4	-1	0	0	0	53
1951	3	4	20	10	0	-17	-6	6	-2	-1	0	0	17
1952	2	6	24	-4	0	-43	-17	-10	-4	-3	0	-1	-50
1953	-1	0	15	23	-2	7	10	5	4	0	-1	0	62
1954	1	2	6	15	15	7	4	3	-1	0	-1	0	52
1955	0	1	9	12	7	-2	15	8	-1	0	0	0	49
1956	0	2	33	-17	-3	-8	2	28	-2	-1	0	0	35
1957	1	1	3	7	13	15	8	30	2	0	0	0	81
1958	1	1	8	17	3	-31	-58	-9	-4	-1	0	0	-73
1959	0	0	-1	15	8	0	0	0	0	0	0	1	22
1960	1	0	0	8	29	6	6	3	0	0	0	0	53
1961	0	6	5	1	7	13	6	8	1	0	0	0	45
1962	0	1	7	2	5	4	-2	0	0	0	0	0	17
1963	11	0	10	9	16	2	8	10	-2	-2	-1	-1	62
1964	1	5	0	7	0	9	3	3	0	-1	0	0	27
1965	1	9	20	-20	-5	2	2	-6	-3	-2	-1	0	-2
1966	-1	5	7	12	5	-2	2	0	0	0	0	0	28
1967	0	6	18	11	4	-12	-20	-8	-4	-2	-1	0	-8
1968	1	0	8	13	19	9	1	-1	-1	0	0	0	48
1969	1	8	13	-43	-38	-18	-12	-8	-4	-2	-1	-1	-105
1970	1	2	14	8	0	-19	-1	-2	-2	-2	-1	-1	-2

Table D-12. UF 15 — Calaveras River at Jenny Lind Simulated minus Unimpaired (TAF) contd.

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1971	-1	0	29	2	-5	6	-2	2	-2	-1	-1	-1	25
1972	1	3	28	11	3	0	7	-2	-1	0	0	-1	49
1973	1	9	13	17	-22	-14	-6	-4	-3	-3	-2	-1	-14
1974	2	14	23	6	7	-27	-6	-3	-3	-2	-1	-1	8
1975	0	3	5	10	22	-14	0	-6	-1	-1	0	-1	18
1976	2	2	2	-1	9	3	4	0	-1	0	0	1	21
1977	0	1	0	2	1	2	0	5	0	-1	-1	0	10
1978	0	3	26	36	-5	-7	10	-5	-3	-1	0	0	55
1979	0	1	5	18	-13	-12	-5	2	-1	-1	0	0	-6
1980	2	7	5	24	-24	-8	-3	0	-2	-3	-1	-2	-5
1981	0	-1	1	4	15	3	5	1	0	-1	-1	0	27
1982	2	10	20	13	-6	-33	-50	-11	-5	-3	-1	-1	-65
1983	3	2	1	-22	-39	-87	-9	-10	-7	-5	-2	-2	-177
1984	-2	3	24	0	7	1	-1	-3	-2	-1	0	0	26
1985	0	11	4	5	8	4	-1	-2	-1	-1	-1	0	26
1986	0	3	13	25	-25	-21	-7	-3	-2	0	0	-1	-17
1987	0	-1	-1	5	13	16	0	0	0	0	0	0	33
1988	0	2	9	16	3	7	10	3	1	-1	-1	0	48
1989	0	7	8	8	15	40	8	1	0	0	0	1	88
1990	4	4	2	15	11	13	4	16	10	0	0	0	80
1991	0	1	1	1	1	18	5	7	2	1	0	0	37
1992	2	3	4	3	17	12	0	-1	0	1	-1	0	41
1993	1	2	23	1	10	-7	-3	-2	6	0	0	-1	30
1994	-1	0	4	4	14	4	8	10	0	-1	0	-1	40
1995	2	10	26	25	7	-63	11	11	-9	-3	0	-2	15
1996	-2	-3	8	32	2	-9	8	15	-2	-2	-2	-1	43
1997	-1	2	15	-61	-7	-7	-5	-3	0	-1	0	0	-67
1998	1	2	13	24	-65	-24	-20	9	-3	-5	-3	-2	-73
1999	-2	0	6	11	-1	-3	4	-5	-4	-2	-1	-1	3
2000	-1	2	2	39	-8	-9	-1	12	-1	-1	-1	-1	34
2001	0	2	4	11	21	3	18	0	-1	-1	-1	-1	56
2002	0	3	33	17	14	9	0	8	1	0	0	0	84
2003	0	4	37	13	12	13	37	10	-2	-1	0	0	123
2004	0	2	48	13	9	2	-1	-1	0	0	-1	0	72
2005	8	6	14	-9	-1	-26	-3	12	-2	-1	-1	0	-3
2006	-1	0	33	-2	2	-48	-78	-2	-3	-2	-1	-1	-104
2007	0	0	5	1	18	11	11	5	0	0	-1	0	49
2008	0	1	3	16	8	6	1	3	1	-1	0	0	37
2009	1	3	2	6	14	13	10	20	0	0	-1	-1	68
2010	2	1	5	4	7	0	-1	-2	-1	-1	0	0	11
2011	4	6	-8	-2	-9	-78	-15	-6	-1	-1	-1	0	-111
2012	0	-1	-1	2	2	12	3	-1	0	-1	-1	-2	13
2013	0	4	11	4	-2	1	4	-1	-1	0	-1	0	19
2014	0	0	1	0	14	13	7	1	0	0	-1	-1	34
Average	**1**	**3**	**10**	**8**	**1**	**-5**	**-1**	**2**	**-1**	**-1**	**0**	**0**	**17**

Table D-13. UF 16 — Stanislaus River at Melones Reservoir Simulated minus Unimpaired (TAF)

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1922	-2	-4	-9	-11	-66	-23	2	-98	-107	-40	-11	-3	-372
1923	-1	24	13	-40	-17	19	51	-102	-9	51	-2	1	-14
1924	17	-3	-6	1	35	7	30	83	11	2	1	1	179
1925	14	39	-2	-8	54	15	-48	-151	85	47	1	-1	45
1926	2	1	15	11	22	79	89	-34	-16	0	-1	-2	166
1927	0	101	-17	-29	-41	7	70	-84	-95	-45	-10	-4	-147
1928	17	22	-10	-21	2	54	-41	52	5	-3	-2	-1	74
1929	-1	1	8	-8	-3	24	21	97	58	-1	0	1	197
1930	3	-2	14	-6	62	102	2	-42	124	-11	-2	-4	240
1931	1	8	5	52	37	43	20	71	34	3	2	2	278
1932	1	5	-23	-25	-54	39	37	-17	-58	-51	-14	-4	-165
1933	-3	-2	-5	-9	6	113	53	1	-13	-12	-3	-2	123
1934	2	2	14	-3	38	64	48	0	-1	-1	1	1	166
1935	10	18	7	-22	-11	13	129	-134	-1	-15	-8	-2	-15
1936	3	-1	-3	1	7	-24	-15	2	61	3	-6	-5	25
1937	-3	-1	2	-17	33	-2	-15	168	-9	-11	-6	-3	136
1938	-1	14	52	-21	-84	-87	-53	-32	51	5	-18	-8	-181
1939	6	-3	5	-6	4	34	22	41	20	-4	3	23	144
1940	27	5	5	15	-5	-9	-60	-50	-10	-17	-4	-1	-105
1941	-3	13	55	-20	33	27	12	-111	32	66	-8	0	96
1942	-7	13	6	-17	-28	-9	-25	16	109	69	-10	-3	115
1943	-2	14	5	-37	-17	-84	0	44	38	15	-10	-2	-38
1944	-2	0	3	5	7	37	54	-1	-2	1	-2	1	101
1945	1	37	-8	-22	10	-35	65	-26	43	-15	-8	-2	41
1946	16	9	-2	-60	-29	-16	92	-4	81	-7	-3	0	77
1947	9	44	26	-4	44	65	54	16	-4	-6	-1	2	245
1948	21	11	-3	13	1	35	53	-25	-9	3	-4	2	98
1949	-1	-8	-12	-11	-8	20	103	-25	-41	-11	-2	3	6
1950	1	18	6	49	80	62	91	-89	-101	-31	-3	-1	83
1951	29	-54	-114	-2	15	30	26	66	85	24	-2	-1	102
1952	2	9	13	-42	-31	-11	120	47	-123	-22	-16	-3	-57
1953	2	7	-4	15	10	80	62	-36	-57	-3	-5	1	72
1954	0	16	5	16	70	40	45	-75	-32	-10	1	0	76
1955	-1	3	28	12	38	34	32	30	-14	-12	0	4	153
1956	1	-4	-107	-154	-39	98	94	176	25	9	-4	-3	94
1957	2	1	4	60	71	65	11	-2	-12	-10	-4	-2	182
1958	4	2	9	42	97	-34	12	23	-105	-46	-17	6	-7
1959	-3	-2	4	38	41	67	8	-24	-18	-8	3	27	133
1960	21	4	2	11	125	62	-8	-10	-19	-2	5	6	195
1961	16	18	10	15	20	38	34	38	40	6	4	8	246
1962	7	5	4	6	33	12	97	-104	-23	-25	1	3	17
1963	77	16	21	-11	20	23	30	-31	30	20	-4	1	192
1964	28	23	-13	-20	5	31	66	43	40	0	3	2	206
1965	12	31	-135	-164	-27	43	14	72	86	41	-2	-2	-31
1966	-1	33	-16	-27	-12	21	98	10	-13	-3	3	4	98
1967	4	28	3	-40	-17	-21	-59	86	-66	-23	-26	-3	-134
1968	7	7	3	11	13	47	-2	-23	12	-2	2	6	80
1969	7	41	-19	-94	-126	-31	-8	81	23	27	-7	2	-104
1970	18	21	56	-98	-31	-5	34	66	122	13	-3	3	196

Table D-13. UF 16 — Stanislaus River at Melones Reservoir Simulated minus Unimpaired (TAF) contd.

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1971	2	43	-11	-57	2	14	8	-42	95	17	0	7	78
1972	6	4	-23	-16	20	76	-10	-18	-11	-6	5	13	41
1973	6	20	2	-38	-40	-54	82	115	-1	-14	3	3	85
1974	20	21	-20	-102	-26	5	-3	28	102	13	-7	1	32
1975	17	9	15	17	26	-25	-22	91	-48	-50	2	4	37
1976	5	5	-8	-7	18	12	-4	79	16	13	21	24	175
1977	13	8	6	5	32	17	60	19	44	12	8	6	228
1978	10	17	42	15	-17	72	4	68	45	-28	-15	28	242
1979	-1	2	-6	-11	-49	7	6	71	-9	-11	0	0	1
1980	14	24	-2	-163	-69	-40	72	-41	10	80	-9	-3	-129
1981	0	2	5	19	28	28	61	26	6	5	5	3	189
1982	21	62	-69	-146	-104	-30	-65	-1	123	133	0	15	-62
1983	35	-19	-86	-117	-116	-156	-39	137	-87	-5	-21	5	-469
1984	3	-17	-39	-106	-25	49	61	64	84	4	0	8	87
1985	10	15	-13	-10	14	14	71	-9	27	12	12	27	170
1986	30	-12	-7	-7	-115	32	-5	21	101	12	-6	-13	30
1987	11	9	2	1	37	72	119	22	-5	-1	3	4	274
1988	11	12	0	2	56	51	53	72	22	3	5	6	293
1989	1	19	7	-2	16	63	90	32	-12	-8	3	41	250
1990	41	22	7	16	15	92	65	72	69	9	10	10	426
1991	8	8	8	7	32	43	39	35	91	16	8	5	301
1992	9	12	9	-1	34	73	60	67	8	56	5	4	335
1993	12	11	3	-126	-35	42	43	111	99	21	-5	6	183
1994	6	4	1	13	20	60	57	7	1	6	9	6	188
1995	22	-2	-5	-96	3	-105	27	-13	-7	196	31	-6	45
1996	-2	-1	29	-40	-59	-36	41	53	137	12	7	9	151
1997	5	25	-112	-299	-20	70	90	178	190	25	0	6	156
1998	5	8	9	-58	-167	-64	8	1	136	79	-2	-1	-45
1999	-1	-8	-2	11	-95	-53	30	81	66	-10	-4	-7	7
2000	7	17	2	63	-50	-48	96	146	-12	-8	3	9	226
2001	8	2	4	46	6	55	66	29	-12	13	9	8	233
2002	8	48	52	-5	36	76	-22	18	-7	-3	6	8	212
2003	7	71	75	-4	19	29	24	49	-79	-3	13	7	208
2004	8	15	106	7	17	122	4	-74	-45	-7	4	10	166
2005	52	28	35	-30	-27	37	15	-13	-131	-74	-5	6	-106
2006	3	10	-13	-77	11	-66	-91	80	-160	-65	-12	-5	-384
2007	1	20	20	6	44	76	-2	-53	-20	5	8	12	117
2008	7	17	20	18	21	53	69	-9	-56	1	6	7	153
2009	19	61	11	84	27	38	37	-88	-72	-13	7	7	115
2010	69	9	22	26	18	45	106	-27	-157	-54	1	4	63
2011	105	34	-28	-41	-37	-102	-56	12	-76	-105	-30	-3	-326
2012	-2	1	2	21	7	26	28	-14	-13	-5	1	7	59
2013	4	38	36	-1	-1	16	2	28	3	4	0	7	137
2014	4	11	9	18	90	56	-104	-91	-21	-12	-7	-4	-52
Average	**10**	**14**	**0**	**-20**	**0**	**20**	**29**	**14**	**7**	**2**	**-1**	**4**	**79**

Table D-14. UF 18 — Tuolumne River at Don Pedro Reservoir Simulated minus Unimpaired (TAF)

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1922	-1	1	96	5	62	37	-21	-121	-354	-163	-21	-8	-490
1923	9	57	144	57	12	27	-15	-139	-82	-48	-18	1	4
1924	12	0	-1	27	39	21	18	-54	-5	-14	1	2	45
1925	34	68	43	23	125	63	-29	-171	-73	-63	-6	3	16
1926	13	12	16	65	142	34	-4	-81	-34	-8	2	0	157
1927	2	149	8	74	66	3	27	-47	-183	-129	-19	-8	-56
1928	93	66	38	32	31	140	-40	-35	-45	-18	-4	-1	256
1929	2	30	41	19	27	95	36	-27	-24	-26	0	4	178
1930	5	2	42	69	118	128	-28	-107	-67	-38	-5	7	128
1931	11	30	11	87	37	59	18	16	-3	-2	6	6	276
1932	8	25	153	31	14	66	-9	-56	25	-72	-24	-9	154
1933	0	6	10	45	35	163	65	20	-102	-58	-10	0	172
1934	23	31	176	60	82	116	-13	-64	-40	-3	0	2	370
1935	37	74	50	82	20	58	48	-135	-22	-67	-11	3	137
1936	24	2	13	118	147	104	41	-128	-98	-81	-8	4	137
1937	12	6	107	8	152	93	-36	-9	-90	-56	-8	-1	178
1938	5	28	263	63	-21	-41	-4	-111	-95	-127	-44	-9	-94
1939	42	-4	13	20	18	168	7	-67	-30	-8	-2	25	181
1940	40	8	20	188	36	56	-27	-57	-154	-42	-6	3	65
1941	7	19	150	37	76	-42	-27	-145	-52	-5	-16	-1	1
1942	1	41	93	71	-16	12	-12	-67	-16	-48	-19	3	42
1943	6	97	85	75	13	28	-65	-61	-65	-1	-14	0	98
1944	4	13	17	58	57	77	16	-56	-61	-28	-3	3	98
1945	67	117	29	-6	24	3	71	-105	-52	-85	-7	10	66
1946	105	28	153	-21	11	28	9	-131	-16	-27	3	7	148
1947	38	116	66	-2	59	84	-2	-56	-51	-11	5	4	251
1948	64	16	-4	22	22	107	164	-59	-139	-50	3	2	148
1949	6	12	13	11	35	87	181	-96	-59	-16	5	4	182
1950	4	53	19	55	113	90	110	-64	-178	-46	3	8	167
1951	109	209	52	-24	2	11	-38	9	17	-21	1	8	335
1952	15	71	95	36	25	-2	26	-138	-131	-22	-28	-5	-58
1953	4	19	78	81	1	36	-4	-79	-74	-43	-3	5	21
1954	4	45	37	69	125	41	84	-70	-99	-25	5	5	220
1955	2	35	124	16	34	40	-22	48	-12	-13	9	6	266
1956	5	7	319	-133	-81	9	25	22	-32	-29	-25	-2	84
1957	19	26	15	45	113	74	23	6	-140	-52	0	6	135
1958	17	17	113	113	125	37	59	-130	-223	-138	-35	9	-36
1959	6	11	21	100	68	41	32	-92	-57	-7	7	102	231
1960	19	1	-1	52	125	157	26	-53	-64	-1	5	5	270
1961	15	63	55	39	22	69	29	-62	14	-2	11	17	271
1962	9	28	43	42	158	57	116	-125	-115	-85	-2	14	140
1963	105	14	83	315	110	27	41	-40	-102	-25	-18	1	512
1964	36	96	4	26	10	54	30	-34	-44	-21	1	4	162
1965	24	84	214	-45	12	1	38	-111	-55	43	10	-8	208
1966	7	92	33	-3	-6	44	26	-68	-45	-11	0	1	70
1967	4	88	74	86	9	-48	-65	81	-116	-96	-55	2	-34
1968	14	28	25	96	83	58	-39	-97	-37	-5	7	8	142
1969	36	103	16	166	-89	13	-97	-224	-135	30	-29	-1	-211
1970	49	53	65	95	10	-13	-61	76	75	-48	-12	-3	286

Table D-14. UF 18 — Tuolumne River at Don Pedro Reservoir Simulated minus Unimpaired (TAF) contd.

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1971	-1	113	45	3	19	51	-41	-110	21	12	1	8	121
1972	8	34	35	16	91	75	7	-59	-71	-15	-2	17	136
1973	16	52	29	80	50	-28	60	-41	-138	-41	1	5	46
1974	60	67	150	-18	0	102	-17	-90	-57	-33	-10	0	154
1975	23	37	64	71	101	57	7	-21	-194	-121	1	5	28
1976	41	22	5	19	27	42	1	13	-13	13	22	26	217
1977	11	13	10	18	43	15	39	-9	8	2	7	8	164
1978	12	51	179	120	43	181	-1	-153	-113	-109	-42	29	198
1979	2	-2	11	65	35	87	9	-68	-21	-46	-4	1	69
1980	23	54	67	60	-28	-72	21	-129	-80	39	-33	-6	-83
1981	6	14	63	100	74	63	73	-68	-32	-7	-9	4	279
1982	41	170	71	-61	-4	-14	-146	-161	-69	-11	-48	4	-226
1983	62	54	-42	9	-4	-125	-66	38	-220	-229	-131	-22	-677
1984	9	-6	-25	-67	-9	-9	-9	39	-37	-51	-6	7	-162
1985	28	80	2	9	75	33	103	-138	-48	-6	-1	19	157
1986	29	35	77	113	98	30	-126	-120	-135	-103	-16	4	-112
1987	13	6	9	46	96	105	125	-51	-25	4	4	9	341
1988	30	24	3	66	73	38	38	22	-13	-7	8	13	293
1989	9	39	29	23	44	158	96	-83	-40	-12	14	60	338
1990	72	54	17	55	33	93	-5	-36	41	10	13	14	361
1991	22	14	14	18	70	166	24	-74	51	-18	-4	10	292
1992	51	50	41	46	126	102	33	-17	-9	0	3	12	438
1993	49	31	98	70	23	250	-15	-120	-99	-101	-39	-14	135
1994	12	26	39	48	89	95	-3	-49	-66	-20	-13	8	167
1995	55	17	36	139	62	-35	26	-168	-212	-120	-88	-21	-309
1996	0	7	149	99	81	80	11	-110	-25	-77	-9	2	208
1997	14	108	132	-193	-79	37	-73	-6	-29	20	-33	-5	-108
1998	14	54	44	144	-9	91	5	-158	-252	-164	-63	4	-288
1999	3	32	27	148	37	-29	15	-174	-119	-78	-18	-3	-158
2000	23	66	15	245	101	2	29	-94	-143	-53	-21	10	180
2001	35	20	28	76	40	205	62	-97	-33	10	12	15	372
2002	28	100	141	6	100	95	-17	-50	-60	-8	5	10	350
2003	15	160	142	90	10	100	37	4	-169	-32	1	2	359
2004	8	34	197	46	71	168	-46	-98	-75	-18	1	6	295
2005	106	31	145	81	19	34	-69	-203	-158	-28	-23	-2	-68
2006	12	24	305	5	78	-45	-57	-178	-163	-157	-22	-3	-200
2007	15	39	62	36	116	134	8	-121	-45	-1	4	10	259
2008	20	17	55	115	117	64	2	-69	-77	-14	9	8	247
2009	55	73	37	140	94	60	-12	-27	-125	-40	9	8	272
2010	114	21	63	109	94	86	52	-107	-173	-68	1	7	199
2011	116	43	127	19	-8	52	-36	-91	-144	-252	-60	6	-228
2012	25	7	15	69	28	111	80	-98	-24	2	9	10	233
2013	14	138	149	26	4	63	-22	-43	-43	-3	5	13	300
2014	13	21	19	44	154	95	25	-76	-34	14	10	14	298
Average	**27**	**46**	**67**	**53**	**50**	**58**	**10**	**-73**	**-75**	**-41**	**-10**	**6**	**118**

Table D-15. UF 19 — Merced River at Exchequer Reservoir Simulated minus Unimpaired (TAF)

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1922	-1	-2	25	0	-65	-9	15	-64	-154	-13	-11	-6	-284
1923	-1	26	35	2	-11	15	2	-59	-82	63	-2	-5	-15
1924	-2	-5	-5	4	6	5	-7	-21	8	-2	-2	-1	-22
1925	9	26	6	8	21	26	6	-58	-1	8	-10	-3	39
1926	2	0	5	3	42	27	-22	-83	36	-1	-2	-2	4
1927	-1	80	7	16	-23	-17	7	-34	-73	-25	-7	-1	-71
1928	18	35	-1	0	1	25	-31	28	9	-1	0	0	84
1929	-3	9	14	4	11	31	9	-15	5	4	1	0	71
1930	1	-2	19	29	56	62	4	-70	35	-6	-1	-3	122
1931	2	14	2	20	18	25	-8	-2	24	6	-2	0	98
1932	1	3	13	-13	-46	89	0	-27	73	34	-5	-3	118
1933	-5	-2	4	-2	26	75	49	-40	33	0	0	-3	135
1934	-1	14	55	31	22	85	-9	16	1	3	-1	-2	212
1935	7	48	24	16	13	-5	-9	-82	17	1	-8	1	24
1936	9	-2	0	47	-54	61	46	-117	-8	-5	-6	1	-27
1937	0	2	31	-7	-49	27	-9	0	-26	25	-4	0	-8
1938	2	3	120	0	-118	-115	-9	-77	-77	25	-13	-9	-267
1939	-3	1	-9	0	3	70	-18	-45	54	-2	0	4	56
1940	23	0	-2	46	-27	23	29	-7	9	-11	-4	0	78
1941	3	7	13	5	-10	-35	-27	2	-39	46	-7	-3	-46
1942	-6	5	15	9	-20	-14	-15	-30	19	62	-12	-7	6
1943	-4	28	19	-31	-1	-47	3	-5	-14	83	-6	-4	22
1944	-2	1	5	18	-1	21	10	-28	-50	41	-3	0	13
1945	3	81	0	-14	-66	-53	46	-30	0	18	-11	-2	-26
1946	4	31	16	-23	-11	-1	56	-65	36	46	1	2	93
1947	7	33	18	-14	8	35	16	3	1	-1	3	0	108
1948	17	4	-5	-2	-2	41	86	-51	-70	37	0	0	55
1949	-1	1	-1	-3	6	36	126	-91	23	-4	0	1	93
1950	-2	14	4	-4	49	21	88	-60	-26	14	1	1	100
1951	14	53	-54	-47	-2	-3	12	65	93	40	2	0	173
1952	1	19	16	-61	24	-58	90	-54	-79	53	3	-5	-52
1953	-3	-2	16	17	9	26	8	-35	2	48	2	1	90
1954	-2	10	7	19	40	20	87	-48	-19	17	3	0	134
1955	-2	16	47	8	10	12	-3	33	10	7	5	0	144
1956	-2	-1	15	-91	-51	10	55	57	95	94	-2	-3	176
1957	2	-3	-5	8	33	21	7	-19	27	-11	-3	1	57
1958	1	-1	46	29	37	-37	22	-4	-123	12	-15	-3	-37
1959	-1	-2	-3	47	12	37	8	-40	26	1	1	28	114
1960	6	1	-2	21	26	103	17	-54	43	-2	1	0	159
1961	6	23	16	6	11	21	18	-40	74	8	2	2	147
1962	2	8	25	-4	25	8	130	-90	-32	-3	-4	2	66
1963	14	2	20	-18	116	-2	-19	55	-20	63	2	3	217
1964	8	42	-8	-11	3	19	34	-26	12	24	4	2	104
1965	1	38	-18	-84	14	8	19	-7	45	96	13	-4	120
1966	-3	38	-18	-18	-4	8	73	-51	5	-1	-3	-4	23
1967	-11	24	21	3	18	-38	-113	106	-36	-2	-31	-9	-66
1968	0	-1	2	13	44	30	-2	-35	40	-1	-2	-3	85
1969	6	33	7	-71	-135	-31	9	-33	-32	101	33	-3	-117
1970	1	14	13	16	-8	-9	-22	95	84	8	-4	-4	183

Table D-15. UF 19 — Merced River at Exchequer Reservoir Simulated minus Unimpaired (TAF) contd.

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1971	-2	28	24	-12	17	38	8	-44	28	40	2	3	130
1972	2	8	0	-5	35	64	-5	-9	30	9	1	-5	126
1973	0	22	-1	10	-17	-42	44	-11	-40	-14	-8	-2	-58
1974	11	21	31	-22	-7	17	-3	-51	29	3	-9	-4	16
1975	5	11	22	17	-16	4	-12	8	-92	-25	-5	-2	-83
1976	0	12	-8	-7	6	18	-17	-7	10	3	0	9	20
1977	3	1	1	7	9	1	7	-11	28	-2	-1	-1	42
1978	-1	19	66	30	-33	43	2	-74	-71	-14	-9	-18	-60
1979	-9	-9	1	-20	-37	25	12	7	10	-5	-12	-4	-41
1980	-3	22	-1	-19	-104	-67	32	-15	-31	103	10	-8	-81
1981	-8	-2	14	14	45	32	35	-28	37	-8	-4	-5	122
1982	13	64	0	-55	-44	-55	-169	-13	6	58	0	-8	-203
1983	-5	15	-66	-92	-107	-165	-52	31	-109	-206	-26	-7	-788
1984	-9	-6	-70	-48	-20	10	-23	51	36	16	-2	1	-63
1985	4	26	-1	-9	19	7	47	-98	34	-5	-2	-4	19
1986	1	14	18	45	-75	-44	-30	-76	52	13	-2	-3	-89
1987	-1	0	-3	5	29	25	54	-10	2	-1	-2	0	98
1988	5	10	1	17	29	32	-6	19	10	-10	-5	-3	99
1989	-1	9	6	1	23	90	74	-44	9	8	-1	8	183
1990	27	8	-2	35	16	49	-29	-33	51	-1	-3	-2	117
1991	0	2	2	-3	10	27	30	-14	55	19	1	0	129
1992	9	10	8	13	38	52	4	19	4	-3	-1	-1	152
1993	2	12	21	-57	-13	167	-24	-143	-36	52	-12	-6	-37
1994	-3	1	11	3	29	47	2	-26	11	-5	-8	-1	61
1995	8	3	2	-16	36	-112	-35	-110	-72	10	13	-6	-280
1996	-10	-7	32	6	-8	22	-24	-19	82	8	-9	-5	68
1997	0	26	-52	-363	-53	63	-19	79	80	74	4	-2	-165
1998	2	12	23	23	-112	56	-37	-57	-140	0	-20	-21	-271
1999	-11	-5	10	41	-5	-1	24	-83	19	12	-8	-6	-12
2000	-1	10	5	69	-25	33	52	-51	25	-15	-10	-2	91
2001	9	4	-4	13	6	81	16	-13	-1	-3	-2	-1	107
2002	1	31	15	18	35	34	38	-48	82	4	-2	0	207
2003	0	57	39	14	4	46	-5	26	19	-16	0	-3	180
2004	-2	-2	55	7	12	132	-19	-41	53	-7	-5	-3	179
2005	35	8	20	-52	-21	-23	-24	-57	-47	72	-15	-8	-112
2006	-5	-1	74	-6	-18	-18	-114	-7	-15	-17	-14	-9	-150
2007	-8	-1	11	1	24	69	-22	-17	-5	-10	-8	-4	30
2008	-3	-1	15	28	25	38	-2	-23	9	-15	-6	-4	61
2009	6	21	4	27	24	21	8	30	-44	8	-8	-4	92
2010	27	4	15	19	3	37	16	-75	-54	25	-12	-7	-2
2011	16	10	82	-43	-62	-113	27	-70	-85	29	-20	-8	-234
2012	-2	-3	-5	1	8	30	45	-24	12	-4	-4	-3	51
2013	-2	9	36	-1	4	34	15	19	41	1	-2	-1	152
2014	1	0	-1	0	20	35	-2	-6	2	-5	-2	0	42
Average	**2**	**13**	**11**	**-5**	**-3**	**16**	**8**	**-25**	**0**	**13**	**-4**	**-2**	**24**

Table D-16. UF 20 — Chowchilla River at Buchanan Reservoir Simulated minus Unimpaired (TAF)

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1922	0	0	0	1	-9	1	1	-2	-1	0	0	0	-7
1923	0	4	0	1	0	1	5	-2	-1	0	0	0	9
1924	1	1	0	0	1	5	4	1	0	0	0	0	13
1925	1	8	5	4	15	4	4	-1	0	0	0	0	41
1926	1	1	1	3	25	2	6	1	1	0	0	0	40
1927	0	4	4	7	4	0	5	-1	0	0	0	0	21
1928	1	2	3	0	8	21	8	0	0	0	0	0	42
1929	0	2	2	4	8	14	14	1	1	1	0	0	48
1930	0	0	1	2	11	16	6	3	1	0	0	0	41
1931	1	2	2	6	8	4	2	2	1	0	0	0	27
1932	0	1	4	-1	-21	8	6	1	0	0	0	0	-2
1933	0	0	1	2	4	14	2	1	1	0	0	0	26
1934	0	0	5	7	8	2	0	1	0	0	0	0	24
1935	1	5	7	0	0	4	-4	-4	-1	0	0	0	6
1936	0	1	0	9	-11	-6	2	-2	-1	0	0	0	-7
1937	0	1	5	3	-8	2	-3	-4	-1	0	0	0	-6
1938	0	1	14	7	-6	-54	-8	-6	-3	-1	0	0	-56
1939	0	1	3	7	7	13	4	0	1	0	0	0	36
1940	1	1	1	13	-3	-1	1	-2	0	0	0	0	11
1941	0	1	11	8	-10	-15	-10	-4	-2	-1	0	0	-23
1942	0	0	6	10	11	2	5	-1	-1	-1	0	0	31
1943	0	11	9	27	10	2	-4	-2	-1	0	0	0	53
1944	0	0	2	8	12	3	2	0	0	0	0	0	27
1945	0	13	6	1	22	4	-4	-3	-1	0	0	0	38
1946	1	3	16	9	8	14	3	-1	0	0	0	0	53
1947	1	13	10	5	10	9	4	0	1	0	0	0	52
1948	1	2	1	4	6	27	15	1	1	1	0	0	58
1949	0	1	1	2	8	23	5	1	1	0	0	0	42
1950	0	2	2	7	11	15	9	1	1	0	0	0	48
1951	1	14	3	1	6	9	0	1	1	0	0	0	35
1952	0	3	8	-6	8	-4	6	-2	-1	-1	0	0	11
1953	0	0	10	13	6	11	2	1	1	1	0	0	44
1954	0	2	2	13	23	19	2	1	1	0	0	0	62
1955	0	2	8	8	9	7	3	1	1	0	0	0	39
1956	0	1	0	-4	4	3	0	-2	-1	0	0	0	2
1957	0	1	0	4	13	15	1	2	1	1	0	0	38
1958	1	1	6	8	19	7	-26	-5	-1	-1	0	0	9
1959	0	0	1	7	17	5	2	1	1	0	0	3	37
1960	2	0	0	2	20	10	4	1	1	0	0	0	40
1961	0	3	6	1	4	9	1	1	1	0	0	0	27
1962	0	1	7	1	9	8	-1	-1	1	0	0	0	25
1963	1	1	3	6	21	7	-3	-5	-1	-1	0	0	30
1964	1	7	4	1	1	8	2	0	1	0	0	0	24
1965	0	8	7	-9	4	7	-4	-4	-1	0	0	0	9
1966	0	11	3	1	8	3	0	0	0	0	0	0	27
1967	0	3	20	3	3	15	-29	-15	-5	-1	0	0	-4
1968	0	1	3	7	16	12	2	0	1	0	0	0	42
1969	0	4	14	17	-20	-8	0	-2	-1	0	0	0	5
1970	1	3	9	28	11	4	0	0	0	0	0	0	56

Table D-16. UF 20 — Chowchilla River at Buchanan Reservoir Simulated minus Unimpaired (TAF) contd.

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1971	0	5	14	8	4	11	2	1	0	0	0	0	46
1972	0	2	6	5	9	4	6	2	1	0	0	0	34
1973	1	7	6	15	-5	-2	-5	-2	0	0	0	0	14
1974	1	11	10	6	5	12	-4	-2	0	0	0	0	39
1975	0	2	8	8	10	8	0	-3	-1	0	0	0	32
1976	1	1	0	0	7	6	2	1	0	0	0	0	19
1977	1	1	1	2	1	3	1	1	1	0	0	0	11
1978	0	1	12	7	-16	-13	-21	-10	-2	-1	0	1	-40
1979	1	0	3	8	7	6	-3	-2	-1	-1	0	0	16
1980	0	1	3	23	16	1	-2	-2	-1	0	0	0	40
1981	0	1	2	3	10	12	0	0	0	0	0	0	29
1982	0	10	12	-3	17	4	-16	-5	-1	0	0	-1	19
1983	2	13	11	-24	-19	-43	-9	-10	-4	-1	-1	-1	-87
1984	1	9	7	6	10	6	1	0	-1	0	0	0	39
1985	1	7	6	1	12	11	2	0	-1	0	0	0	39
1986	1	6	9	8	22	2	-2	-1	0	0	0	0	44
1987	1	0	1	2	12	13	2	1	0	0	0	0	33
1988	0	3	3	8	2	8	5	1	1	0	0	0	32
1989	0	5	5	3	9	26	3	2	1	0	0	0	54
1990	2	3	2	6	8	6	1	2	1	0	0	0	32
1991	0	0	1	1	2	46	3	0	0	-1	0	0	52
1992	0	2	2	3	8	6	3	-1	0	-2	0	0	21
1993	0	1	8	-3	14	9	0	-2	0	1	0	0	27
1994	0	0	2	1	13	3	4	1	-1	-1	0	0	24
1995	1	4	5	11	7	18	-2	0	-2	0	0	-1	41
1996	0	0	7	8	9	9	1	0	0	-2	-1	0	30
1997	0	10	-15	-54	2	1	0	0	0	0	0	0	-58
1998	-1	1	6	11	-11	-2	-12	-4	-7	-2	-1	-1	-22
1999	0	0	3	13	21	8	5	0	-1	-1	0	0	49
2000	0	1	1	21	8	-3	-1	-1	0	0	0	0	26
2001	1	1	1	7	15	13	3	1	0	0	0	0	43
2002	0	7	24	5	8	9	0	0	1	0	0	0	54
2003	0	13	17	5	5	9	11	4	1	0	0	0	66
2004	0	1	12	10	13	5	0	0	0	0	0	0	40
2005	12	6	14	1	3	-1	-4	1	0	0	0	0	31
2006	0	0	18	20	6	9	-17	-7	0	0	0	-1	29
2007	-1	0	3	4	16	4	1	1	0	-1	-1	0	27
2008	0	0	4	35	13	2	0	0	0	0	0	0	56
2009	0	3	7	14	18	10	1	2	1	0	0	0	56
2010	6	1	15	14	11	8	7	-1	0	0	0	0	61
2011	3	8	26	5	8	3	-1	0	0	0	0	0	52
2012	1	0	0	7	5	11	8	1	1	-2	-4	0	29
2013	0	2	36	4	1	1	1	1	-1	-2	0	0	44
2014	0	1	1	1	4	7	5	2	0	0	0	0	21
Average	**1**	**3**	**6**	**5**	**7**	**6**	**0**	**-1**	**0**	**0**	**0**	**0**	**27**

Table D-17. UF 21 — Fresno River near Daulton Simulated minus Unimpaired (TAF)

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1922	0	0	-7	0	-6	-4	1	-12	-3	-2	0	0	-33
1923	0	3	-7	-4	-2	3	-1	-13	-7	-3	0	0	-31
1924	1	0	0	-1	1	3	-1	0	0	0	0	0	3
1925	1	11	3	4	18	4	-1	-7	-5	-1	0	0	28
1926	1	0	1	3	33	2	12	-4	-1	0	0	0	48
1927	0	4	5	7	18	1	7	-8	-5	-1	0	0	29
1928	0	2	1	-1	5	19	7	-4	-1	0	0	0	29
1929	0	2	2	2	7	17	13	-3	-2	1	0	0	37
1930	0	0	1	-1	15	13	6	0	-1	0	0	0	34
1931	1	1	1	2	7	5	1	2	1	0	0	0	23
1932	0	0	-3	-5	3	29	13	-5	-6	-2	0	0	25
1933	0	0	0	-1	2	26	-2	-3	-5	0	0	0	18
1934	0	1	4	12	12	1	-1	-1	0	0	0	0	29
1935	1	7	5	15	3	7	18	-9	-9	-3	0	0	36
1936	-1	0	0	15	32	4	0	-13	-6	-1	0	0	31
1937	0	0	6	0	12	13	-2	-11	-9	-3	0	0	6
1938	-1	0	34	14	23	-14	-17	-12	-14	-10	-3	-1	0
1939	2	3	4	4	1	11	-2	-3	-1	0	0	1	20
1940	2	0	0	28	4	4	-2	-10	-4	-1	0	0	23
1941	0	0	15	13	-3	-22	-11	-11	-13	-6	-1	-1	-40
1942	-1	0	20	14	9	-2	13	-5	-9	-5	-1	0	33
1943	0	16	8	58	19	11	-5	-6	-3	-2	0	0	95
1944	-1	1	2	6	11	10	0	-7	-5	-1	0	0	17
1945	0	14	1	-1	33	-1	-8	-10	-7	-2	0	0	20
1946	0	4	25	9	5	15	4	-9	-3	-1	0	0	49
1947	1	18	13	3	11	5	0	-3	0	0	0	0	46
1948	1	1	1	3	1	31	30	-2	-4	-2	0	0	61
1949	0	0	-1	0	3	34	8	-7	-4	-1	0	0	33
1950	0	3	1	4	22	15	10	-6	-4	-1	0	0	43
1951	1	39	21	5	8	6	-1	-4	-3	-1	0	0	73
1952	0	2	12	-3	9	-8	22	0	-5	-4	-1	0	25
1953	0	2	3	14	6	11	1	-3	-4	-2	0	0	27
1954	0	1	1	14	31	24	1	-6	-3	-1	0	0	62
1955	0	2	7	5	6	6	3	-2	-3	-1	0	0	22
1956	0	-1	49	3	4	3	3	-1	-4	-1	0	0	56
1957	1	0	0	4	14	13	-2	-1	-3	-1	0	0	24
1958	1	0	5	12	27	20	-16	-2	-5	-4	-2	-1	37
1959	0	0	2	11	27	7	-1	-2	-1	0	0	6	48
1960	2	0	-1	2	24	12	2	-2	-2	0	0	0	37
1961	1	3	5	0	4	9	1	0	0	0	0	0	22
1962	0	1	5	-1	21	5	-2	-5	-6	-1	0	0	16
1963	2	1	1	13	29	4	10	-6	-6	-3	0	0	44
1964	0	11	1	-2	-2	2	0	-4	-2	-1	0	0	3
1965	1	8	12	-7	9	12	-6	-3	-5	-2	-1	0	18
1966	-1	17	1	-3	5	1	-4	-5	-1	0	0	0	11
1967	0	2	44	2	3	37	-31	-16	-9	-5	-2	0	25
1968	0	1	2	4	11	8	-2	-3	-1	0	0	0	19
1969	0	3	11	59	-21	-8	18	-1	-2	-4	-2	-1	54
1970	3	5	12	41	14	7	0	-4	-3	-1	0	0	74

Table D-17. UF 21 — Fresno River near Daulton Simulated minus Unimpaired (TAF) contd.

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1971	0	7	13	-1	7	13	1	-4	-4	-1	0	0	31
1972	0	1	3	-1	6	0	7	-3	0	0	0	1	15
1973	1	8	2	22	1	-1	-7	-7	-3	-1	0	0	16
1974	0	17	14	6	6	38	6	-4	-3	-1	0	0	79
1975	0	1	9	4	15	26	6	-6	-7	-2	0	0	46
1976	1	1	-1	0	5	2	0	-1	-1	-1	0	1	5
1977	1	1	0	0	1	1	0	1	0	0	0	0	4
1978	0	2	13	23	-6	-8	-17	-12	-9	-3	-1	2	-15
1979	1	-1	3	14	10	16	2	-4	-4	-2	0	0	36
1980	1	2	1	39	42	2	-4	-5	-4	-3	0	0	70
1981	0	0	2	7	13	17	0	-2	-1	-1	0	0	36
1982	1	10	9	-4	29	15	5	-3	-3	-1	-2	1	56
1983	4	22	22	-22	-12	-46	-15	-7	-3	-2	-2	0	-60
1984	1	16	17	6	10	6	-2	-4	-3	-2	-1	0	44
1985	0	6	4	0	10	12	0	-2	-2	-1	-1	0	26
1986	0	5	10	9	55	2	-3	-4	-4	-2	-1	-1	66
1987	1	0	2	5	15	10	3	-1	-4	0	-1	0	30
1988	1	3	2	6	5	10	5	1	0	-1	0	0	32
1989	0	3	2	1	6	25	1	1	1	-1	-1	1	39
1990	3	2	1	7	4	8	0	1	1	-2	0	0	25
1991	0	0	1	1	2	54	4	-2	-1	-2	-2	0	54
1992	1	2	1	4	15	8	0	0	0	-1	-1	0	29
1993	0	1	6	6	8	19	2	-4	-4	-4	-1	0	30
1994	-2	0	2	2	13	3	4	2	-2	0	-1	0	20
1995	3	2	2	17	3	40	-1	2	-2	-1	-1	-1	62
1996	-1	1	12	6	22	19	5	-2	-2	-1	-1	-1	57
1997	-1	14	-1	-27	2	1	1	0	-2	-2	-1	-1	-18
1998	-1	0	6	13	2	-2	-15	-6	-7	-3	-1	-1	-14
1999	1	1	1	13	19	3	2	-4	-2	0	0	-2	32
2000	-1	1	0	24	20	-4	-4	-4	-2	0	0	0	29
2001	-1	1	0	5	19	17	3	-1	0	0	-1	0	41
2002	0	6	31	7	5	9	-1	-1	0	0	0	0	56
2003	0	15	22	5	5	9	11	4	-2	-2	0	0	68
2004	0	1	16	14	14	6	-1	-2	0	0	0	0	47
2005	12	5	18	21	4	-1	-6	-3	-4	-2	-1	-1	42
2006	0	0	22	28	4	10	-10	-11	-4	-2	-1	-1	36
2007	0	1	3	3	14	3	-1	-1	0	0	0	0	20
2008	0	0	4	38	15	2	-2	-3	-1	0	0	0	53
2009	0	5	6	13	17	10	0	-1	0	0	0	0	50
2010	12	1	16	15	12	10	10	-1	-2	-1	0	0	70
2011	5	8	33	6	3	11	0	-4	-4	-2	0	0	54
2012	2	2	1	11	6	9	8	0	-1	0	0	0	37
2013	0	2	38	4	1	3	0	0	0	0	0	0	49
2014	0	1	0	0	4	9	5	1	0	0	0	0	22
Average	**1**	**4**	**7**	**8**	**11**	**9**	**1**	**-4**	**-3**	**-1**	**0**	**0**	**33**

Table D-18. UF 22 — San Joaquin River at Millerton Reservoir Simulated minus Unimpaired (TAF)

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1922	-4	-6	1	-17	-16	-28	13	-78	-285	1	-21	-11	-451
1923	-9	4	-24	-3	-16	13	10	-175	-77	66	6	-8	-212
1924	-4	8	-1	-2	6	36	18	54	52	19	3	-4	185
1925	1	49	34	1	75	71	6	-63	82	38	-12	1	283
1926	-7	2	10	16	61	46	-50	-38	108	24	9	-3	179
1927	-5	45	40	-8	-12	-11	54	-76	-152	-37	-10	-5	-176
1928	4	36	16	1	28	74	-3	4	47	17	7	-1	229
1929	-8	0	13	7	13	59	67	62	32	50	10	2	308
1930	0	-3	-4	12	57	66	48	-15	84	22	6	-1	272
1931	-2	6	4	12	21	45	58	116	64	29	4	-2	353
1932	-1	5	10	-11	-61	34	30	-78	-8	127	11	3	60
1933	-8	-5	-7	12	3	65	95	38	-54	-13	-2	-8	116
1934	-5	0	60	21	29	79	38	103	36	36	8	-2	402
1935	0	51	34	20	0	-5	21	-110	80	62	0	-5	147
1936	-3	0	-3	40	25	30	49	-25	69	42	7	4	236
1937	-3	7	68	10	-51	14	-75	-60	-76	83	13	1	-70
1938	-7	-6	109	13	-23	-190	-173	-233	-212	-31	-14	-16	-783
1939	-15	-2	-5	10	-7	28	35	5	65	14	-6	-7	115
1940	18	21	10	43	29	31	-36	-15	29	17	6	-1	151
1941	-4	7	12	-9	-35	-53	-54	-161	-131	57	3	6	-362
1942	-12	-15	62	-25	-3	-16	2	-82	-54	46	-8	-1	-106
1943	-6	17	18	-1	10	33	4	-26	25	66	8	1	150
1944	-5	-6	0	11	36	5	42	19	-62	38	10	-3	84
1945	-2	73	-7	-17	-14	-48	-23	-41	-77	2	-27	-12	-192
1946	-28	17	2	-22	-18	25	49	-115	-7	-18	-3	-7	-125
1947	-3	45	23	1	8	40	21	-1	-2	10	2	-5	139
1948	-5	10	-1	-4	9	30	114	-15	-89	66	9	-7	118
1949	-6	5	9	3	8	52	99	-95	1	8	-4	-7	74
1950	-5	-1	19	3	19	64	82	-29	-11	-12	3	-7	125
1951	1	96	-49	-45	-24	-7	42	58	182	72	6	-2	329
1952	-8	6	14	-5	-16	-59	25	-150	-127	29	19	6	-265
1953	4	-5	2	-14	2	29	35	7	-14	52	16	0	114
1954	-5	-1	5	31	83	92	66	-12	-37	2	6	-2	227
1955	-3	2	37	11	3	19	22	15	38	24	14	2	186
1956	-1	-7	-111	-82	-57	-46	68	-11	-70	73	50	12	-183
1957	-1	-1	-6	15	20	61	6	-3	-61	-4	-5	-9	11
1958	-6	0	24	15	40	25	-15	-27	-220	-10	-44	-11	-229
1959	9	-4	-8	7	19	33	61	-14	4	7	-2	16	130
1960	31	11	-1	2	60	86	105	35	46	6	0	-2	379
1961	-1	8	14	2	19	46	84	36	83	33	-5	2	321
1962	3	-1	11	-2	102	3	93	-65	-109	28	-3	-5	56
1963	5	9	1	114	132	20	18	43	-104	68	42	0	348
1964	1	27	19	4	-4	16	82	58	21	21	-2	0	242
1965	-3	33	-25	-50	-38	-15	25	82	11	95	-36	-1	79
1966	-5	-5	7	-29	-19	-11	55	-31	-6	1	-7	-3	-53
1967	-1	1	13	-29	-8	21	-75	13	-148	14	-25	-33	-256
1968	-1	-8	1	-3	5	55	29	11	81	6	-4	-1	172
1969	-1	18	37	-49	-51	-90	-29	-179	-211	29	61	3	-463
1970	-3	4	1	-12	25	24	0	94	148	37	-4	-2	313

Table D-18. UF 22 — San Joaquin River at Millerton Reservoir Simulated minus Unimpaired Flow (TAF) contd.

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1971	-6	10	32	-35	-10	22	46	-51	27	100	3	-3	136
1972	0	-1	15	-15	5	93	33	12	60	25	6	-28	205
1973	0	4	-20	2	1	-24	-20	-20	-79	25	-10	-3	-144
1974	-9	31	17	-39	2	14	4	-113	5	-27	-21	-6	-143
1975	-10	6	24	9	62	67	5	8	-83	-18	-4	-7	58
1976	1	22	-3	-7	19	34	22	98	39	9	-1	1	235
1977	21	8	1	10	9	28	43	44	78	32	5	1	279
1978	0	5	30	42	-3	22	-46	-149	-151	-71	26	-51	-346
1979	0	-14	-8	-15	-5	36	11	-30	32	34	3	-3	42
1980	-12	17	15	-50	11	-39	-22	-102	-132	58	83	-1	-175
1981	-9	-8	-7	6	24	82	45	22	39	6	-2	-8	191
1982	-2	85	30	1	-5	45	-177	-183	-54	39	20	-92	-292
1983	5	20	-65	-126	-88	-148	-95	-142	-262	-159	-51	-16	-1127
1984	0	-27	-64	-56	-7	19	6	32	85	-43	-33	-24	-111
1985	-18	24	13	-20	-3	38	71	-73	20	8	2	-6	55
1986	9	15	17	10	46	-81	-126	-205	-38	28	-14	-9	-349
1987	-4	-2	-6	-5	47	55	85	13	0	13	1	-3	193
1988	-8	36	20	17	27	47	39	59	60	29	5	-1	331
1989	0	6	23	3	10	150	155	18	11	29	7	1	414
1990	37	30	10	27	21	86	42	47	54	26	14	2	396
1991	2	5	2	0	28	157	27	36	80	56	15	1	411
1992	3	15	13	22	31	64	74	63	38	16	16	2	360
1993	-1	21	40	-38	22	63	-33	-142	-114	40	3	-3	-142
1994	-9	-1	13	6	42	68	43	4	24	15	2	-6	202
1995	9	10	-5	-7	0	24	-70	-92	-304	-114	25	-16	-541
1996	-6	-9	3	21	15	23	7	-45	87	2	-9	-3	86
1997	-11	29	-7	-365	-94	5	-33	87	179	99	14	0	-97
1998	-5	-8	19	23	0	-25	-38	-89	-291	-5	68	-21	-373
1999	-6	-16	0	24	19	10	38	-73	34	71	5	-5	101
2000	-2	8	7	29	93	4	60	-55	7	0	-12	-2	137
2001	-2	17	2	20	43	49	63	64	69	0	8	-3	328
2002	-2	35	65	37	26	54	-2	-38	136	29	11	0	350
2003	1	79	83	8	6	-12	-15	56	174	-9	-1	6	377
2004	1	-2	60	39	18	55	-69	-28	119	54	23	5	275
2005	28	36	34	61	22	22	-72	-157	-110	13	-2	6	-121
2006	-5	-5	136	105	20	-2	-134	-237	-133	-76	-5	-6	-341
2007	-10	4	16	18	74	111	29	-4	28	19	1	-2	283
2008	3	6	18	60	29	42	4	7	28	23	14	1	233
2009	5	42	39	72	62	36	-19	21	-63	-2	6	3	201
2010	49	31	27	21	13	18	-10	-86	-83	25	7	0	12
2011	1	38	30	-21	-3	-87	-71	-131	-218	17	4	-13	-451
2012	-21	4	1	25	19	10	93	10	5	6	-10	0	143
2013	-5	-13	115	190	84	158	112	83	104	25	6	2	861
2014	-3	-1	-2	5	14	71	67	22	1	4	-1	3	178
Average	**-1**	**12**	**14**	**1**	**13**	**25**	**15**	**-28**	**-16**	**20**	**3**	**-5**	**54**

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APPENDIX E   CONCEPTUAL DIFFERENCES BETWEEN NATURAL AND UNIMPAIRED FLOWS

How unimpaired flows and natural flows differ in magnitude and interpretation depends on the degree of land use development (i.e., alteration of pre-development native conditions due to agriculture or urbanization).

Consider an undeveloped (no agricultural, urban, or other anthropogenic influences) upper watershed area in the Central Valley (Figure E-1). It is subject to precipitation in the form of both rainfall and snowfall. Precipitation runoff from both rainfall and snowmelt (F1) would appear as outflow at the location 1. If the flow is gaged (observed or measured) at location 1 (labelled O1) then that flow would be an approximation of the water supply generated in the area due to precipitation runoff; a water supply index. In this case the runoff F1 would be equal to O1. So using the gaged flow one can come up with a water supply index for the area (F1) indirectly through the measured flow O1, which will be called Unimpaired Flow UF1. In other words the observed streamflow O1 is a surrogate for the runoff which is difficult to measure directly.
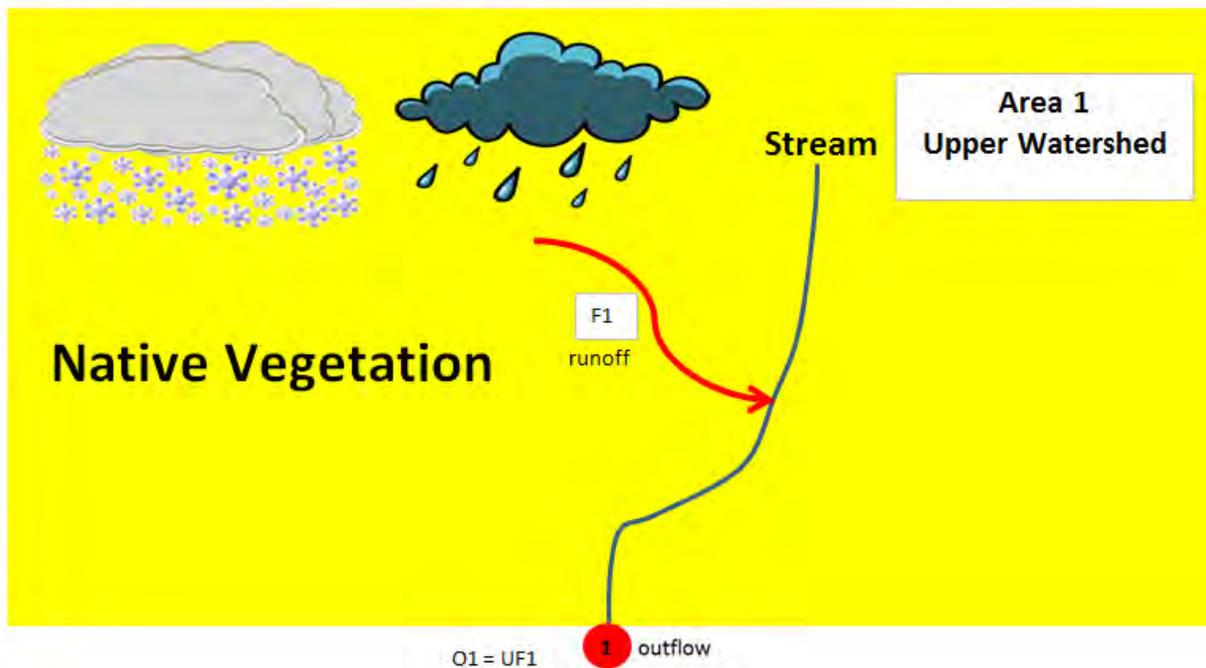
Figure E-1. An Undeveloped Upper Watershed Area

If we call USF1* the estimated "unimpaired streamflow" at location 1, then USF1*=UF1=O1

Now consider the same watershed of Figure E-1 but subject to an import M1 from outside the area, an export X1 to outside the area, and a gaged measured/observed flow O1 (Figure E-2). Conceptually, if M1 and X1 did not exist (i.e., under unimpaired conditions) the observed or gaged outflow O1 would be modified as follows to get the unimpaired outflow at G1:

UF1 = O1 − M1 + X1

Again the unimpaired streamflow USF1* = UF1
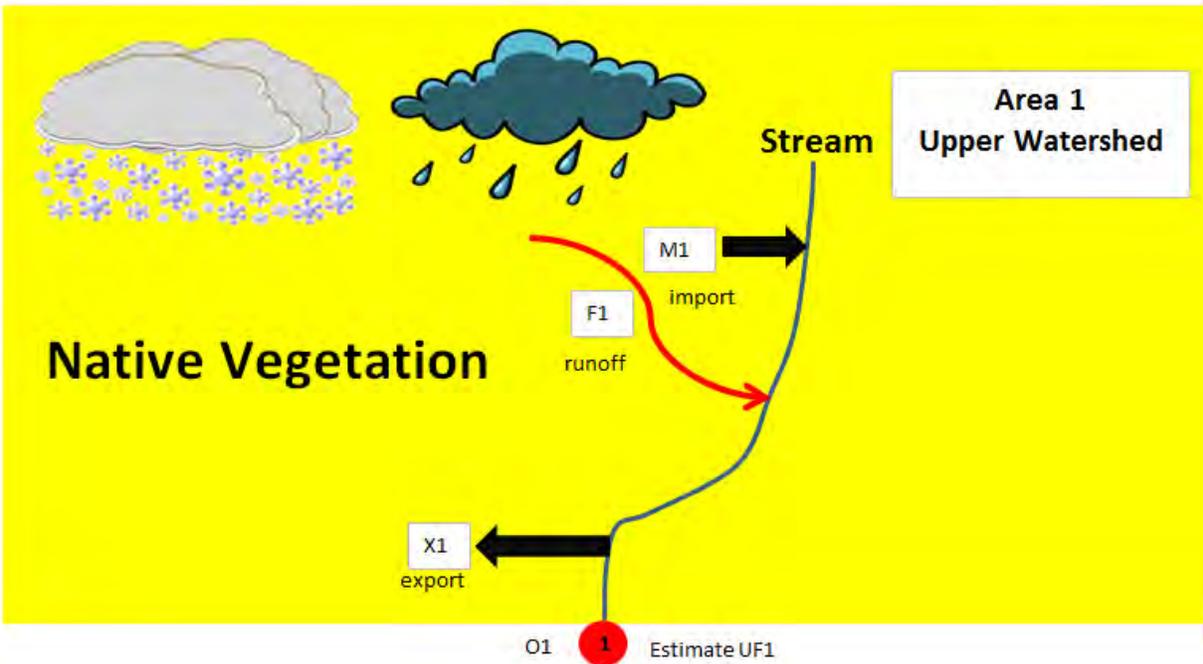
Figure E-2. An Upper Watershed Area with Simple Import and Export

Now consider a slightly more complicated situation. Suppose the upper watershed in Figure E-2 also include a regulated reservoir and some agricultural and urban development with estimated or measured diversion D1 and return flow R1, and the gaged location 1 is just below the reservoir, as show in Figure E-3. The reservoir release is the gaged flow O1 at location 1, and there is a reservoir storage increase of DELS1 and reservoir evaporation of E1. (Note: if the reservoir storage actually decreased then the value of DELS1 is negative.)
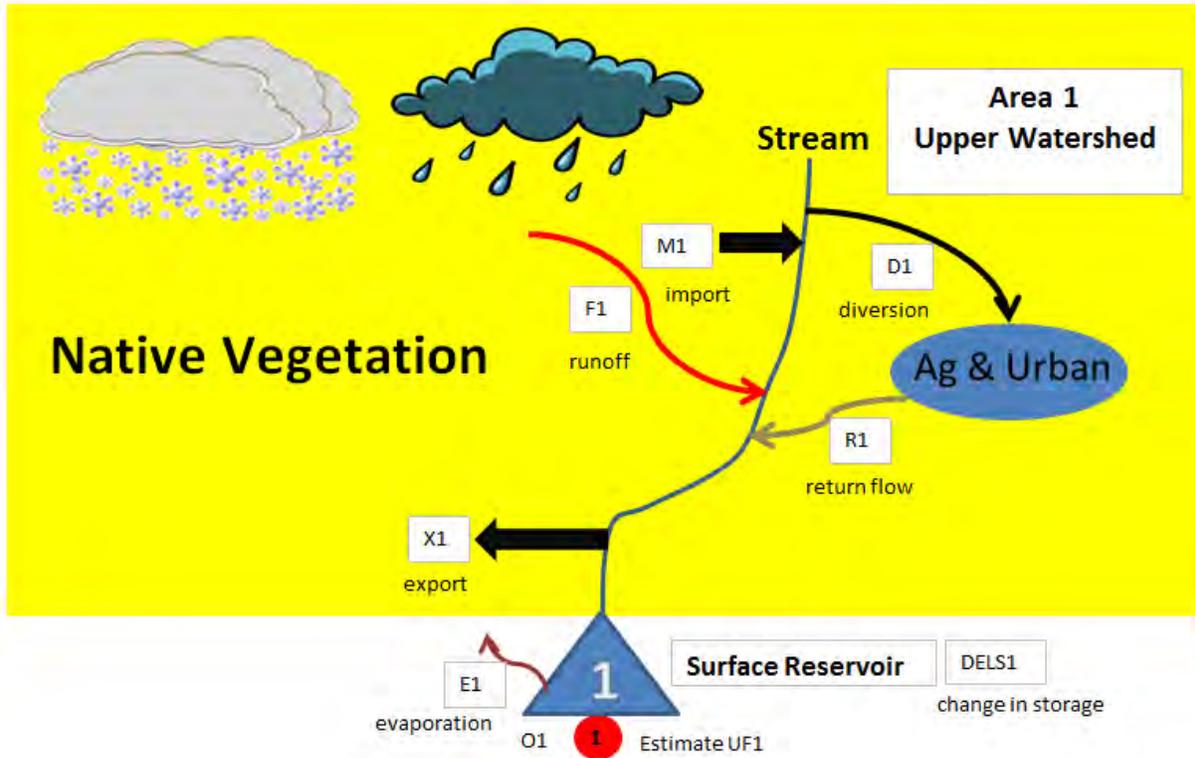
Figure E-3. A Developed Upper Watershed with a Regulated Surface Reservoir

Estimating the Unimpaired Flow for the area is similar to the previous example for Figure E-2 except now it includes the modification to the outflow due to the regulated surface reservoir.

UF1 = O1– M1 + X1 + D1 – R1 + DELS1 + E1

Again, the unimpaired streamflow USF1* = UF1

Note: Computing USF1 would now have to include building back in the consumptive use from the native vegetative lands that would exist if the agricultural and urban areas were not there.

Next consider the same watershed shown previously but under natural conditions, as shown in Figure E-4. As mentioned earlier this report discusses how to estimate the natural outflow using simulation models which will be described later. The additional hydrological components than need to be considered include consumptive use of the native vegetative land classes Cnv1, deep percolation Pn1, runoff F1, and stream seepage S1. The result is estimated natural flow NF1 at the outflow location 1.
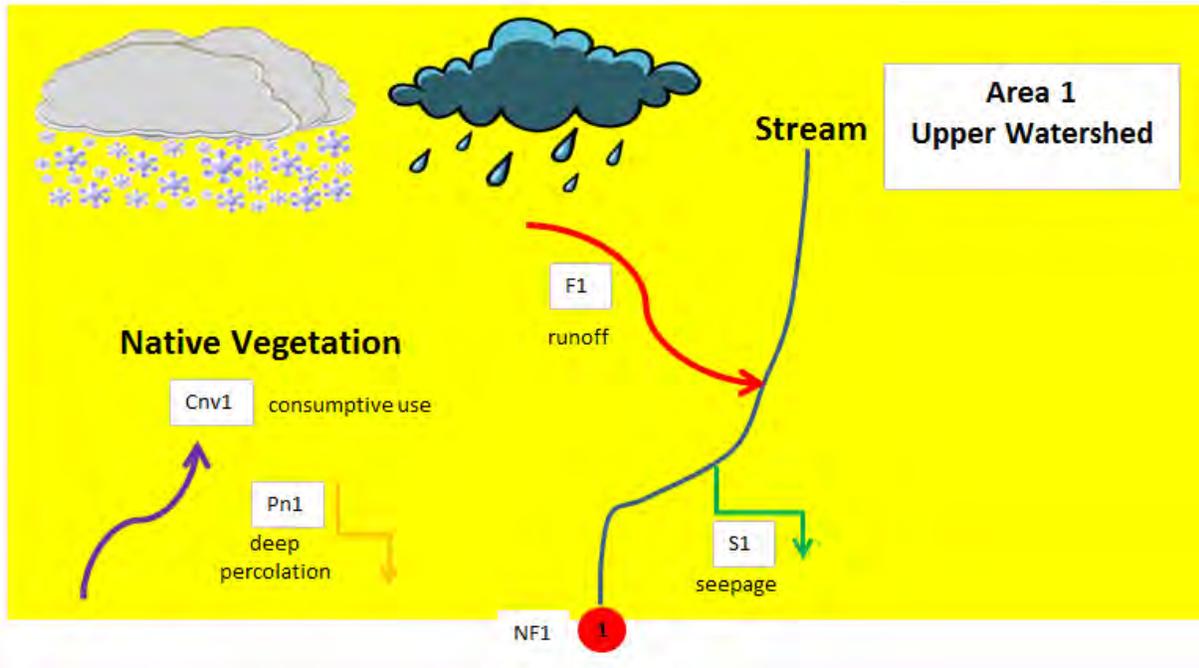
Figure E-4. An Upper Watershed Area Simulated for Natural Outflow

How different are the values NF1, UF1, and USF1? That depends to a large extent on how developed the area is, how complete all the diversion and return flow records are, and how good (calibrated) is the natural flow simulation model. In general, with good record keeping and technical simulation, the values UF1, USF1, and NF1 will be close numerically to one another.

Now consider a developed watershed Area 2 that is downstream of Area 1 (from previous figures) shown in Figure E-5. Under developed conditions key differences compared to Area 1 (from previous figures) include:

1. Precipitation is almost all rainfall, thus no snow accumulation and melting as would occur in an upper watershed.

2. The amount of agricultural and urban development is significantly greater than in Area 1.

3. As part of flood protection, man-made levees are built on streams to protect both urban and agricultural areas from extreme flood events. These levees in effect "channel" the water along the stream to prevent over topping the embankments, and allow passage of the flow to downstream areas.
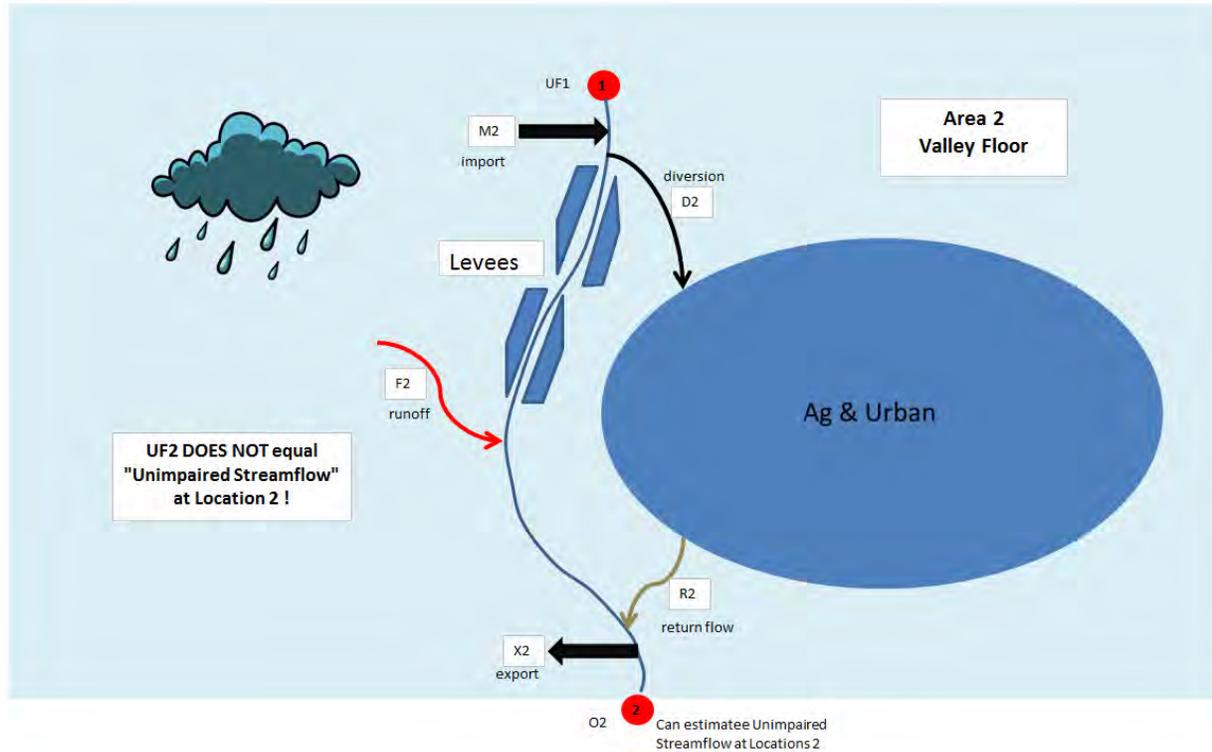
Figure E-5. A Lower Elevation Developed Watershed Area

The measure of the water supply index in this case is again the precipitation runoff (F2). This is termed UF2. In addition, one can estimate an "unimpaired streamflow" at the outflow location 2 in a manner similar to Area 1, as follows:

"Unimpaired Streamflow at 2" or USF2= O2 – USF1 + D2 – R2 – M2 + X2 + F2

The actual computation shown in the above equation needs to also be modified for the precipitation consumptive use of the native vegetation that would occur if the agricultural and urban areas did not exist. This minor adjustment will not be considered in this report to simplify the discussion. It is important to re-emphasize at this point that UF2 does not equal in value to USF2. The two terms now mean two different things: UF2 is the supply index for Area 2, while USF2 is an "unimpaired streamflow" at the outflow of Area 2. In other words USF2 implies modifying a gaged historical flow at location 2, O2, and "building back in" anthropogenic hydrologic affects such as diversions, returns, etc, while maintaining levees, etc. Also, considering Central Valley floor area for example diversion D2 far exceeds locally developed water supplies; it would be met to a large extent by surface water inflows from the upper watersheds (regulated). Note that relying completely on imported surface water and/or ground water is an extreme and unlikely sustainable alternative.

UF2 represents local (Area 2) water supply generated from precipitation (i.e., the precipitation runoff that would show up at the outflow location 2), whereas USF2* is an estimate of the unimpaired streamflow at location 2.

Area 2 under natural conditions is shown in Figure E-6. Under natural flow (pre-development) conditions the landscape is composed of various native vegetative classes such as grasslands, hardwood, riparian areas, as well as lakes, wetlands, and vernal pools. There are only natural levees on the riverbanks which are would frequently be overtopped or breached during flood events. These waters can then flow into interconnected lakes and wetlands, and possibly reconnect to streams downstream. Note: Vernal pools are natural depressions that fill with rainfall during to the wintertime.

Figure E-6. A Lower Elevation Watershed Area Simulated for Natural Outflow

As shown in Figure E-6 the hydrological components that need to be simulated are more complicated than under developed conditions. However, with simulation models one can estimate the natural flow at outflow location 2, NF2.

Comparing unimpaired flows to natural flows one would expect USF2* (the estimated "unimpaired streamflow") to be closer to NF2 in magnitude annually, but differing within the year both spatially and temporally.

Finally consider Area 3 representing the Delta under developed (historical) conditions as shown in Figure E-7. Similar to Area 2 one can estimate an estimate of the locally generated water supply (= UF3). However, to estimate an "unimpaired streamflow" at the outflow location 3, one must start with the unimpaired streamflow at location 3 (USF3*) and modify for anthropogenic impacts.
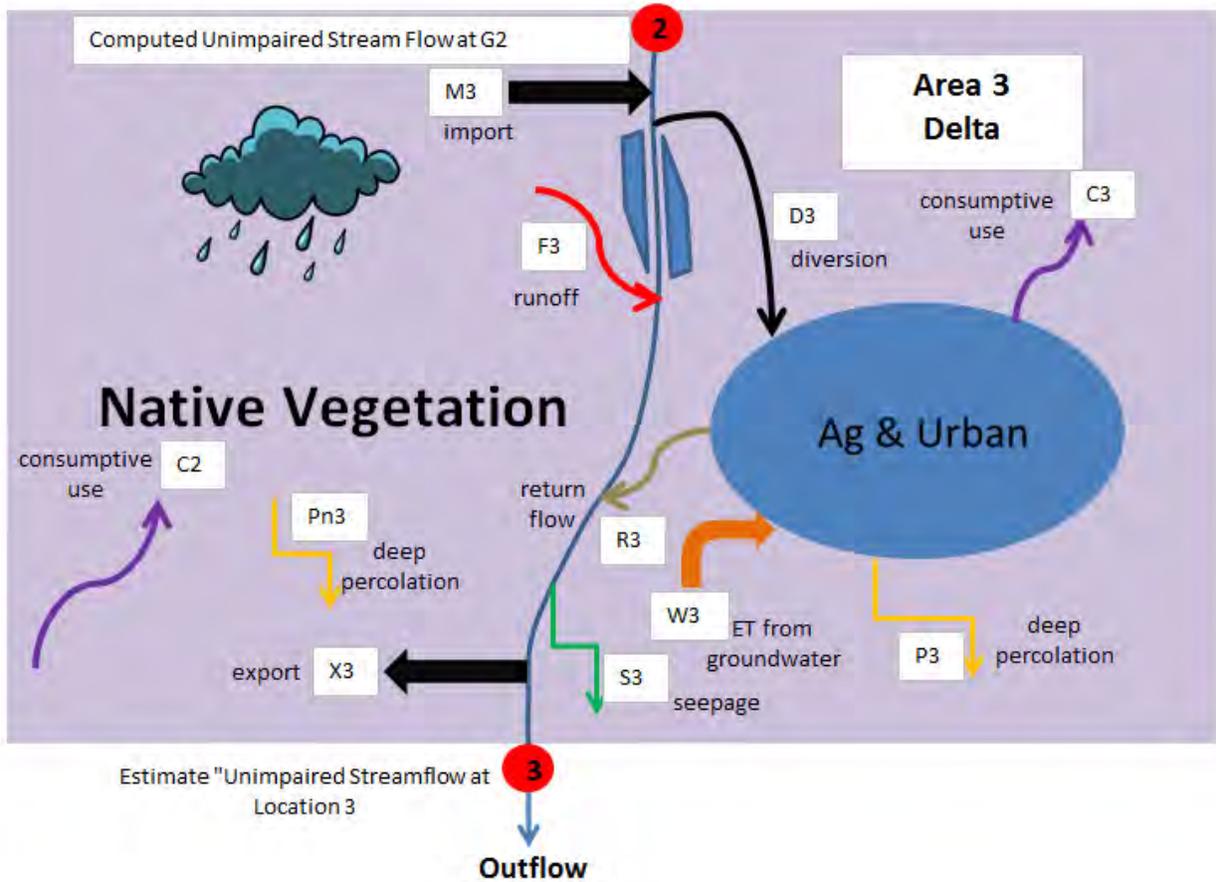
Figure E-7. A Developed Watershed Area Representing the Delta

USF3* = USF2* - M3 + X3 + D3 − R3 + F3

Area 3 under natural conditions is shown in Figure E-8. Similar to Area 2 one can use a simulation model to estimate the natural flow NF3, which is the stream outflow at location 3.

For estimating unimpaired flows interconnected watersheds can be represented as shown if Figure E-9. For simulating natural flow conditions interconnected watersheds can be represented as shown if Figure E-10.
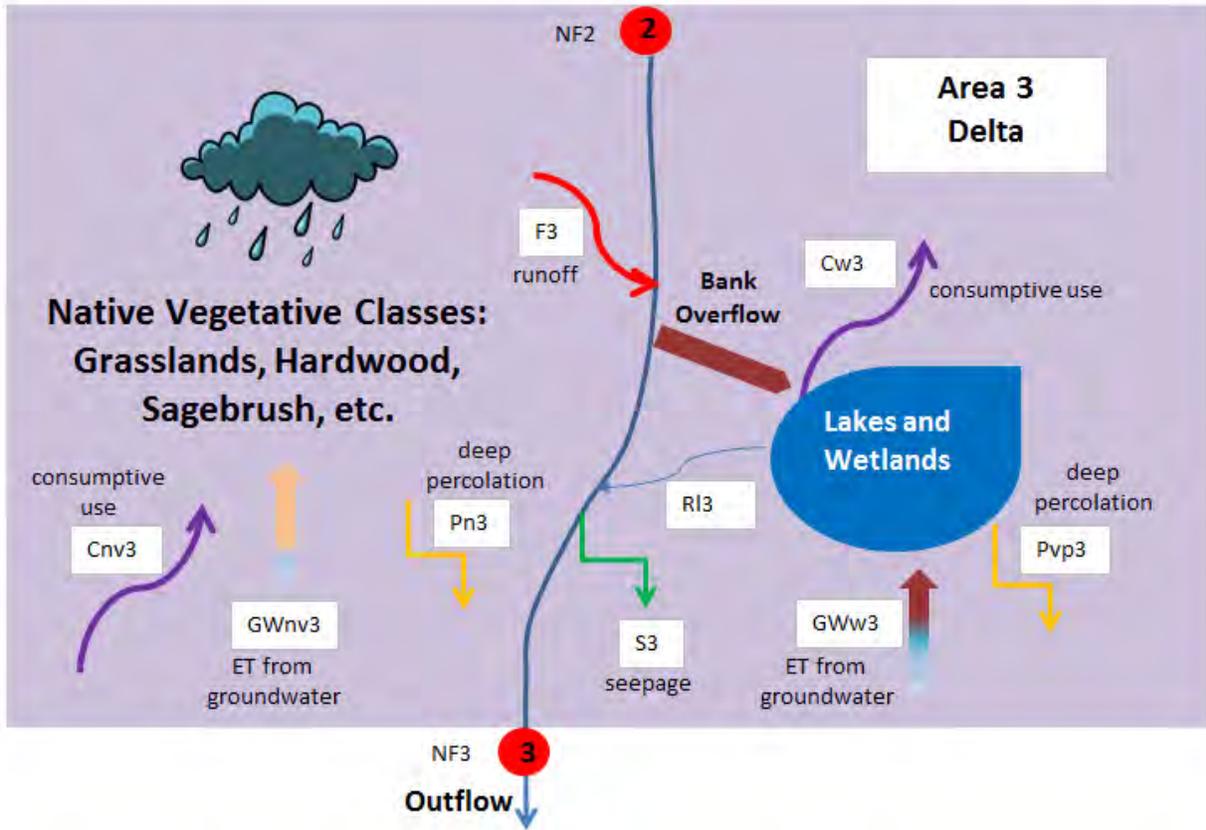
Figure E-8. A Developed Watershed Area Representing the Delta Simulated for Natural Flow
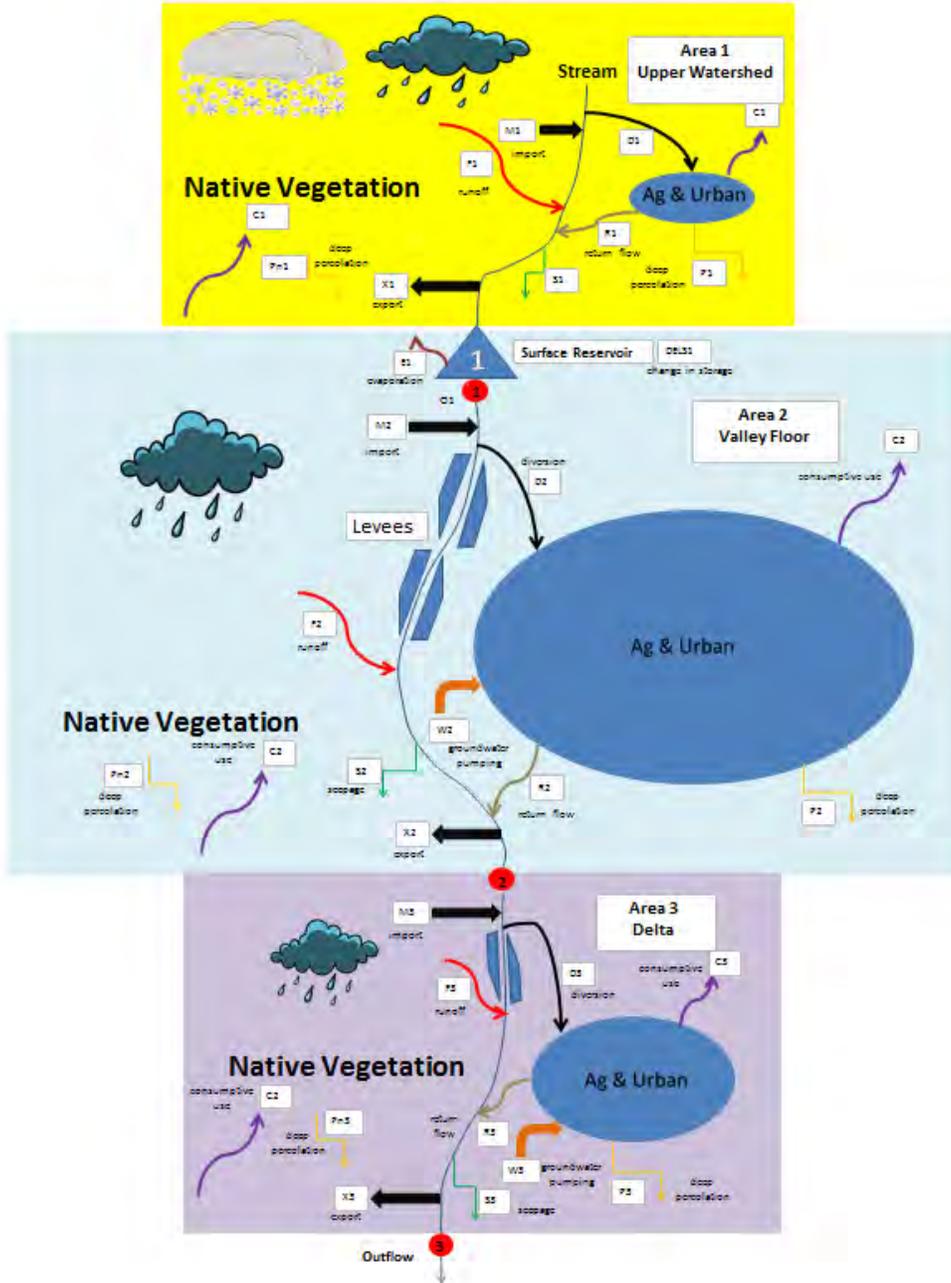
Figure E-9. Representative Areas for Historical (Developed) Conditions
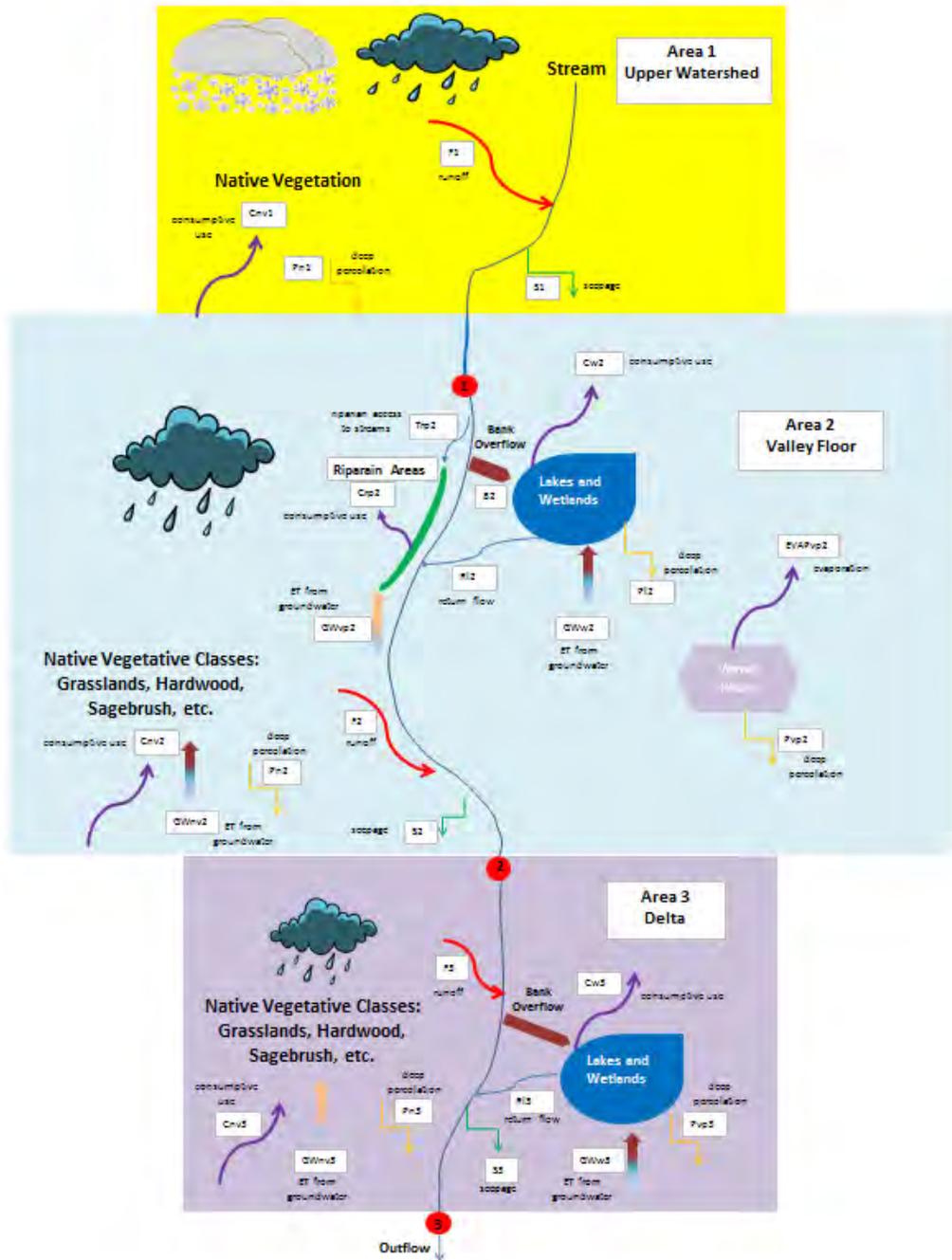
Figure E-10. Representative Areas for Natural (Pre-development)

ATTACHMENT 13

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TRIBUTARIES AUTHORITY

7

8

9   BEFORE THE CALIFORNIA STATE WATER RESOURCES CONTROL BOARD

10   IN THE MATTER OF

11 CALIFORNIA DEPARTMENT OF WATER) **TESTIMONY OF SUSAN PAULSEN**
RESOURCES AND UNITED STATES) **(San Joaquin Tributaries Authority (SJTA)**
12 BUREAU OF RECLATION PETITION FOR) **Case in Chief, Part 2, EXHIBIT 304 Errata)**
WATER RIGHT CHANGE RE: CALIFORNIA)
13 WATERFIX.)
)
14   )
)
15 _____)

16   **QUALIFICATIONS**

17 1.   My name is Susan Paulsen and I am a Registered Professional Civil Engineer in the State of

18 California (License # 66554). My educational background includes a Bachelor of Science in Civil

19 Engineering with Honors from Stanford University (1991), a Master of Science in Civil

20 Engineering from the California Institute of Technology ("Caltech") (1993), and a Doctor of

21 Philosophy (Ph.D.) in Environmental Engineering Science, also from Caltech (1997). My education

22 included coursework at both undergraduate and graduate levels on fluid mechanics, aquatic

23 chemistry, surface and groundwater flows, and hydrology, and I served as a teaching assistant for

24 courses in fluid mechanics and hydrologic transport processes.

25 2.   I currently am a Principal and Director of the Environmental and Earth Sciences practice of

26 Exponent, Inc. ("Exponent"). Prior to that, I was employed by Flow Science Incorporated, in

27 Pasadena, California, where I worked for 20 years, first as a consultant (1994-1997), and then as an

28 employee in various positions, including President (1997-2014). I have 25 years of experience with

- 1 -

1 projects involving hydrology, hydrogeology, hydrodynamics, aquatic chemistry, and the

2 environmental fate of a range of constituents.

3 3.   My Ph.D. thesis was entitled, "A Study of the Mixing of Natural Flows Using ICP-MS and

4 the Elemental Composition of Waters," and the major part of my Ph.D. research involved a study of

5 the mixing of waters in the Sacramento-San Joaquin Bay-Delta (the Delta) using source water

6 fingerprints. I also directed model studies to use chemical source fingerprinting to validate

7 volumetric fingerprinting simulations using Delta models (including the Fischer Delta Model

8 (FDM) and the Delta Simulation Model (DSM)). I have designed and directed numerous field

9 studies within the Delta using both elemental and dye tracers, and I have designed and directed

10 numerous surface water modeling studies within the Delta.

11 4.   A copy of my curriculum *vitae* is included as Exhibit SJTA-307.

12 **SUMMARY OF TESTIMONY**

13 5.   I was retained by the San Joaquin Tributaries Authority (SJTA) to assist with the evaluation

14 of the California WaterFix Project (WaterFix). The SJTA requested that I evaluate the fate of San

15 Joaquin River water that flows into the Delta for both existing conditions and for one of the

16 WaterFix project scenarios, with a focus on critical, dry, and below normal water year (WY) types.

17 My analysis and testimony can be summarized as follows.

18 6.   Opinion 1: In below normal, dry and critical water years, very little of the San Joaquin River

19 water that enters the Delta between February 1 and June 30 flows to San Francisco Bay as Delta

20 outflow. Most San Joaquin River water that enters the Delta during this time period is either

21 consumed within or diverted / exported from the Delta.

22 7.   Opinion 2: The WaterFix operations show that in dry and critical water years, a large

23 fraction of the water exported from the Delta continues to be exported by the CVP/SWP pumps in

24 the south Delta.

25 **METHODS**

26 8.   As described in Antioch-202 Errata Section 3.1, the DSM2 model can be used to perform

27 "volumetric fingerprinting" to track inflows to the Delta throughout the model domain. Exponent

28 used volumetric fingerprinting to "tag" San Joaquin River inflows to the Delta, to determine the

source of water within the Delta, and to determine the fraction of San Joaquin River inflows that exit the Delta as Delta outflow (i.e., that exit the model domain at the western boundary). Because the model input and output files provided to the public by the Department of Water Resources (DWR) did not include volumetric fingerprinting results to address the questions asked by the SJTA, Exponent used the DSM2 modules HYDRO and QUAL, together with the model input files provided by DWR, to perform fingerprinting analyses. Exponent simulated the fate of San Joaquin River inflows in the Delta for the existing condition scenario (EBC2) and for the H4 Project scenario.[1] These two scenarios were chosen to compare the fate of San Joaquin River water under present-day conditions to the future WaterFix scenario most similar to the preferred alternative as described in the Biological Opinions (BiOps) and WaterFix Final Environmental Impact Report/ Environmental Impact Statement.[2]

9.   The San Joaquin River inflow at Vernalis between February 1 and June 30 of each year ("February-June San Joaquin River inflow") was tagged to evaluate its fate in the Delta. (Modeled San Joaquin River flows into the Delta continued before and after this time period but were not tagged.) The volumetric fingerprinting results from the DSM2 model were used to track the tagged San Joaquin River inflow exported at Jones Pumping Plant (Central Valley Project, or CVP) and Clifton Court Forebay (State Water Project, or SWP); diverted at Rock Slough (CCWD); and exiting the Delta at Martinez (Delta outflow) by the end of each water year (September 30). San Joaquin River water that did not exit the Delta via these four pathways was assumed to remain in the Delta or to have been diverted to satisfy in-Delta consumptive use.

10.   In addition, we tabulated the percentage of San Joaquin River water that entered the Delta throughout each WY (not just during the period of February 1 to June 30) that was exported by the CVP. This work was performed using existing DSM2 fingerprinting results generated by DWR during Part 1 of the WaterFix change petition proceedings (acquired May 2016).

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[1] The EBC2 model run was released by DWR with the March 2013 Revised Administrative Draft BDCP. In my opinion, EBC2 is the model run most representative of existing conditions in the Delta, as it includes Fall X2, which is a requirement under the 2008 USFWS biological opinion (BiOp). See Antioch-202 Errata section 6.1 for additional information.

[2] WaterFix scenario H4 was chosen over H3 because the preferred alternative (Alternative 4A) and H4 include additional spring outflow, whereas WaterFix scenario H3 does not.

TESTIMONY

OPINION 1

In below normal, dry and critical water years, very little of the San Joaquin River water that enters the Delta between February 1 and June 30 flows to San Francisco Bay as Delta outflow. Most San Joaquin River water that enters the Delta during this time period is either consumed within or diverted / exported from the Delta.

11.   I was asked to evaluate the fate of San Joaquin River water during critical, dry, and below normal water year types. The results of the fingerprinting analysis are presented for each critical, dry, and below normal water year in the 16-year modeled period (WY 1976-1991) in SJTA-306. For reference, SJTA-306 also presents the total annual volume of water (all sources) exported or diverted during critical, dry, and below normal water years.

12.   An example of the fingerprinting results for scenario H4 is shown in Figure 1a, which presents mean daily San Joaquin River inflows between February 1 and June 30, 1977 (a critical WY), and the mean daily exports from the CVP and SWP, diversions by CCWD, and Delta outflow. The cumulative totals of these inflows, exports, and diversions are shown in Figure 1b, and the cumulative percentages are shown in Figure 1c. In this analysis, San Joaquin River water entering the Delta after June 30 was not tagged and tracked in the model, such that the "SJR Inflow" appears to drop to zero at the end of June in Figure 1a, and "SJR Inflow" and "SJR Export (Sum)" reach a horizontal asymptote in Figure 1b. [Note that the model included San Joaquin River inflows to the Delta before and after this period, but those flows were not tracked within the model. Model results after June 30 are shaded to indicate that the tracking of San Joaquin River inflows stopped after this date.]

13.   Figures 2a, 2b, and 2c show results for Scenario H4 for 1985 (a dry year), and Figures 3a, 3b, and 3c show results for Scenario H4 for 1979 (a below normal year). Results for these three years are also summarized in Table 1. Similar figures were prepared for each critical, dry, and below normal year in the 16-year model period for both scenario H4 and the existing conditions scenario (EBC2), and are included in SJTA-306. Figures 1a, 1b, and 1c as well as similar figures in SJTA-306, show that San Joaquin River inflows begin to be exported by the CVP and/or the SWP

1 within days after they enter the Delta. In addition, these figures indicate that very little San Joaquin

2 River water that enters the Delta between February 1 and June 30 leaves the Delta as Delta outflow

3 during critical, dry, and below normal water years.

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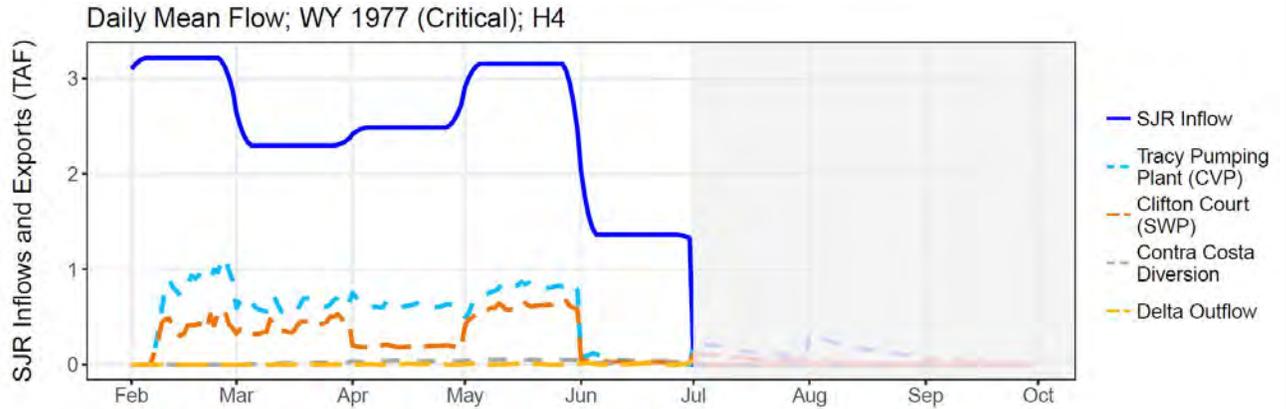
Figure 1a.   Mean daily San Joaquin River inflow volume for February 1 to June 30, 1977
(critical WY), and the mean daily volume of February-June San Joaquin River water
exported, diverted, and exiting the Delta as outflow for scenario H4.
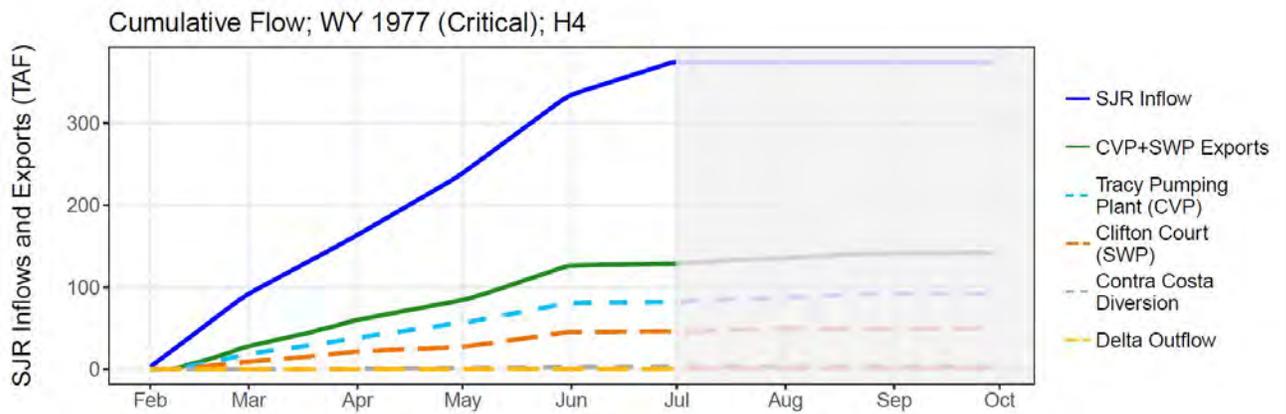
Figure 1b.   Cumulative San Joaquin River inflow volume for February 1 to June 30, 1977
(critical WY), and the cumulative volume of February-June San Joaquin River water
exported, diverted, and exiting the Delta as outflow for scenario H4.
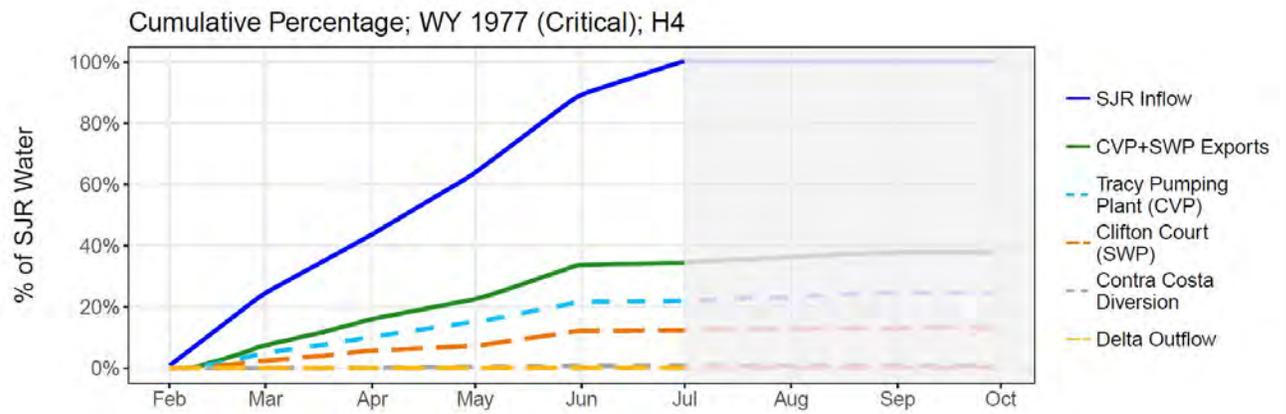
Figure 1c.   Cumulative percentage of San Joaquin River inflow volume for February 1 to June
30, 1977 (critical WY), and the cumulative percentage of February-June San Joaquin
River water exported, diverted, and exiting the Delta as outflow for scenario H4.
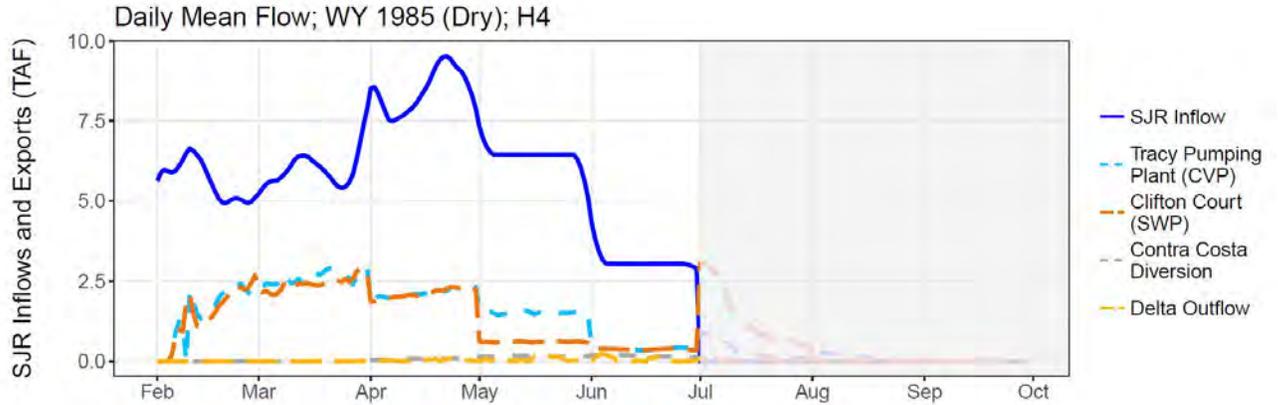
Figure 2a.   Mean daily San Joaquin River inflow volume for February 1 to June 30, 1985 (dry WY), and the mean daily volume of February-June San Joaquin River water exported, diverted, and exiting the Delta as outflow for scenario H4.
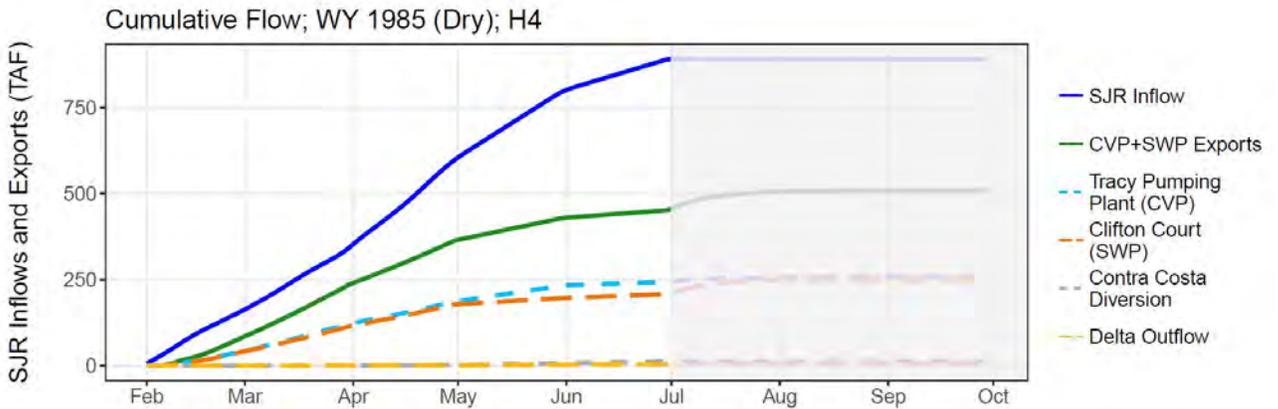
Figure 2b.   Cumulative San Joaquin River inflow volume for February 1 to June 30, 1985 (dry WY), and the cumulative volume of February-June San Joaquin River water exported, diverted, and exiting the Delta as outflow for scenario H4.
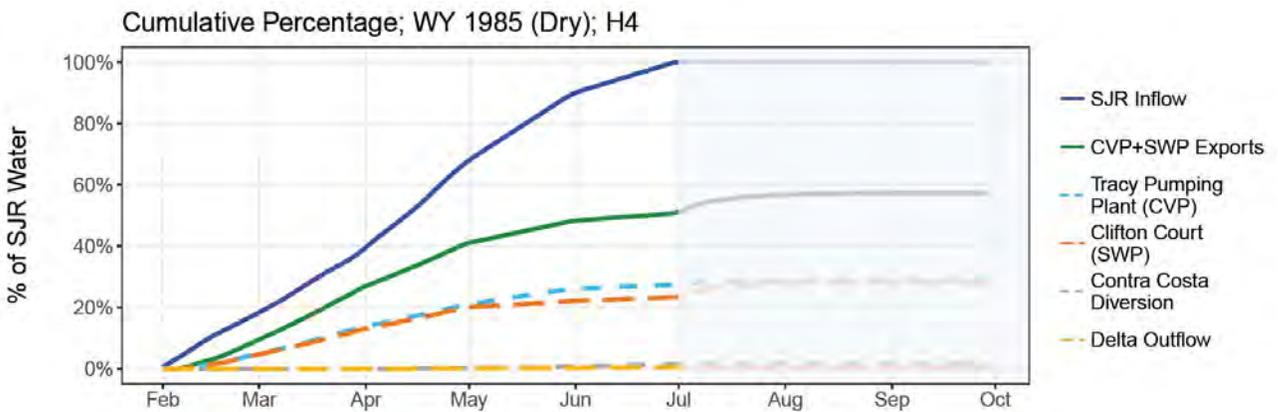
Figure 2c.   Cumulative percentage of San Joaquin River inflow volume for February 1 to June 30, 1985 (dry WY), and the cumulative percentage of February-June San Joaquin River water exported, diverted, and exiting the Delta as outflow for scenario H4.
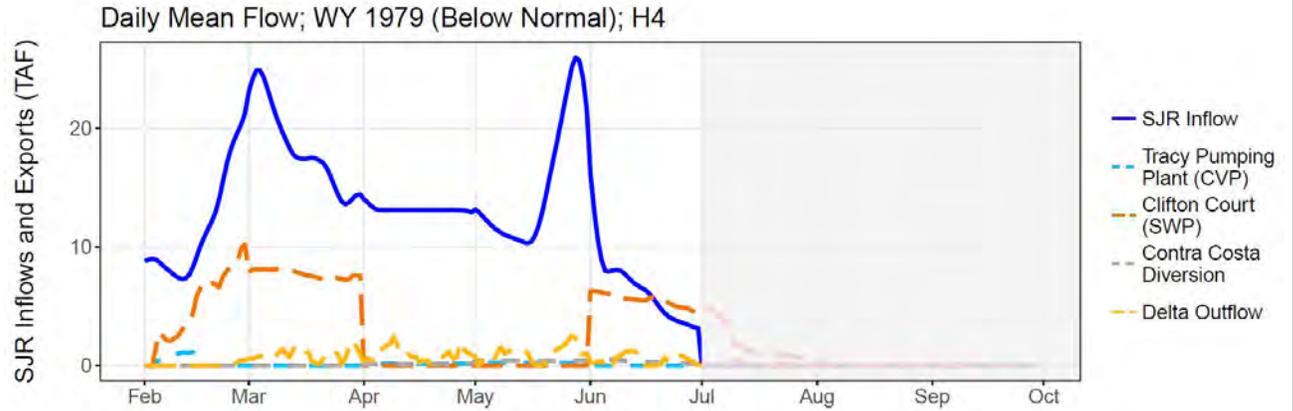
Figure 3a.   Mean daily San Joaquin River inflow volume for February 1 to June 30, 1979 (below normal WY), and the mean daily volume of February-June San Joaquin River water exported, diverted, and exiting the Delta as outflow for scenario H4.
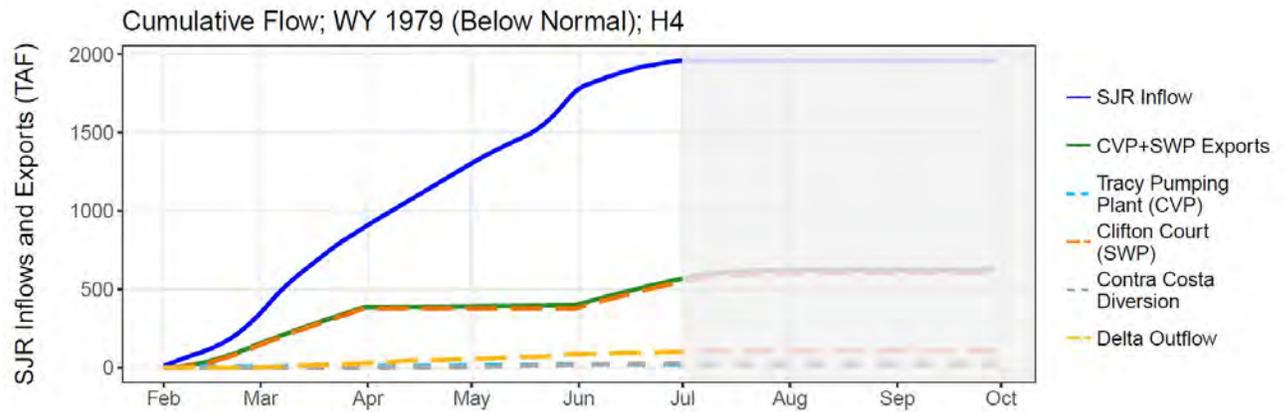
Figure 3b.   Cumulative San Joaquin River inflow volume for February 1 to June 30, 1979 (below normal WY), and the cumulative volume of February-June San Joaquin River water exported, diverted, and exiting the Delta as outflow for scenario H4.
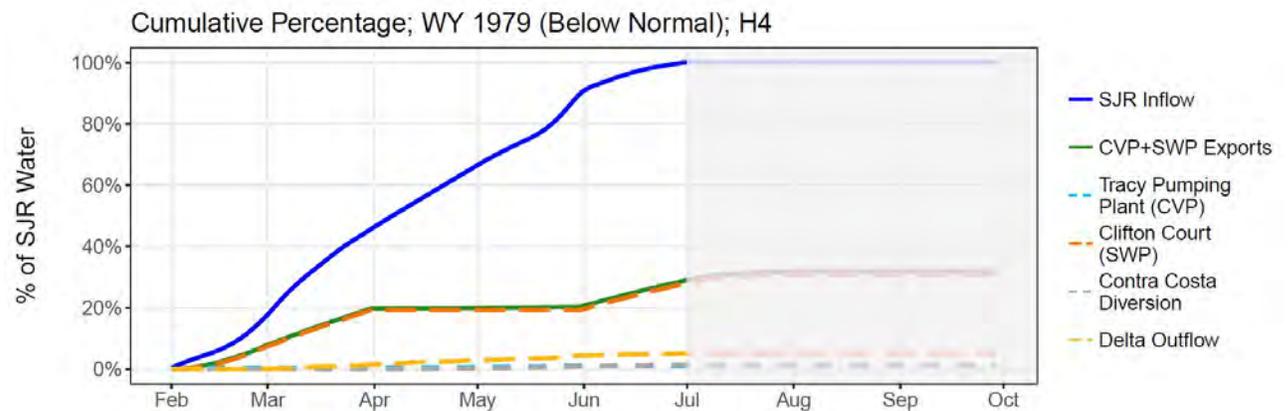
Figure 3c.   Cumulative percentage of San Joaquin River inflow volume for February 1 to June 30, 1979 (below normal WY), and the cumulative percentage of February-June San Joaquin River water exported, diverted, and exiting the Delta as outflow for scenario H4.

14.   I chose WY 1977 (critical WY), WY 1985 (dry WY), and WY 1979 (the sole below normal WY in the 16-year modeled period) for a detailed evaluation of the fate of San Joaquin River inflows. During dry and critical water years for both existing conditions and H4 scenarios, less than 1% of the February-June San Joaquin River inflows exit the Delta as Delta outflow. During 1979, the only below normal water year in the 16-year simulation period, 3.1% of San Joaquin River February-June inflows leave the Delta as Delta outflow under existing conditions, and 5.3% of this flow leaves the Delta as outflow under WaterFix Scenario H4 operations.

15.   Under existing conditions (EBC2), the CVP and SWP together export 60 percent (in 1979, a below normal WY), 54 percent (in 1977, a critical year), and 77 percent (in 1985, a dry WY) of February-June San Joaquin River inflows. For the WaterFix H4 scenario, the CVP and SWP together export 32 percent (in 1979, a below normal WY), 38 percent (in 1977, a critical year), and 57 percent (1985, a dry WY) of February-June San Joaquin River inflows. The differences in the fraction of February-June San Joaquin River inflows that are exported from the Delta is due to the shift in pumping from the South Delta pumps to the NDD export locations, which export Sacramento River water. For example, for existing conditions in WY 1985, the CVP and SWP pumps together export about 5.3 million acre feet (MAF) of water.[3] Under H4 operations for WY 1985, the CVP and SWP pumps together export just under 2.7 MAF, and the NDD exports just less than 1.5 MAF.[4] (See also Opinion 2.)

Table 1. Fate of San Joaquin River water for WY 1979, WY 1985, and WY 1977.[5]

Water Year	Existing Conditions (EBC2): Percent of San Joaquin River water			H4 Scenario: Percent of San Joaquin River water		
	CVP	SWP	Delta Outflow	CVP	SWP	Delta Outflow
1977 (Critical)	39	15	0.1	25	13	0.3
1985 (Dry)	39	38	0.4	29	28	1
1979 (Below normal)	28	32	3.1	1	31	5.3

[3] SJTA-306, p. 40.
[4] SJTA-306, p. 85.
[5] The data presented in Table 1 were summarized from SJTA-306, pp. 37, 38, 40, 82, 83, and 85.

16.   The model results also show that under existing conditions, almost 40 percent[6] of CVP

exports are from San Joaquin River inflows during dry and critical water years. Figures 4 and 5

show the annual volume of water exported by the CVP as well as the volume of San Joaquin River

water exported by the CVP under existing conditions (EBC2) and WaterFix scenario H4.
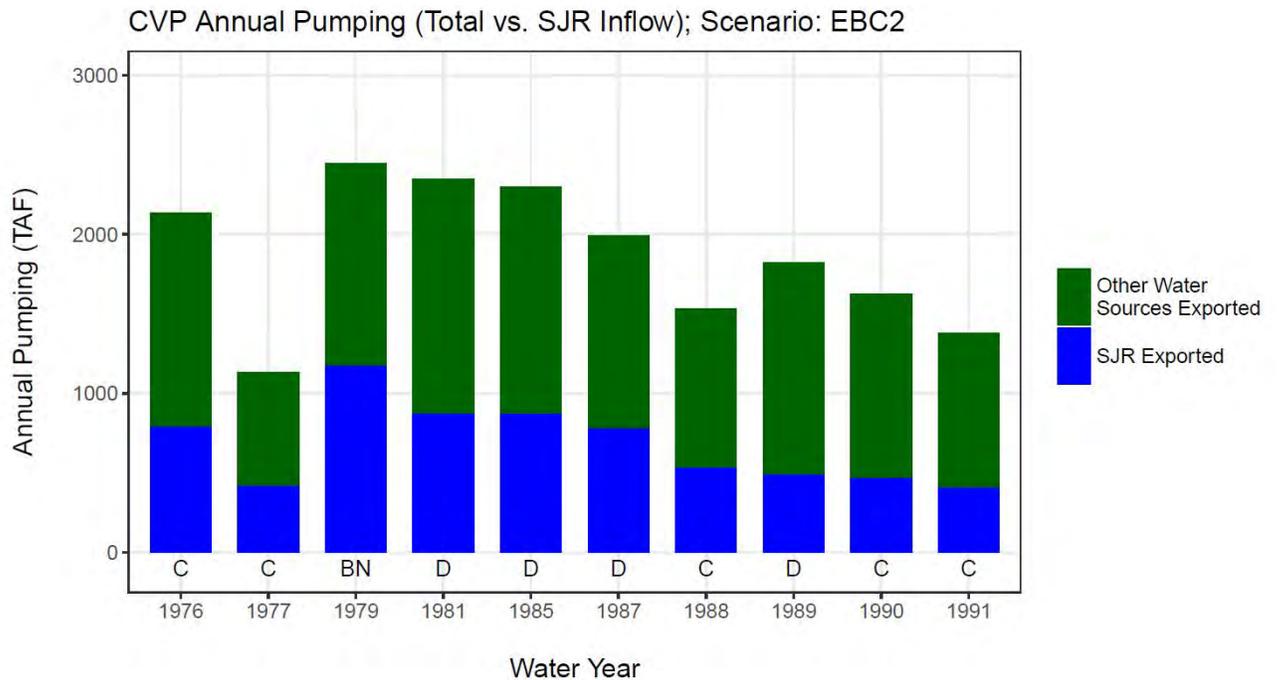
Figure 4.   Annual volume of water exported by the CVP (Tracy Pumping Plant) and the
volume of San Joaquin River that is exported by the CVP for existing conditions.
The water year type is indicated in text below each bar.

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[6] The average percent of San Joaquin River water exported by the CVP was calculated as an average of all dry water
years (1981, 1985, 1987 and 1989) and critical water years (1976, 1977, 1988, 1990, and 1991).

CVP Annual Pumping (Total vs. SJR Inflow); Scenario: H4
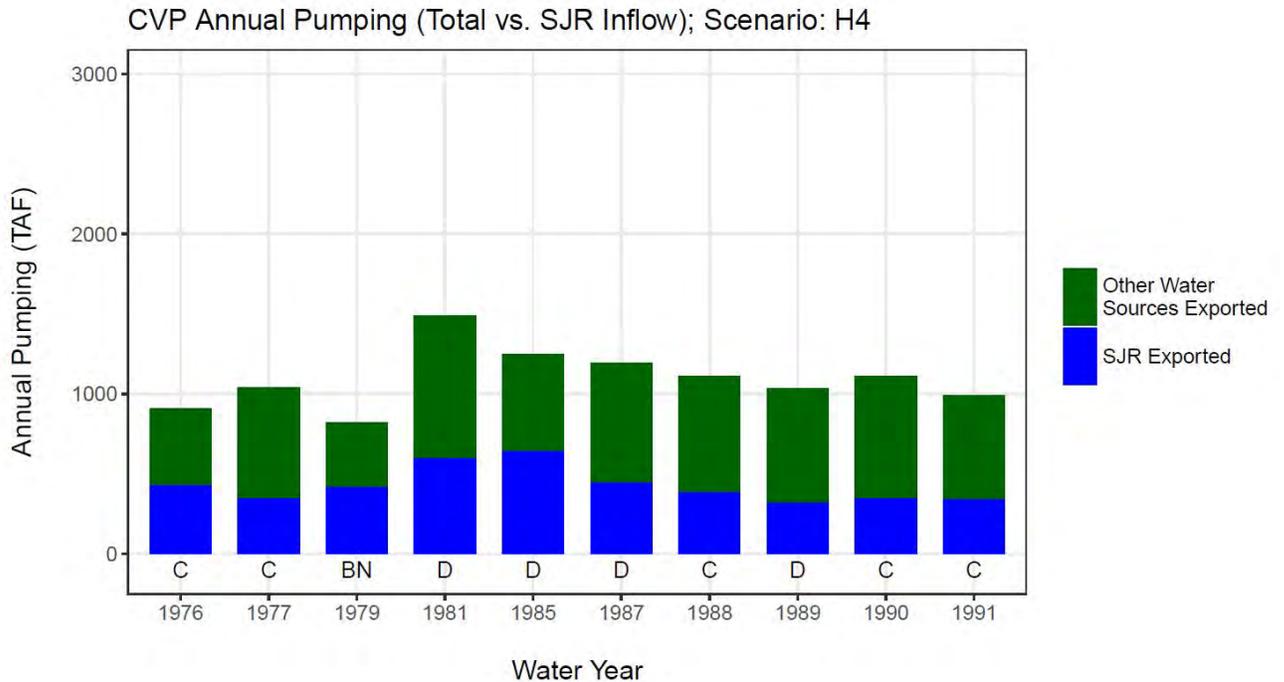
Figure 5.   Annual volume of water exported by the CVP (Tracy Pumping Plant) and the volume of San Joaquin River that is exported by the CVP for the H4 scenario. The water year type is indicated in text below each bar.

OPINION 2

The WaterFix operations show that in dry and critical water years, a large fraction of the water exported from the Delta continues to be exported by the CVP/SWP pumps in the south Delta.

17.   As shown in Opinion 1, in critical, dry, and below normal years, nearly all February-June San Joaquin River inflows to the Delta are either exported by the CVP and SWP or diverted for consumptive use within the Delta. This conclusion holds for both existing conditions (EBC2) and WaterFix operations scenarios (as illustrated by H4). Note that critical, dry, and below normal water year types comprise 54 % of the historic record (1906-2016), but 62.5 % of the simulation period of 1976-1991 (10 of 16 years).

18.   In WaterFix Scenario H4 and the other WaterFix project scenarios, water is exported from the Sacramento River channel at the three north Delta diversion (NDD) locations, in addition to continuing to be exported from the existing CVP and SWP pumping locations in the south Delta as well. Because the San Joaquin River enters the Delta near the CVP and SWP export locations, a

- 11 -

1 large fraction of San Joaquin River water flows directly down Old River toward the export pumps.

2 In addition, a portion of the San Joaquin River flow that travels past the head of Old River mixes

3 with other flows in the central Delta and travels via other channels (e.g., Middle River, Victoria

4 Canal) to the CVP and SWP export pumps in the south Delta.

5 19.   Despite the export of Sacramento River water from the north Delta diversion (NDD)

6 locations under the H4 scenario (most similar to the preferred alternative), significant quantities of

7 water continue to be exported from the CVP and SWP pumps in the south Delta. Figures 6a, 6b, and

8 6c were prepared from DWR's DSM2 model results and show the average rate of water pumped

9 monthly from the south Delta (CVP and SWP) and from the NDD for Scenarios EBC2 and H4

10 during critical, dry, and below normal water years.

11 20.   Figures 6a, 6b, and 6c show total exports from the CVP and SWP for the existing condition

12 (EBC2) as a green bar.[7] For Scenario H4, the bar is divided into two parts; the yellow part of the bar

13 indicates the rate of water exported from the south Delta pumps (CVP and SWP), while the red part

14 of the bar indicates the rate exported from the NDD. Figures 6a and 6b demonstrate that during dry

15 and critical water years, the CVP/SWP exports typically comprise a majority of the water exported,

16 and CVP/SWP exports are significantly greater than NDD exports in most months. The bars on the

17 right hand side of each figure present the annual average values of the diversion rate during each

18 water year type, and show that on an annual basis, more water is diverted from the CVP and SWP

19 pumping locations in the south Delta than from the NDD during critical and dry water year types.

20 During the sole below normal water year (Figure 6c), the annual average CVP/SWP exports are

21 nearly identical to the NDD exports.

22 21.   In summary, scenario H4, the proposed starting point for WaterFix operations, continues to

23 result in the export of a significant volume of San Joaquin River water during dry and critical water

24 years. Under both existing conditions and WaterFix scenario H4, the south Delta pumps will

25 continue to export a substantial percentage of San Joaquin River water.

26

27

28 [7] Figures 6a and 6b in Opinion 2 of SJTA-304 presented maximum monthly exports and diversions from the south Delta pumps and the proposed north Delta diversion locations, not average monthly exports and diversions. Figures 6a and 6b were replaced with average monthly values. This is the only change made in this errata document.
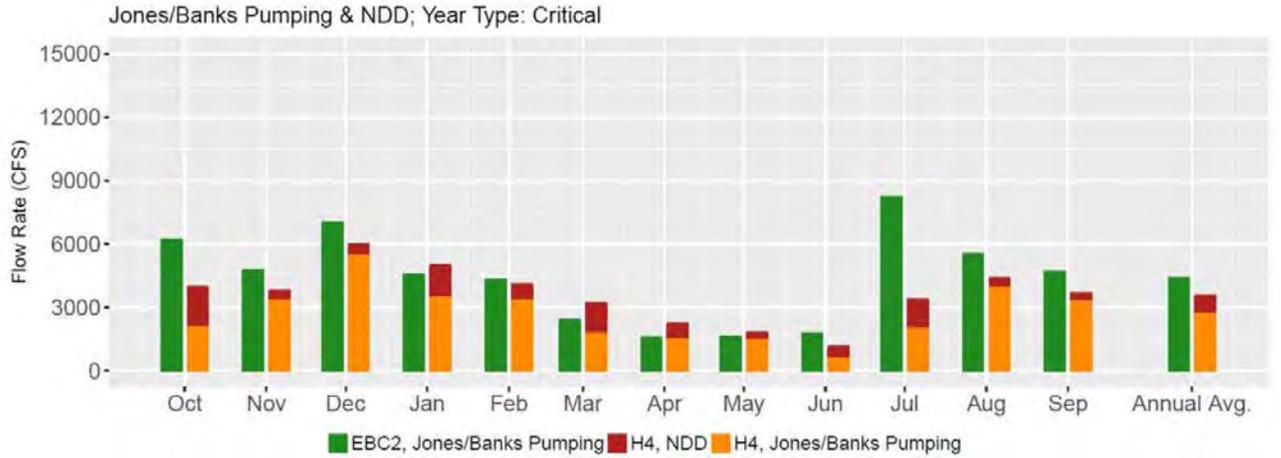
Figure 6a.   Simulated monthly pumping totals (in cfs) during critical water years under the existing condition scenario (EBC2) and scenario H4.
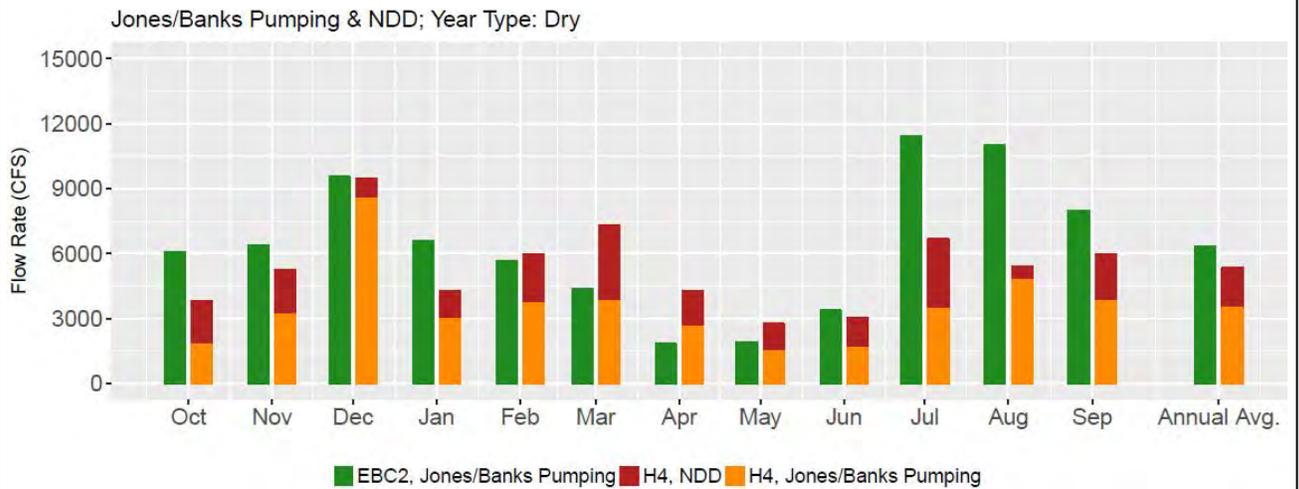
Figure 6b.   Simulated monthly pumping totals (in cfs) during dry water years under the existing condition scenario (EBC2) and scenario H4.
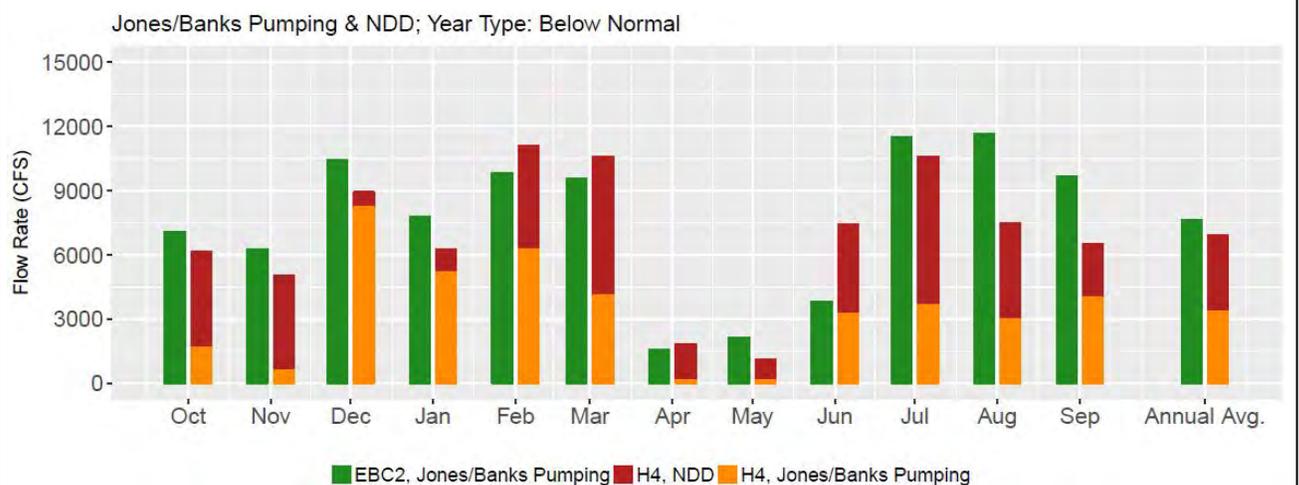
Figure 6c.   Simulated monthly pumping totals (in cfs) during below normal (1979) water years under the existing condition scenario (EBC2) and scenario H4.

Executed on March 15, 2018 in Pasadena, CA.

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Susan C. Paulsen, Ph.D., P.E.
Principal Scientist and Practice Director at Exponent

ATTACHMENT 14

July 2018 Framework for the Sacramento/Delta Update to the Bay-Delta Plan

<table>
<tr><td>Chapter 1</td><td>Overview of the Framework</td></tr>
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The State Water Resources Control Board (State Water Board or Board) is actively engaged in urgent efforts in the San Francisco Bay/Sacramento-San Joaquin Delta Estuary (Bay-Delta) to address prolonged and precipitous declines of native aquatic species and the ecosystem they depend upon. The Bay-Delta is an integral part of California's environment, economy, and way of life. Protecting the Bay-Delta watershed and its many beneficial uses is one of the State Water Board's primary responsibilities and top priorities. Regulatory requirements relating to flow and water diversions are included in the Bay-Delta Water Quality Control Plan (Bay-Delta Plan). The State Water Board is currently updating the Bay-Delta Plan through two separate processes (Plan amendments) that are critically important to the health and survival of the Bay-Delta ecosystem.

The first effort is focused on Lower San Joaquin River flows and Southern Delta salinity. On July 6th, 2018 the State Water Board released the proposed final Lower San Joaquin River and Southern Delta updates to the Bay-Delta Plan, the associated final draft environmental document in support of those changes, and a notice of a board meeting to consider adoption of the changes and finalization of the environmental document later this summer.

The second effort, which is described in this framework, is focused on the Sacramento River and its tributaries, Delta eastside tributaries (including the Calaveras, Cosumnes, and Mokelumne rivers), Delta outflows, and interior Delta flows. Throughout this document and going forward, the areas where the proposed changes described in this framework document would apply will be referred to as the "Sacramento/Delta." The update to the Bay-Delta Plan will be referred to as the Sacramento/Delta update to the Bay-Delta Plan, Plan amendments, etc.[1] The Sacramento/Delta Plan update is at an earlier stage procedurally than the Lower San Joaquin River and Southern Delta update. The State Water Board released a fact sheet and Scientific Basis Report (Science Report) in the fall of 2017, which generally describes recommended Sacramento/Delta updates to the Bay-Delta Plan (Plan amendments) and documents the science upon which those changes are based. The Science Report was reviewed by the Independent Science Board (ISB) and was peer reviewed before release.

This updated framework is being provided with the release of the Lower San Joaquin River and Southern Delta update material to assist the public in understanding how the two updates relate to one another. This framework is specifically intended to provide additional details about the proposed Plan amendments and preferred alternative that will be identified in a forthcoming draft Staff Report, including proposed flow levels and a program of implementation. The draft Staff Report will be released for public review and comment later this year, and will include a

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[1] Previously referred to as the Phase II update to the Bay-Delta Plan.

thorough analysis and evaluation of the potential water supply, environmental, economic, and related effects of both the preferred alternative and a range of other alternatives.

The State Water Board will determine what changes to make to the Bay-Delta Plan based on public comments, further analysis, and other information. The State Water Board will carefully review and consider the public comments it receives and will integrate them as appropriate into the proposed Plan amendments and Staff Report for the State Water Board's future consideration. In determining what changes to make to the Bay-Delta Plan, the State Water Board will need to consider and balance other competing needs for water, and the economic and environmental impacts of those changes, with the needs of the ecosystem.

This framework begins with background information on the Bay-Delta watershed and the purpose and need for the Sacramento/Delta update to the Bay-Delta Plan. It then provides a summary of the information that has informed the proposed Plan amendments. The framework also includes a summary of information that will be included in the draft Staff Report on the anticipated benefits and water supply effects for a range of flow levels that were identified in the Science Report. The framework then provides a summary of the proposed changes to the Plan objectives, including narrative objectives (describing the environmental conditions required to be achieved) and numeric objectives (prescribing specific flow and water project operational requirements). The framework provides a summary of the major provisions of the program of implementation, gives an overview of Plan-related public comments, and concludes with next steps and a description of how to obtain additional information.

This framework describes a comprehensive package of objectives and implementation measures that are intended to work together to provide reasonable protection of fish and wildlife, from natal streams to the ocean, using the holistic approach described in the Science Report. The Science Report specifically recommends the use of unimpaired flows, which would dedicate a portion of the inflow to a watershed to protect instream fish and wildlife. Unimpaired flow is the flow that would accumulate in surface waters in response to rainfall and snowmelt and flow downstream if there were no reservoirs or diversions to change the quantity, timing, and magnitude of flows. It differs from natural flow because unimpaired flow is the flow that occurs at a specific location under the current configuration of channels, levees, floodplain, wetlands, deforestation and urbanization. While unimpaired flows are not natural flows, they do provide for the general magnitude, timing, and duration of flows that are important to protecting native species. Adaptive management provisions are proposed where unimpaired flows differ from what is needed to protect fish and wildlife.

The framework describes two new proposed objectives on the Sacramento/Delta tributaries for: 1) inflows, and 2) related cold water habitat measures. The proposed new inflow objective includes a narrative component and a numeric component. The Science Report indicated that a range of flows from 35-75% of unimpaired flow would be analyzed in the Staff Report. Staff conducted additional modeling and analyses following the completion of the Science Report; this information and data will be included and analyzed as part of the upcoming draft Staff Report. Based on analyses prepared for the Staff Report, including analysis of expected benefits and water supply effects, the Staff Report will propose an inflow level of 45-65% of unimpaired flow, with a starting point of 55%. The proposed program of implementation would allow voluntary agreements with nonflow measures to be lower in the range – so long as the measures provide the same level of resource protection as 55%, and that the agreement is still within the range of 45-65%. However, the State Water Board is particularly interested in

receiving potential plan amendment language which would authorize, with the affirmative concurrence from the California Department of Fish and Wildlife (DFW), a coordinated control of flows and other, non-flow factors that would achieve benefits comparable to the unimpaired flow requirements. Lower flows could also be required if needed to protect cold water habitat. The proposed program of implementation would also provide for flows to move higher in the range if lower flows are not reasonably protecting fish and wildlife, or if existing flows are already higher and are needed to reasonably protect fish and wildlife.

A proposed new narrative cold water habitat objective would require tailored measures based on the specific needs within each tributary to ensure that reservoirs are operated in a manner that provides needed cold water habitat for salmonids, or that other measures to provide cold water habitat are taken. New narrative and numeric Delta outflow objectives are also proposed. A proposed outflow objective would be based on the inflow to the Delta, thereby ensuring that required tributary inflows reach San Francisco Bay while also accounting for accretions and depletions that affect the system within the Delta.

Finally, the Framework describes new objectives for fall Delta outflows and interior Delta flows that would carry over requirements from existing biological opinions (BiOp) and an incidental take permit (ITP) into the Bay-Delta Plan. The Framework specifies that these requirements could be changed if the BiOps or ITP change. During public consideration of the proposed amendments, the Board will be particularly interested in comments related to whether an dhow best to incorporate the BiOp and ITP protections consistent with existing regulatory processes at other agencies.

The Framework describes proposed implementation provisions for the objectives and related actions. Specific provisions are proposed for adaptive management, including provisions for shaping and sculpting of flows to provide functional flows and provisions for establishing biological goals to measure success at achieving the objectives to inform decisions regarding the required flow levels, shaping and sculpting of flows, and future revisions to the Bay-Delta Plan. The Framework also describes proposed implementation provisions to encourage voluntary agreements to implement the Plan amendments; necessary accounting provisions for flows, water diversions, and water rights; monitoring and assessment; and other implementation actions to provide for coordination and integration with other existing and needed actions like the Sustainable Groundwater Management Act (SGMA), drought planning, habitat restoration, water use efficiency and conservation, and other measures.

This section provides a general overview of the Bay-Delta watershed, environmental and water supply concerns within the watershed, and the role of the State Water Board in water quality planning in the Bay-Delta watershed. The section also includes the purpose and need for Bay-Delta Plan updates, and an overview of the Science Report released in October 2017 that summarizes the available science supporting the Plan update.

2.1   Setting, Use, and Regulatory Oversight

The Bay-Delta watershed includes the Sacramento and San Joaquin river systems, the Delta, Suisun Marsh, and San Francisco Bay. The Sacramento and San Joaquin river systems, including their tributaries, drain water from about 40% of California's land area, supporting a variety of beneficial uses of water. The Bay-Delta is one of the most important ecosystems in California as well as the hub of California's water supply system. As the largest tidal estuary on the western coast of the Americas, it nurtures a vast array of aquatic, terrestrial, and avian wildlife in the Delta, San Francisco Bay, and near shore ocean, as well as a diverse assemblage of species upstream of the Delta. The water that flows down the Sacramento and San Joaquin rivers into the Delta helps keep the taps running for more than two-thirds of Californians, supports industry, and irrigates millions of acres of farmland. It is the lifeblood of commercial and recreational fishing and boating businesses on the rivers, the Delta, the Bay, and into the ocean.

Native species in the Bay-Delta ecosystem are also experiencing an ecological crisis. For decades, valuable habitat has been converted to farmland and urban uses, the quality of water in the channels has been degraded, there has been a substantial overall reduction in flows and significant changes in the timing and distribution of those flows, and species have been cut off from natal waters. This has led to severe declines, and in some cases extinctions, of native fish and other aquatic species. The overall health of the estuary for native species is in trouble, and expeditious action is needed on the watershed level to address the crisis, including actions by the State Water Board, fisheries agencies, water users, and others to address the array of issues impacting the watershed. The State Water Board is the primary agency responsible for addressing the flow and water quality issues. Other agencies are responsible for and are currently engaged in addressing habitat and other concerns. Those efforts should continue in an integrated way with the State Water Board's efforts.

The State Water Board is responsible for allocating surface water rights and protecting water quality, including drinking water, surface water, and groundwater, while protecting the public trust and public interest and preventing the waste and unreasonable use of water. These responsibilities all converge in the Bay-Delta where the State Water Board must balance many responsibilities and interests. State law requires that the State Water Board and the nine regional water quality control boards (regional water boards) adopt Water Quality Control Plans that ensure beneficial uses of water in an area are protected. The State Water Board and regional water boards establish water quality objectives for the protection of beneficial uses of

water and programs of implementation to achieve those objectives that seek to maximize all beneficial uses of water. The State Water Board adopts the Bay-Delta Plan because the Plan is largely flow dependent, the State Water Board has authority over water rights, and because the Plan covers more than one region of the state. The Bay-Delta Plan includes water quality objectives to protect municipal and industrial, agricultural, and fish and wildlife beneficial uses, among others. The objectives are both narrative and numeric. Narrative objectives describe the general water quality and flow conditions that must be attained through watershed management. They also serve as the basis for the detailed numeric objectives. Numeric objectives are exactly how they sound: specific numbers, for example, cubic-feet per second (cfs) of flow or percentages of unimpaired flow. The Bay-Delta Plan also includes other flow-related requirements, like salinity, dissolved oxygen, and water project operational requirements to protect fish and other aquatic species.

The State Water Board has typically implemented the Bay-Delta Plan through changes to water rights. Currently, responsibility for meeting the Bay-Delta Plan objectives falls primarily on only two water right holders in the watershed: the California Department of Water Resources (DWR) and U.S. Bureau of Reclamation (Reclamation) for the State Water Project (SWP) and Central Valley Project (CVP) (collectively Projects), respectively. The Bay-Delta Plan is implemented through the State Water Board's water right Decision 1641 (D-1641), adopted in 2000. In D-1641, the State Water Board accepted various agreements between DWR and Reclamation and other water users to assume interim responsibility for meeting specified Bay-Delta Plan objectives for a period of time.

The current Bay-Delta Plan is implemented by a limited subset of water users, on a limited subset of streams, for only parts of the year. Implementation of the current Bay-Delta Plan has failed to protect fish and wildlife that require protection throughout the watershed and throughout the year. The current Bay-Delta Plan requirements, as implemented, result in overburdening some streams to the detriment of all beneficial uses in that stream while at the same time failing to protect beneficial uses in other streams and the watershed. The Bay-Delta Plan and its implementation require updating to address these and other issues.

The State Water Board identified the need to update the Bay-Delta Plan and its implementation many years ago, and plans to complete that process without further delay. The State Water Board is pursuing prompt completion of the update of the Bay-Delta Plan, and will explore all available options for timely implementation. Because voluntary agreements may provide the most efficient and effective route to durable solutions to ensure the reasonable protection of fish and wildlife, the State Water Board is encouraging voluntary agreements that achieve and implement the objectives.

2.2   Purpose and Need for the Plan Updates

Populations of native aquatic species in the Bay-Delta watershed have shown significant signs of decline since the last major update and implementation of the Bay-Delta Plan in the 1990s. While natural conditions have not existed in the Bay-Delta watershed for more than a hundred years, many of the native fish and wildlife species that are now at the verge of extinction maintained healthy populations until the past several decades when water development intensified. While there are also other factors involved in the decline of these species, water diversions and the corresponding reduction in flows those diversions cause, are significant

contributing factors. A significant and compelling amount of scientific information indicates that restoration of natural flow functions is needed now to halt and reverse these declines in an integrated fashion with physical habitat improvements.

Though various state and federal agencies have adopted requirements to protect the Bay-Delta ecosystem, the best available science indicates that the existing requirements are insufficient and that a comprehensive regulatory strategy addressing the watershed as a whole is needed. Many of the current requirements in the Bay-Delta watershed are the sole responsibility of the Projects, including water quality objectives implemented by D-1641, two BiOps addressing Delta smelt and salmonids, and an ITP addressing longfin smelt. These existing requirements address only portions of the watershed and there are a number of tributaries that do not have any requirements to protect fish and wildlife, or that have minimal requirements. Current conditions may be protective of fish and wildlife in some locations, but action is needed to ensure that conditions are not degraded in the future, and that conditions in the Bay-Delta improve based on more complete and coordinated watershed management.

Under the current requirements, flows are completely eliminated or significantly reduced at certain times in some streams in the Sacramento/Delta watershed, and a significant portion of the inflows that are provided to the Delta are exported without contributing to Delta outflows. At the same time, dams in the watershed disconnect migratory corridors for native aquatic species, blocking access to significant portions of historical habitat while also impeding the downstream flow of nutrients, gravels, woody debris, and other materials that are the building blocks of the food chain and habitat for native species. Dams and other diversions also significantly alter the timing and quality of flows in ways that impact fish and wildlife, including through eliminating and altering peak and base flow events and changing the temperature, dissolved oxygen, salinity, and other water quality parameters. Further, the Projects' operations in the southern Delta can entrain or impinge native fish and other aquatic organisms and alter circulation patterns impacting migration of native fish, water quality, and Delta habitats conditions for these species.

Studies of river-delta-estuary ecosystems in Europe and Asia conclude that water quality and fish resources deteriorate beyond their ability to recover when spring and annual water withdrawals exceed 30 and 40-50% of unimpaired flow respectively. Total average unimpaired outflows from the Bay-Delta watershed are about 28.5 million acre-feet (MAF). Upstream diversions and water exports have reduced annual average outflows by a little less than half (to 15.5 MAF) and outflows during the critical January through June period by more than half. However, average regulatory minimum Delta outflows are only about 5 MAF – or about a third of current average outflows and less than 20 percent of average unimpaired outflows. Existing regulatory minimum Delta outflows are too low to protect the ecosystem, and without additional regulatory protections, existing flows will likely be reduced in the future as new storage and diversion facilities are constructed, and as population growth continues.

Already, existing permitted, licensed, and claimed consumptive (not including power and other non-consumptive uses) water rights in the Bay-Delta watershed are many times the total annual average unimpaired flows. Although there is not demand for all of this water every year, in the future there could be even greater diversions under existing rights and claims of right (including riparian and pre-1914 appropriative claims) that place additional demands on the available supplies.[2]

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[2] To the extent that adequate supplies do not exist to meet demands and existing regulatory requirements water users would need to reduce or cease diversions based on water right priorities.

In addition to existing water right claims, new water rights may also be requested. The volume of water in active or pending water right applications, in addition to water that was set aside and reserved by the state (referred to as 'state filed water rights'), far exceeds the average annual unimpaired runoff from the Bay-Delta watershed. Further, state filings maintain the water right priority of the date they were established, which for many date back about a hundred years ago, making water rights under these filings senior to many existing water rights. Given these potential future demands and limited existing flow requirements in the Bay-Delta watershed, it is imperative that updated flow requirements be established in order to protect fish and wildlife beneficial uses in the Bay-Delta watershed.

2.3   Science Supporting the Proposed Plan Updates

The Science Report released in October 2017 documents the science supporting potential changes to the Bay-Delta Plan, including the current ecological crisis in the watershed and the prolonged and precipitous decline in numerous native species of spring-run and winter-run Chinook salmon, longfin smelt, Delta smelt, Sacramento splittail, and other species. The species declines are attributable to numerous stressors in the ecosystem, including reduced and modified flows, loss of habitat, invasive species, and water pollution. The Science Report discusses the impacts non-flow stressors like habitat loss are having on the ecosystem, and the importance of addressing these stressors to protect the Bay-Delta ecosystem, and acknowledges that habitat restoration and other nonflow actions can reduce the needs for flows. However, the Science Report focuses on flows, because flows are an essential part of restoring a healthy ecosystem, and flows are the responsibility of the State Water Board. The Science Report presents evidence indicating that native fish and other aquatic species require more flow of a more natural pattern than is currently required under the Bay-Delta Plan to provide appropriate quantities of quality habitat and to support specific functions needed to protect these species. The information summarized in the Science Report specifically establishes the need for new and modified inflow and cold water habitat, Delta outflow, and interior Delta flow requirements that work together in a comprehensive framework with other complementary actions to protect the Bay-Delta ecosystem.

The Science Report documents the needs for both inflow and cold water habitat requirements on the Sacramento/Delta tributaries to provide for instream flows within tributaries, while contributing to Delta outflows at the same time. Inflow requirements are needed to both preserve existing protective flows on some tributaries, and to improve existing flow conditions on other tributaries. Specifically, inflows are needed to protect salmonids and other native species. Different runs of salmonids (including Chinook salmon and steelhead), as well as other native species, are present in the Delta and its tributaries all year. To protect these species, flows are needed that more closely resemble the conditions to which native fish species have adapted, including the frequency, timing, magnitude, and duration of flows, as well as the proportionality of flows from tributaries, and connectivity of flows between the tributaries and the Delta. These flow attributes support key functions that are important to native species. Those functions include providing for floodplain inundation that improves growth and survival of native fish through improved food supplies and shelter, temperature control to prevent mortality and disease, and migratory cues for fish and other aquatic species that help fish to stay on the appropriate migratory route. Flows that come from the entire watershed throughout the year are critical to the long-term survival of native fish species. These flows support both genetic and life history diversity that allow native species to distribute the risks that droughts, fires, disease, food availability, and other natural and human-made stressors present to populations.

The Science Report also documents the needs for new and modified Delta outflow requirements to protect estuarine species and to contribute to protection of species in the Bay and near shore ocean. The survival and abundance of many of these native species is closely related to Delta outflows. The dramatic declines in population size of these species, like longfin smelt, indicate that current Delta outflows are not sufficient to protect the ecosystem. Freshwater outflow influences chemical, physical, and biological conditions through its effects on food, pollution, and the movement of flows not only in the Delta, but throughout the watershed and into the Bay and ocean. Outflows affect the location where freshwater from the rivers mixes with seawater from the ocean, referred to as the low salinity zone (the location of the 2 parts per thousand salinity isohaline or X2 position). The quality, location, and extent of habitat in the estuary fluctuates in response to outflows and other factors. Coastal and near-shore marine species also rely on flows to aid the migration of their young into the estuary. Generally, more downstream X2 locations past the confluence of the Sacramento and San Joaquin rivers benefit a wide variety of native species, including commercial seafood species, through improved habitat conditions for various life stages These benefits extend all the way through the Bay and out into the ocean.

Outflows are a product of inflows, and proportional inflows are needed to produce outflows necessary to provide both the quantity of needed flows and functioning migratory corridors that transport, distribute, and mix nutrients, aquatic organisms, sediments, gravel, and other materials up and down the watershed. Limiting Delta outflow contributions to only part of the watershed results in overreliance on certain stream systems and watersheds, and fails to protect beneficial uses in that watershed and in the greater Bay-Delta watershed. Existing regulatory requirements rely on the Projects to provide Delta outflows; such reliance will not be feasible in the future as water use increases and climate change intensifies, particularly if higher outflow levels are needed to protect fish and wildlife.

Finally, the Science Report documents the needs for interior Delta flow requirements. Diversions in the south Delta and associated operations cause unnatural flow patterns, with inflows traveling toward the Project export facilities rather than toward the ocean. Fish that travel into the interior Delta have very low survival levels due to operation of the Projects' export pumps and the poor habitat surrounding the pumps, including large numbers of predators and warm channels devoid of food and shelter. Interior Delta flow requirements are needed to keep migrating fish out of the interior Delta and on the correct migration pathway.

Based on the above information, the Science Report proposes new and modified Sacramento/Delta inflow and cold water habitat, Delta outflow, and interior Delta flow requirements described in more detail in this framework. The science indicates that flows that more closely mimic the shape of the unimpaired hydrograph and the conditions to which native species adapted, including the general seasonality, magnitude, and duration of flows, generally provide for improved ecological functions to support native species. Due to the altered nature of the watershed, however, it is also necessary to consider flows and cold water habitat preservation requirements that do not mimic the natural hydrograph, but nonetheless produce more natural temperature, salinity, or other water quality conditions for fish in locations where these fish now have access to them. For example, it may be necessary to provide additional colder reservoir release flows for salmonids in the summer and fall due to lack of access to historic upstream cooler spawning and rearing habitat after construction of dams to keep fish in good condition below dams in conformance with Fish and Game Code section 5937. Pelagic (open water) species may also require more Delta outflow in the summer and fall to position the low salinity zone in a hospitable habitat location downstream of the confluence of the Sacramento and San Joaquin Rivers into Suisun March and Suisun Bay where temperatures, food resources, and other conditions are improved.

While the need for the proposed changes to the Bay-Delta Plan is clear, there are significant challenges to establishing flow requirements in a reasonable timeframe for a watershed of this size and complexity. The critical role that the watershed plays in the State's water supply adds more complexity. The Science Report proposes a holistic instream flow approach. The approach described in the Science Report recognizes that: (1) the flow regime is the primary determinant of structure and function in riverine ecosystems, (2) environmental flows should be based generally on the natural flow regime, (3) all features of the ecosystem should be considered, and (4) that the reality of multiple needs for water must play a significant role.

The Science Report recommends new inflow objectives for the Sacramento/Delta salmon bearing tributaries and tributaries that provides flows that support salmon (including Cache Creek) based on a percent of unimpaired flow and a new inflow-based outflow objective that would require that inflows from the Sacramento/Delta tributaries and the San Joaquin River be provided as outflow. The approach for the Sacramento/Delta is similar to that proposed for the Lower San Joaquin River flow updates to the Bay-Delta Plan.

The Science Report provides information about potential benefits of flow levels between 35 and 75% of unimpaired flow, but does not propose a specific flow level. This framework does propose a recommended flow level (described in detail in the "Proposed Updates to the Sacramento/Delta Objectives" section, below), based in part on the information in the Science Report. Unimpaired flow represents the total amount of water available at a specific location and time, a percentage of which can be allocated to beneficial uses and the environmental functions supporting those uses. As indicated above, while unimpaired flow is not the same as natural flow, it is generally reflective of the frequency, timing, magnitude, and duration of the natural flows to which fish and wildlife have adapted, particularly in tributaries. A flow requirement based on a percent of unimpaired flow is intended to ensure that a minimum amount of available supply from a watershed is allocated for the reasonable protection of native fish and wildlife beneficial uses. Where unimpaired flows may not provide for all of the attributes of natural flow functions that would be protective of the ecosystem, the Science Report recommends the use of adaptive management, including sculpting of flows, to provide specific functions informed by established biological goals.

In addition to the above inflow and inflow-based outflows, the Science Report also recommends a new cold water habitat objective to ensure that there are not redirected impacts of the inflow objective and to ensure that there are adequate cold water supplies to protect salmonids. In addition, a new fall Delta outflow objective and interior Delta flow objectives are recommended that are consistent with the existing BiOps and ITP to ensure that the protections in the Bay-Delta Plan are integrative and comprehensive.

Chapter 3   Estimates of Environmental Benefits and Water Supply Costs

This section summarizes the estimated environmental benefits and water supply costs associated with different levels of unimpaired flow ranging from 35 to 75%, including analysis of benefits that were described in the Science Report and updated analyses based on hydrologic modeling that will be included in the upcoming draft Staff Report. In general, the analysis suggests that benefits consistently occur at flows of 55% of unimpaired flow and higher, and are absent or very modest at 45% of unimpaired flow and lower

3.1   General Background

The Science Report and associated Fact Sheet released in October of 2017 described the proposed Sacramento/Delta updates to the Bay-Delta Plan, but did not identify specific alternatives, including a preferred alternative, with specific flow levels or implementation provisions. Since the Science Report was released and the State Water Board received public input on the Science Report (see Chapter 6, below), State Water Board staff have been preparing a draft Staff Report that identifies alternatives the State Water Board may take to update the Bay-Delta Plan. The alternatives will include a range of flows between 35-75% of unimpaired inflow and associated outflows, as well as interior Delta flow alternatives, fall Delta outflow alternatives, and implementation alternatives. The Staff Report will also provide an analysis of a range of potential nonflow measures that may support potential voluntary agreements. The State Water Board is cognizant of the many important beneficial uses of water in addition to fisheries, including municipal and industrial, agriculture, hydropower, and recreation. Actions that could potentially reduce water supplies for these other uses must be taken carefully, and only after serious and thoughtful consideration of effects and consistency with overall goals of the State.

An analysis of the environmental, economic, and related impacts and benefits of those alternatives will be included in the Staff Report, including hydrologic and operational modeling analyses. State Water Board staff have developed the preferred alternative summarized in Chapter 4 based on these analyses. The preferred alternative will be detailed in the Staff Report, along with other alternatives. A summary of the environmental benefits and water supply costs that has helped to inform the proposed preferred alternative is provided below.

3.2   Environmental Benefits of Additional Flow

The Science Report contains preliminary quantitative analyses of potential benefits to native species that would be expected to result from a range of required flows. The Science Report presented the expected benefits based on a calculated percent of unimpaired flow. The Science Report did not, however, include operational analyses (i.e., detailed flow modeling that reflects how the system is operated) showing what the expected flows would be when

considering other regulatory requirements, flood control operations, diversion capacity limitations and needs, and other operational and hydrologic circumstances that would generally lead to higher flows. The forthcoming draft Staff Report will include these additional operational analyses, and will describe additional expected environmental benefits that differ from the benefits described in the Science Report. Both the Science Report and draft Staff Report analyses are informative, and are useful in assessing expected ecosystem and water quality benefits associated with new flow requirements. The calculated percent of unimpaired flow analysis in the Science Report illustrate the "floor" of the expected benefits, assuming that the percent of unimpaired flow requirement were the only requirement driving flows.[3] The operational analyses that will be included in the Staff Report will illustrate the flows that would be expected to occur under a percent of unimpaired flow regulatory requirement, in combination with other currently required flows and current water supply demands and infrastructure. Future changes to water supply development, reservoir operations, and other regulatory requirements may result in flows, and thus benefits, that fall between the operational analyses and the percent of unimpaired flow requirements. The discussion below describes the expected benefits for a range of inflow levels between 35 and 75% of unimpaired flow, as well corresponding inflow-based outflows based on a calculated percent of unimpaired flow and with additional expected operations.

The hydrological analysis in the Science Report compares estimated unimpaired flows to modeled existing conditions, and demonstrates substantial changes to Sacramento/Delta hydrology. Inflows from tributaries with large reservoirs are, in general, significantly reduced during the wet season, particularly April through June, when inflows from many tributaries are reduced to less than 35% of unimpaired flow. Flows below Project reservoirs such as Shasta, Oroville, and Folsom reservoirs are generally much higher than unimpaired during summer and fall months, when water is released for delivery, export, salinity control, or other water quality requirements. In contrast, tributaries without reservoirs have essentially unimpaired flows during much of the wet season, while under drier conditions, these tributaries can run dry or nearly so due to direct diversion for agricultural water supply. At the larger scale of the Delta, inflow is rarely decreased below 35% of unimpaired flow, while outflow is reduced below 50% of unimpaired flow about 80% of the time during April through June.

The Science Report draws on published literature and monitoring data to identify flow thresholds that are correlated with improved survival and abundance of native species. For salmonids, the thresholds are based on flows that are associated with greater juvenile outmigration success and less entrainment of Sacramento origin salmonids into the interior Delta. Flows that position estuarine habitat in more hospitable locations or favor population growth are used as thresholds for other estuarine species such as longfin smelt. The Science Report contains an analysis of how often these thresholds are met under a range of calculated unimpaired flow scenarios compared to existing conditions, as well as how abundance indices of several species may change based on well-established flow-abundance relationships.

As discussed above, the calculated unimpaired flow levels in the Science Report demonstrate the minimum expected benefits. Under existing conditions, most of these thresholds are met

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[3] The calculated percent of unimpaired flow represents the hypothetical lowest flows that would comply with a percent of unimpaired flow regulatory requirement; however, in reality flows would not be this low because there are other additional regulatory requirements (for example: flood operations or other flow requirements, including export limits) that control flows to some extent, and there are flows that cannot be captured or are not needed by water users.

during the wettest one third to one half of years. In general, the analysis suggests that benefits consistently occur at flows of 55% of unimpaired flow and higher, and are absent or very modest at 45% of unimpaired flow and lower (see Tables 5.3-3 and 5.3-4 in the Science Report for specific results regarding achievement of flow thresholds and species abundance indices associated with calculated unimpaired flows).

However, as mentioned above, the methodology used to calculate unimpaired flow volumes in the Science Report does not account for other flows that would contribute to inflows and outflow including existing regulatory requirements, flood control operations, limits on diversion capacity, and other operational and hydrologic considerations. The draft Staff Report will include additional analyses that consider the effect of other regulations, operations, and system parameters. These additional analyses show greater benefits than the results contained in the Science Report, because the combination of the above constraints generally results in greater flow than would result from any single requirement on its own.

The draft Staff Report analyses generally show some incremental benefit for all flow scenarios relative to existing conditions. The draft Staff Report modeling indicates that abundance indices[4] of targeted species may be expected to increase from about 5 to 15% at 35% of unimpaired flow, 20 to 40% at 55% of unimpaired flow, and 35 to 85% for 75% of unimpaired flow. Table 1 compares the approximate change in species abundance indices between the analyses in the Science Report and the analyses that will be included in the upcoming draft Staff Report.

TABLE 1*: Approximate Change in Species Abundance Relative to Existing Conditions

Percent Unimpaired Flow	Change in Species Abundance Indices Using Analysis from Science Report (Unimpaired Flow)**	Change in Species Abundance Indices Using Unimpaired Flow + Other Flows***
35%	0%	+5-15%
55%	+10-20%	+20-40%
75%	+30-80%	+35-85%

*Illustrates the difference in modeled species responses between the Science Report, which utilized a straight calculation of percent of unimpaired flow, versus the forthcoming draft Staff Report that will include consideration of other regulatory flows, uncontrolled flows, systems operations, and other factors.
** See Table 5.3-4 in the Science Report
*** Analyses will be included in the forthcoming draft Staff Report

3.3   Water Supply Costs

The operations studies being prepared for the draft Staff Report include estimates of the water supply costs of the various unimpaired flow levels, including surface water supplies for use within the basin and exported outside of the basin. Total water use in these areas is about 41 MAF, of which about a third of this (12.1 MAF) is surface water from the Sacramento/Delta (the remainder is water derived from other watersheds, groundwater, recycled water, or desalinated water). Estimated average reductions in supplies for all of these areas combined are approximately 700 thousand acre-feet (TAF) at 35%, 1.1 MAF at 45%, 2 MAF at 55%, 3.1 MAF

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[4] It is typically very difficult to measure the absolute size of a population in nature, so population sizes are often represented by estimates of relative population size, or "abundance indices," based on the use of a consistent survey design, such as the California Department of Fish and Wildlife's (DFW) Fall Midwater Trawl or San Francisco Bay Study.

at 65%, and 4.7 MAF at 75% of unimpaired flow. These costs represent a reduction in the total supply of 41 MAF of about 2, 5, and 12% at 35, 55, and 75% of unimpaired flow, respectively (see Table 2). These values correspond to reductions of surface water supplies derived from the Sacramento/Delta of about 6, 17, and 39% at 35, 55, and 75% of unimpaired flow, respectively. Of the overall water supply reductions, about 75% goes to increased Delta outflow during winter and spring, with the remainder going to increased carryover storage to maintain cold water in reservoirs under dry conditions, as well as increased summer and fall Delta outflow.

TABLE 2: Water Supply Costs at Different Levels of Unimpaired Flow

Percent Unimpaired Flow	Water Supply Reduction (MAF)	Percent of reduction relative to total area supply (41 MAF)	Percent of reduction relative to supply derived from Sacramento/Delta surface water
35%	0.7	2%	6%
45%	1.1	3%	9%
55%	2.0	5%	17%
65%	3.1	8%	26%
75%	4.7	12%	39%

The draft Staff Report will also include evaluations of reservoir storage effects of the percent of unimpaired flow levels. Staff Report modeling includes reasonable assumptions for preserving cold water supplies in accordance with the proposed changes to the Bay-Delta Plan. The reservoir storage analysis indicates that there are escalating water supply costs and difficult challenges in maintaining reservoir storage to protect cold water habitat at 65 to 75% unimpaired flow, mainly due to the large increases in outflow combined with large water supply costs associated with those scenarios. Throughout most of the watershed, reservoir carryover storage can be maintained for cold water habitat protection at 55% unimpaired flow or lower, although cold water management challenges may still exist in some reservoirs at lower flow levels, particularly when storage capacity and demand are large relative to average reservoir inflow.

| Chapter 4 | Proposed Updates to the Sacramento/Delta Objectives |

As discussed in the Science Report, protection of the Bay-Delta ecosystem and its native aquatic species requires an integrated approach to effectively connect upstream suitable cold water nursery habitat, floodplains, tidal marshland, and turbid open water habitats in the Delta and Bay – and to connect those environments to the ocean. Accordingly, changes to the Bay-Delta Plan are proposed to provide for a flow regime that supports a connected and functioning ecosystem linking and integrating inflow, cold water habitat, Delta outflow, and interior Delta flow measures with complementary physical habitat restoration and other nonflow measures. Changes are proposed to the water quality objectives, including narrative and numeric objectives, and the program of implementation for those objectives, as well as changes to monitoring, reporting, and assessment requirements. As described in Chapter 5 below, the proposed objectives may be implemented through several mechanisms, including voluntary plans. Voluntary plans that are consistent with the updated Bay-Delta Plan objectives are encouraged for their ability to achieve tailored, timely, and more durable ecosystem and fishery benefits at the least cost to water supply.

This section includes the proposed Sacramento/Delta flow objectives, including new inflow objectives, a new cold water habitat objective, modified Delta outflow objectives, and modified interior Delta flow objectives along with an expanded description of the purpose, need, and rationale for each.

4.1   Sacramento/Delta Inflow Objectives

The proposed new inflow objectives include both a narrative and numeric component. The narrative portion of the inflow objective: 1) describes the needs for inflows to provide appropriate conditions in tributaries and to contribute flows to the Delta, and; 2) describes the conditions the numeric inflows and other provisions in the Bay-Delta Plan are intended to produce. The numeric component requires a portion of the inflows coming into a tributary to remain in the stream for environmental purposes to the confluence to protect instream beneficial uses and to contribute to outflows in the Delta.

The proposed objective is as follows:

> *Maintain inflow conditions from the Sacramento River/Delta tributaries sufficient to support and maintain the natural production of viable native fish populations and to contribute to Delta outflows. Inflow conditions that reasonably contribute toward maintaining viable native fish populations include, but may not be limited to, flows that more closely mimic the natural hydrographic conditions to which native fish species are adapted, including the relative magnitude, duration, timing, quality and spatial extent of flows as they would naturally occur.*

> *Maintain inflows from the Sacramento/Delta tributaries at 55% of unimpaired flow, within an allowed adaptive range between 45 and 65% of unimpaired flow.*

The new inflow objective is intended to set the foundation for integrating inflow objectives, cold water habitat objectives, and outflow objectives, and to provide a unified framework for comprehensive protection of the Bay-Delta ecosystem. All three of these objectives are proposed to work together as part of a comprehensive package. The proposed starting point for the percent of unimpaired flow level is 55%. As proposed, flows may be lower in the 45-65% of unimpaired flow range in cases where there are successful voluntary plans that can demonstrate that they achieve the narrative using a combination of flow and other measures or if the State Water Board determines that lower flows are needed to meet the narrative objectives, including to preserve cold water resources upstream for use later in the year for the protection of species. Flows may be higher in the range on tributaries where flows under current conditions are already higher than 55% unimpaired flow, and where those higher flows are needed to protect fish and wildlife and meet the narrative objective. Required flows may also be higher than 55% if lower flow levels are not achieving the narrative objective and protecting fish and wildlife beneficial uses, specifically, if biological goals5 (see Chapter 5.9) are not being met and monitoring and assessment information indicates that higher flows are needed.

The proposed inflow objective was developed based on the analyses included in the Science Report, comments received to date, and the water supply modeling and environmental and economic analyses that are partially summarized above and will be further described in the draft Staff Report. The need for flows that protect uses within the tributaries, as well as Delta outflow needs, were considered in determining the proposed 55% unimpaired flow starting point for the inflow objective. Delta outflows were considered because inflows from the tributaries provide the majority of the flows for Delta outflows. The range of unimpaired flow levels provide for flexibility to address the unique circumstances of different tributaries and actions that may be taken to implement the inflow objective on those tributaries both initially and over time. As indicated above, an inflow of 55% of unimpaired flow and corresponding outflow is generally the level at which there are marked expected improvements in protection of fish and wildlife beneficial uses. These improvements are greater at 65%, however at this level conservation of cold water resources in reservoirs becomes more challenging and water supply costs increase substantially. At 75% of unimpaired flow, the water supply costs are large and cold water conservation is very difficult, particularly without significant additional water supply costs. Expected benefits to fish and wildlife are marginal at 45% unimpaired flow, but could be increased by implementing non-flow actions.

On some tributaries it may not be possible to maintain cold water pool protections and any meaningful level of water supplies while meeting a higher flow level. The implementation provisions described below provide for evaluation of this issue and determination of appropriate adjustments on a tributary by tributary basis. At the same time, it is possible that voluntary agreements may be reached that provide for both flow and habitat restoration actions that can achieve the same benefits as 55% of unimpaired flow or more with a lower water supply cost. Because the science does not indicate that flows below 45% from the Sacramento/Delta tributaries would be adequately protective on the tributaries or adequate to contribute needed flows for outflow purposes, inflows would be required to be at least 45%. As mentioned previously, the State Water Board is particularly interested in receiving potential plan

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5 Biological goals are quantitative metrics that can be used to assess the achievement of narrative objectives and guide future adaptive changes to the numeric objectives and other efforts to restore and maintain native species.

amendment language which would authorize, with the affirmative concurrence from the DFW, a coordinated control of flows and other, non-flow factors that would achieve benefits comparable to the unimpaired flow requirements. Outflows of 55% are expected to provide substantial benefits. It is expected that total inflows from the Delta tributaries will be close to 55% since some tributaries will be higher and some will be lower and there will be other regulatory requirements and other flows that contribute to outflows.

4.2   Cold Water Habitat Objective

A new narrative objective for cold water management is proposed to be added to the Bay-Delta Plan to address tributary-specific temperature needs. The objective would require that cold water flows from reservoirs are maintained and timed to provide for downstream temperatures to protect salmon species at critical times of year, or that alternate protective measures are implemented (e.g., passage above dams, changes to physical setting) to ensure that fish below dams are kept in good condition (consistent with Fish and Game Code section 5937). The narrative objective would apply on all of the Sacramento/Delta tributaries and the associated reservoirs. Actions to manage temperatures; however, will need to be tailored based on the needs and circumstances of that tributary.

The proposed narrative objective is as follows:

> *Maintain stream flows and reservoir storage conditions on Sacramento River/Delta tributaries to protect cold water habitat for sensitive native fish species, including Chinook salmon, steelhead, and sturgeon. Cold water habitat conditions to be protected include maintaining sufficient quantities of habitat with suitable temperatures on streams to support passage, holding, spawning, incubation, and rearing while preventing stranding and dewatering due to flow fluctuations.*

Cold water habitat protection is a necessary companion to inflow objectives, and is important for maintaining salmon species in tributaries and protecting against exhaustion of cold water pool resources from storage withdrawals that may occur with new inflow requirements. Needed temperature conditions depend on the race of salmon, life stage, and other factors. Currently the Bay-Delta Plan does not include a cold water habitat objective. While some other temperature requirements exist pursuant to requirements of the State Water Board and other agencies (including State Water Board Water Right Order 90-5), those requirements are not comprehensive. Existing requirements also need to be reviewed and updated as appropriate to ensure that they are protective and that measures are integrated with the inflow and outflow objectives and implementation measures.

4.3   Delta Outflow Objectives

Three new Delta outflow objectives are proposed, including a narrative objective, an inflow-based Delta outflow objective, and a fall Delta outflow objective, as well as minor modifications to existing objectives. The Delta outflow objectives, working with the inflow objectives, are intended to provide for a comprehensive integrated flow regime that protects fish and wildlife, all the way from natal streams out to the ocean, in a feasible and flexible way. The changes are proposed both to enhance Delta outflow protections and to ensure that existing protections are

not diminished. As discussed above, current outflow volumes are inadequate to protect the ecosystem, and current outflow requirements are even lower and less protective. Specific proposed changes to Delta outflow objectives include a new narrative Delta outflow objective, a new inflow-based Delta outflow objective, and a new fall Delta outflow objective. Because it will take time to implement the new inflow and outflow objectives, the existing outflow objectives are proposed to be retained (with some minor modifications) at this time. When the new inflow and outflow objectives are fully implemented, some of the existing outflow objectives would be phased out (particularly those that are intended to the achieve the same purpose as the inflow-based Delta outflow objective, including the X2 based objectives in Table 4 of the Bay-Delta Plan that require flows based on an index of unimpaired flow). Others are proposed to be retained as base Delta outflows to ensure that these minimal protections are retained in the rare instances when the inflow-based outflow levels are lower.

4.3.1 Narrative Delta Outflow Objective

The narrative Delta outflow objective is proposed to describe the outflow conditions that protect native fish and aquatic species populations and provides the description of the conditions the numeric outflows are intended to produce along with other measures in the watershed. The proposed narrative is as follows:

> *Maintain Delta outflows sufficient to support and maintain the natural production of viable native anadromous fish, estuarine fish, and aquatic species populations rearing in or migrating through the Bay-Delta estuary. Delta outflows that reasonably contributes toward maintaining viable native fish and aquatic species populations include, but may not be limited to, flows that connect low salinity pelagic waters to productive tidal wetlands and flows that produce salinity distributions that more closely mimic the natural hydrographic conditions to which these species are adapted, including the relative magnitude, duration, timing, quality and spatial extent of flows as they would naturally occur. Indicators of viability include population abundance, spatial extent, distribution, productivity and genetic and life history diversity. Viability is dependent on maintaining migratory pathways, sufficient quantities of high quality spawning and rearing habitat, and a productive food web.*

4.3.2 Inflow-Based Delta Outflow Objective

The proposed new inflow-based Delta outflow objective specifies that the inflows required in the Bay-Delta Plan, including the proposed Sacramento/Delta and San Joaquin River flows specified in the Bay-Delta Plan, are provided as outflows.

The proposed new inflow-based Delta outflow objective is as follows:

> *The inflows required above, including for the Sacramento/Delta tributaries and San Joaquin River are required as outflows with adjustments for downstream natural depletions and accretions.*

The required outflow would be calculated by adding up the applicable required inflows in the Bay-Delta Plan and making appropriate adjustments for natural losses and gains, including floodplain inundation flows.   As discussed further below, an accounting method would be developed for the inflow-based Delta outflows. It is also proposed that a salinity based method for complying with the inflow-based Delta outflow objective could be developed as an alternative or a backstop to the calculated method similar to the existing salinity based methods included in

the Bay-Delta Plan, provided that doing so better measures compliance toward meeting the inflow-based Delta outflow objective and the narrative.

As discussed above, the proposed Sacramento/Delta tributary inflow objective is 55% of unimpaired flow within an adaptive range from 45-65% of unimpaired flow. Outflow needs were considered when evaluating needed inflow levels. As discussed above, inflow levels are expected to vary from tributary to tributary, with most at 55% of unimpaired flow, some lower, and some higher in the range. The volume of San Joaquin River flow that would contribute to the Delta outflow objective would be consistent with requirements in the Bay-Delta Plan. That volume includes any changes to the San Joaquin River inflow objectives that may result from the update to the Bay-Delta Plan for the Lower San Joaquin River, thus ensuring that required San Joaquin River inflows are protected and contribute to outflows.

Other flows to the Delta downstream of the tributaries would also be subject to the inflow-based Delta outflow objective, including precipitation that falls in the Delta itself and runoff from minor Delta tributaries and lands in the Delta. To the extent that those flows represent net accretions to the system without water diversions (which would generally be the case during the wet season), the required flows would be scaled similar to the inflow objectives requiring that 55% be provided to Delta outflow with an adaptive range of 45-65%. To the extent there are net natural depletions from the Delta without water diversions, including losses due to evaporation and riparian vegetation that are greater than accretions (which would generally occur during the summer and fall), those depletions would be factored into the required Delta outflow levels.

4.3.3   Fall Delta Outflow Objective

A new fall Delta outflow objective is proposed as part of the Bay-Delta Plan update. The proposed objective describes the fall outflow conditions that protect native fish and aquatic species populations and describes conditions the program of implementation is intended to produce. The proposed objective is as follows:

> *Maintain Delta outflow levels during the fall to provide suitable quantities of quality habitat for sensitive native estuarine species consistent with provisions of the 2008 USFWS Biological Opinion, and updates to the biological opinion as appropriate.*

The proposed objective would incorporate provisions of the Fall X2 component of the Reasonable and Prudent Alternative (RPA) Action 4 of the US Fish and Wildlife Service's (USFWS) 2008 Delta Smelt BiOp for the coordinated operations of the SWP and CVP into the Bay-Delta Plan. These requirements were developed as an adaptive management action, to be tested and refined, and reconsidered by the regulatory agencies over time. As such, while these requirements already exist under the USFWS BiOp, the requirements may change pursuant to federal ESA provisions related to jeopardy to listed species. However, the State Water Board has an independent and distinct obligation to reasonably protect beneficial uses of water in the Bay-Delta watershed separate from the ESA that may require measures in addition to federal ESA or California Endangered Species Act (CESA) requirements to achieve reasonable protection. Flows and water diversion-related actions are within the State Water Board's purview and responsibilities related to protection of fish and wildlife. The proposed fall Delta outflow objective is intended to ensure that fall Delta outflow measures needed to reasonably protect fish and wildlife occur (even with future modifications to the USFWS BiOp), while providing for coordination with implementation of the BiOp. The proposed changes to the Bay-Delta Plan will also provide for adaptive management and allow for potential changes as a result of changes to the BiOp. However, such changes would be subject to concurrence by DFW, public review, and approval by the State Water Board. For example, the USFWS will be

reevaluating the Fall X2 component in the near future, and any changes could be included in the Plan update if concluded in time, or could be incorporated through the procedure described in Chapter 5.

4.3.4 Modifications to Existing Delta Outflow Objectives

The current Delta outflow objectives included in the Bay-Delta Plan are proposed to be retained in order to ensure that minimum quantities of Delta outflow are provided to the estuary in all months and all years and during the transition to implementation of the proposed new objectives. Current Delta outflow objectives are referred to as "base Delta outflows." Specifically, the amended Plan would maintain existing year-round Delta outflow objectives currently found in Table 3 of the Bay-Delta Plan that range from 3,000 cfs to 8,000 cfs based on water year type from July through January. In addition, February through June outflow objective of 7,100 cfs would also be maintained (Footnote 11 to Bay-Delta Plan Table 3). Under the existing Bay-Delta Plan, this objective may be met by achieving a salinity (as measured by electrical conductivity) level of 2.64 millimhos per centimeter, or X2 location, at Collinsville on a daily average or 14-day running average basis. The methods by which this objective may be met are proposed to be reevaluated in the program of implementation (see Chapter 5, below) along with potential salinity based methods for implementing the inflow-based Delta outflow objective to ensure that intended protections are provided, including implementation of the narrative objective.

It is anticipated that when fully implemented the inflow-based Delta outflow objective will meet and exceed the existing Delta outflow requirements included in Table 4 of the Bay-Delta Plan that provide increased winter and spring Delta outflows following the natural hydrograph. Pursuant to the existing Bay-Delta Plan and D-1641, the Projects are required to meet a specified number of days of flows of 11,400 cfs or 29,200 cfs (or equivalent salinity) between February and June. The number of days ranges from 0 to 31 based on month and an index of unimpaired flows (the Eight River Index). Because the inflow-based outflow objective will be implemented over time, the flow requirements included in Table 4 are proposed to be maintained until such time as the inflow-based Delta outflow objective is fully implemented. Upon full implementation of the inflow-based Delta outflow objective, and a determination that that objective is achieving at least the same level of protection as Table 4, the program of implementation would allow for the Table 4 provisions to be phased out.

4.4 Interior Delta Flow Objectives

Finally, new and modified interior Delta flow objectives are proposed to complete the package of measures needed to provide for an integrated and comprehensive functioning flow regime in the Bay-Delta watershed. The proposed narrative interior Delta flow objective would establish needed flow conditions in the interior Delta to reasonably protect native fish populations migrating through and rearing in the Delta, and would provide the description of the conditions the numeric objectives and implementation provisions are intended to produce along with other measures in the watershed.

The proposed narrative objective is as follows:

> *Maintain flow conditions in the interior Delta sufficient to support and maintain the natural production of viable native fish populations migrating through and rearing in the Delta. Interior Delta flow conditions that reasonably contribute toward maintaining viable native fish populations include, but may not be limited to, flows that more closely mimic the*

natural hydrographic conditions to which native fish species are adapted, including the relative magnitude, duration, timing, quality, and spatial extent of flows as they would naturally occur. Indicators of native fish species viability include population abundance, spatial extent, distribution, productivity and genetic and life history diversity. Viability is dependent on maintaining migratory pathways, sufficient quantities of high quality spawning and rearing habitat, and a productive food web.

For the most part, the proposed numeric changes to interior Delta flow objectives involve the addition of existing BiOp and ITP requirements into the Bay-Delta Plan, including requirements included in the USFWS BiOp, 2009 National Marine Fisheries Service (NMFS) BiOp for the Projects, and the 2009 DFW longfin smelt ITP for the SWP. As indicated above, the State Water Board has primary authority over the regulation of water diversions and has an independent obligation to reasonably protect beneficial uses separate and distinct from ESA and CESA requirements. Given the complexity of the regulatory regime, it is simpler to build on existing requirements rather than develop an overlapping set of requirements.

Specific proposed changes to the interior Delta flow objectives include new Old and Middle River reverse flow limitations, as well as additional Project export restrictions and Delta Cross Channel gate closure requirements. The proposed changes are intended to ensure that interior Delta flow measures needed to reasonably protect fish and wildlife occur (even with future modifications to the BiOps and ITP) while providing for coordination with the BiOps and ITP. The proposed Plan amendments for the interior Delta flow objectives would provide for adaptive management of the objectives, and would allow for nimble modification as a result of changes to the BiOps and ITP, with concurrence by DFW and approval by the State Water Board.

In addition to the proposed narrative, the other proposed changes to the interior Delta flow objectives include the following:

- Additional provisions for Delta Cross Channel gate closures from the NMFS BiOp: The NMFS BiOp includes actions to reduce the proportion of salmonids and green sturgeon that enter the interior Delta through either the open Delta Cross Channel gates or Georgiana Slough from October through June 15, including additional Delta Cross Channel gate closure requirements based on fish presence from October 1 through December 15 and required closures from December 15 through January 31.

- New Old and Middle River reverse flow limits from December through June consistent with the USFWS and NMFS BiOps and DFW ITP. Provisions consistent with the BiOps and ITP are proposed to be added to the Bay-Delta Plan, including the addition of an objective limiting negative Old and Middle river flows from December through June to between -1,250 cfs and -5,000 cfs and other changes to incorporate provisions that are consistent with the triggers and consultation processes described in the BiOps and ITP.

- Modified export constraints based on San Joaquin River flows that apply from April through May consistent with the NMFS BiOp: Provisions consistent with the NMFS BiOp are proposed to be added to the Bay-Delta Plan, including the addition of all of April and May to the objective, the range of export restrictions to the objective, and the process for determining the applicable level to the program of implementation. In addition, adaptive management provisions are proposed to be added that would allow for the export time period to be shifted during the larger window of San Joaquin River salmonid outmigration between February and June in coordination with the fish agencies if agreeable to NMFS.

Chapter 5   Program of Implementation for the Sacramento/Delta Updates to the Bay-Delta Plan

This section begins with a general description of how the State Water Board may implement proposed changes to the Bay-Delta Plan, including through voluntary agreements. A description is then provided of specific implementation provisions for the objectives discussed above and other companion measures that are proposed to be identified in the program of implementation.

5.1   Implementation Options

5.1.1   Voluntary Agreements Facilitated by Other State Agencies[6]

The State Water Board has responsibility and authority for addressing flow and other water quality impairments, but recognizes that additional tools to improve ecological conditions can be brought to bear through voluntary agreements. Successful voluntary measures to implement the Bay-Delta Plan could provide comprehensive, enduring, and timely benefits to the ecosystem. The State Water Board is aware of, and encourages, the ongoing negotiations between interested stakeholders and various other state agencies to achieve voluntary solutions that could implement the updated plan.

The State Water Board encourages parties, facilitated by other state agencies, to present voluntary agreements to the State Water Board for its review as soon as feasible. Voluntary agreements may be a preferred implementation pathway for some stakeholders, as voluntary agreements could reduce the volume of water that needs to be dedicated for instream purposes, and therefore reduce the potential impacts associated with decreased consumptive water uses, such as impacts to agriculture. In addition, the State Water Board's review and acceptance of agreements would be streamlined if agreements are reached before the Board adopts the Plan amendments, because those voluntary agreements could be integrated into the program of implementation and implemented upon adoption.

At a minimum, to be considered by the State Water Board, voluntary agreements would need to include provisions for transparency and accountability, monitoring and reporting, and for planning, adaptive management, and periodic evaluation. Voluntary agreements would also need to be supported by DFW. In evaluating any proposal, the Board will need to make an independent finding to determine whether the agreement will be enforceable and will contribute to achieving the water quality objectives and protection of fish and wildlife beneficial uses.

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[6] The California Natural Resources Agency, DFW, and DWR are leading efforts to negotiate voluntary settlement agreements among stakeholders that could implement the plan objectives.

5.1.2 State Water Board's Proposed Program of Implementation

The proposed program of implementation will provide two paths: a default path absent a voluntary agreement, or a voluntary path that could be implemented through voluntary agreements. The paragraphs below describe the State Water Board's authorities and responsibilities, describe the default implementation pathway, and describe the requirements for voluntary agreements developed by individual or groups of tributaries in the absence of agreements reached through the state-facilitated effort.

5.1.2.1 Default Implementation

The State Water Board has authority and responsibility to adopt statewide Water Quality Control Plans, and oversees Bay-Delta planning because of its importance as a major source of water for the state. The State Water Board is the only state agency with authority to administer water rights. Because California combines its water rights and water quality authorities (Wat. Code, § 174), the Bay-Delta Plan addresses water diversions and use in the water quality planning context, including the federal Clean Water Act and state Porter-Cologne Water Quality Control Act. The State Water Board relies on both its water quality and water rights authorities when regulating water diversion and use to implement water quality objectives. The State Water Board is required to adopt a program of implementation that describes the actions that will be taken to achieve water quality objectives. There are a variety of water right and water quality authorities the State Water Board may utilize to implement new and revised objectives.

The State Water Board conducts both quasi-legislative and quasi-judicial administrative proceedings, and different rules apply depending on the type of action pending before the State Water Board. An adjudicative proceeding is a hearing to receive evidence for determination of facts pursuant to which the Board formulates and issues a decision. A decision determines a legal right, duty, privilege, immunity, or other legal interest of a particular person or persons. In the past, the State Water Board has conducted adjudicative water rights hearings to implement the Bay-Delta Plan. The procedural rules are similar to a court, and ex parte (off the record) communications with the decision-maker are prohibited. This type of hearing works well for cases with a discrete set of issues and a few individual parties.

Rulemaking and informational proceedings are not adjudicative proceedings and are subject to different procedures. (See Cal. Code Regs., tit. 23, § 649 et. seq.) A rulemaking proceeding is most effective when a large number of parties will be subject to the regulation. The process can be time and resource intensive, but the procedures are less structured, and can be better tailored for actions that require a comprehensive approach. The basin planning process is a rulemaking proceeding.

The hearing for D-1641, implementing the latest major revisions to the Bay-Delta Plan, took several years to complete. Because agreements were largely reached on implementation activities, those hearings were much shorter than they would have been otherwise and implementation occurred sooner than it would have otherwise. An all-encompassing, comprehensive adjudicative hearing may not be the most effective or efficient procedure for implementation of Bay-Delta Plan updates. Alternatives exist; for example, the Board may structure a set of smaller hearings for each tributary. The Board may also consider rulemaking to impose some of the approaches listed above that are applicable across a broad group of

water users (such as Term 917), or impose a regulation with the opportunity for a hearing for those who object for specific reasons or otherwise require an individual investigation into a specific water right. The State Water Board will determine specific implementation provisions at a later date and will provide opportunity for public review and comment on the proposal.

5.1.2.2   Other Voluntary Agreements

Voluntary solutions other than the state-facilitated process will still be encouraged in the proposed program of implementation for their ability to achieve tailored, timely, and more durable ecosystem and fishery benefits at the least cost to water supply. While enhanced flows are the principle means proposed to implement the updated objectives, the proposal recognizes that other measures are also needed that could be implemented through voluntary agreements including measures to address barriers to fish passage, habitat loss, predation, increased water temperature, contaminants, and other conditions. Such voluntary agreements can provide large-scale benefits (like habitat restoration) that will amplify the ecological benefit of new and existing flows beyond what the State Water Board can require through flow and water project operations alone. Voluntary agreements may also reduce the volume of water that needs to be dedicated for instream purposes, and therefore reduce the potential impacts associated with decreased consumptive water uses, such as impacts to agriculture. To this end, the proposed program of implementation provides a framework for accepting voluntary agreements that include alternative methods for enhancing fish and wildlife throughout the Sacramento/Delta watershed.

The proposed program of implementation provides for adaptive management for both the voluntary and default implementation paths to maximize the benefits of inflows in protecting native fish and wildlife. Adaptive management through either voluntary or default implementation measures would be required to be informed by regular monitoring and evaluation of the effectiveness of the measures in meeting the narrative objectives and biological goals, including regular independent peer review. Adaptive management actions would be subject to concurrence by DFW and consultation with the federal fish agencies and approval by the State Water Board. Both the voluntary and default implementation of the numeric objectives would be required to conform with the proposed narrative objectives and would include provisions to avoid or minimize redirected impacts to refuges, groundwater, and other undesirable effects and provisions to address droughts and minimum health and safety needs.

In order to pursue the voluntary implementation path and avoid the default path, the proposed program of implementation would require water users to submit a plan for developing an agreement to the State Water Board within a specified time. To be approved, the plans would need to demonstrate that such groups are adequately organized, funded, and committed to successfully develop voluntary plans to implement the objectives in a reasonable timeframe.

If voluntary groups are not formed and a plan that meets the requirements discussed above is not submitted in the time allotted, or if the voluntary groups are not meeting the time schedules

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[7] Term 91 is a standard water right permit condition that has been included in a limited subset of water right permits and licenses in the Bay-Delta watershed that has a process for limiting diversions when water is determined to be unavailable for those diversions.

identified for development or implementation of the voluntary plans, it is proposed that the default implementation provisions would apply as described below. After the time allotted, voluntary groups could still form but would be subject to the default provisions until such time as they develop and begin to implement a successful voluntary tributary plan.

5.2   Sacramento/Delta Inflow Proposed Program of Implementation

Both the narrative and numeric portions of the inflow objective are proposed to apply throughout the watershed, including on upstream tributaries and distributaries, and on all of the Sacramento/Delta tributaries that support or contribute to the protection of anadromous fish species (including tributaries like Cache Creek which provides flows for floodplain inundation of the Yolo Bypass that benefit native species). Under the proposed program of implementation all water users on these tributaries, except those determined to have a de minimis effect on flows, would have responsibility for achieving the objectives. Smaller naturally intermittent streams that do not support anadromous fish that have little effect on the Bay-Delta ecosystem would not be subject to the inflow objective at this time, but may be in the future and may also be subject to the inflow-based Delta outflow objective discussed below.

In addition to requiring that the numeric flow levels be achieved on tributaries, the proposed program of implementation would require that existing flows be maintained on tributaries with flows that are already higher than the required numeric levels if those flows are needed to protect fish and wildlife. The program of implementation would also specify that the inflow objective is intended to contribute to floodplain inundation benefits to native species but is not intended to contribute to flooding related public safety concerns and major property damage.

Compliance points are proposed to be established at the confluence of tributaries with the Sacramento River; for the Cosumnes, Calaveras, and Mokelumne rivers at the confluence with the Delta; and on the mainstem of the Sacramento River on the confluence with the Delta. Intermediate compliance points could also be established as necessary to ensure that the narrative is met and that necessary flow contributions from various stretches of tributaries and the mainstem Sacramento River are achieved. The proposed program of implementation will include provisions for developing accounting methods needed for implementation of the inflow objective, as well as the cold water habitat and Delta outflow objectives, including provisions to account for floodplain inundation flows and other natural accretions and depletions.

Under the proposed program of implementation, voluntary groups would have a specified time to develop proposed voluntary plans for implementing the inflow and cold water habitat objectives for concurrence by DFW and approval by the State Water Board. The voluntary plans could be developed for individual tributaries or groups of tributaries. It is proposed that where two or more tributaries develop a voluntary plan together, compliance with the numeric components of the objective may be shared between the tributaries but each tributary must comply with the narrative provisions of the inflow, cold water, and Delta outflow objectives. The voluntary plans would be required to provide 55% percent of unimpaired flow unless a lesser flow is necessary to protect cold water resources or nonflow measures that achieve an equivalent level of protection to 55% are provided, in which case flows may be no lower than 45%. If flows below 55% are proposed, robust scientific information, including quantitative

evaluations of the benefits to native species, would be required to be submitted indicating that the combined actions included in the agreement achieves at least the same level of protection as 55% and are in compliance with the narratives. Concurrence from DFW on any such determination would also be needed prior to submittal of the voluntary plan to the State Water Board for consideration. In tributaries that are already achieving a higher flow level than 55%, voluntary plans would be required to provide for protection of those flows to ensure that the protections those flows provide are not degraded.

As part of the voluntary plans, the required percent of unimpaired flow would be allowed to be managed as a total volume or block of water and released on an adaptive schedule where scientific information indicates a flow pattern different from that which would occur by tracking the unimpaired flow percentage would adequately protect fish and wildlife beneficial uses based on the specific needs of specific tributaries. Specifically, the numeric requirements could be sculpted to provide maximum benefits to fish and wildlife, including targeted pulses to cue migration, respond to observed presence of species, summer cold water releases, minimum flows, floodplain inundation, and other functions. The total volume of water would be required to be at least equal to the volume of water that would be released by tracking the required unimpaired flow percentage, with an averaging period that protects fish and wildlife. The voluntary plans would be permitted to include a time schedule for implementation but would be required to begin implementation expeditiously and achieve full implementation in a reasonable time frame (e.g. 3-5 years) with incremental substantial progress every year.

At the minimum, the proposed program of implementation would require that voluntary plans identify: provisions to ensure that proposed commitments are met; an analysis of how the proposed voluntary measures meet the narrative and numeric inflow and cold water habitat objectives as well as contribute to Delta outflows and integrate with other requirements; a time schedule for implementation; and monitoring, evaluation, and reporting provisions.

To avoid redirected impacts (e.g., changes in reservoir storage/releases, cold water habitat, Delta outflow, or operations in other areas outside of the voluntary agreement area that are needed in order to maintain compliance with the Bay-Delta Plan or other regulatory requirements) caused by implementation of the voluntary plans, the proposed program of implementation would also require that the plans provide for: integration with SGMA; avoiding impacts to aquatic and terrestrial species of concern; measures to plan for and effectively protect aquatic beneficial uses during sustained dry conditions, including droughts; and measures to ensure that minimal health and safety water supplies are available to communities while meeting the inflow and cold water habitat objectives.

Prior to submittal of any voluntary plans to the State Water Board, the proponents would be required to receive the concurrence of DFW and to consult with the USFWS and NMFS and other appropriate entities with a major role in provisions of the plan. Any comments from the fisheries agencies or other significant comments affecting the viability of the plan would be considered by the State Water Board prior to accepting a voluntary agreement. The public would also have the opportunity to review and comment on any voluntary plans prior to the State Water Board's approval. Voluntary plans that achieve at least 55% of unimpaired flow and meet the required time schedules and other provisions could be approved by the Executive Director of the Board. Voluntary plans that would provide less than 55% UF or that do not meet the required time schedule and other provisions would be required to be approved by the State Water Board.

For default implementation, water users on the tributaries would be required to contribute to the inflow objectives following the rule of water right priority, unless adjustments are needed to conform to the narrative objectives. All water users in the tributary, including upstream tributaries would be subject to the inflow objective. The proposed program of implementation would require tributaries without voluntary agreements to provide 55% of unimpaired flow, based on a minimum 7-day running average, measured at the confluence of the tributary. Temporary (less than one year) adjustments to these requirements would be allowed per the above voluntary flexibilities in order to maximize the protection of fish and wildlife, if recommended by DFW and approved by the State Water Board.

The proposed program of implementation would allow the State Water Board to refine the default implementation measures on a tributary basis over time in order to maximize benefits for native fish and wildlife while avoiding redirected impacts. Refinements could be made using the same flexibilities provided for in the voluntary process, and would be prioritized based on the importance of the watershed to protection of fish and wildlife beneficial uses, including shaping or shifting of flows to maximize ecological functions and benefits to fish and wildlife. Specific refinements that could be made include: measures to integrate the inflow and cold water habitat provisions with physical habitat restoration measures and other measures to protect fish and wildlife; measures to avoid groundwater impacts and terrestrial impacts; and specific provisions for addressing droughts and minimal health and safety water supply needs.

5.3 Cold Water Habitat Proposed Program of Implementation

Inflow and cold water habitat protection are intricately linked since releases from reservoirs to meet instream flow requirements early in the year can reduce the volume of cold water remaining to meet temperature requirements later in the year (for example, flows to aid in smolt migration in the spring can impinge on cold water flows necessary to adult spawning and later for protecting eggs). Specific implementation measures would depend on the circumstances in individual tributaries including their structural, operational, and hydrological characteristics. Cold water management actions could include a variety of different measures depending on these circumstances, including, management of reservoir storages and associated temperature control devices, efforts to establish cold water refugia like riparian revegetation, passage above reservoirs or other impediments to allow access to cold water refugia, and other measures.

Implementation of the cold water habitat objective would require reservoir owners/operators to develop and implement a long term strategy and annual plans for maintaining downstream temperatures. The strategies and plans would be developed in coordination with the State Water Board, fisheries agencies, and other appropriate entities. The plans and strategies would be based on the best available scientific information and provide for integration with other relevant temperature management requirements. The plans and strategies would also be required to include appropriate modeling, monitoring, and assessment provisions and would be subject to modification and update as directed by the State Water Board based on new information.

The voluntary tributary plans would be required to include specific provisions for protecting cold water habitat for the protection of native species, including salmon and steelhead. In the

absence of voluntary tributary plans, reservoir operators would be immediately subject to the narrative and would be required to comply with the implementation provisions described above. Specific measures to implement the cold water habitat objective in an integrated fashion with the inflow objectives could then be refined as appropriate through the default implementation process described in the inflow discussion. Temperature management processes already exist for some reservoirs and tributaries. To the extent those processes already exist they could be employed to implement the cold water habitat objective as well as the other requirements for which they were formed.

5.4   Inflow-Based Delta Outflow Proposed Program of Implementation

Implementation of the inflow-based Delta outflow objective would be achieved over time as the inflow objectives discussed above are implemented. The required inflows must be provided as outflow on a monthly basis with appropriate adjustments. All water users, except those determined to have a *de minimis* effect on flows in the Delta would bear responsibility for achieving the narrative objective and would be responsible for contributing to the objective, including diverters upstream and in the Delta. The Projects would bear a significant portion of that responsibility since they are the largest, most junior diverters in the watershed and have diversions at the end of the watershed that significantly affect outflows. However, they would not bear the entire responsibility because flows are necessary on all of the tributaries to achieve ecological benefits.

As discussed above, contributions to the inflow objectives on the tributaries would provide for implementation of the inflow-based outflow objective. However, water users on the tributaries may also need to bypass additional flows to satisfy more senior water right holders in the Delta while achieving the inflow-based Delta outflow objective. DWR and Reclamation frequently release previously stored water from their reservoirs to meet water quality and flow requirements, as well as to provide water to meet Project contract demands within the basin and exports out of the basin. However, unauthorized diversions of the Projects' previously-stored water may compromise the Projects' abilities to meet requirements and contract obligations. While DWR and Reclamation's direct diversions from the watershed are amongst the most junior diversions in the watershed, their diversions of previously stored water are not junior to other diverters. The proposed program of implementation calls for the State Water Board to curtail the unauthorized diversions of DWR and Reclamation's previously stored water to the extent that users do not have a contractual or other right to that water in order to provide for implementation of the inflow-based Delta outflow objective while ensuring that the Projects' water supplies needed for cold water habitat, inflows, and other purposes are not diminished by unauthorized diversions of water.

Similar to the inflow and cold water habitat objectives, the inflow-based Delta outflow objective may be implemented through a voluntary or a non-voluntary process. Flexibility would be provided through adaptive management of the inflow-based outflow objective to address the complexities of the watershed in manner compatible with the inflow objectives. Flexibility could also allow for implementation of nonflow measures that reduce the need for flows and allow for transfers, exchanges, purchases, and other agreements. The proposed program of

implementation will include proposed conditions to avoid redirected impacts to refuges, groundwater, and other undesirable effects, and will also include provisions for addressing drought and ensuring minimal human health and safety supplies.

Voluntary agreements for meeting the inflow-based Delta outflow objective would need to include provisions to address the above issues and coordinate with implementation of the inflow objectives. Through the voluntary process, Delta water users could propose a method for implementing the inflow-based Delta outflows, including how that responsibility would be shared, proposed accounting, monitoring, adaptive management, and reporting provisions. Voluntary plans to implement the inflow-based outflows would have the same requirements as voluntary agreements to implement the inflow objectives, including the time schedules and minimum requirements. Because there will likely be different schedules for implementation of tributary inflows, any voluntary plan would need to provide a process for adjusting outflows as the inflows are implemented. Modeling and other information necessary to ensure that any voluntary agreement complies with the inflow-based outflows would be required.

As with inflows, if voluntary groups are not formed and an executed agreement that meets the requirements discussed above is not submitted in the time allotted or the voluntary groups are not meeting the time schedules identified for development of implementation of the voluntary plans, it is proposed that the State Water Board will pursue the default implementation actions. After the time allotted, voluntary groups could still form but would be subject to the default provisions until they develop and begin to implement a successful voluntary plan.

In the absence of voluntary agreements, the proposed program of implementation would call for the State Water Board to expeditiously undertake efforts to implement the inflow-based Delta outflow objectives, including methods for determining when water users are not permitted to divert based on their water right priority and how those water users are to contribute to monitoring and assessment activities.

In consultation with DWR, Reclamation, DFW, and other appropriate entities, the State Water Board would develop specific accounting measures for this implementation, including integration with the other outflow objectives, inflow objectives, and biological opinion and related ecosystem protection requirements. The proposed program of implementation would also include provisions for allowing for adjustments to implementation measures to meet the narrative objective, including adjustments to address floodplain inundation.

5.5   Fall Delta Outflow Proposed Program of Implementation

The proposed program of implementation would require the Projects to provide Delta outflows during the fall to protect sensitive native estuarine species, consistent with provisions of the 2008 USFWS BiOp and subsequent updates to the BiOp as appropriate. The proposed program of implementation would specify that the Projects are required to meet the 2008 BiOp provisions unless the USFWS approves adaptive management actions or other modifications to this requirement, DFW concurs that the adaptive management or modifications are based on sound science, and the Board approves of the action. The proposed program of implementation would include specific provisions to allow for the State Water Board's decisions on adaptive

management and modification of implementation of the fall Delta outflow objective to be made in a timely and efficient manner.

Specifically, the BiOp calls for the USFWS to conduct a comprehensive review, including peer review, of the Fall X2 action 10 years after the BiOp was signed to determine the efficacy of this action and any needed changes. Based on that review, the BiOp specifies that the action will be either continued, modified, or terminated. USFWS is anticipated to conduct such a review in the near future. The proposed program of implementation would allow for the State Water Board to quickly and efficiently implement the fall Delta outflow objective, consistent with any changes that result from that review, a subsequent review, or other adaptive management actions the USFWS approves. Implementation would be contingent on DFW concurrence that the modifications are based on sound science, and on the State Water Board's approval of the modifications.

5.6   Interior Delta Flows Proposed Program of Implementation

As discussed above, the changes to the interior Delta flow objectives are proposed to be implemented in an integrated manner with the BiOp and ITP processes, based on real time monitoring and consultation that includes the State Water Board. Because the export facilities and the Delta Cross Channel gates are Project facilities, the Projects would have sole responsibility for ensuring that these operational objectives are implemented, in consultation with the State Water Board, fish agencies, and other parties as appropriate. As the largest diverters in the south Delta affecting Old and Middle River flows, the Projects would also have primary responsibility for implementing that objective. Other water users could also be involved in implementation to the extent that they affect Old and Middle River reverse flows. As discussed above, the proposed program of implementation for the interior Delta flow objectives would provide for adaptive management of the objectives and allow for nimble modification of the implementation of the objectives as a result of changes to the BiOps and ITP with concurrence by DFW and approval by the State Water Board.

5.7   Changing Climate Considerations

Climate change is already bringing warmer temperatures, longer and more severe droughts, and altered precipitation patterns to California. Maintaining a reliable water supply and suitable habitat for native species will be increasingly challenging considering expected climate change scenarios, particularly the likelihood of significantly reduced snowpack and advancing seas.

The current Bay-Delta Plan requirements are largely rigid and unadaptable, requiring a lengthy process to adjust. The proposed flow objectives represent a major shift in regulatory philosophy and methods that are better equipped to accommodate the effects of climate change and other needs for adaptive management to respond to new and changing information and conditions. For example, the proposed inflow and outflow objectives automatically scale to water availability in a watershed that may change because of climate change. Incorporating a range, rather than a discrete number, allows for adjustment that may be needed to provide more protection for the

environment or additional water for consumptive use due to drought. Sculpting and shaping of flows is also allowed in recognition that runoff patterns will change and that consideration of and adaptation to these changes are needed to protect native fish and wildlife. In addition, cold water habitat requirements are proposed and emphasized in response to these same issues.

Different tools may be needed to address climate change, including cold water pool management in reservoirs, passage projects, riparian reforestation, and other measures. Accordingly, actions by others will be needed to address climate change and other future challenges. The proposed program of implementation encourages voluntary agreements that can help advance habitat restoration and other physical improvements that make the ecosystem and the State's water infrastructure more resilient to the effects of climate change.

5.8   General Implementation Provisions

It is the State Water Board's intent to implement the changes to the Bay-Delta Plan as expeditiously as possible, using the most effective tools available to the Board. The proposed program of implementation includes actions that the State Water Board would take to implement the changes to the Bay-Delta Plan in this manner through its water right or water quality authorities. As discussed above, those processes would encourage and allow for voluntary agreements with regulatory backstops.

The proposed changes to the Bay-Delta Plan represent a significant shift in the methods by which the State Water Board has historically implemented the Bay-Delta Plan. For the most part, most of the water users in the watershed other than DWR and Reclamation have not been directly responsible for implementing the Bay-Delta Plan and have had little to no limitations on their diversions of water to protect fish and wildlife beneficial uses. The proposed updates to the Bay-Delta Plan would bring all water users to the table with responsibility to protect fish and wildlife beneficial uses and contribute toward achieving the objectives included in the Bay-Delta Plan in a biologically meaningful and equitable way.

To accomplish this shift, the State Water Board, in cooperation with others, will need to provide for necessary accounting, monitoring, assessment, and adaptive management to successfully implement the proposed Plan amendments. The proposed program of implementation will include the following elements:

- **Accounting**: The proposed program of implementation would call for the State Water Board to prioritize development of practical and efficient accounting methods for flows, water right priorities, and diversions based on existing information that can be improved upon over time. Those efforts include: accounting for inflows and inflow-based outflows, including depletions and accretions; methods to improve existing outflow calculations; and information to establish the bases, relative priorities, quantities, and seasons of diversion for water rights in the Bay-Delta watershed; and other relevant information to determine and inform water availability in order to implement the Bay-Delta Plan. Accounting methods should build on efforts taken during the recent drought to better determine water availability.

- **Adaptive Management**: Adaptive management is a component of all of the proposed changes to the Bay-Delta Plan, including both the voluntary and default implementation provisions. Adaptive management actions are proposed to be guided by measuring

success at achieving biological goals specific to tributary and estuarine needs. Specifically, adaptive management provides opportunities to shift and sculpt flows and other measures to more effectively achieve functional flows for fish and wildlife protection, to perform experiments to improve understanding of the underlying biological mechanisms, and to adapt based on that information.

- **Biological Goals**: The proposed program of implementation calls for the State Water Board to develop biological goals with input from the fisheries agencies and other interested stakeholders. The biological goals could be modified based on new information developed through the monitoring and evaluation activities described below or other pertinent sources of scientific information. Biological goals are specifically proposed to assess the health of the Bay-Delta ecosystem for representative anadromous and estuarine fish species. The biological goals are specifically proposed to address abundance, productivity as measured by population growth rate, genetic and life history diversity, and population spatial extent, distribution, and structure for native species.

- **Monitoring, Assessment, and Reporting:** Bay-Delta Plan implementation will require robust monitoring and assessment throughout the Sacramento/Delta watershed. Monitoring and assessment is needed to: 1) evaluate compliance with specific implementation provisions by responsible parties; 2) evaluate the effectiveness of implementation measures in meeting the narrative and numeric objectives, biological goals and otherwise reasonably protecting fish and wildlife beneficial uses; and 3) inform when and how to reevaluate the objectives and program of implementation. Adequate monitoring and assessment will also be required elements of any voluntary implementation program.

5.9 Other Implementation Actions

Because regulations to protect fish and wildlife in the Bay-Delta watershed in the past have not been comprehensive and water diversions have had little regulation for the protection of fish and wildlife, implementation of the proposes changes to the Bay-Delta Plan will present challenges related to redirected impacts and other issues. The program of implementation is proposed to include provisions to address these issues:

- **Groundwater:** The proposed program of implementation would indicate that the State Water Board will take actions as necessary pursuant to its authorities, including its authorities to prevent the waste, unreasonable use, unreasonable method of use, and unreasonable method of diversion of water (Cal. Const., art. X, § 2; Wat. Code, §§ 100, 275) and to enforce SGMA (Wat. Code, § 10720 et seq.) and actions needed to ensure that reductions in surface water diversions do not result in groundwater pumping that reduces the required instream flows.

- **Drought:** The proposed program of implementation would include provisions to plan for extended dry conditions to ensure that fish and wildlife are protected at these critical times.

- **Efficiency and Conservation:** The proposed program of implementation would include provisions to increase water use efficiency and conservation in order to reduce reliance on the Delta consistent with the Delta Reform Act to ensure that critical water supplies are available for fish and wildlife.

- **Health and Safety Supplies:** The proposed program of implementation would identify actions that it may take to ensure that implementation of the objectives does not impact supplies of water for minimum health and safety needs, including providing assistance with funding and development of water conservation efforts and regional water supply reliability projects, and regulation of public drinking water systems and water rights.

- **Fully Appropriated Streams List:** The State Water Board has adopted and periodically revised a Declaration of Fully Appropriated Streams (FAS list). The FAS list includes stream systems found to be fully appropriated for all or part of the year. The State Water Board cannot accept any new applications to appropriate water from watercourses listed on the FAS. The Sacramento-San Joaquin Delta is included on the FAS list as fully appropriated from June 15 to August 31. Many Sacramento/Delta tributaries are on the FAS list independently and pursuant to their own specific orders that contain certain seasonal limits or other criteria for new water right applications. The proposed program of implementation calls for the State Water Board to consider additional FAS determinations to assist with implementation of the inflow, outflow, and cold water habitat objectives.

- **Recommendations to Other Entities**: Ecosystem recovery in the Delta depends on more than adequate flows. It also requires implementation of comprehensive complementary measures, including habitat restoration, fisheries management, control of waste discharges and invasive species, and other efforts by other agencies and parties in the watershed that are responsible for these actions. The proposed changes to the program of implementation would identify these other actions, including actions included in the Delta Stewardship Council's Delta Plan, and provides recommendations and direction to other agencies and parties for actions they should take to protect fish and wildlife beneficial uses. The proposed program of implementation would include provisions for the State Water Board to use its authorities to assist with implementation of these actions to the extent possible and includes provisions for reviewing the status of implementation of these other actions on a regular basis as part of the monitoring, reporting, and assessment process.

The State Water Board has provided several opportunities for public input on the Sacramento/Delta updates to the Bay-Delta Plan. The State Board has received valuable input from many interested persons, which has informed development of proposed changes to the Bay-Delta Plan and will be further considered through the planning process. The State Water Board has received comments on the following: the draft Science Report, the final Science Report (including comments from the ISB and an independent expert panel); general comments on the update to the Bay-Delta Plan solicited with release of the final Science Report; and comments on the notices of preparation of environmental documentation that have been prepared for this project. There will be further opportunities to comment on the upcoming draft Staff Report. Major themes from the recent request for comments on the Plan update are summarized below.

The State Water Board received input from several interested parties on the Science Report, including input from water users; environmental groups; and local, state, and federal agencies. In recognition of the vision for "one Delta, one science" articulated in the Delta Stewardship Council's Delta Plan, the State Water Board also requested that the Delta Independent Science Board conduct a review of the working draft version of the Science Report. The final version of the Science Report was also reviewed by five independent external scientific peer reviewers with a broad range of expertise who determined that the report is based on sound science.

The State Water Board sent a notice to water users in the Sacramento/Delta watershed and other interested persons in the fall of 2017, updating them on the Board's efforts related to potential changes to the Bay-Delta Plan for the Sacramento/Delta. An opportunity to provide early constructive input on potential changes to the plan, particularly focused on implementation measures, was also provided. The State Board received valuable input from many interested persons that have informed development of proposed changes to the Bay-Delta Plan discussed further below, that will be further considered through the planning process.

The State Water Board received comments supportive of providing time and flexibility to allow voluntary agreements and adaptive management to be considered as part of the update to the Bay-Delta Plan. Several commenters offered suggestions for existing adaptive management efforts that the proposed Plan amendments could utilize, including EcoRestore, the Collaborative Science and Adaptive Management Program, and the Central Valley Project Improvement Act Adaptive Resource Management. As described further above, the proposed Plan amendments provide for voluntary agreements and adaptive management.

The State Water Board received comments supportive of providing time and flexibility to allow voluntary agreements to be considered as part of the update to the Bay-Delta Plan. The proposed changes to the Bay-Delta Plan described above include provisions related to voluntary agreements. The Staff Report will provide an analysis of a range of proposed flows (35-75% of unimpaired flow) and potential nonflow measures that may support potential voluntary agreements. Local and State agencies may be able to rely upon those analyses to meet their environmental review requirements pursuant to the California Environmental Quality Act for decisions related to entering into voluntary agreements. Federal agencies may also be

able to incorporate or rely upon the Staff Report in part to meet their obligations under the National Environmental Policy Act.

There were also comments on the proposed approach related to the percent of unimpaired flow concept and the flexibility included in this concept to optimize fisheries benefits. Some commenters contend that this concept is not consistent with a "functional flow" approach. The proposed flexibility that would allow for sculpting and shaping of unimpaired flows pursuant to the proposed Plan amendments allows for and encourages implementation of a functional flow approach to the extent that information is available to do so. The approach also acknowledges that our understanding of functional flows is imperfect and that unimpaired flows may be a surrogate while that understanding is improving.

The State Water Board received several comments offering suggestions on improving the administration of the water rights system, including a suggestion that the State Water Board develop regulations for determining when water is available for diversion, similar to existing standard water right Term 91. There is general recognition that the State Water Board must be able to effectively administer the water right priority system to implement and enforce updates to the Bay-Delta Plan. The need for accounting of water rights and participation by other water users in implementing the Bay-Delta Plan became apparent during the recent drought of 2012-2016, when there were significant issues with maintaining water quality objectives and cold water storage, as well as issues with enforcing water right priorities in the watershed. The proposed program of implementation would prioritize efforts to develop appropriate accounting of flows and water rights, including determining the relative priorities of water rights and the quantities of water diversions under those rights to inform when water is available for diversion.

Several commenters, including parties currently responsible for Bay-Delta Plan implementation (DWR and Reclamation) also emphasized the need for all water users in the system to participate in implementing the Bay-Delta Plan. While DWR and Reclamation currently have primary responsibility for implementing the Bay-Delta Plan, that responsibility was established based on agreements and is interim and subject to change, especially to the extent that the Projects are releasing previously stored water to meet the objectives. With climate change, additional water demands in the Bay-Delta watershed, and new flow objectives, it will likely not be possible or equitable based on water right priorities for the Projects to continue to retain sole responsibility for Bay-Delta Plan objectives, particularly during dry periods. Likewise, assigning responsibility to only two water right holders will not protect fish and wildlife throughout the ecosystem. All water users throughout the Sacramento/Delta watershed, including diverters upstream of dams and in the Delta, would be subject to the proposed inflow, cold water habitat, and Delta outflow requirements for the Sacramento/Delta watershed (with the exception of *de minimis* diversions). With possible modifications for health and safety protections, drought provisions, or voluntary agreements, the objectives are proposed to be met in accordance with water right priorities and narrative objectives.

Comments were also received regarding the need to include measures in the proposed Plan amendments to address water supply management issues including drought provisions, coordination with SGMA, measures to ensure that refuge water supplies are provided, and funding mechanisms. As described further above, the proposed Plan amendments include provisions related to these issues.

Chapter 7   Next Steps

The State Water Board is currently in the process of preparing proposed changes to the Bay-Delta Plan for the Sacramento/Delta as well as a supporting draft Staff Report. The draft Staff Report will include a comprehensive analysis of the benefits and impacts of the proposed changes to the Bay-Delta Plan, including an assessment of alternatives. The draft will be made available for public review and comment later this year. Based on the public comments, the State Water Board will make any needed changes to the Staff Report and proposed Sacramento/Delta updates to the Bay-Delta Plan and provide responses to comments. The final Staff Report and proposed changes to the Sacramento/Delta updates to the Bay-Delta Plan will then be considered by the State Water Board at a public board meeting. The public will also have the opportunity to participate in that process.

Chapter 8   Additional Information

For additional information concerning the State Water Board's review of the Bay-Delta Plan, please visit the State Water Board's website at
http://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/.

If you would like to receive updates on the process to revise the Bay-Delta Plan please sign up for the State Water Board's "Bay-Delta Notices" email distribution list at
http://www.waterboards.ca.gov/resources/email_subscriptions/swrcb_subscribe.shtml.