Recommendations on Monitoring and Evaluating Interim Flows to the Upper San Joaquin River

Prepared for:
San Joaquin River Restoration Program Restoration Administrator
Ane D. Deister (RA 2008)
Roderick J. Meade (RA 2009)

Prepared by:
San Joaquin River Restoration Program Technical Advisory Committee

February 2009

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EXECUTIVE SUMMARY

The San Joaquin River Restoration Program Technical Advisory Committee (TAC) is required under the Stipulation of Settlement in *NRDC* v. *Rodgers* (CIV-S- 88-1658-LKK/GGH) (Settlement) to develop recommendations for implementation of a program of Interim Flows from Friant Dam in order to collect relevant data concerning flows, temperatures, fish needs, seepage losses, recirculation, recapture and reuse. The recommendations of the TAC are provided to the Restoration Administrator (RA) for consideration in preparing recommendations to the Secretary of the Interior for initial Interim Flow recommendations as required under the Settlement.

The Interim Flow recommendations are based on three objectives: (1) identify processes needed to refine annual Interim Flow and Restoration Flow releases, (2) identify short-term monitoring, modeling, and studies needed to address specific areas of uncertainty in implementing required actions of the Settlement, including refinement of Interim and Restoration Flows, and (3) identify baseline monitoring needed to document and refine management objectives, as well as assess the ecological and hydrologic responses to the Interim Flow releases. The TAC, which includes members from the California Department of Fish and Game (CDFG) and California Department of Water Resources (DWR), developed Interim Flow monitoring and evaluation recommendations for the following categories: Interim Flow processes, hydrology and hydraulics, water quality, fisheries, geomorphology, and riparian vegetation. The recommendations for each of these categories were developed based on the best available information, and are summarized below. The TAC recommendations were informed by technical discussions with federal implementing agencies. The recommendations in this document represent the independent work product of the TAC.

Interim Flow Process

Recommendation #1: Prior to March 31, 2009, the RA should, in consultation with the TAC and U.S. Bureau of Reclamation (Reclamation) staff, initiate a process for recommending 2009 Interim Flows and identify a process for developing annual Interim Flow releases that integrates monitoring information, seasonal hydrology from the upper watershed, water supply operations, experimental study needs, and ecological objectives.

Recommendation #2: Prior to June 30, 2009, the RA should, in consultation with the TAC and Reclamation staff, develop a preliminary release schedule for Interim Flows for the October 1-November 20, 2009 period. Following these releases, the TAC will review results and develop a preliminary release schedule for the February 1-February 28, 2010 period by December 31, 2009.

Recommendation #3: Prior to March 31, 2009, the RA should meet with Reclamation staff to review their plans for the recirculation, recapture, and reuse of Interim Flows.

Recommendation #4: The TAC should be provided an opportunity to review all study plans recommended below, and if needed, provide input and recommendations to the RA for suggested adjustments to those study plans to better inform Interim Flows.

Hydrology and Hydraulics

Recommendation #5: Water surface elevations should be measured over a range of flows in Reaches 1-5 to enable hydraulic model calibration and improve predictions of water surface elevation and inundation as a function of local streamflow.

Recommendation #6: Pulse flow releases should be used (within the scope of the Interim Flow releases) to test and calibrate the flow routing model, and evaluate hydraulic conditions (depth and velocity) for adult and juvenile fish passage/migration within the channel (riffles) and artificial structures (bifurcations, drop structures).

Recommendation #7: The existing network of streamflow gaging stations should be expanded to better document flows in each reach and better establish flow magnitude as a function of ecological and/or hydraulic management objectives.

Recommendation #8: Flow losses and gains should be evaluated using the streamflow gaging network in Recommendation #7, as well as shallow groundwater and seepage monitoring, to be prioritized in Reach 2A, Reach 2B, and the Eastside Bypass adjacent to Reach 4B.

Water Quality

Recommendation #9: Water temperatures should be continuously monitored in Millerton Lake at a variety of locations and depths to document changes to the cold-water pool as a function of water operations and meteorological conditions, and provide input/calibration data for the reservoir temperature model in Recommendation #10.

Recommendation #10: Further refinement of water temperature model(s) for Millerton Lake should be made to predict changes to the cold-water pool as a function of water operations and meteorological conditions, and provide upstream boundary conditions for the river temperature model in Recommendation #12.

Recommendation #11: Water temperatures should be continuously monitored in the San Joaquin River from Friant Dam to the Merced River confluence, and the Eastside Bypass adjacent to Reach 4B1 at a variety of locations to document water temperature as a function of Friant Dam releases, and provide input/calibration data for the river water temperature model in Recommendation #12.

Recommendation #12: Further refinement of water temperature model(s) for the San Joaquin River from Friant Dam to the Merced River confluence should be made to predict changes in river water temperatures as a function of meteorological conditions, riparian vegetation, flow releases from Friant Dam, downstream flow routing paths, flow losses and gains, and channel geometry.

Recommendation #13: Water temperatures should be continuously monitored in Reach 1 gravel mining pits connected to the San Joaquin River at a variety of locations and depths to document how gravel mining pits affect water temperature as a function of Friant Dam releases and pit morphology.

Recommendation #14: A reconnaissance-level water temperature survey should be conducted in the late spring and/or early fall to evaluate thermal features (cold-water refuges, warm water contributions) between Friant Dam and the Merced River confluence.

Recommendation #15: Additional water quality parameters should be measured continuously and/or through grab sampling in the San Joaquin River from Friant Dam to the Merced River confluence at a variety of locations to document dissolved oxygen, turbidity, pH, conductivity, and other water quality parameters.

Recommendation #16: The results of water quality monitoring should be used to assess potential impacts to health and survival of salmon and other native fish species based on the biological response to water quality conditions available in the scientific literature.

Fisheries

Recommendation #17: A study plan should be developed and implemented that assesses the relationships between fish habitat availability and flow in Reaches 1-5. Components of this study plan should include:

- Habitat suitability criteria initially obtained from studies on Central Valley rivers that define "suitable" habitat for target species and life stages in the San Joaquin River.

- Habitat rating curves developed from field studies in Reach 1 and numerical computations that estimate the amount of suitable habitat as a function of local flow magnitude.

- Flow-to-inundated surface area rating curves in Reaches 2-5 as a function of local flow magnitude to identify areas that satisfy depth criteria for juvenile salmon emigration and rearing.

- Habitat availability developed by integrating habitat or inundated surface area rating curves with seasonal water quality data to define how much habitat is actually available for target species and life stages.

Recommendation #18: Spawning gravel availability should be re-quantified in Reach 1 early in the Interim Flow period.

Recommendation #19: A spawning gravel quality assessment study plan should be developed and implemented in Reach 1A early in the Interim Flow period.

Recommendation #20: Fall-run adult and juvenile Chinook salmon test fish should be introduced into Reach 1 during the Interim Flow period, and their use of existing habitat be monitored to gain insight into the future responses of reintroduced Chinook salmon and potential habitat restoration actions.

Recommendation #21: In combination with Recommendation #6, hydraulic conditions should be monitored in the Reach 4B1 channel (once reactivated), Eastside and Mariposa bypasses adjacent to the Reach 4B1 channel, and at various structures in the bypasses and river to evaluate suitability for adult and juvenile Chinook salmon passage.

Recommendation #22: Fish surveys should be conducted in Reaches 1-5 early in the Interim Flow period (spring-summer 2010) to document baseline species composition, distribution, and abundance of resident fish.

Recommendation #23: More detailed fish surveys should be conducted in Reach 1 gravel mining pits connected to the river to quantify species composition, distribution, and abundance of species known to prey on juvenile salmon.

Recommendation #24: A study plan should be developed and implemented that further evaluates potential predation impacts of non-native fish species on juvenile salmonids, and once Chinook salmon are reintroduced to the San Joaquin River, monitoring should be conducted to evaluate predation of juvenile Chinook salmon.

Recommendation #25: A baseline assessment of the benthic macroinvertebrate community should be conducted in all reaches (with emphasis in Reach 1) to assess potential food supplies for juvenile Chinook salmon.

Geomorphology

Recommendation #26: Field-based bed mobility studies should be initiated in Reach 1A to document flow thresholds that initiate movement of different bar surfaces during flood control releases, and Interim Flows and Restoration Flows (during wetter water years once channel capacity constraints have been removed).

Recommendation #27: Field-based bedload transport measurements should be conducted in Reach 1A in the event of flood control releases, and during Interim Flows and Restoration Flows, to document sand, gravel, and cobble transport rates as a function of flow.

Recommendation #28: Baseline topographic surveys should be conducted in Reach 2A, Reach 2B, and the upstream-most 5 miles of Reach 3 to enable future evaluation of potential channel incision or deposition during high flow events.

Riparian Vegetation

Recommendation #29: A subset of the 125 riparian vegetation transects in Reaches 1-5 should be re-sampled to evaluate if substantial changes have occurred between 2000 and present. If substantial changes are observed, the remainder of transects should be monitored, along with a new riparian vegetation map using 2008 aerial photos as a basemap, to establish baseline conditions to document future changes anticipated from Settlement implementation.

Recommendation #30: A 1-D hydraulic model should be developed and coupled with a riparian initiation/establishment model to predict riparian initiation, establishment, and evolution over time under various time series scenarios, as well as to refine daily flow releases from Friant Dam during Wet water years to better achieve natural riparian regeneration on target floodplain surfaces.

Recommendation #31: Three monitoring sites should be established for three years in Reach 1, Reach 3, and Reach 5 to document annual and inter-annual riparian seed dispersal magnitude, duration, and timing.

While these recommendations are all inherently "high priority," the highest priority tasks are those that inform Interim Flows, Reach 4B management, and other specific tasks listed in the Settlement. The TAC realizes that these recommendations represent a substantial amount of work, and may exceed staff and financial resource capability of the Program to fully implement. To provide some additional guidance to the RA, the TAC recommends that the highest priority is developing coordination processes, predictive tools, and studies to inform Interim Flows and Reach 4B management, including:

- Processes for developing annual Interim Flow recommendations;
- Water Temperature Models;
- Flow-habitat Evaluations;
- Juvenile salmonid predation and implications to gravel mining pit restoration; and,
- Opportunistic data collection during flood control releases (geomorphology and riparian issues).

In addition, the TAC recommends additional discussions involving the RA, Federal liaisons, and state agencies to identify the extent of recommended tasks/work products that realistically can be expected to be completed in 2009 and 2010 given Program budgets and Settlement schedule requirements. To the extent feasible, these future discussions with Federal liaisons should: (1) develop additional detail on methods, spatial extent, and temporal scale via study plans or scopes of work; (2) develop cost and Program staff time estimates based on these scopes of work; and (3) evaluate staff and budget needed to implement these recommendations with respect to available resources and other workload priorities. The TAC will continue to provide technical assistance to the RA during these discussions.

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1 INTRODUCTION

The San Joaquin River Restoration Program Technical Advisory Committee (TAC) is required under the Stipulation of Settlement in *NRDC* v. *Rodgers* (CIV-S- 88-1658-LKK/GGH) (Settlement) to develop recommendations for implementation of a program of Interim Flows in order to collect relevant data concerning flows, temperatures, fish needs, seepage losses, recirculation, recapture and reuse. The recommendations of the TAC are provided to the Restoration Administrator (RA) for consideration in preparing recommendations to the Secretary of the Interior for initial Interim Flow recommendations as required under the Settlement. The TAC will review studies, data collection, and other activities undertaken by the implementing agencies during the Interim Flows to provide additional recommendations to the RA as necessary.

1.1 Interim Flow Definition and Phasing

Interim Flows as required by the Settlement are flow releases from Friant Dam that begin in October 2009 and end at the commencement of Restoration Flows (no later than January 1, 2014). The Interim Flows are to be of the approximate timing and magnitude as defined in the appropriate year type hydrograph and within the volumetric limits as defined by the Settlement. The purpose of the Interim Flows is to provide information to inform and improve implementation of the Settlement to achieve the two primary goals of the Settlement:

1. *Restoration Goal*: restore and maintain fish populations in good condition in the main stem of the San Joaquin River below Friant Dam to the confluence of the Merced River, including naturally-reproducing and self-sustaining populations of Chinook salmon and other fish.

2. *Water Management Goal*: Reduce or avoid adverse water supply impacts to all of the Friant Division long-term contractors that may result from the Interim Flows and Restoration Flows.

The Interim Flow period is also a transition into implementation of the Restoration Flow hydrographs (Figure 1). The magnitudes of releases within each Restoration Flow hydrograph vary among seasons of the year to respond to the life history and habitat requirements of Chinook salmon. The conceptual relationship between the seasonal characteristics of the hydrograph and the life history of Chinook salmon is presented in Figure 2. The Interim Flow period will allow time for downstream channel and infrastructure improvements to be constructed, as well as regulatory compliance, legislation, and legal requirements to be addressed. Accordingly, Paragraph 15 of the Settlement defines initiation of Interim Flows as follows:

(a) In 2009, release flows from October 1 through November 20 of a timing and magnitude as defined in the appropriate year type hydrograph in Exhibit B, and without exceeding the then existing channel capacities;

(b) In 2010, release flows from February 1 through December 1 of a timing and magnitude as defined by Exhibit B for the appropriate year type, and without exceeding the then existing channel capacities;

(c) In 2011 and 2012, assuming in-channel construction begins May 1 of any given year, release flows from February 1 through May 1 of a timing and magnitude as defined by Exhibit B for the appropriate year type, and without exceeding the then existing channel capacities. From May 1 through September 1, release flows to wet the channel down to the Chowchilla Bifurcation Structure to collect information regarding infiltration losses;

(d) In subsequent years, if the highest priority channel improvements identified in Paragraph 11(a) are not completed, release flows for the entire year of a timing and magnitude as defined by Exhibit B for the appropriate year type, without exceeding the then existing channel capacities or interfering with any remaining in-channel construction work on the highest priority Paragraph 11 improvements.

The legislation introduced to authorize the Settlement includes specific requirements and conditions that must be met prior to release of any Interim Flows. These requirements include establishment of a seepage monitoring program, an evaluation of possible impacts associated with the release of Interim Flows, and mitigation measures for any significant impacts.

Developing an effective restoration program for anadromous salmonids on the San Joaquin River requires that a number of uncertainties and potentially limiting factors affecting salmon within the river be identified and addressed. The Settlement acknowledges that additional information needs would be addressed through experiments conducted during the Interim Flow period beginning in October 2009 and continuing until full Restoration Flows begin.

1.2 Spatial Extent

The spatial extent of these recommendations ranges from the upstream extent of Millerton Lake downstream to the Merced River confluence, including the Chowchilla, Eastside, and Mariposa bypasses. Monitoring recommendations for water temperature and other parameters are constrained to reaches upstream of the Merced River confluence; however, some assessment and coordination with resource agencies and water managers in downstream reaches will likely be needed to assess potential effects of Settlement flow releases on water temperatures and water quality downstream of the Merced River.

1.3 Temporal Extent

The Interim Flow period begins October 1, 2009, and can end as soon as channel improvements and other requirements are met to enable implementation of Restoration Flows, which are to occur no later than January 1, 2014. This document provides more detailed recommendations for the early portion of the Interim Flow period (Water Year 2010 and 2011), but in several instances, extends recommendations later in the Interim Flow period. As Interim Flows are released, information is gained, and uncertainties are addressed, additional recommendations are likely to be required during the Interim Flow period.

Therefore, although this report summarizes initial recommendations on Interim Flows, the TAC anticipates that these recommendations will need to be reviewed, re-evaluated, refined, and potentially expanded. This process should be a component of the annual flow development process described in Section 3.1; however, if the TAC recognizes an immediate need or opportunity, the TAC will make recommendations to the RA at that time.

1.4 Topic Extent

As described in TAC recommendations on restoring spring-run and fall-run Chinook salmon to the San Joaquin River (TAC 2007 and 2008), achieving the Restoration Goal described in Section 1.1 prioritizes spring-run Chinook salmon, but restoration actions that benefit spring-run Chinook salmon will benefit other native fish species, including fall-run Chinook salmon, steelhead, lamprey, and other species. In addition, TAC recommendations reflect an interdisciplinary approach to achieving the Restoration Goal that includes fish biology, hydrology, geomorphology, terrestrial biology, water project operations, engineering, geohydrology, water quality, recirculation, recapture and reuse.

1.5 Expected Benefits and Uses of Interim Flow Information

The Interim Flow period provides an opportunity to collect information that will improve implementation of actions to achieve the Restoration Goal and Water Management Goal by:

- Reducing scientific uncertainties;
- Providing information needed to enable real-time flow management;
- Identifying refinements to the existing flow and water quality monitoring program;
- Providing information to inform decisions on fish migration pathways (e.g., Reach 4B versus Eastside Bypass) and design of physical facilities (e.g., headgates, channel modifications) to better achieve flow routing and fish migration objectives;
- Providing information that will shape and refine the seasonal instream flow releases (hydrographs) under inter- and intra-annual variation in hydrology, including the decision process necessary to accommodate hydrologic and forecasting uncertainties;
- Providing information that will assist planning and decisions regarding potential mechanisms for recirculation, recapture, and reuse;
- Identifying additional information needed prior to reintroduction of salmon into the river;
- Providing baseline information upon which future changes can be documented; and,
- Establishing a foundation for future management decisions and program refinements as part of long-term adaptive management for the river within the terms of the Settlement.

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2 GOAL AND OBJECTIVES

As stated in Section 1.1, a goal of the Interim Flows is to provide information to inform and improve implementation of the Settlement to achieve the Restoration and Water Management Goals of the Settlement. Therefore, recommendations on Interim Flows were developed to satisfy the following three objectives:

Objective # 1: Identify planning and coordination processes needed to refine annual Interim Flow and Restoration Flow releases;

Objective #2: Identify short-term monitoring and studies needed to address specific areas of uncertainty in implementing the Settlement, including testing and refining the Settlement hydrographs shown in Figure 1; and

Objective #3: Identify baseline monitoring needed to document whether ecological and hydrologic management objectives of the Interim Flow and Restoration Flow releases are being achieved.

The TAC developed recommendations on Interim Flows based on the best available information. These recommendations first develop a planning and coordination process necessary to develop annual recommendations on Interim Flow releases (Objective #1). Subsequent recommendations are organized into data collection and analyses that address Objectives #2 and #3: (1) hydrology and hydraulics that affect habitat and migration for salmon and other aquatic resources; (2) water quality, including water temperatures and other parameters that affect habitat suitability for salmon and other aquatic resources; (3) fisheries, including relationships between flow and fish habitat, spawning gravel quantity and quality, habitat use, fish passage, and fish and benthic macroinvertebrate assemblages; (4) physical processes, including bed mobility thresholds, coarse and fine sediment transport rates, and channel incision and deposition; and (5) riparian vegetation, including baseline surveys and predictions of flow releases to improve natural riparian regeneration. Each of these data collection and analysis methods are discussed in more detail in Sections 4-8 of this report.

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3 INTERIM FLOW DEVELOPMENT PROCESS

3.1 Information Gathering, Analysis, and Coordination Process

Refining the restoration hydrographs, developing an implementation plan for the Interim Flows, and developing Restoration Flow Guidelines require a number of considerations. These include, but are not limited to, establishing triggers and a hydrologic basis for predicting water-year type or hydrologic conditions that would be used to develop and manage appropriate releases (Figure 1). Information is needed on (a) seasonal timing of pulse flows for migration, (b) magnitude and duration of pulsed migration flows, including flow attenuation effects on Chinook salmon migration, (c) resulting fish habitat conditions within the river in response to different flow releases, and (d) management of low flows together with other seasonal flows (e.g., flood control releases) for fish and habitat restoration/maintenance. Many of these issues require additional analyses of seasonal hydrology within the watershed, with refinements made to the restoration hydrographs (within the confines of the Settlement) based on information collected in other elements of the Interim Flow program.

The TAC recommends that prior to March 31, 2009, the RA should, in consultation with the TAC and Reclamation staff, initiate a process for developing annual flow releases that integrates monitoring information, seasonal hydrology from the upper watershed, hydrologic forecasts, water supply operations, experimental study needs, and ecological objectives [**Recommendation #1**]. Using this process, the TAC recommends that prior to June 30, 2009, the RA should, in consultation with the TAC and Reclamation staff, develop a preliminary release schedule for Interim Flows for the October 1-November 20, 2009 period. Following these releases, the TAC will review results and develop a preliminary release schedule for the February 1-February 28, 2010 period by December 31, 2009 [**Recommendation #2**]. The experimental schedule should be developed to include flow releases that allow for evaluation of relationships between flow and various ecological objectives (e.g., temperature, habitat, inundated area), and to test specific hypotheses that can reduce scientific uncertainty in management actions to achieve the Restoration and Water Management Goals. The TAC has identified the process of collaboratively developing an experimental flow schedule for the Water Year 2010 Interim Flow investigations as a high priority. The TAC acknowledges that the process used in developing the Interim Flow investigations, and the linkage to the flow schedule, will serve as a basis for developing and refining the testing protocol, experimental design, and flow schedules to be tested in subsequent years of the Interim Flow element of the program, as well as Restoration Flows that are scheduled to begin no later than January 1, 2014.

3.2 Recirculation, Recapture and Reuse Process

The Settlement requires that relevant data on flow recirculation, recapture, and reuse be collected during the Interim Flow period. As part of planning and implementation of Interim Flows, the TAC assumes that Reclamation will develop and implement a plan to increase recirculation, recapture, and re-use opportunities for water released from Friant Dam during this Interim Flow period. The TAC recommends that, prior to March 31, 2009, the RA meet with Reclamation staff to review their plans for the recirculation, recapture, and reuse of

Interim Flows [**Recommendation #3**]. Elements should include: locations for recovery or recapture; physical mechanisms for recirculation and reuse; identification and resolution of institutional, legal, conveyance, and infrastructure constraints; and monitoring and accounting for water supply losses and returns as part of the development of the Recovered Water Account.

3.3 Study Plan Review Process

There are many scientific uncertainties and information gaps addressed by recommendations in the following sections. Several of these require study plans to be developed prior to implementing monitoring, studies, or research to address those uncertainties or information gaps. Therefore, the TAC recommends that they be provided an opportunity to review study plans recommended in the following sections, and if needed, provide input and recommendations to the RA on suggested adjustments to those study plans to better inform Interim Flows [**Recommendation #4**].

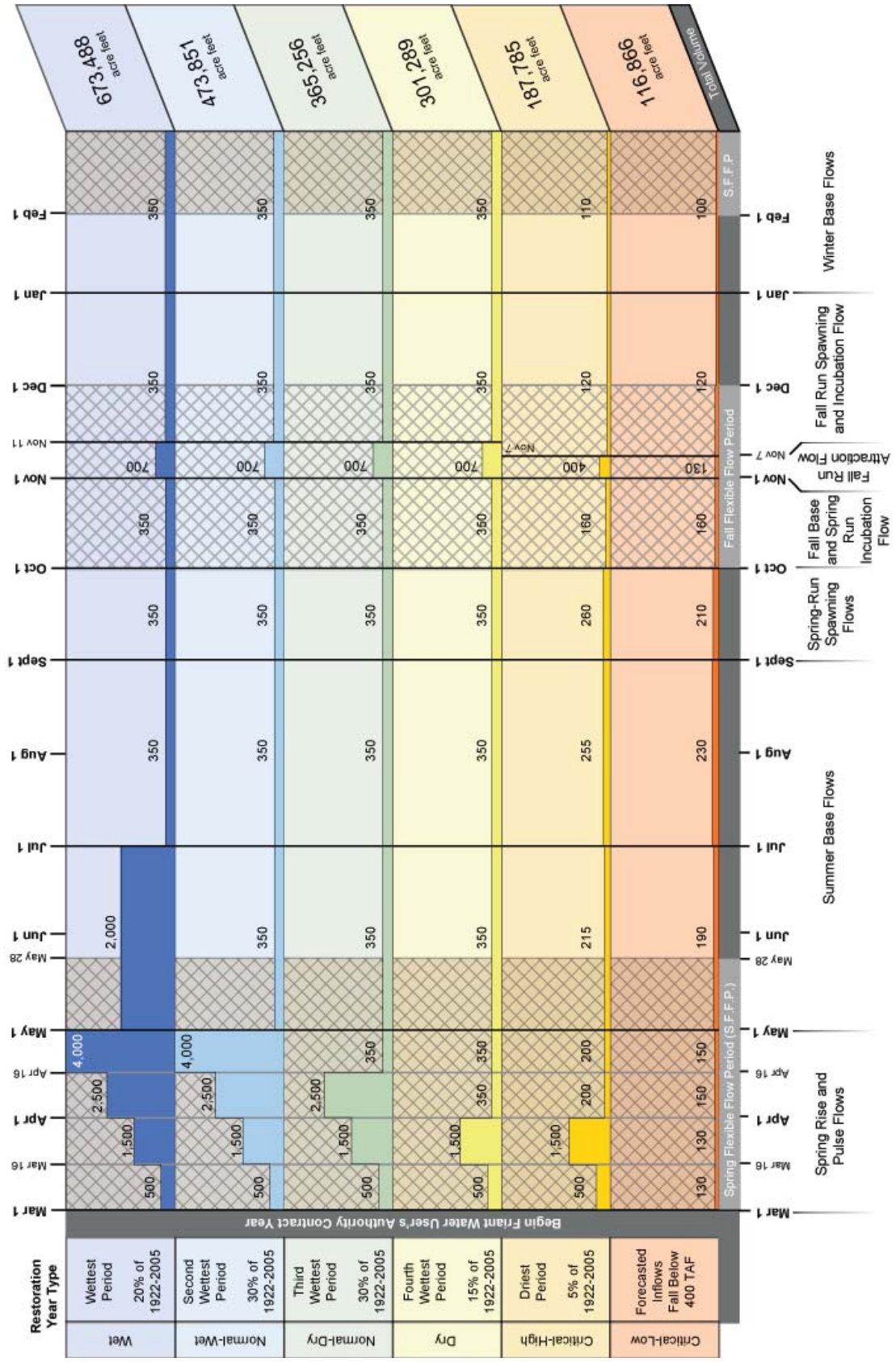

Figure 1. San Joaquin River Settlement Agreement Restoration Flow Hydrographs.

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4 HYDROLOGY AND HYDRAULICS

4.1 Hydraulic Model Calibration

One-dimensional and two-dimensional hydraulic models are currently being developed that will predict water depths, water velocities, water surface elevations, and other hydraulic parameters in Reaches 1-5 of the San Joaquin River. The models will enable predictions of these hydraulic variables as a function of flow under current conditions and various possible future conditions (i.e. restoration activities). Topographic information is one important data requirement needed to develop these models; another is hydraulic roughness imposed on the flow by the bed surface grains, bars, vegetation, and planform of the river. The predictive capability of hydraulic models is improved if roughness values are consistent with field conditions.

Therefore, the TAC recommends that when opportunities occur via Interim Flow releases or flood conditions, water surface elevations over a range of flows from 300 cubic feet per second (cfs) up to 8,000 cfs (within existing channel capacity) be surveyed during the Interim Flow period to enable calibration of the hydraulic models and improve their predictive capability [**Recommendation #5**]. Reaches with flood conveyance limitations (e.g., Reach 2B), higher risk of flood-induced risk to residential areas (e.g., Reach 3), and reaches with large scale opportunities for juvenile salmon rearing habitat and natural riparian regeneration should be prioritized.

4.2 Pulse Flow Hydrodynamics

Successful upstream migration by adult Chinook salmon and downstream migration by juveniles is a fundamental element of the restoration program. The hydrographs include pulsed flows of various magnitudes and durations to attract adult spring-run and fall-run Chinook salmon (Figure 1), and to provide flows that allow unimpeded migration from the confluence with the Merced River to Friant Dam (Figure 2). However, uncertainty exists regarding flow attenuation that would occur, water depths and velocities at critical riffles and structures as a function of releases from Friant Dam, migration rates of adult and juvenile salmon, attraction flow cues for migration, water temperatures during the fall period of adult fall-run salmon migration, and water temperatures during the spring period of adult and juvenile spring-run salmon migration and juvenile fall-run salmon emigration.

To better understand these uncertainties, the TAC recommends that experimental releases be designed as part of the Interim Flow program that can be used to test and evaluate pulse flow dynamics and fish passage [**Recommendation #6**]. The TAC recognizes that the ability to conduct these investigations as part of the Interim Flow program will be constrained by conveyance limitations within various reaches of the river, with the greatest constraint currently being that flows cannot be introduced into Reach 4B. The flows that would be used to test this element of the restoration hydrographs will be managed within the constraints imposed by channel conveyance. Developing an experimental flow schedule that effectively tests the relationship between releases from Friant Dam and fish passage/migration conditions, seasonal water temperatures throughout the migration corridor, and other relationships will

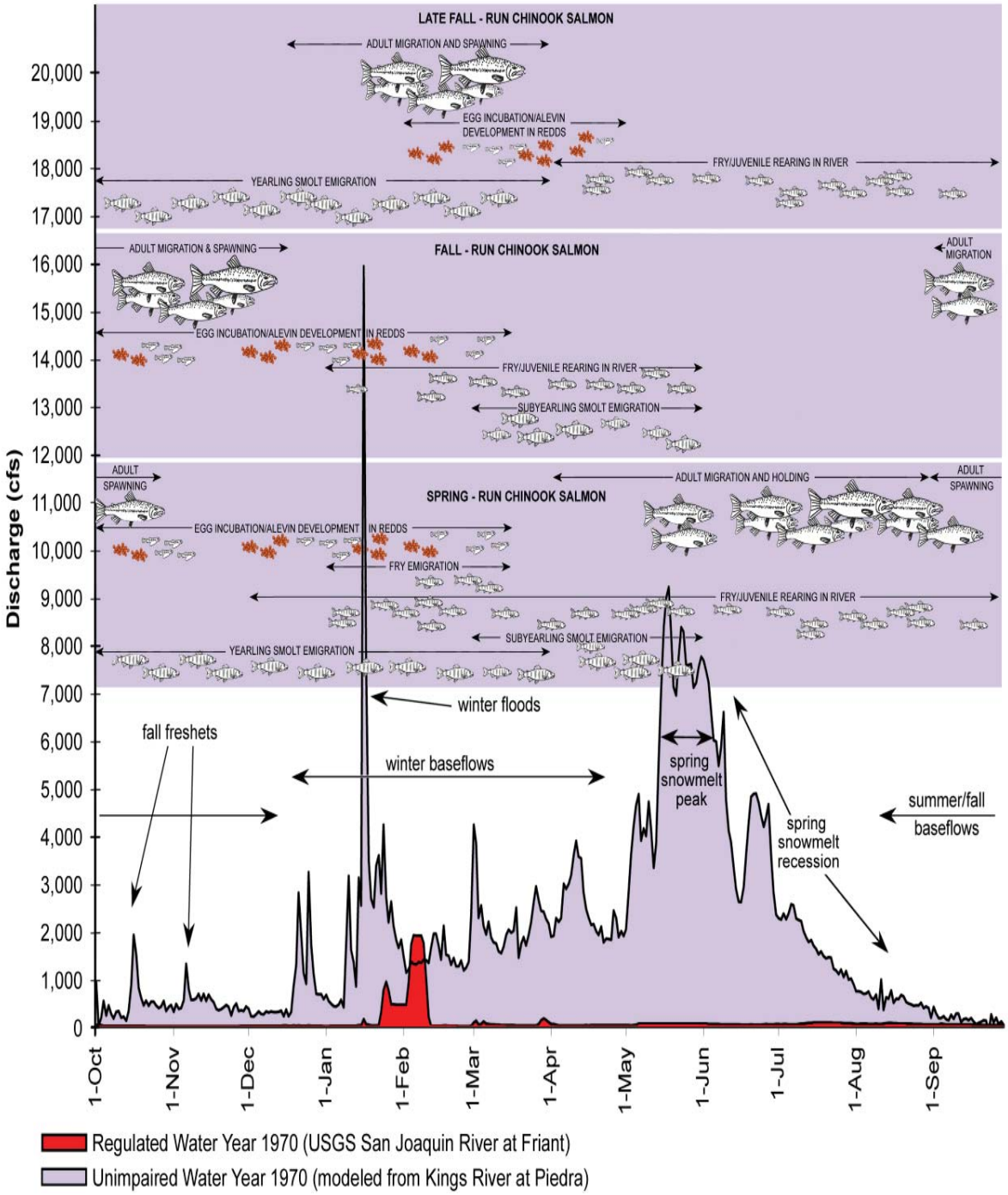

Figure 2. Conceptual model of relationship between river flow for an example water year and Chinook salmon life histories, showing timing of different life stages for potential runs of Chinook salmon to be reintroduced and relationship to unimpaired hydrograph components.

require further consideration as part of developing the experimental flow schedule for the 2010 and/or 2011 Interim Flow investigations. The fish passage assessment should focus on adult and juvenile Chinook salmon passage needs, but other native species should also be considered (e.g., lamprey, steelhead, native minnows).

4.3 Flow Rate Monitoring

River flow rates need to be measured at locations along the longitudinal gradient of the river to assess habitat conditions (water depth, velocity), as well as flow accretions and depletions (including both seepage and water diversions). Information on river flows can be used to help refine seasonal hydrographs, design conveyance facilities, relate performance measure response (e.g., fish habitat, bed mobility) to local flow conditions, ensure compliance with Interim Flow and Restoration Flow decisions, and develop predictive models of flow-habitat relationships.

The extent and location of existing flow monitoring gaging stations has been critically reviewed by the TAC with respect to information gathering during the Interim Flow period, and the TAC recommends the following priority stream gaging stations be continued (for "existing" gages) or installed (for "new" gages) at least through the Interim Flow period (Figure 3) [**Recommendation #7**]:

- Permanent gaging station immediately below Friant Dam to document actual flow releases from Friant Dam (existing gage);
- Permanent gaging station at Gravelly Ford to document flows entering Reach 2A (existing gage);
- Temporary gaging station immediately above Chowchilla Bifurcation structure to better document Reach 2A flow losses (new gage);
- Permanent gaging station immediately below Chowchilla Bifurcation structure to document flows entering Reach 2B and better document Reach 2B flow losses (upgrade existing gage);
- Temporary gaging station immediately above Mendota Pool backwater or at San Mateo Crossing to better document Reach 2B flow losses (new gage);
- Permanent gaging station immediately below Mendota Dam to document flows entering Reach 3 and to better document Reach 3 flow losses/gains (existing gage);
- Permanent gaging station immediately below Sack Dam to document flow rates entering Reach 4A and to better document Reach 3 flow losses/gains (new gage);
- Permanent gaging station immediately below Reach 4B headgate to document flow rates entering Reach 4B and to better document flow losses/gains in Reach 4A and 4B (new gage);

- Permanent gaging station in the Sand Slough Control Structure to document flow rates entering the Eastside Bypass and to better document Reach 4A flow losses/gains (new gage);

- Permanent gaging station immediately below Mariposa Bypass confluence to document flow rates entering Reach 4B2 as flows are returned via Mariposa Bypass (new gage);

- Permanent gaging station immediately downstream of the Eastside Bypass confluence to document flow rates entering Reach 5 (existing gage);

- Permanent gaging station between Salt Slough and Mud Slough to estimate flow contributions from Salt Slough and Mud Slough into Reach 5 (existing gage); and,

- Permanent gaging station immediately upstream of the Merced River confluence to estimate flow contributions from Mud Slough and document flow rates exiting Reach 5 (new gage).

These gages should be installed prior to initiating Interim Flows. Streamflow gages should be installed, operated, and maintained per USGS protocols. Streamflow measurements should be collected over the full range of flows to ensure high quality rating curves, develop appropriate rating curve shift corrections, and provide good quality streamflow estimates. Stage data should be collected on a 15-minute interval to document instantaneous maximum floods, as well as enable computation of daily average flows. In addition to basic documentation of flows in different reaches and documentation of flow losses/gains in those reaches, the gaging stations will provide accurate flow values to relate to other variables (e.g., water temperatures, water elevations, geomorphic processes, fish habitat).

4.4 Flow Losses and Gains

Local groundwater conditions, groundwater overdraft, riparian diversions/pumping, and agricultural return flows affect flow losses and gains in different reaches of the San Joaquin River. The streamflow gaging network described above provides reach-scale documentation of flow gains and losses; however, more detail is needed in certain reaches where impacts are more severe. One of the most important reaches is Reach 2A, where groundwater overdraft has reduced the groundwater table elevation by nearly 80 ft (McBain & Trush 2002). Previous short-duration experimental flow releases have shown that flow losses in Reach 2A can be as high as 100 cfs. There is considerable uncertainty in flow losses in this reach under different antecedent conditions. If the Eastside Bypass is used to route fish around the upstream half of Reach 4B during baseflow periods, documentation of flow losses in the bypass would be important.

Therefore, the TAC recommends assessing flow losses in the lower portion of Reach 1B, the entirety of Reach 2A, and the upstream portion of Reach 2B, Reach 4, and Eastside Bypass [**Recommendation #8**]. The streamflow gaging network described above will provide reach-wide estimates of flow losses. However, the TAC also recommends more detailed synoptic flow measurements as needed to better understand local deviations in flow losses through

these reaches. The TAC also recommends that the shallow groundwater table elevations be monitored at locations along the longitudinal gradient of these reaches to assess relationships between river flow, shallow groundwater table elevation, and seepage losses. The monitoring efforts conducted as part of the Pilot Program in the early 2000's (FWUA and NRDC 2002) should be reinitiated and conducted through the Interim Flow period. Information on the rate of accretions and depletions in channel flows is important in refining the restoration hydrographs, developing the water temperature model, and modeling hydraulic conditions expected to occur (e.g., floodplain inundation, water depths, velocities, etc.) as a function of releases from Friant Dam. Rates and patterns of accretions and/or depletions may vary in response to antecedent conditions, flow equilibrium, groundwater recharge rates (e.g., continuous surface water flows over a long period of time may result in hydraulic equilibrium between the river and groundwater), and river flow rates. Information on changes in groundwater conditions in response to restoration flows is also important in assessing levee seepage conditions and potential effects on local land use.

By March 1, 2009, the TAC will review the specific locations of existing groundwater monitoring wells along the river channel, as well as those installed as part of the Pilot Program (FWUA and NRDC 2002) and will recommend, if needed, additions or modifications to the monitoring system that should be installed prior to the Interim Flow releases. Evaluating seepage losses is a high priority and the TAC recommends that streamflow measurements be made to document flow gains/losses in different reaches during the Interim Flow releases, and conduct field reconnaissance during those releases to identify areas where seepage is occurring. If merited by the results and observations of Water Year 2010 monitoring, further consideration should be given to experimental flow releases and/or streamflow monitoring to evaluate seepage issues and test flow accretion/depletion relationships.

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5 WATER QUALITY

5.1 Reservoir Temperatures

River water temperatures are defined by or greatly influenced by the temperature of water as it is released from Millerton Lake. Providing water temperatures adequate for salmonid restoration will require an adequate cold-water pool within Millerton Lake. There is concern that some hydrologic conditions may reduce the cold-water pool to a point where undesirable warmer water is released to the river. Therefore, the TAC recommends that the water temperature monitoring currently being conducted in Millerton Lake to document seasonal changes in the cold-water pool be continued [**Recommendation #9**]. Water temperature profiles of Millerton Lake should assess the volume of the cold-water pool and changes in cold-water pool volume in response to atmospheric conditions (including monitoring weather conditions such as air temperature and wind speed), reservoir inflow, releases, diversions, and reservoir storage. The TAC recommends that these data and assessments be used to refine the water temperature model for Millerton Lake to predict changes to the cold-water pool as a function of water operations and meteorological conditons [**Recommendation #10**]. The location of existing water temperature monitoring gages (thermistors) and the need to install additional thermistors to monitor conditions within Millerton Lake will be critically reviewed by the TAC by March 31, 2009, and additional thermistors will be recommended, if needed, prior to initiating Interim Flows.

5.2 River Temperatures

Adequate spatial and seasonal river water temperatures will be key to establishing naturally reproducing, self sustaining salmon populations. There are numerous challenges in managing water temperatures suitable to salmon in certain reaches at certain times of the year. In addition, there is considerable uncertainty in the accuracy of predictions of water temperature as a function of flow release and distance downstream of Friant Dam, the role of gravel pits and bypasses in these longitudinal relationships, and future conditions resulting from physical and riparian restoration efforts.

Therefore, the TAC recommends that water temperature be continuously measured at locations along the longitudinal gradient of the river (both fixed locations and supplemental monitoring locations responding to specific experimental conditions) to assess relationships among flow, meteorological conditions, seasonal water temperature, and habitat suitability for various Chinook salmon life stages [**Recommendation #11**]. Temperature monitoring results will be used to assess habitat quality and distribution within the river, as well as to refine the water temperature model developed by Reclamation to evaluate the effects seasonal water releases, meteorological conditions, riparian vegetation, flow routing, and channel morphology have on salmon habitat and survival [**Recommendation #12**]. The water temperature model will also need metrological data (air temperature, relative humidity, etc), and these data should be readily available from nearby CIMIS weather stations (e.g., Madera, Firebaugh, Los Banos). The TAC has reviewed the location of existing thermistors and considered additional thermistor needs to monitor conditions within various reaches of the river. Table 1 summarizes TAC recommendations on priority thermistor placement

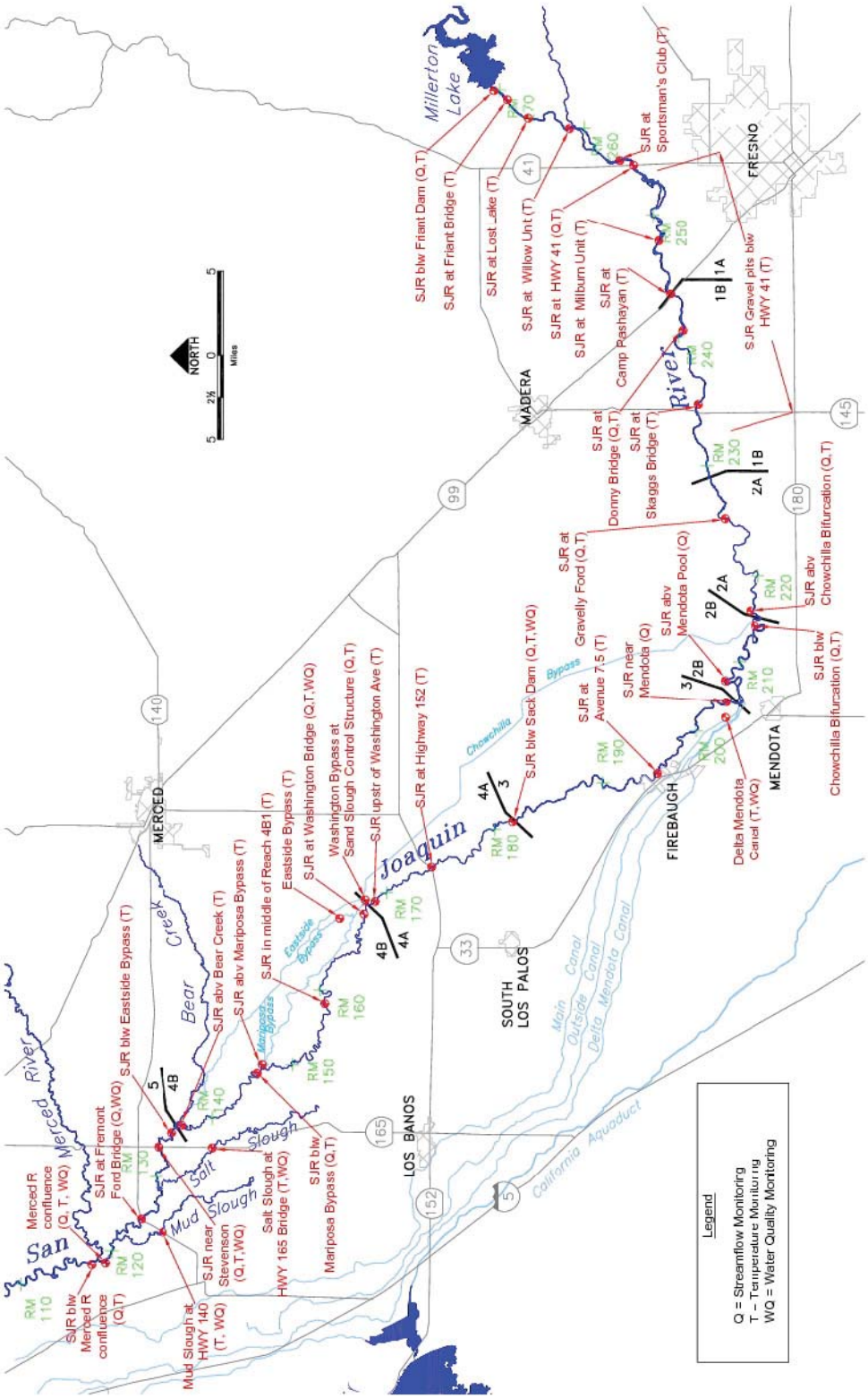

Figure 3. TAC recommendations on streamflow, water temperature, and water quality monitoring locations from Friant Dam to the Merced River confluence at the initiation of the Interim Flow period.

locations for monitoring water temperatures through the Interim Flow period, most of which have already been installed by DWR, Reclamation, USGS, or CDFG. All thermistors should be programmed on a 15-minute increment to gather daily average, daily maximum, and daily minimum temperatures, and remain in the stream year-round. The TAC also recommends that the thermistors be doubled up (but in slightly different locations) to ensure consistency in temperature readings and reduce risk of data gaps due to scour, damage, theft, or vandalism. The TAC recommends that an array of thermistors be placed in one or more gravel pits between Lanes Bridge and Skaggs Bridge to document thermal effects of the gravel pits, and support initial evaluations of fish species that prey on juvenile salmon [**Recommendation #13**]. Five to ten thermistors should be placed laterally across the pits to document spatial differences due to mixing/stagnation, and several thermistors should be placed vertically to evaluate whether thermal stratification is occurring. A specific monitoring plan should be developed.

Results of existing and additional monitoring during the Interim Flow period will provide important information on flow-temperature relationships at the locations listed in Table 1 for the flow and meteorological conditions experienced during the monitoring period; however, future management of flows, channel morphology, and riparian vegetation will need the ability to predict water temperatures under different flow and meteorological conditions. Therefore, the TAC recommends that a water temperature model be developed between Friant Dam and the Merced River. Water temperature monitoring information collected from the river during the Interim Flow program, in combination with information on local weather conditions, groundwater accretions and depletions, and coldwater pool dynamics within Millerton Lake, will provide the foundation for developing and calibrating this model. The temperature model should be used to test the effects of various restoration hydrographs on habitat suitability for salmon and other aquatic species. Data collected on actual water temperature responses to changes in flows and environmental conditions will be used to calibrate and validate model predictions. Results of the temperature modeling will be used, in combination with information on habitat suitability as a function of water temperature for the various life stages of salmon, to provide an important element in refining the restoration hydrographs. Based on the sensitivity of salmon to seasonal water temperatures and exposure of the lower San Joaquin River to hot conditions during the spring, summer, and fall, the TAC recommends that water temperature monitoring and modeling be given a high priority in the design and implementation of the Interim Flow investigations.

5.3 In-River Thermal Features

Studies conducted in other California rivers have shown that there are often local thermal "anomalies" along the river that deviate from mean water temperatures as the result of local input of groundwater, tributary flow, agricultural return flows, and hyporheic flows. Cool water upwelling from groundwater or hyporheic flows can create thermal refuges during warm meteorological conditions, which can provide important habitat for salmon during egg incubation, juvenile rearing, and migration. Water temperatures in Reach 1 should be adequate for salmon habitat use due to releases from the cold-water pool in Millerton Lake. However, the water will quickly warm as it travels downstream during the spring and summer months, and the existence of thermal refuges in downstream reaches, particularly in Reaches

3-5, has not been evaluated. If these refuges exist and are of sufficient extent, they could be important as additional suitable habitats for Chinook salmon, and restoration actions could enhance these habitats. Identifying warm-water inputs could also be important because they could reduce the longitudinal extent of cold-water releases from Friant Dam, or require higher releases to counteract the warming effect of these sources. If these cold-water or warm-water sources are large enough to have a measurable effect on mean water temperatures in the river, they would need to be incorporated into the predictive water temperature model for the river.

The TAC recommends that a Forward Looking Infrared (FLIR) flight, or other applicable technology, be used during the Interim Flows in late spring and/or early fall 2010 (e.g., April or October) to assess the occurrence, locations, and influence of cool upwelling flows on surface water conditions affecting salmon habitat, particularly in Reaches 3-5 where the shallow groundwater table is high [**Recommendation #14**]. Sources of high water temperature should also be investigated. The survey should include the reaches of the river from Friant Dam to the confluence with the Merced River. The TAC, in collaboration with state and federal agencies, will review the results of the initial survey and develop a recommendation as to whether additional aerial and/or ground surveys should be conducted in the future.

5.4 Other River Water Quality Parameters

Salmon growth, health, and survival are closely related to water temperature; however, salmon growth, health, and overall survival are also related to other water quality parameters, which are less well understood than temperature. Therefore, as part of conducting habitat and water quality monitoring during the Water Year 2010 Interim Flow period, the TAC recommends that water quality parameters, such as chlorophyll, pH, DO, turbidity, conductivity, and other water quality constituents listed in the 303(d) listing for the lower San Joaquin River known to be stressful or lethal to Chinook salmon, resident fish, benthic macroinvertebrates, or other indicator species, be collected (continuously and grab sampling) at appropriate time intervals. Many of the existing gaging stations currently monitor water quality, and the TAC recommends that monitoring at these stations be continued, and additional water quality monitoring locations be established as shown on Figure 3 [**Recommendation #15**]. Additional stations may be recommended depending on observed relationships between river flow and water quality parameters during Interim Flow releases.

Based on: (1) results of the initial water quality monitoring during the Water Year 2010 Interim Flow releases, (2) relationships, if any, observed between river flow and these water quality parameters, (3) potential limiting factors of these water quality parameters on fish, benthic macroinvertebrates, and other indicator species, and (4) the most up to date scientific understanding of impacts of these water quality parameters on fish health, growth, and mortality thresholds, the TAC will make recommendations for continuation or modification of water quality monitoring as part of subsequent Interim Flow tests no later than January 31, 2011. The TAC also recommends that the results of water quality monitoring be used to assess potential impacts to health and survival of salmon and other native fish species (lamprey, steelhead, native minnows) [**Recommendation #16**]. Results of these assessments may also be used to guide continuation or modification of the water quality monitoring program.

Table 1. Summary of TAC recommended thermistor locations for Interim Flow period.

Location	Description	Operator	River Mile
SJR blw Friant Dam	Trench pool just under dam	CDFG	267.2
SJR at Friant Bridge	Below bridge just below dam	CDFG	266.6
SJR at Lost Lake	Downstream of Lost Lake Park	CDFG	264.7
SJR at Willow Unit	Access from Vulcan Gravel site	CDFG	260.9
SJR at Sportsman's Club	Upstream of boat launch	CDFG	256.4
SJR at Hwy 41	At Hwy 41 Bridge	USBR	255
SJR Gravel pits below Hwy 41	Vertically and laterally arrayed in gravel pits	Recommended	255-233
SJR at Milburn Unit	Underneath culvert	CDFG	247.5
SJR at Camp Pashayan	Just upstream of Hwy 99 Bridge	CDFG	243.2
SJR at Donny Bridge	At Donny Bridge	USBR	240.6
SJR at Skaggs Bridge	Upstream of bridge at Skaggs Park	CDFG	234.5
SJR at Gravelly Ford	At Gravelly Ford gaging station	USBR	227.5
SJR blw Chowchilla Bifurcation	Downstream of Bifurcation Structure	Recommended	216
SJR near Mendota	Downstream of Mendota Pool	CDFG	204.5
Delta Mendota Canal	In Delta Mendota Canal	DWR	N/A
SJR at Avenue 7.5	Under Avenue 7.5 Bridge	CDFG	195.2
SJR blw Sack Dam	Immediately downstream of Sack Dam	CDFG	182
SJR at Hwy 152	Below bridge at Hwy 152	CDFG	173.9
SJR upstr of Washington Avenue	Upstream of Washington Avenue Bridge	CDFG	169.1
Sand Slough Control Structure	In Sand Slough Control Structure	CDFG	N/A
SJR at Washington Bridge	Under Washington Road Bridge	CDFG	168.1
Eastside Bypass	In Eastside Bypass near town of El Nido	CDFG	N/A
SJR in upper Reach 4B	Upper half of Reach 4B	Recommended	158 +/-
SJR abv Mariposa Bypass	At head gate of Mariposa Bypass	CDFG	147.2
SJR blw Mariposa Bypass	Below Mariposa Bypass	Recommended	147.0
Salt Slough	Salt Slough at Hwy 165 Bridge	USGS	N/A
SJR blw Eastside Bypass	Downstream of Eastside Bypass confluence	Recommended	135.6
SJR abv Bear Creek	Upstream of Eastside Bypass confluence	CDFG	135.8
SJR near Stevenson	At Hwy 165 Bridge	DWR	133
Mud Slough at Hwy 140	At Hwy 140 Bridge	DWR	N/A
SJR abv Merced R confluence	Upstream of Merced River confluence	CDFG	118.5
SJR blw Merced R confluence	Downstream of Merced River confluence	Recommended	118.3

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6 FISHERIES

6.1 Habitat Suitability Criteria

A key element in refining the restoration hydrographs is an understanding of the anticipated habitat requirements (water depth, velocity, substrate, habitat structure/cover, etc.) for each life stage of Chinook salmon. These "habitat suitability criteria" (HSC) are used to consistently define suitable habitat and serve as a foundation for estimating habitat as a function of flow or other restoration actions. Therefore, HSC information is a foundation for assessing baseline habitat conditions, estimating habitat as a function of flow, and evaluating future habitat changes with implementation of the Settlement.

HSC information is available from other fish studies conducted within the Central Valley and elsewhere, and the TAC recommends that information from these studies on habitat requirements for spring-run and fall-run Chinook salmon be compiled, analyzed, and applied on the San Joaquin River [**Recommendation #17**]. Specific attention should be given to information available from Central Valley streams, such as Butte Creek, Mill Creek, and Deer Creek where spring-run salmon currently occur, and from the Tuolumne River and other San Joaquin River tributaries where fall-run currently occur. This HSC information will inform habitat requirements and desired habitat conditions (importance of seasonal floodplain habitat, suitable water temperatures, water depths and structure in adult holding and juvenile rearing habitat, etc) that would be applicable to the various reaches of the San Joaquin River.

The TAC recommends that the implementing agencies develop species- and life stage-specific habitat suitability criteria from the available scientific literature for initial use during the period of the Interim Flow investigations. These criteria will provide an initial foundation for refining and evaluating the restoration hydrographs and non-flow components of the restoration program. The TAC recommends that habitat suitability criteria (e.g., hydraulic parameters such as water depth and velocity, water temperature, dissolved oxygen concentrations, etc.) be initially compiled from the scientific literature and analyzed with respect to anticipated hydrologic conditions on the lower San Joaquin River for Chinook salmon including, but not limited to:

- General spawning habitat;
- Fry and juvenile rearing habitat;
- Yearling rearing habitat;
- Adult holding and pre-spawning habitat; and,
- Adult and juvenile migration.

The primary focus should be on habitat suitability criteria for spring-run Chinook salmon, but criteria should also be compiled for fall-run Chinook salmon and other migratory and resident fish. The TAC is not recommending that field studies to develop San Joaquin River specific habitat suitability criteria be conducted as part of the Interim Flow investigations at this time.

6.2 Flow versus Habitat Rating Curves

Once HSC have been compiled and analyzed, the TAC recommends that the relationship between flow and habitat quantity (based on the HSC) be developed. Numerous approaches are available (e.g., 1-D PHABSIM, 2-D hydraulic and habitat modeling, Habitat Mapping) that relate local flow magnitude to habitat quantity, and the implementing agencies should develop specific methods and identify study sites prior to October 2009. Developing habitat rating curves will enable refinement of summer, fall, and winter baseflow releases to improve habitat quantity, particularly in Reach 1. Because of the large effort needed to conduct the field data collection and analyses, the TAC recommends that these curves be developed for Reach 1 during the Interim Flow period, and that a simpler method relating flows to inundation area be used in downstream reaches to assess juvenile rearing habitat opportunities (see Section 6.4). Once these habitat rating curves are developed, they need to be integrated with the temperature modeling to predict habitat availability. Habitat rating curves do not factor in water temperature, but suitable habitat is only available to fish if it occurs in combination with adequate water temperatures (see next section).

6.3 Flow versus Habitat Availability Relationships

Water temperature has been identified as an important factor affecting habitat within the lower San Joaquin River for all life stages of Chinook salmon. As part of the analyses of HSC discussed above, the TAC recommends that specific consideration be given to identifying water temperatures (average daily temperature, instantaneous temperature, etc.) that define the range of conditions representing suitable habitat for each life stage of Chinook salmon. Using results of the water temperature model (see section 5.2), the TAC recommends that the flow-temperature relationships be assessed during each season and location within the river that would be used to manipulate habitat as part of the restoration program for salmon. Flow and water temperature information collected as part of the Interim Flow program would be used to calibrate and validate predictions of habitat availability for salmon based on actual temperatures observed in the river over a range of seasonal flows. The primary focus on water temperatures during the Interim Flow period should be during low flow releases (particularly summer, fall, and winter months) within Reach 1 for supporting adult holding, spawning, egg incubation, and juvenile rearing, and during spring high flow releases through Reaches 1-5 during the adult and juvenile migration periods. The analysis of river flow-temperature relationships should be integrated, as part of refining restoration hydrographs during the Interim Flow period, with results of the reservoir water temperature analyses.

The TAC recommends that implementing agencies incorporate temperature criteria into the temperature sensitivity model, and ensure that air and water temperature monitoring proposed will be sufficient for river temperature model calibration. Based on: (1) collaborative interaction with implementing agencies, (2) TAC review of uncertainties related to calibrating and applying the river water temperature model, and (3) results of various initial Interim Flow investigations, the TAC will make specific recommendations to the RA by January 31, 2010 on how to incorporate river water temperature model predictions and field measurements

into further management decisions as part of the annual Interim Flow development process (Section 3.1). Results of these analyses may be used by the TAC and RA to recommend refinements to seasonal Interim Flow or Restoration Flow hydrographs.

6.4 Flow versus Inundation Area Relationships

Recently discovered CDFG historical San Joaquin River juvenile salmon migration data from the 1940s suggests that spring-run fry and juveniles migrated past Mendota Dam in February and March (Figure 4), and migrated past Mossdale in April and May (Figure 5), with the difference in timing suggesting that the juveniles spent substantial time migrating downstream between February and May, presumably rearing and growing. If the juveniles were rearing and growing as they migrated through Reaches 3-5, this strategy would be additive to the strategy of primary rearing and growth in Reach 1. This strategy of using multiple reaches for juvenile rearing could have provided several "life-history tactics" that could be potentially successful for Chinook salmon during different water years. While rearing will likely be important in Reach 1 where adequate water temperatures should be available for most water years, Reaches 2-5 may also be important for seasonal juvenile rearing, and provide additional successful life-history tactics that will contribute towards meeting the Restoration Goal.

Creating habitat rating curves as described in Section 6.2 for the extensive lower gradient reaches in Reaches 2-5 would be a time and labor intensive effort, and could be very expensive to generate for all reaches. Therefore, the TAC at this point only recommends developing habitat rating curves for Reach 1, but initially recommends a simpler approach for downstream reaches that focuses on fry and juvenile rearing habitat, only using inundated surface area as an index to rearing habitat. Using the depth criteria from the HSC information in Section 6.1 for fry and juvenile floodplain rearing, the TAC recommends that inundated floodplain habitat area curves be developed to be used as an index of fry and juvenile rearing habitat in Reaches 2-5. Data collected on stage-discharge relationships, channel geometry, channel conveyance, and other parameters assessed as part of the Interim Flow program would be used to develop hydraulic model predictions of flow relationships that would inundate floodplain habitat. Seasonally inundated floodplain habitat has been shown to be high-value rearing areas for juvenile salmon during downstream migration. Information on topography of the channel and adjacent areas would be used to examine the frequency, area, and duration of inundation. The hydraulic model could then be linked with the water temperature model to assess seasonal changes in habitat suitability as a function of river flows under the restoration hydrographs and environmental seasonal conditions.

Observations and measurements of floodplain inundation should be made as part of the Interim Flow program beginning in October 2009, although the TAC anticipates that more extensive measurements and analyses will be made during the Interim Flow releases in Water Years 2011 and 2012. Based on results of these observations and analyses during the Interim Flow investigations, the TAC recommends that information gained from flow-to-inundation area evaluation be used to recommend future management actions: (1) subtle refinements to Restoration Flow release schedules, (2) alternative management of infrastructure (e.g.,

bifurcation structures, headgates, inflatable dams), and/or (3) physical modifications to channel geometry to improve access to floodplain habitat during the juvenile rearing and emigration period for Chinook salmon (Figure 2).

There are many methods and analytical techniques available to implement the information needs listed in Sections 6.1-6.4; therefore, the TAC recommends that as a first step development of a study plan of methods, study site locations, analytical approaches, expansion approaches, how to integrate habitat predictions in each reach to maximize successful salmon life-history tactics, and how to integrate habitat predictions from the analytical techniques with an appropriate level of professional judgment (i.e., do the output predictions make sense?) [**Recommendation #17**]. This study plan should be developed in a collaborative manner and peer reviewed, ideally before initiation of Interim Flows in October 2009.

6.5 Spawning Habitat Quantity

The TAC recommended long-term escapement targets for spring-run Chinook salmon of 30,000 adults, and a combined escapement target of 10,000 adults for fall-run and late fall-run Chinook salmon (TAC 2007 and 2008). Therefore, adequate spawning gravel is required to support these Chinook salmon escapement targets. Current spawning habitat has been estimated by Stillwater Sciences (2003), Jones and Stokes (2001), and others, yet different criteria and reaches were included in the estimates.

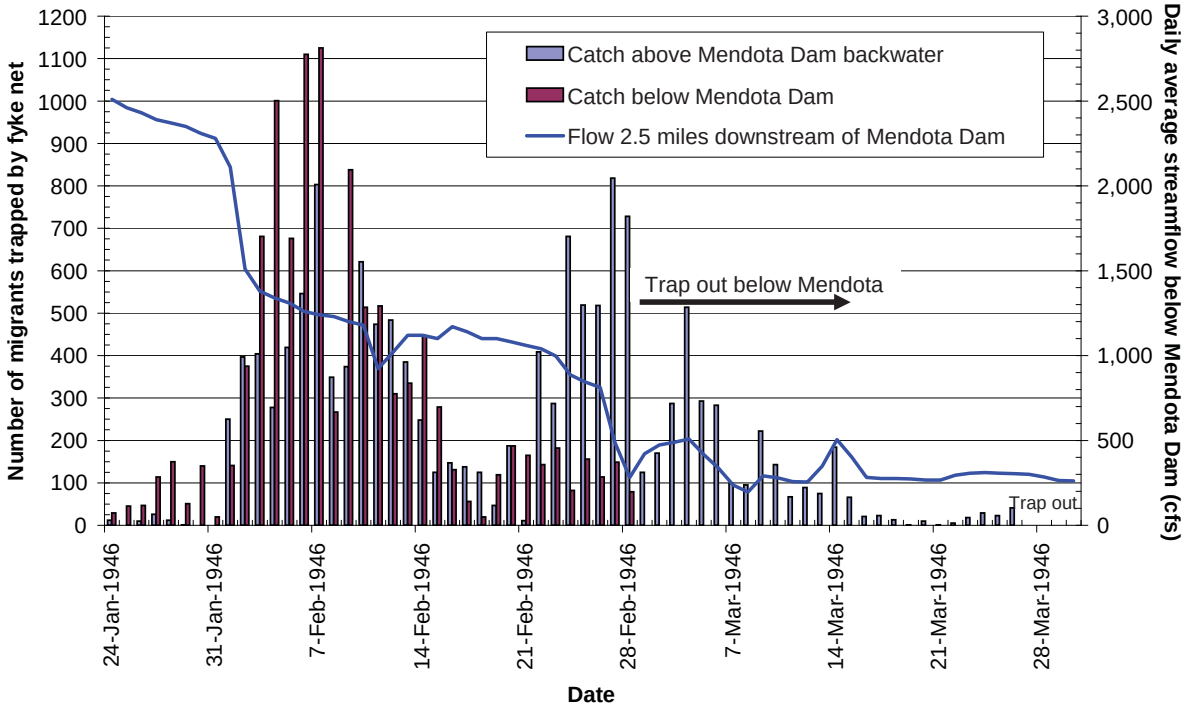

Figure 4. Downstream Chinook salmon migrants upstream and downstream of Mendota Dam in spring 1946 (from unpublished CDFG data obtained by Colleen Harvey, CDFG biologist, Red Bluff, CA).

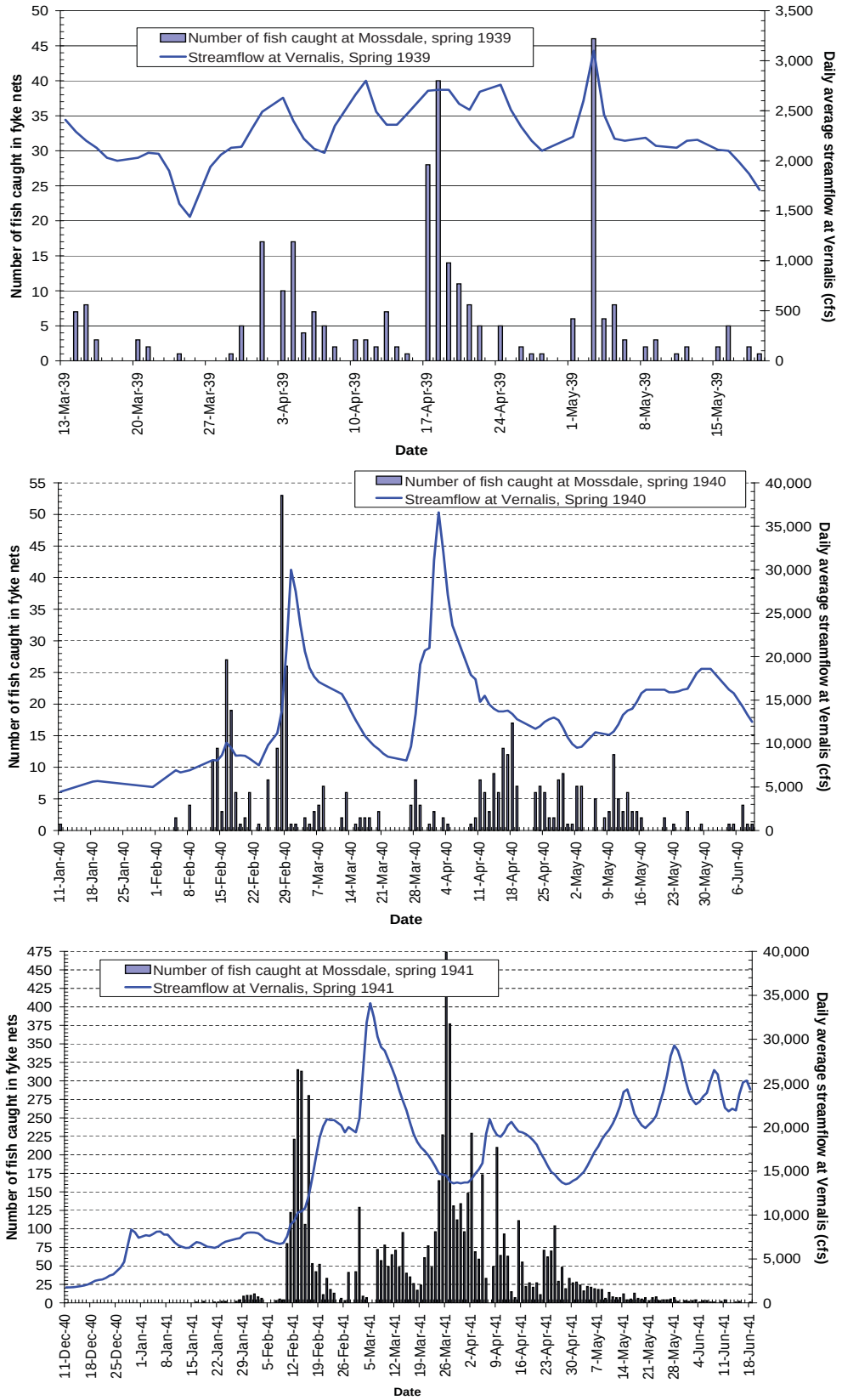

Figure 5. Downstream Chinook salmon migrants at Mossdale in spring 1939-41 (from unpublished CDFG data obtained by Colleen Harvey, CDFG biologist, Red Bluff, CA).

The TAC recommends that spawning gravel availability be quantified in Reach 1 by mapping suitable patches of gravel available for spawning use by flows ranging from 100 cfs (lowest Friant Dam releases during Critical Low water year types) up to 700 cfs (fall-run attractant flow during Dry and wetter water year types) [**Recommendation #18**]. A census of spawning gravel storage is recommended for the entire length of Reach 1, with mapping boundaries driven more by gravel size suitable for Chinook salmon use rather than depth and velocity criteria. These spawning gravel surveys within Reach 1 are proposed as an element of the Interim Flow program to provide improved estimates of gravel availability. Results of gravel surveys during the Interim Flow period would then be used to (1) determine whether gravel addition would be a beneficial restoration action, and (2) whether the availability of gravel suitable for salmon spawning will change in response to restoration actions or flood flow events. Gravel surveys would subsequently be conducted only periodically as part of an ongoing baseline monitoring program (e.g., at intervals of 5-years or following channel forming flood control releases). Future restoration activities in Reach 1 may need to include construction of new riffles, modification of existing riffles, and/or supplementation of spawning gravel.

6.6 Spawning Habitat Quality

Reconnaissance-level evaluations conducted by Jones and Stokes (2001) and Stillwater Sciences (2004) show that fine sediment storage on the bed surface and in spawning gravels is currently substantial. Therefore, substrate composition, size distribution, and embeddedness within Reach 1 may also be a potentially limiting factor for salmon restoration in some years.

The TAC recommends that a study plan for spawning gravel quality assessment be developed and implemented within Reach 1 during the Interim Flow period to provide improved estimates of gravel quality during the early phase of the restoration program [**Recommendation #19**]. Based on the spawning gravel mapping results described above, areas predicted to receive high spawner use should be identified, and gravel quality sampling should be conducted there. A study plan will need to be developed and implemented, but may include bulk sampling, permeability, embeddedness, and/or other gravel quality metrics. Results of gravel quality surveys during the Interim Flow period would then be used to (1) determine whether gravel addition would substantially improve predicted egg-to-emergence success, and (2) whether the quality of gravel suitable for salmon spawning changes in the future in response to Restoration Flows or flood flow events. Gravel quality surveys would subsequently be conducted only periodically as part of an ongoing baseline monitoring program (e.g., at intervals of 5-years or following channel forming spill events).

6.7 Habitat Use by Adult and Juvenile Test Fish

There is general understanding of habitat use preferences by adult and juvenile salmonids, but there is uncertainty on the likely spatial and temporal use of that habitat for salmon reintroduced to the San Joaquin River from other streams. For example, if Butte Creek spring-run salmon are used as a parent stock for re-introduction on the San Joaquin River, will they hold in pools immediately below Friant Dam, or be more broadly distributed within Reach 1? Will fry and juveniles outmigrate earlier in the year (February-March) as indicated

in 1940s outmigrant data on the San Joaquin River, or will they outmigrate later in the year (April-May) as they do on Deer, Mill, and Butte creeks? The Interim Flow period can provide experimental opportunities to investigate the habitat selection, behavior, and potential mortality of juvenile salmon, as a function of flow releases. Juvenile fall-run Chinook salmon, produced in hatcheries, could be individually tagged, released into Reach 1, and monitored to observe how they use existing habitats. The juvenile salmon could be tagged using a variety of methods including radio or acoustic tags, coded wire tags (CWT), passive integrated transponder (PIT) tags, and other technologies depending on the specific requirements of the investigation. Changes in habitat selection, distribution, behavior and movement, and potential mortality could be investigated over a range of hydrograph base flows, as well as changes in seasonal water temperatures within the river. Similar studies could be conducted with adult fall-run Chinook salmon to investigate changes in spawning habitat selection, behavior, and success over a range of base flow conditions.

The TAC recommends that these types of experimental studies be designed as part of the 2010 and 2011 Interim Flow investigations to gain insight into the actual response of Chinook salmon to flow and habitat conditions, primarily in Reach 1 [**Recommendation #20**].

6.8 Fish Passage through Infrastructure, Channels, and Bypasses

Several subsections in Paragraph 11 of the Settlement require restoration actions to address fish passage if determined to be necessary. These actions include potential modifications to Reach 4B, the headgates at the top of Reach 4B, the Sand Slough Control Structure, Sack Dam, the Eastside and Mariposa Bypass channels and structures, and the Chowchilla Bifurcation Structure. The need to modify these structures was left undetermined in the Settlement specifically either because sufficient information did not exist on possible fish passage constraints in the current structures or channels (e.g. the Eastside Bypass), or because there is a need to first make decisions regarding desired fish migration pathways. Similarly, as required by the Settlement, the RA needs to make a recommendation on routing higher flows down Reach 4B or the Eastside Bypass. Information collected using Interim Flows could be essential for evaluating fish passage as a function of flow at individual structures, as well as evaluating possible remedial actions that could be taken to improve passage at these structures. Some adult fish passage impediments, if managed carefully, could help separate spring-run and fall-run Chinook salmon spawning to reduce superimposition and hybridization risk (if found to be a problem). As such, the TAC makes the following recommendations regarding these actions [**Recommendation #21**]:

- Reach 4B. Upon completion of Reach 4B channel modifications to route at least 475 cfs, release Interim Flows up to the existing channel capacity to assess habitat suitability for adult fish passage and juvenile rearing. As noted previously, the Federal legislation introduced to authorize the Settlement includes specific requirements for a seepage monitoring program, an evaluation of possible impacts associated with the release of Interim Flows, and mitigation measures for any significant impacts. Therefore, this evaluation would be complementary to other data collection efforts addressing groundwater seepage, water temperature, channel conveyance capacity, and other restoration and impact-related information needs.

- Reach 4B Headgates, Sand Slough Control Structures, Sack Dam and Reach 2 Bifurcation Structure. During Interim Flow releases, adult and juvenile salmon fish passage should be assessed at the structures over a range of flows which reflect the conditions likely to exist in the future once salmon are reintroduced. This information should be used to assess the need to replace or modify the structures in accordance with the Settlement.

- Eastside and Mariposa Bypasses. Interim Flows or the receding limb of flood control releases should be used to assess fish passage criteria (depth as a function of flow) of the low flow channel at a range of flows from 35 cfs to 500 cfs to determine if the existing low flow channel has sufficient depth and connectivity to meet fish passage objectives. The drop structures and control gates in the bypasses should also be assessed for fish passage at a range of flows starting at 65 cfs and greater to investigate conditions during which adults would be migrating upstream.

The fish passage assessment must focus on adult and juvenile Chinook salmon passage needs, but other native species should also be considered (e.g., lamprey, steelhead, native minnows).

6.9 Fish Species: Composition, Distribution, and Abundance Surveys

Implementing the Settlement, including release of Interim Flows and Restoration Flows, should benefit resident fish species (native minnows, etc) as well as Chinook salmon, steelhead and/or resident trout. Some preliminary fishery surveys have been performed by CDFG to document fish species contribution, distribution, and abundance, but a more complete survey is needed to adequately document baseline conditions.

The TAC recommends that additional fish surveys be designed and conducted in spring or summer Water Year 2010 at a time when all reaches have connected flow (but without instream construction) to assess the species composition, distribution, and abundance of resident fish currently inhabiting the river [**Recommendation #22**]. The surveys would help determine how rapidly native fish populations are recovering, and whether reintroductions of some native fish species will be needed. The surveys would also help to determine prospects for development of fisheries for non-native fish populations. The TAC also recommends that periodic surveys continue to monitor changes in the fish community following implementation of the Interim Flows and as part of the long-term river restoration. A survey should be designed to assess characteristics of the aquatic community at approximately 25 representative sites that encompass the diversity of habitats within the river in Water Year 2010 (in the early portion of the Interim Flow period and prior to the reintroduction of salmon) and at 5-year intervals after initiating Interim Flows.

6.10 Salmon Predator Populations and Diets

Largemouth bass, smallmouth bass, striped bass, and other non-native warm-water species inhabiting the San Joaquin River will likely prey on juvenile Chinook salmon during rearing and migration. Results of initial surveys conducted by CDFG suggest that predation mortality by these non-native fish species, as well as other wildlife species, may be a particular concern

within captured gravel pits. Preliminary research on the Tuolumne River suggests that predation of juvenile salmonids by non-native piscivores (largemouth and smallmouth bass) may be limiting smolt production during periods of low flows, higher water temperatures, low turbidities, and other factors (EA Engineering, 1992). However, more research is needed to expand our understanding of the role of predation on juvenile salmon under different environmental conditions. For example, are current piscivore populations large, and how are those populations distributed through Reaches 1-5? Are there different predation rates for different species? What are expected predation rates under various environmental conditions (e.g., turbidity, water temperatures, flow rates, juvenile salmon densities)? Can flow management or channel rehabilitation efforts help spatially segregate juvenile salmonids from predatory piscivores during rearing and outmigration periods? A large proportion of predatory fish species likely inhabits instream and connected off-channel gravel mining pits in Reach 1, and these pits are sometimes filled or isolated as part of restoration efforts on the Merced, Tuolumne, and Stanislaus rivers. A primary objective of these projects is to reduce piscivore habitat and populations, and their predation on juvenile salmonids. These projects are being discussed on the San Joaquin River as well, and given the extremely large expense of implementing them (tens of millions of dollars), we need better information on potential benefits of these projects on improved smolt production from the San Joaquin River. For example, do we need anticipate smolt production benefits by implementing a single project, or do we need to implement at least twenty before we can expect a benefit to smolt production? Are there ways to construct the projects that are less expensive, but still achieves predator reduction benefits?

The TAC first recommends that composition, abundance, and distribution of the fish community be documented in Reach 1 during to the Interim Flow period to document baseline conditions for those fish species that prey on juvenile salmon [**Recommendation #23**]. In parallel, the TAC recommends that a study plan be developed and implemented that expands work done by EA Engineering (1992) to address the management questions posed above, and evaluate whether salmonid predation is a limiting factor, and if so, under what conditions [**Recommendation #24**]. Given the cumulative potential expenditure of over $100 million on gravel pit restoration projects in Reach 1, this research can greatly inform restoration actions in the reach that improves smolt production and potentially save the Program money. Once salmon are reintroduced into the San Joaquin River, salmon predation monitoring should include dietary composition and predation rates, and changes to both as a function of water temperature, flow magnitude, season, and habitat unit to compare observed results with predicted results. Results of these studies during the Interim Flow period would provide information on the risk of predation within the gravel pits and at other locations within the river that would help inform the design of restoration actions and/or predator control programs.

6.11 Benthic Macroinvertebrate Composition, Distribution, and Abundance Surveys

Benthic macroinvertebrates form the food base for fry and juvenile salmon (and other fishes), and these food sources must be abundantly available to ensure proper growth and health, and increased likelihood of successful Chinook salmon outmigration to the ocean. These food sources must be available in specific reaches at specific times of the year when fry and juvenile salmon are using those reaches. Benthic macroinvertebrates also are good indicators of how well the stream is functioning as a natural system (stream health).

Therefore, the TAC recommends that a baseline assessment of the benthic macroinvertebrate community inhabiting the river be conducted in all reaches in Water Year 2011 to assess potential food supplies for juvenile salmon rearing, with particular emphasis in Reach 1 (and Reach 4B1 and Eastside Bypass when re-watered) [**Recommendation #25**]. Species composition and abundance of macroinvertebrates inhabiting the various reaches of the river should be periodically characterized in the future as Interim Flows and Restoration Flows are implemented. A survey should be designed to assess characteristics of the aquatic community at approximately 25 representative sites that encompass the diversity of habitats within the river in Water Year 2011 (prior to the reintroduction of salmon) and at 5-year intervals after Restoration Flows commence.

7 GEOMORPHOLOGY

7.1 Coarse Sediment Transport Thresholds and Rates

Restoring self-sustaining, naturally reproducing salmon populations to the San Joaquin River will include geomorphic processes that create and maintain salmon habitat (e.g., sediment movement resulting in scour and deposition, meander formation, riffle formation, etc.). Many of these physical geomorphic processes vary in response to the river flow rate and the size distribution of sediment particles (e.g., gravel size). Channel forming flows in managed rivers, such as that downstream of Friant Dam, occur typically during high-flow events such as reservoir spill and flood control releases, which may occur during the latter portion of the Interim Flow period and commencement of the Restoration Flow period in Normal-Wet and Wet water years. During the beginning of the Interim Flow period, natural hydrologic conditions (i.e., a wet water year) may opportunistically create sufficient flows to result in bed mobilization and sediment movement.

To gain information on the relationship between the magnitude of high flow events and coarse sediment transport thresholds and rates, the TAC recommends that two geomorphology studies be conducted in Reach 1 during the Interim Flow period [**Recommendation #26**]. First, to document channel bed mobilization thresholds in riffles, bars, and pool tails during the Interim Flow period, tracer rocks and scour chains/cores should be installed in a variety of alluvial deposits in Reach 1 prior to the potential flood control release season. If it appears that spring snowmelt will result in flood control releases, these experiments should be installed during low flows prior to the release (March 2009 or March 2010). Measurements of bed mobilization and scour could then be made in the event that a channel forming flood control release occurs.

Second, bedload transport measurements should be conducted if a flood control release occurs in the early Interim Flow years, or during Normal-Wet and Wet water years later in the Interim Flow period when high flow constraints have been removed [**Recommendation #27**]. The particle size distribution of the bedload samples should be obtained to determine the coarse sediment (e.g., greater than 2 mm) and fine sediment (e.g., less than 2 mm) transport rates. Bedload transport measurements will also help evaluate: (1) bed mobility thresholds, (2) rates of coarse sediment movement (including spawning gravel), and (3) coarse sand movement. Coarse sediment transport rates will help evaluate future gravel augmentation needs, and fine sediment transport rates will help evaluate the fine sediment budget and the long-term implications to spawning gravel quality under different management scenarios (e.g., how will future restoration flows and flood control releases change fine sediment storage in Reach 1). The TAC is not recommending that bedload transporting flows be provided during the Interim Flow period prior to downstream constraints being remedied, but rather that plans be developed to rapidly implement monitoring and measurement methods that would be deployed opportunistically in response to high flow events that occur naturally within the watershed. Given the opportunistic nature of collecting information on substrate movement under high flows, these elements of the monitoring and measurement program should be implemented beginning as soon as possible and continue opportunistically throughout the Interim Flow investigation period.

7.2 Sedimentation and Incision

Gradual channel incision has occurred in the upstream portion of Reach 2A, with subsequent deposition in the downstream portion of Reach 2A and the Chowchilla Bypass, requiring periodic excavation in the upstream end of the Chowchilla Bypass to maintain flood conveyance capacity. These reaches, and Reach 1A described above, have historically experienced the most substantial imbalances in the sediment budget compared to other reaches. Under Restoration Flows, the operational scheme for the Chowchilla Bifurcation structure will likely be modified such that more flow (and the attendant sediment) is conveyed downstream into Reach 2B. Ideally, this additional sediment will route through the future Mendota Dam bypass channel into Reach 3 in a way that minimizes future incision or deposition in Reach 2A, 2B, or Reach 3.

To document baseline conditions upon which possible future channel incision or deposition can be monitored, the TAC recommends that topographic surveys be conducted within the levees in Reaches 2A, 2B, and the upstream-most 5 miles of Reach 3 at a sclae and accuracy sufficient to determine real changes in deposition or incision [**Recommendation #28**]. Once the Mendota Dam bypass is constructed, a survey should be conducted to provide baseline topographic conditions for that channel. After future flood control releases and high flow releases during Normal-Wet and Wet water years, the topographic surveys should be repeated to document trends in channel incision or deposition resulting from those high flows. The TAC recommends that topographic documentation via terrestrial LiDAR and supplementary bathymetric surveys be conducted as a cost-effective and accurate method to document local imbalances in the sediment budget; conversely, the TAC does not recommend bedload or suspended load sampling in these reaches as the basis for documenting imbalances in the sediment budget due to inherent variability in these sediment transport measurements.

8 RIPARIAN VEGETATION

8.1 Riparian Baseline Conditions

Riparian vegetation is an important factor affecting sediment scour and deposition, cover for fish habitat, and the contribution of leaf litter and insects to the river. Implementation of the Settlement will increase riparian vegetation in some reaches of the river by increasing potential establishment areas through physical manipulation of the channel, as well as through riparian flow releases during Wet water years. Riparian vegetation along the San Joaquin River was mapped in 1998 (JSA 1998), and again in 2000 (DWR 2002), but considerable changes to riparian vegetation have likely occurred since that mapping effort and may not adequately represent baseline conditions for evaluating future changes in riparian vegetation due to Settlement implementation.

To document future changes from Settlement implementation, a subset of the 125 vegetation transects established by DWR (2002) should be re-occupied early in the Interim Flow period to determine whether substantial changes in riparian vegetation have occurred along the longitudinal gradient extending from Friant Dam to the confluence with the Merced River [**Recommendation #29**]. If substantial changes are found based on this subset of transects, then the TAC recommends that the remaining transects be surveyed, and a new riparian map be developed using the 2008 aerial photographs as a basemap. Thereafter, cross section surveys and mapping should be conducted periodically to characterize riparian vegetation changes over time (e.g., 5-10 years).

8.2 Riparian Initiation and Establishment

The riparian recruitment flows should be gently ramped down over a 60-90 day period after the peak flow releases in Wet years to promote establishment of riparian vegetation on appropriate elevations in the channel. This gentle ramping will require changes in daily flow releases to allow initiating seedling roots to follow the gradually receding soil moisture front (capillary fringe) on target surfaces. Several riparian vegetation initiation and establishment uncertainties remain, including: (1) the effects of riparian vegetation on flood control and channel conveyance, (2) relationships between flow release and inundated area that could potentially support natural riparian regeneration, (3) flow releases (magnitude, timing, and rate of change) needed for natural riparian regeneration along the channel margin in different reaches of the river, (4) flow releases needed for regeneration in seasonally inundated floodplain habitats, (5) the timing of riparian seed dispersal at different locations along the river, and (6) alternatives to natural regeneration, such as planting riparian vegetation.

Reclamation is currently developing a riparian establishment model (SRH-1DV) coupled with a 1-D hydraulic model to predict riparian initiation, establishment, and evolution over time (drought and scour) for all reaches. In addition, a riparian initiation model has been developed on the Trinity River that predicts flow releases and floodplain design surface elevations that would successfully achieve riparian initiation at a site-scale. The TAC recommends that these predictive models be applied to inform floodplain designs and future Wet water year Restoration Flow releases to encourage natural riparian establishment on the San Joaquin

River [**Recommendation #30**]. The TAC also recommends that three sites be established to monitor riparian seed dispersal (in Reach 1, in Reach 3, and in Reach 5), and that these sites be monitored for three years to better understand seasonal timing, magnitude, and duration, as well as inter-annual variability [**Recommendation #31**]. The Interim Flow program can provide information to refine the hydraulic model for the river and predict the locations along the channel where natural riparian regeneration is most likely under various potential restoration hydrographs. Data collection efforts supporting development, calibration, and validation of the riparian vegetation models should be continued, and applied in the event flood control releases occur during the Interim Flow period, or if a Wet water year occurs during the Interim Flow period after channel capacity constraints have been remedied. The analyses should also include consideration of whether the hydrograph recession can be managed at the end of a flood control release to successfully recruit tree seedlings. Information on the duration and magnitude of river flows to achieve natural riparian regeneration on floodplains would help in refining estimates of daily average flow releases and ramping rates needed to establish riparian vegetation. Once the natural riparian regeneration model is developed, monitoring and modeling should be conducted opportunistically during and following high flow releases to evaluate and refine the predictions of riparian growth along the river channel. Riparian vegetation surveys should be conducted more frequently at these natural regeneration study sites (e.g., after Wet water year releases) and sites where planting and/or irrigation is provided to encourage and support establishing riparian vegetation growth along the river channel (e.g. every 1-3 years).

9 SUMMARY

Implementing the recommendations presented in this report will require more specificity and refinement. We recommend continued discussion with, and technical input from, Federal liaisons and state agencies to refine the tasks and sequence them in time. To facilitate this process, the TAC has summarized metrics contained in the recommendations, suggested methods to quantify those metrics, recommended spatial and temporal extent of these metrics, discussed how the information would be applied to Interim Flows or baseline monitoring. This summary is presented in the following pages in Table 2, and potential sequencing is shown in Figure 6.

While these recommendations are all inherently "high priority," the highest priority tasks are those that inform Interim Flows, Reach 4B management, and other specific tasks listed in the Settlement. The TAC realizes that these recommendations represent a substantial amount of work, and may exceed staff and financial resource capability of the Program to fully implement. To provide some additional guidance to the RA, the TAC recommends that the highest priority is developing coordination processes, predictive tools, and studies to inform Interim Flows and Reach 4B management, including:

- Processes for developing annual Interim Flow recommendations;
- Water temperature models;
- Flow-habitat evaluations;
- Juvenile salmonid predation and implications to gravel mining pit restoration; and,
- Opportunistic data collection during flood control releases.

With these tasks in mind, the TAC recommends additional discussions involving the RA, Federal liaisons, and state agencies to identify the extent of recommended tasks/work products that realistically can be expected to be completed in 2009 and 2010 given Program budgets and Settlement schedule requirements. To the extent feasible, these future discussions with Federal liaisons should: (1) develop additional detail on methods, spatial extent, and temporal scale via study plans or scopes of work; (2) develop cost and Program staff time estimates based on these scopes of work; and (3) evaluate staff and budget needed to implement these recommendations with respect to available resources and other workload priorities. The TAC will continue to provide technical assistance to the RA during these discussions.

Table 2. Summary of Interim Flow information needs and experimental studies.

Metric	Method	Location and Time	Application of Results
Water depth and velocity	Measurements at channel cross-sections over a range of flows, compare to fish passage criteria, evaluate flow or structure modification to improve passage.	At critical adult and juvenile fish passage locations in Reaches 1-5 in first year of Interim Flows at riffle crests and artificial structures.	Relationships between water depth and river flow at various locations would be used to assess physical conditions for juvenile and adult salmon migration. Assessment of fish passage as a function of local flows may be used to revise flow releases from Friant Dam, adjust other water management actions, and/or modify structures.
Water quality (dissolved oxygen, turbidity, conductivity, other parameters)	Grab sample collection at locations in each reach of the lower river for certain parameters, continuous instrumentation for other parameters. Laboratory or field instrument chemical analysis using standard protocols.	At recommended water quality sampling locations from Reaches 1-5 as shown in Figure 1, sampling should occur year-round using standard protocols.	Habitat suitability for various life stages of Chinook salmon depends on water quality (e.g., dissolved oxygen concentrations). Information would be used to assess habitat suitability, identify potential stressors or toxic conditions for various species, and determine the response of various water quality parameters to changes in river flow.
River water temperature	Continuous air and water temperature measurements at various locations along the longitudinal gradient of the river from the Friant Dam outlet downstream to the Merced River confluence. Integrate water temperature measurements into a predictive flow-temperature simulation model for Reaches 1-5. Install lateral and vertical grid of continuous recording thermistors in several Reach 1 gravel pits.	At recommended water temperature monitoring locations shown in Figure 3, sampling should occur year-round using standard protocols at least through the Interim Flow period. Water temperature monitoring in gravel pits should emphasize the April-June period during the first 2-3 years of the Interim Flow period.	Results of analyses and modeling would be used to assess seasonal periods when water temperature would be stressful or unsuitable for various life stages of Chinook salmon at different locations in the river, and how river flow can be managed to provide suitable water temperatures. Results of water temperature monitoring in gravel pits would be used to assess: (1) the overall temperature effect of individual gravel pits, (2) the spatial warming of different gravel pits based on mixing, and (3) the vertical temperature effects of gravel pits on thermal stratification. Each would be used to help assess whether gravel pits need to be modified, and how modification may best improve water temperatures downstream.
Reservoir water temperature	Continuous water temperature measurements at various water depths within Millerton Lake. Integrate water temperature measurements into a predictive reservoir simulation model.	Year-round.	Evaluate reservoir dynamics and cold-water pool storage as a function of seasonal changes in atmospheric conditions (e.g., air temperature, wind speed), reservoir inflow, reservoir releases to the lower river, and canal diversions for water supply deliveries. Information would be used to assess whether future operations and hydrologic conditions would impact the cold-water pool for downstream releases to the river. A reservoir temperature model would be used to develop initial boundary conditions for the river temperature model.

Table 2. Summary of Interim Flow information needs and experimental studies.

Metric	Method	Location and Time	Application of Results
Flow-inundation curves	Measure river stage and channel cross-sectional elevations at transect locations. Integrate field stage-discharge information with topographic mapping results to estimate inundation area as a function of river flow.	Reaches 1-5, data collected in the first few years of Interim Flows, particularly during higher flows caused by flood control releases or Interim Flows.	Results would be used to assess the area and locations of channel margin habitat that would be inundated and available as juvenile rearing habitat at various flow rates. Results would also be used to identify potential locations for floodplain and riparian vegetation restoration. Stage-discharge information at transects would be used to calibrate 1-D and 2-D hydraulic models, improving their predictive accuracy over a wide range of flows.
Fish and macroinvertebrate species composition and density	Grab sample collections using various sampling techniques to collect, identify, measure, and determine relative density (number/1,000 m^2) for fish and macroinvertebrates at sampling sites in Reaches 1-5.	At representative sample locations in Reaches 1-5, document baseline conditions throughout the Interim Flow period and the first few years of Restoration Flows.	Results would be used to characterize the existing fish and macroinvertebrate community inhabiting each reach of the river, document how species change in response to Settlement implementation over time, and evaluate potential predation, competition, and prey availability for juvenile salmon with other native and non-native species.
Predator populations and diet	Collect predatory fish (largemouth bass, etc.) using various sampling techniques (hook and line, electrofishing, etc.). Examine stomach contents to assess diet and salmonid consumption rates.	Sample predator populations in Reach 1, particularly in gravel pits, with less intensive sampling in Reaches 2-5 prior to or during first year of Interim Flows. Assessing juvenile salmon component of diet would need to be done on downstream tributary or on the SJR after reintroduction.	Results would be used to assess the potential significance of predation on the survival of juvenile salmon rearing and migrating in the river, and identify specific locations where vulnerability to predation is increased, as well as restoration actions that would contribute to reduced predation (e.g., gravel pit filling). Could also help assess other management actions that may suppress predation, including water temperatures, channel morphology, turbidity, and other factors.
Anadromous fish presence monitoring	Low intensity surveys (canoe surveys to observe redds, limited beach seining, etc.).	Low intensity in Reach 1 during the Interim Flow period once flow connectivity is achieved, higher intensity after salmon reintroduction.	Determine if anadromous fish have successfully migrated upstream into the river during flood control releases or Restoration Flow releases when surface water connectivity is established from Friant Dam to the confluence with the Merced River.
Habitat use by adult and juvenile Chinook salmon test fish	Tag juvenile and/or adult fall-run Chinook salmon from the Merced River hatchery or other source and release into the San Joaquin River. Monitor fish movement and habitat use as a function of river flow, water temp, and habitat conditions.	Initiate as soon as possible, reintroducing test fish in Reach 1.	Results would be used to validate predictions of habitat suitability and use, and changes in habitat use over a range of river flows (e.g., where would spawning likely occur in Reach 1). Results would also be used to determine the response of various life stages of salmon to water temperature gradients, and identify potential sources of mortality (e.g, predation).

Table 2. Summary of Interim Flow information needs and experimental studies.

Metric	Method	Location and Time	Application of Results
Thermal refugia	Reconnaissance-level aerial infrared survey or other suitable water temperature monitoring method (e.g., longitudinal profile measurement by boat or snorkeling).	Reaches 2-5, conducted during hot days in April/May (end of juvenile outmigration period and adult spring-run Chinook salmon immigration period) and/or October (adult fall-run Chinook salmon immigration) early in Interim Flow period.	Results would be used to assess whether local cool-water habitats exist along the river, and if they do, additional work should be conducted to identify the extent of these habitats, assess whether these habitats could benefit juvenile and adult Chinook salmon during migration, and determine the effects of surface water flows within the river on these local cold-water habitats.
WY 2010 Interim Flows	Develop a flow scheduling process that refines Interim Flows, supports experimental investigations to determine the response of various parameters to rate of release from Friant Dam and other factors, and develop Interim Flow recommendations for WY2010.	Develop and initiate process in February 2009, continue through Interim Flow and Restoration Flow periods.	The flow scheduling process would provide a structured and informed process for the RA to make annual flow recommendations to the Secretary, and allow for coordination with Reclamation and other agencies on water supply, water operations, and reuse/recirculation opportunities. Interim Flows would be used to identify and quantify various relationships in response to changes in flows, and establish a basis for calibrating and validating predictive statistical and simulation models used to guide restoration activities.
Pulse flow hydrodynamics	Release from Friant Dam managed pulse flows of various magnitude and duration, and measure surface water flows at downstream locations to determine flow attenuation, surface water connectivity, and other parameters as a function of releases. Compare hydrodynamic model results with field monitoring to calibrate model, then compare with fish migration capabilities/requirements to assess/refine pulse flow.	Reaches 1-5, conduct during flood control releases or Interim Flow releases early in Interim Flow period.	The Interim Flows would be used to identify and quantify various hydrodynamic relationships in response to changes in flows, calibrate and validate predictive statistical and simulation models, and evaluate/refine future flow releases designed to provide suitable habitat conditions throughout the lower river for adult upstream and juvenile downstream migration.
Shallow groundwater dynamics	Continuous measurement of shallow groundwater surface elevation, and analysis of relationships between surface water flows and shallow groundwater elevation.	Focus on Reaches 2A, 2B, and 4 during early portion of Interim Flow period; expand to other reaches if needed later in Interim Flow period.	Results would be used to assess how changes in river flows affect groundwater levels in the area, seepage into and under levees, and assess surface water flow losses as a function of antecedent conditions and ground water recharge. In coordination with landowners, could relate seepage and groundwater response to soil moisture and crop conditions.

Table 2. Summary of Interim Flow information needs and experimental studies.

Metric	Method	Location and Time	Application of Results
Water operations	Continuous measurements of flow releases from Friant Dam and at downstream diversion locations	Reaches 1-5 over Interim Flow and Restoration Flow periods	Results would be used by the Bureau of Reclamation to determine the potential physical pathways, institutional mechanisms, and agreements that can result in the recapture of water at various locations in the river, the conveyance and possible storage of recaptured water and the delivery or exchange of water into the Friant service area.
Coarse sediment mobility and transport rates, channel aggradation and degradation	Install and observe scour chains and/or painted (marked) gravel movement. Conduct bedload transport measurements during high flows. Topographically measure changes in bed elevation to assess sediment accretion and depletion.	Reach 1 for coarse sediment dynamics during flood control releases in Interim Flow period. Reach 2A, Reach 2B, and uppermost 5-miles of Reach 3 for channel aggradation and degradation before and after high flow events	Results would be used to determine the relationship between river flows and gravel mobilization thresholds, the potential effectiveness of using managed flow releases for gravel scour, and the effects of flow rates on gravel recruitment, gravel cleaning or augmentation, accretions, and depletions within Reach 1. Topographic monitoring of Reach 2A, Reach 2B, and Reach 3 would assess potential trends in channel downcutting and deposition as a result of future high flows, Settlement activities (e.g., Mendota Pool Bypass), and changes to the flood control system.
Spawning habitat quality and availability	Visual observations, surveys, and mapping of gravel deposits within Reach 1. Grab sample collections of bulk gravel and analysis of particle size distribution (gravel size and weight measurement).	Reach 1, with focus on Reach 1A where spawning is most likely to be concentrated. Conduct during early portion of Interim Flow period.	Survey results would be used to determine the quantity, location, and quality of gravel available at different flows to support salmon spawning, egg incubation, and as substrate for juvenile rearing and food production. Survey results would also be used to determine the need and benefit of gravel cleaning or augmentation, and should identify opportunities for improvement if needed.
Riparian vegetation	Aerial mapping of riparian patches, supplemented with ground plots to document species composition, density, and canopy structure of vegetation patches within representative reaches of the river. Integrate 1-D hydraulic model with riparian initiation and recruitment needs to predict management actions to achieve natural riparian regeneration on appropriate geomorphic surfaces.	Reaches 1-5 during Interim Flow period	Results of surveys would be used to establish a current baseline of information on the species, densities, size, and geographic distribution of riparian vegetation. Results would also be used to monitor changes in vegetation over time and as a basis for determining the locations and benefits of additional riparian vegetation restoration. Model would be used to refine high flow releases during wetter water years to encourage natural riparian regeneration on appropriate geomorphic surfaces.

Table 2. Summary of Interim Flow information needs and experimental studies.

Metric	Method	Location and Time	Application of Results
Surface water flow	Stream gages installed and operated to USGS standards, stage-discharge rating curves calibrated for full range of flows.	At locations shown in Figure 3, water stage and stream discharge measured every 15 minutes (i.e., continuous) over the long-term (Interim Flows and Restoration Flows).	Accurate flow estimates at various locations along the river would be related to fish habitat assessments (e.g., flow-water depth for passage, flow-inundation area for rearing, flow-temperature for spawning/egg incubation, rearing and migration, etc.), geomorphic assessments (e.g., relating sediment transport thresholds and rates to flow), riparian assessments (e.g., relating flow magnitudes and recession rates to riparian germination and initiation), flow losses/gains, flood conveyance, and other parameters. Accurate flow estimates would also document whether reach-specific flow targets are being met by Friant Dam releases and other water management actions.
Habitat suitability criteria	Compilation and analysis of data collected from other rivers and streams regarding habitat suitability (e.g., water depth, velocity, substrate, cover, water temperatures, adult holding pools, etc.) as a function of fish use preference.	Initially obtain from other regional studies (e.g., Butte Creek, Tuolumne River) in 2009.	Habitat suitability criteria are used as the basis for estimating suitable habitat amount required for each run and life stage of Chinook salmon reintroduced to the river.
Water depth, velocity, cover, and substrate	Measurements at field study sites (planform grid or cross-sections) over a range of flows to confirm habitat suitability criteria met.	Reach 1, conducted in first two years of Interim Flow period, Interim Flows altered to gather data over range of flows.	Relationships between water depth, velocity, cover, substrate, water temperature, and river flow would be used to assess physical habitat conditions for juvenile rearing habitat, adult Chinook salmon holding, and adult Chinook salmon spawning as a function of flow.
Flow-habitat rating curves	Develop study plan for Reach 1 where water depth, velocity, and substrate are measured and/or computed over a range of flows. Integrate river measurements with habitat suitability criteria through analysis and modeling to relate changes in suitable habitat quantity for each life stage.	Reach 1, conducted in first two years of Interim Flow period.	Habitat suitability criteria and professional judgment are used as the basis for evaluating the quality and availability of habitat in the river at various flows. Results of flow-habitat curves would also be used to assess how changes in flow would be expected to affect habitat and how non-flow measures, such as gravel augmentation, could be used in restoration to increase habitat quality or availability. Flow-habitat curves could refine baseflow releases needed from Friant Dam to increase habitat availability for adult spawning, adult holding, and/or juvenile rearing.

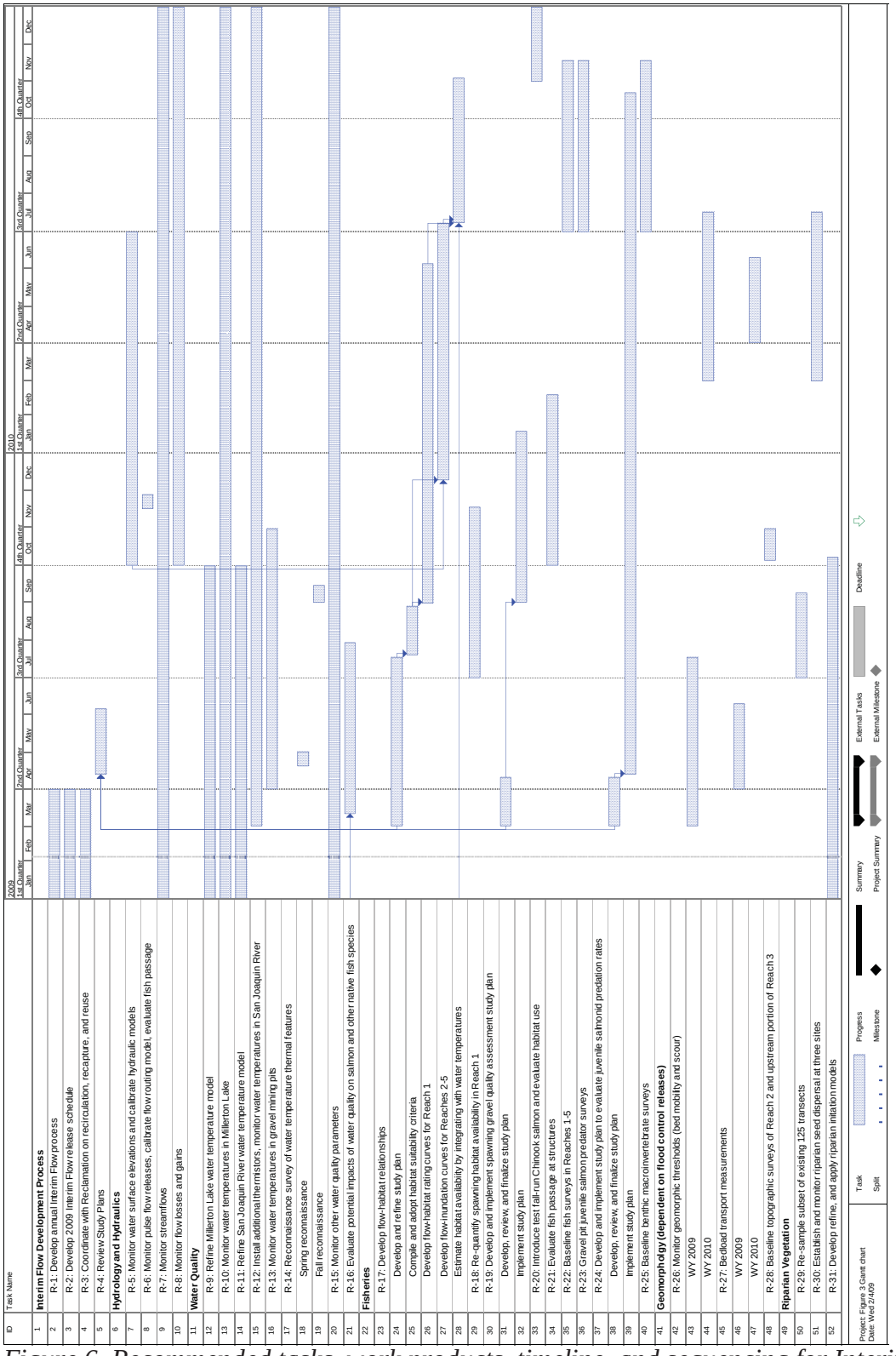

Figure 6. Recommended tasks, work products, timeline, and sequencing for Interim Flow Reommendations.

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