Final

2014 Monitoring and Analysis Plan

SAN JOAQUIN RIVER
RESTORATION PROGRAM

Final
November 2013

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2014 Monitoring and Analysis Plan

Prepared for and in cooperation with the SJRRP by MWH Americas, Inc.

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Abbreviations and Acronyms

°F	degree Fahrenheit
2D	two-dimensional
Act	San Joaquin River Restoration Settlement Act
ATR	Annual Technical Report
CDEC	California Data Exchange Center
cfs	cubic foot per second
CWT	coded wire-tag
Delta	Sacramento-San Joaquin Delta
DFW	California Department of Fish and Wildlife
DO	dissolved oxygen
DPFPA	Delta Pumps Fish Protection Agreement
DWR	California Department of Water Resources
EA/IS	Environmental Assessment/Initial Study
EDT	Ecosystems Diagnosis and Treatment
EIS/R	Environmental Impact Statement/Report
FL	fork length
Framework	Working Draft Framework for Implementation
HFB	Hills Ferry Barrier
HORB	Head of Old River Barrier
HSI	habitat suitability index
Implementing Agencies	agencies responsible for implementing the Settlement
LiDAR	light detection and ranging
m^2	square meter
MAP	Monitoring and Analysis Plan
MID	Merced Irrigation District
MMP	Monitoring and Management Plan
MYTR	Mid-Year Technical Report
NMFS	National Marine Fisheries Services
NOAA	National Oceanic and Atmospheric Administration
PEIR	Program Environmental Impact Report
PEIS/R	Program Environmental Impact Statement/Report
PIT	passive integrated transponder
QA	quality assurance
QC	quality control
RA	Restoration Administrator

Reclamation	U.S. Department of the Interior, Bureau of Reclamation
RM	River Mile
RST	rotary screw traps
RWA	Recovered Water Account
SalSim	Salmon Simulator Model
Settlement	Stipulation of Settlement in *NRDC, et al., v. Kirk Rodgers, et al.*
SIG	small interdisciplinary group
SJRRP	San Joaquin River Restoration Program
SRH	Sedimentation and Review Hydraulics
State Water Board	State Water Resources Control Board
State	State of California
SWAMP	Surface Water Ambient Monitoring Program
The Act	The Salmon, Steelhead Trout, and Anadromous Fisheries Program Act (1988
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
VAMP	Vernalis Adaptive Management Plan

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1.0 Introduction

This Monitoring and Analysis Plan (MAP) is an annual update to the San Joaquin River Restoration Program's (SJRRP) strategy to resolve uncertainties associated with flow scheduling, channel improvements, fisheries reintroduction, and water management on the San Joaquin River. The MAP presents both immediate and long-term objectives to address uncertainties associated with implementing the SJRRP. The immediate objectives of the MAP are to identify monitoring and analysis activities planned for 2014 to support implementation of the SJRRP, and to solicit feedback on 2014 activities through the public review process. The Stipulation of Settlement in *NRDC, et al., v. Kirk Rodgers, et al.* (Settlement) defined Restoration and Water Management goals, and identified actions to achieve both goals using information available in 2006. The SJRRP Settlement Act (Act) of 2009 authorized implementation of the Settlement and identified additional improvements to achieve the Water Management Goal. The SJRRP developed a *Working Draft Framework for Implementation* (Framework) (SJRRP, 2012b) to incorporate information gained subsequent to 2006 to identify the priorities, benefits, schedules, and costs of actions to meet the Settlement and legislation. The MAP identifies strategies to address uncertainties associated with potential actions listed in the Framework.

To organize potential actions under the SJRRP, the following themes describing objectives for accomplishing the Restoration and Water Management goals were developed and are presented below as they are presented the Framework:

- **Rearing Habitat** – Involves establishing or improving rearing habitat to promote a healthy salmon population in the San Joaquin River.

- **Spawning and Incubation** – Involves identifying and providing appropriate conditions to improve survival and hatch eggs successfully.

- **Adult Migration Paths** – Includes actions to remove false migration paths that lead to unsuitable spawning habitat, being trapped, or prohibiting fish from traveling to suitable habitat in time to reproduce.

- **Flow Scheduling** – Encompasses all actions under Paragraph 13 of the Settlement, including operational actions at Friant Dam, compliance with hydrographs defined in the Settlement, recapture accounting, scheduling, water acquisitions, banking, and permit requirements.

- **Conveyance** – Involves establishing nondamaging channel capacities to allow releases that provide for fish movement and to maintain acceptable water temperatures.

- **Entrainment Protection** – Includes actions to screen diversion facilities and identify whether other diversions will entrain large numbers of emigrating juveniles to prevent the loss of juvenile salmon.

- **Predation** – Includes studies to assess and limit predation of juvenile salmon that affects migration survival and impedes the SJRRP from meeting fish population targets.

- **Fish Passage** – Involves creating a reliable passage corridor to help fish move down and up the San Joaquin River to complete their life cycles.

- **Fish Reintroduction** – Includes conducting a series of efforts to further understand the reintroduction process through developing a captive Chinook salmon broodstock, conducting expanded studies to address key uncertainties, and implementing pilot Chinook salmon release efforts to test and refine strategies.

- **Water Management** – Encompasses actions that include identifying, developing, and implementing projects and programs to reduce or avoid adverse water supply impacts to all of the Friant Division long-term contractors that may result from the Interim and Restoration flows provided for in the Settlement.

These themes represent objectives for which additional information will be collected in consideration of releasing and conveying Interim and Restoration flows, reintroducing fish and providing for fishery needs, protecting Third Parties, and reducing or avoiding water supply impacts.

The MAP follows the SJRRP annual planning and reporting process (see Figure 1-1), which includes reporting on studies completed from the previous year, providing a mid-year update on ongoing studies for the current year, and the planning for the following year (i.e., MAP). The studies presented in this MAP are planned for 2014 and will be reported online biannually as data and reports become available.

The MAP is developed with input from the Implementing Agencies, Restoration Administrator (RA), stakeholders, and other technical specialists. This input is necessary to define appropriate data needs, study methods (i.e., define scope and accuracy of the study plans), and any monitoring or analysis that is needed for the SJRRP. The SJRRP makes the MAP available in draft form for public review before finalizing plans for the following year. The public review period provides an opportunity for the public to read and submit comments on the document. Following the public review period, public comments will be evaluated and considered for revising the MAP.

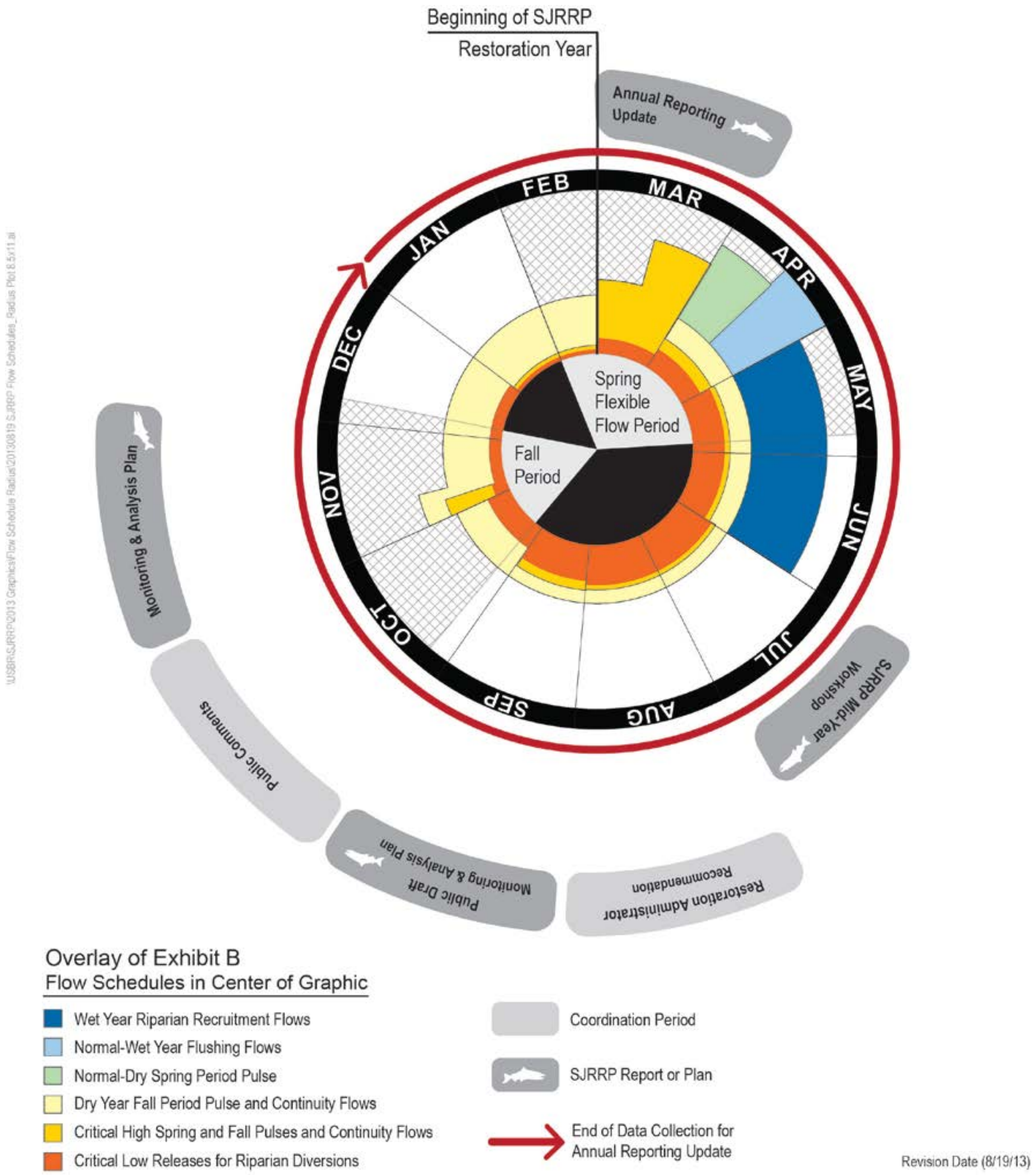

Figure 1-1.
Monitoring and Reporting Schedule

During 2013, the SJRRP convened small interdisciplinary groups (SIG) for three of the ten themes, and anticipates continuing these groups and convening new groups in 2014. The three groups formed in 2013 broadly cover the SJRRP; these were rearing habitat, adult migration, and spawning and incubation. The groups met multiple times throughout 2013 to begin compiling information to document the current state of knowledge surrounding each theme, to develop and refine questions to be addressed through research processes, and to reevaluate any uncertainties associated with their respective themes.

The three SIGs that convened in 2013 created 'states of knowledge' to capture the compiled information, to address the identified gaps in data, and to compile the strategies produced by the groups. The 'state of knowledge' sections were developed to describe the following information:

- Key characteristics associated with each theme
- Existing knowledge regarding these key characteristics as they relate to limiting factors identified in the conceptual population model (Section 2)
- Remaining data gaps or unknowns that should be addressed through future studies which are reflected in their associated questions

These states of knowledge are presented in Section 3.

1.1 Settlement Background

Agencies responsible for implementing the SJRRP (Implementing Agencies) include the U.S. Department of the Interior, Bureau of Reclamation (Reclamation); U.S. Fish and Wildlife Service (USFWS); California Natural Resources Agency; California Department of Water Resources (DWR); California Department of Fish and Wildlife (DFW); U.S. Department of Commerce; and the National Marine Fisheries Service (NMFS). Implementing Agencies of the SJRRP are responsible for developing the approach described above to meet Settlement requirements. Collecting data and performing analyses to address questions about how the San Joaquin River will function under implementation of the Settlement will inform approaches for addressing the issues mentioned above. Questions pertaining to the themes have been identified, or will be identified. Data collection and technical analyses will center on improving understanding of physical and biological processes to contribute to reducing uncertainties related to addressing the questions.

These approaches are being developed to meet the two primary goals of the Settlement. The primary goals are as follows:

- **Restoration Goal –** To restore and maintain fish populations in "good condition" in the main stem San Joaquin River below Friant Dam to the confluence of the Merced River, including naturally reproducing and self-sustaining populations of salmon and other fish.
- **Water Management Goal –** To reduce or avoid adverse water supply impacts on all of the Friant Division long-term contractors that may result from the Interim and Restoration flows provided for in the Settlement.

To meet the Restoration Goal, the Implementing Agencies are faced with the challenge of identifying physical and biological conditions that would support restoring and maintaining fish in "good condition," and how those physical and biological conditions should be met through implementing actions. The Settlement and Implementing Agencies have defined a list of potential projects and actions developed through site-specific studies and the Program Environmental Impact Statement/Report (PEIS/R) (SJRRP, 2012a). These actions are identified and described in the Framework (SJRRP, 2012b). Actions for meeting the Restoration Goal would result in the conveyance of nondamaging flows and provide, at a minimum, a migration corridor for Chinook adult and juvenile salmon to complete their life cycle. Core actions for meeting the Water Management Goal would result in completion of the actions identified in the Settlement and Act to reduce or avoid water supply impacts as a result of Interim and Restoration flows. The core actions were identified in the Framework (SJRRP, 2012b) as being necessary to meet the terms of the Settlement and Settlement Act. Secondary actions were identified in the Framework (SJRRP, 2012b) as potentially being required to meet the terms of the Settlement and Settlement Act. Improvement actions were identified in the Framework (SJRRP, 2012b) as potentially increasing the SJRRP's success. Additional actions identified by Implementing Agencies are included in this MAP.

1.2 Schedule for Implementing Actions

The SJRRP released a draft schedule for implementing actions to support meeting the Restoration and Water Management goals in the Framework. This schedule and the schedule for individual studies submitted and planned for implementation during 2014, are organized by themes and are presented in Figure 1-2. Studies may span multiple years and typically consist of monitoring or data gathering to address a specific uncertainty.

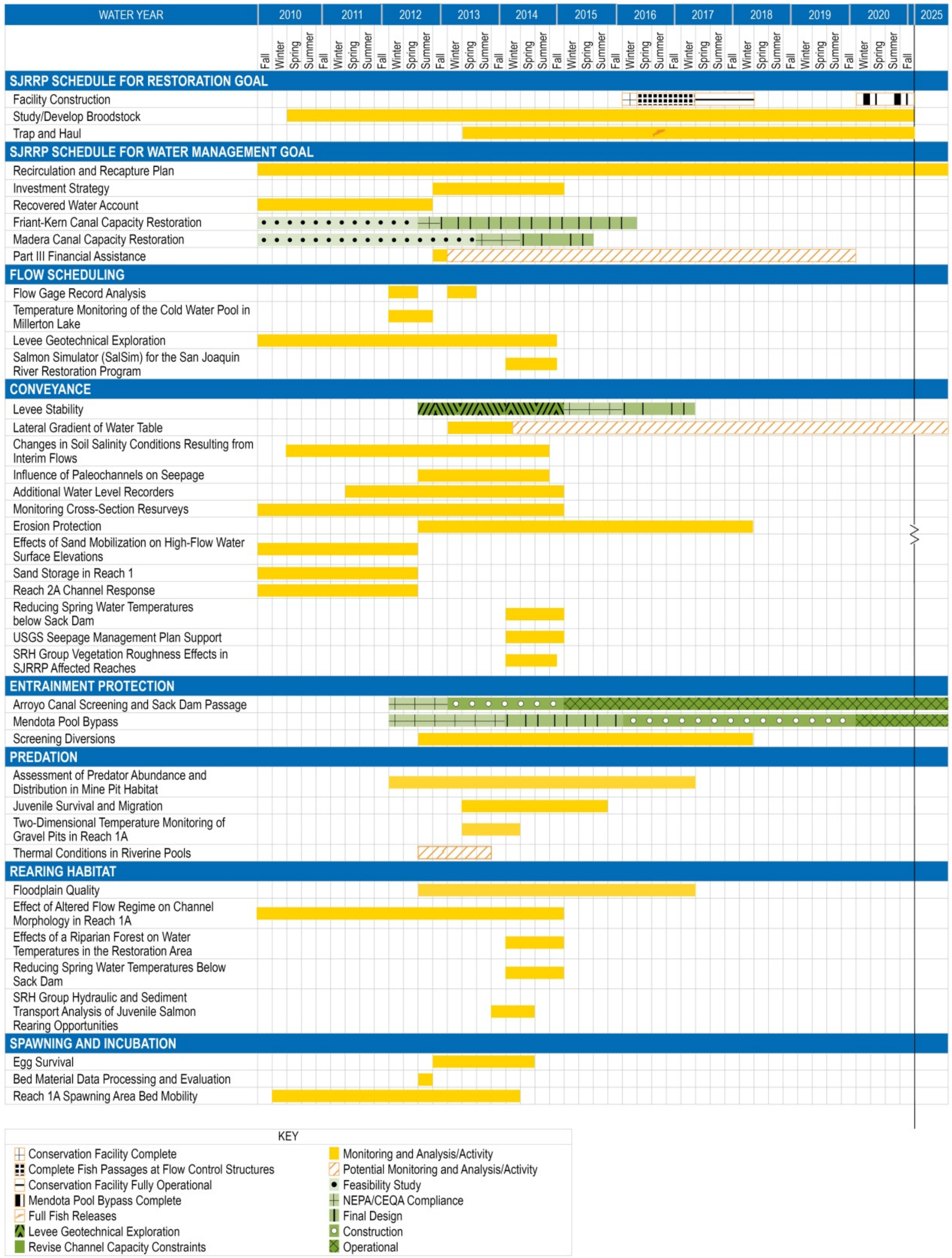

Figure 1-2.
Monitoring and Analysis Schedule

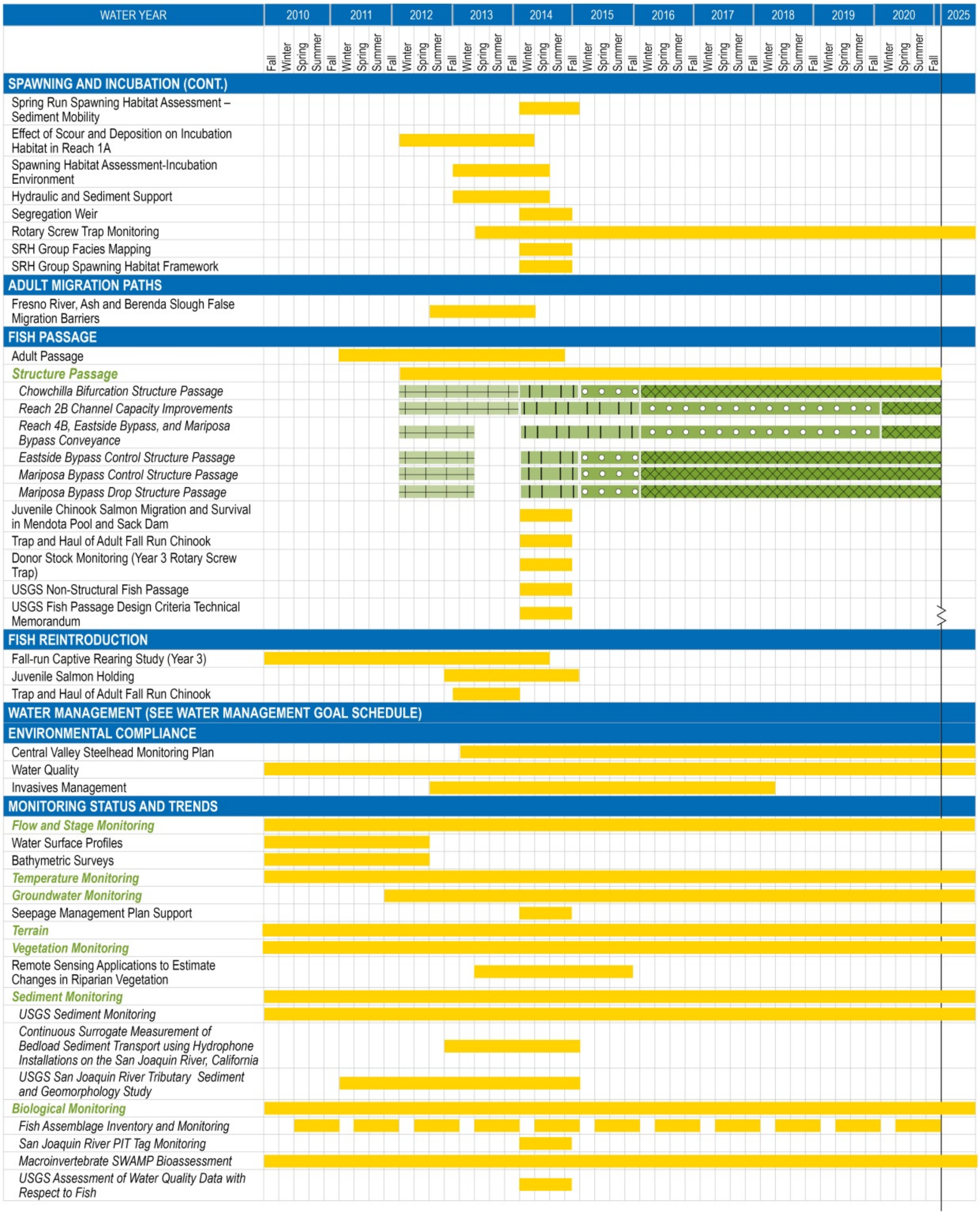

Figure 1-2.
Monitoring and Analysis Schedule (contd.)

1.3 Document Organization

Document organization is presented below.

Section 1, Introduction – Describes the MAP purpose and process, Settlement background, draft schedule for implementing actions described in the Framework, and document organization.

Section 2, Conceptual Population Model – Describes a conceptual model of how environmental factors are likely to affect the abundance of salmon in the Restoration Area.

Section 3, Themes – Lists actions identified in the Framework, provides the current state of knowledge, as available, identifies key questions regarding uncertainties, and describes resulting studies that support further addressing information needs.

Section 4, Monitoring Status and Trends – Describes the long-term monitoring performed to meet Settlement requirements and to record status and trends for different physical and biological conditions.

Section 5, Environmental Compliance – Describes monitoring and analysis components that are incorporated into actions to meet permit conditions and commitments in environmental documents.

Section 6, Monitoring Network – Describes the (1) components monitored, and (2) the presentation of current and proposed monitoring locations.

Section 7, Analytical Tools – Describes (1) available numerical models and other technical tools used to analyze monitoring data, and (2) proposed revisions to analytical tools.

Section 8, Monitoring Activities Summary – Summarizes the schedule and budget for monitoring activities in 2014.

Section 9, Conclusions – Summarizes the anticipated outcomes of 2014 monitoring and analysis activities.

Section 10, References – Lists sources used to compile this MAP.

Attachment 1 – Lists studies for both 2013 and 2014.

Attachment 2 – Lists ongoing and complete studies and relevant conclusions for adaptive management planning.

Appendix A Studies – Presents studies selected for implementation in 2014. The studies presented in Appendix A are supported by information collected from the monitoring network, and analysis conducted using available analytical tools presented in Section7.

The studies presented in Appendix A were developed to address key actions consistent with the SJRRP implementation schedule, and are described in the Framework.

Appendix B Budget Summary – Summarizes the budget for each study during 2014.

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2.0 Conceptual Population Model

This conceptual population model describes the environmental factors in the Restoration Area that may prevent the establishment of viable spring-run and/or fall-run Chinook salmon populations. A viable population has been defined as a minimum escapement of 500 fish, a minimum total escapement of 2,500 fish over 3 years, and a low percentage of hatchery-produced fish (Lindley et al., 2007). Assuming that droughts consisting of two or more consecutive dry/critical high/critical low water year types continue to periodically occur as have occurred historically in 20 percent of years, the greatest challenge for the SJRRP is to identify and implement restoration actions that will produce a minimum escapement of 500 naturally produced adults during these relatively dry years. The SJRRP assumes that hatchery supplementation will be required to mitigate effects to populations associated with low escapement at least during critical high/low water year types (e.g., maintaining genetic diversity). Establishing a viable population will allow the population to gradually adapt to the habitat in the Restoration Area and maintain the genetic diversity needed to survive perturbations in their habitats (Ruckelshaus et al., 2002; Lindley et al., 2007). Therefore, establishing a viable population is an essential step toward achieving the growth population targets of 30,000 adult spring-run Chinook salmon and 10,000 adult fall-run Chinook salmon annually (SJRRP, 2010a).

This conceptual population model will lead to a set of testable hypotheses based on the current state of knowledge of fish habitat conditions in the San Joaquin River between Friant Dam and the Merced confluence, as well as Chinook salmon behavior in the San Joaquin River Basin. One key assumption of the model is that the Settlement Paragraph 11(a) projects will provide hydrologic and morphological conditions suitable for passage of adult and juvenile salmon and suitable juvenile rearing habitat at the 11(a) project sites. Another key assumption influencing the model is that SJRRP flow allocations are limited to those specified in the Settlement and to minimal unimpaired runoff below Friant Dam. The SJRRP formulates flow scheduling hypotheses in this context of limited volumes available and the need to balance between the needs of each of the salmon's life history stages. The hypotheses described in the conceptual population model represent a combination of Restoration Area-specific data and professional judgment and will require testing through monitoring and analysis.

Objectives for this conceptual model include:

- Identify hypotheses on the factors affecting Chinook salmon life cycles on the San Joaquin River.

- Synthesize the state of scientific knowledge of fish habitat conditions in the San Joaquin River.

- Prioritize factors affecting Chinook salmon based on significance to the population goal of a viable population and the ability of program actions to affect or manage factors.

- Focus studies and activities on factors within the scope of the SJRRP.

The Fisheries Management Plan (Chapter 3.0 in Exhibit A) (SJRRP, 2010a) describes numerous habitat stressors that may affect salmon in the Restoration Area, whereas this conceptual model of limiting factors identifies the stressors that are most likely to limit escapement based on our current state of knowledge. Limiting factors are those that impair one life history stage to a greater degree than the other life history stages are impaired, and escapement can only be increased by alleviating the limiting factors. For example, gravel mining and high sand loads in Reach 1 of the San Joaquin River will likely impair spawning and egg incubation life histories; however, salmon populations in the San Joaquin River Basin are typically limited by elevated high springtime temperatures that impair juvenile passage (Mesick, 2012). Because passage is impaired by elevated temperatures, spawning habitat restoration projects in the Stanislaus, Tuolumne, and Merced rivers have not increased fall-run escapements in those rivers (Anadromous Fish Restoration Program, http://www.fws.gov/stockton/afrp/). It is possible that after eliminating the primary limiting factors, the salmon populations may not yet be viable due to secondary limiting factors. It will be important to use an adaptive management approach (Ecosystem Restoration Program, 2013) that includes a cycle of monitoring and research, followed by restoration actions, and further monitoring and research to identify all limiting factors and actions needed to achieve viable salmon populations. Conversely, it is not feasible to alleviate all possible stressors or restore the river to its predisturbance condition due to funding limitations (SJRRP, 2012b; Kondolf et al., 2008).

The SJRRP developed this conceptual population model as a tool for coordination of future planning, monitoring, and analysis for the SJRRP adaptive management program. The SJRRP will revise the model when new information is available that will resolve issues with competing hypotheses. New information may come from monitoring results, RA recommendations, feedback from interested parties, or peer-reviewed research both within and outside the SJRRP. Hypotheses supported by San Joaquin River monitoring and modeling results will receive the highest priority, followed by hypotheses based on Central Valley literature, and then literature from other regions. The SJRRP invites interested parties to present new ideas at Restoration Goal Technical Feedback Group meetings, Fisheries Technical Feedback Group meetings, on the MAP, or by contacting SJRRP staff. In incorporating additional hypotheses, the agencies will look for a description of the conditions specific to the Restoration Area and the supporting literature that documents the rationale for concerns and the significance to the population.

In the absence of a recent history of San Joaquin River salmon, the SJRRP developed hypotheses in the current conceptual model to use the best available information based on habitat studies in the Restoration Area, monitoring under a limited range of flows, and studies in other Central Valley streams. Most of the concepts will require testing through monitoring and targeted research as salmon are reintroduced into the Restoration Area and restoration projects are implemented to increase channel conveyance capacity and improve fish passage. The conceptual model identifies a number of potential factors that could result in high mortality rates for several of the life stages. Efforts to understand cumulative effects may require a long-term process, and the conceptual model will likely change over time as the agencies and stakeholders obtain additional information.

2.1 Chinook Salmon Life-Stage Requirements

The Fisheries Management Plan (Chapter 3.0 in Exhibit A) (SJRRP, 2010a) describes the requirements of life-history stages of spring-run and fall-run Chinook salmon. What makes the restoration of Chinook salmon populations particularly difficult compared to most other species of fish is that salmon are anadromous, which means that the adults migrate from the ocean to Reach 1 in the Restoration Area to spawn, and then the juveniles must migrate back to the ocean to rear. Mortality risks are greatest during these migrations. Adult spring-run Chinook salmon migrate upstream from March through June, whereas adult fall-run Chinook salmon migrate upstream between September and December. Most juvenile salmon will probably disperse downstream soon after emergence to rear throughout the Restoration Area before proceeding to the ocean, whereas some will rear in Reach 1 before directly migrating to the ocean; and a few may rear in Reach 1 for a year before migrating to the ocean (SJRRP, 2010a). A key to restoring salmon populations is to preserve and sustain life history diversity (Ruckelshaus et al., 2002; Beechie et al., 2006). This means that it will be important to provide habitat conditions that facilitate the success of early and late migrants for both juveniles and adults to the greatest extent possible.

2.2 Limiting Factors

The success of spring-run and fall-run fish (at the individual and population level) depends on survival, diverse life history strategies, condition of the individuals, growth rate, positive bioenergetics conditions, and adequate food. A number of stressors or limiting factors that can limit positive conditions necessary for success include flow magnitude (inadequate flow), poor water temperature, structures that impede passage, presence of predators, lack of food base, and unscreened water diversions during their migration. Limiting factors in the Restoration Area that are anticipated to require restoration or other actions to implement the Settlement include inadequate streamflow, entrainment, excessive straying, impaired fish passage, unsuitable water temperatures, reduced genetic viability, degraded water quality, excessive harvest, excessive redd superimposition, excessive hybridization, limited holding pool habitat, limited gravel availability, excessive sedimentation, insufficient floodplain and riparian habitat, limited food availability, and excessive predation (FMWG, 2009).

2.2.1 Spring-Run Chinook Salmon

High water temperatures are hypothesized as to potentially be the most significant limiting factor for the success of spring-run Chinook salmon in the Restoration Area in reaches 3 through 5, which could prevent passage for a majority of adults. Water temperature modeling suggests that almost all adult spring-run salmon will encounter water temperatures in the Restoration Area that will be near or exceed the upper threshold for adult passage in all water year types. To address the temperature issue, as well as passage issues, a large portion of the flow allocation could be required for the adult spring-run life stage, which would leave relatively little water available to improve conditions for juveniles, including both temperature and passage. Juvenile passage and juvenile production in Reach 1 could be impaired by high water temperatures, predation risk at flow control structures and numerous captured mine pits, high sand loads, and large water diversions. Juvenile passage and production in Reach 1 are assumed to be moderate priorities because at least some juveniles should be able to successfully complete their life history stage after scheduled restoration actions have been completed.

Adult Passage through the Restoration Area

As early as mid-April, adults may encounter water temperatures in Reaches 4B and 5 that exceed the maximum target of 68 degrees Fahrenheit (°F) for adult passage. The maximum target of 68°F is computed as the 7-day mean of the daily maximum temperatures. A flow of 4,100 cubic feet per second (cfs) may produce water temperatures near the 68°F target in Reach 4B from mid-April through the end of May. If this target is exceeded by mid-May, it is unlikely that more than 66 percent of the adults would be able to migrate into Reach 1 and successfully spawn. Migration timing for adult spring-run Chinook salmon in the Restoration Area is based on Didson camera counts in Mill Creek in 2006 (Johnson et al., 2006). It is also assumed that the adult passage will have to be provided through at least the end of April (about 30 percent passage) to maintain a viable population based on spreadsheet population models (SJRRP 2013b). The timing of adult spring-run salmon migrations in the San Joaquin River Basin may be later than occurs in Mill Creek fish, based on the video counts at Woodbridge Dam on the Mokelumne River. In 2002 and 2003, very few (less than 3 percent) adult spring-run salmon were counted with the video system at Woodbridge Dam in March and April, whereas most (89 percent) migrated in June and July (Michelle Workman, USFWS, personal communication, 2013). It may be possible to reduce water temperatures in reaches 3 through 5 through a combination of actions, such as (1) planting trees to provide shade (SJRRP, 2008), (2) narrowing and deepening the channel (SJRRP, 2008), (3) managing flow splits in the Reach 4B project, and (4) by planting trees in a wide corridor to reduce air temperatures along the river (Moore et al. 2005).

Juvenile Passage Through the Restoration Area

The number of juvenile salmon that successfully migrate from the Restoration Area will probably depend on (1) whether adequate flows are provided during passage, and (2) juvenile size, numbers, and overall health when they initiate migration. It is highly likely that the relative number of juveniles emigrating as fry (less than 40 millimeter fork length (FL)), will be relatively low to other migrant life stages and survival of juvenile migrants, particularly newly emerged fry, will also be low during base flows (Merz et al. 2013; Sturrock et al., 2013). Presumably, high and variable flows improve juvenile survival via several mechanisms, such as (1) inundating vegetation on the riverbank that provides refuge from predators, (2) stimulating mass juvenile migration that overwhelms predators, (3) reducing stressful springtime temperatures and daily temperature fluctuations, (4) reducing the percentage of flow that is diverted or pumped and thereby reducing entrainment rates, (5) improving other water quality parameters (e.g., dissolved oxygen, toxins) and potentially reduced exposure to stressors within a given reach (Cavallo et al. 2013). Providing adequate passage for fry to downstream reaches may accelerate their growth rates due to warmer water temperatures compared to those in Reach 1 during winter. Accelerated growth rates, leading to larger size, may improve individual migrant survival (Zeug and Cavallo 2013) and potentially increase life history diversity demonstrated in the population. If growth rates can be accelerated, the percentage of juveniles that migrate from the Restoration Area before the time when water temperatures become critical (greater than 64.4 °F) should increase. It is believed that improved growth rates will likely be critical for life history diversity and downstream survival. Survival through the Restoration Area and downstream will depend on among other things, the ability for the juvenile to experience adequate growth. The amount of flow available for juvenile passage may depend on the amount required for adult passage, which, it is hypothesized, will primarily occur in the San Joaquin River after most spring-run juveniles have migrated. Chinook salmon may emigrate at a variety of stages, including fry, parr, and pre- and post-yearling smolts. However, the emigration strategies demonstrated, and the success of each, are likely influenced by genetics, flow variability, and water temperatures (Groot and Margolis, 1991; Mesick, 2012; Zeug and Cavallo, 2013; Merz et al., 2013; Sturrock et al., in preparation). This variability most likely has a strong impact on the long-term viability of salmon populations (Shindler et al., 2012). Therefore, it will be an important objective for targeted research to determine how juvenile passage can be maximized using both flow and non-flow measures, to improve diversity and overall success of emigrant survival within the SJRRP.

There is a relatively high number of captured mine pits, flow control structures, and diversions in the Restoration Area that may result in high predation risk for juvenile salmon migrants. Significant investments made in the San Joaquin River Basin to restore mine pits on the Tuolumne and Merced rivers did demonstrate improve fall-run Chinook salmon escapements. In the Tuolumne River, for example, restoring the large pit at Special Run Pool 9 and isolating the off-channel pit called Special Run Pool 10 did not reduce predation rates nor improve the survival of juvenile salmon during managed flows (Turlock Irrigation District and Modesto Irrigation District, 2005). In addition, results of predation studies are often inconclusive. For example, intensive efforts to study the predation risk of naturally produced juvenile salmon in the Tuolumne River in the late 1980s (Turlock Irrigation District and Modesto Irrigation District, 1992) and again in 2012 (Fishbio, 2013) were not successful due to uncertainties related to total abundance estimates of juvenile salmon and predators, as well as issues with extrapolating predation rate estimates to a 24-hour period based on a single stomach content sample. Passive integrated transponder (PIT) tag and acoustic tag studies cannot evaluate predation risk for fry-sized juveniles, and it is likely that tagged hatchery fish have an elevated risk of predation compared to untagged naturally produced juveniles. It is also likely that predation risk is a function of elevated water temperature (Marine and Cech, 2004) and other stressors, such as contaminants (Ewin, 1999; Scholz et al., 2000) and disease (Mesa et al., 1998). If true, the best solution might be to minimize the stressor, not manage predator populations. New study techniques and/or approaches are needed to evaluate predation risk and, if necessary, possible solutions. For example, if contaminants were determined to elevate predation risk, their impact might be reduced with levee setbacks, riparian restoration, and/or conservation easements to reduce pesticide and herbicide use adjacent to the river.

Juvenile Production in Reach 1 (Pre-Migration Emergence and Survival)

Juvenile production is a combined function of egg survival to emergence and the survival of juveniles until they begin their downstream migration. Juvenile production rates are assumed to be no more than 13 percent in Reach 1 during managed flow releases, based on Stanislaus River fall-run salmon data (SJRRP 2013b). Due to the lack of gravel within the 4-mile-long reach below Friant Dam where water temperatures will most likely be suitable for spawning in September and October when adult spring-run salmon spawn, it is likely that spawning beds will need to be created for spring-run salmon. DFW estimated that there is only a total of 314 square meters (m^2) of spawning habitat in the 4-mile reach below Friant Dam based on their assumption that only 20 percent of riffle habitat will be suitable for spawning. This appears to be a reasonable estimate based on Stanislaus River studies that show that most (64%) adult Chinook salmon spawned in relatively short pool tails whereas few (10%) spawned in the relatively long riffle habitats (Mesick 2001). There are ongoing and proposed studies, discussed in more detail in Section 3.2, which will provide a more accurate estimate of spawning habitat quantity to determine if additional spawning habitat needs to be created to support self-sustaining populations of spring- and fall-run Chinook. It is also likely that high sand loads, loss of floodplain habitat, gravel mining in the channel, and degraded riparian vegetation have decreased the capacity of Reach 1 to produce juvenile salmon. It may be necessary to implement pilot restoration projects to evaluate potential actions intended to improve juvenile survival in Reach 1. For example, planting native riparian species may help reduce sand loads and increase juvenile rearing habitat quality, periodically adding organic matter may help offset the loss of floodplain habitats, and creation of shallow water habitat with refuge may increase the amount of suitable habitat in Reach 1.

Temperature modeling suggests that release temperatures in mid-November to early December could become high enough to impair egg and/or alevin survival near Friant Dam, where spring-run alevins are likely to be developing. However, based on the fall 2011 egg survival study, it is unlikely that warm-winter Friant Dam releases will be a limiting factor. Release temperatures increased to near the upper temperature target in mid-November 2011, as expected, but did not impair the survival of planted eggs in artificial redds near the dam. Temperatures peaked at 57.6°F in mid-November 2011, which is just below the critical level of 58°F for egg incubation. Based on the results of this study, monitoring of the release temperature should be continued to determine whether they might exceed the levels observed in 2011 during periods of egg incubation.

2.2.2 Fall-Run Chinook Salmon

It is likely that additional actions may be needed to restore a viable fall-run population. Fall-run salmon will encounter different habitat conditions because (1) fall-run juveniles will develop and migrate after spring-run juveniles in April and May when higher water temperatures may increase the risk of predation, disease, and direct mortality; (2) fall-run adults may spawn in the lower half of Reach 1A where sand loads are higher; and (3) adults will migrate during base flow releases when passage may be impaired in shallow areas. In general, the habitat in the Restoration Area is impaired to a greater degree compared to the Tuolumne and Merced rivers, where the fall-run escapements decline to less than 500 adults during dry water years (Mesick, 2012). Therefore, it is likely that a combination of actions that improve conditions for each life history stage in the Restoration Area will be needed for a viable population of fall-run salmon.

Juvenile Passage Through the Restoration Area

Survival of fall-run juveniles in the Restoration Area will likely be lower than for spring-run juveniles because a greater portion of fall-run juveniles are expected to migrate when water temperatures are predicted to be in the critical-to-lethal range in reaches 4 and 5. Juvenile fall-run salmon will migrate at approximately the same time as spring-run adults, and so pulse flows for spring-run adult migration could potentially benefit fall-run juveniles if administered at the appropriate time, volume and duration. However, optimum temperatures for juvenile passage are equal to or less than 60°F (SJRRP, 2010a) and water temperatures in Reach 4B are expected to exceed optimum temperatures by April 1 even at a 4,500 cfs release, based on temperature modeling to date. Therefore, targeted research should focus on cues that influence migration at optimal times and habitat restoration that reduces water temperatures in reaches 4 and 5 during the latter portion of juveniles emigration to improve passage conditions for both spring-run adults and fall-run juveniles. Two key factors related to juvenile success are life history diversity and size and timing of outmigration. Therefore, key limiting factors such as these should be considered when developing targeted research to study juvenile passage through the Restoration Area and downstream.

Egg Survival Impacts from Fine Sediment Deposition

It is possible that a segregation weir will be needed to keep fall-run spawners from impacting spring-run spawners and redds near Friant Dam. Restricting fall-run spawners to the lower half of Reach 1A where sand loads are high, will likely result in low egg survival to emergence rates and the development of weak, yolk-sac fry. Adult salmon clean sand from the gravel during redd construction, but sand may infiltrate egg pockets, particularly when other adult salmon spawn nearby and during increases in flow. Egg survival studies with fall-run Chinook salmon eggs in Reach 1A have indicated that egg survival is reduced where sand concentrations are high. However, egg survival rates in Reach 1A in fall 2011 were comparable to those in the Stanislaus and Tuolumne rivers and so it is unlikely that high sand loads will be a primary limiting factor. Targeted research should focus on actions that would provide sustained benefits. For example, gravel augmentation or sand removal projects may not be effective if implemented in areas with high sand loading. Reducing sand loading rates or increasing sand storage in the floodplain may be more effective actions in the long term for improving fall-run spawning habitat. In any case, a long-term sediment budget in association with flow management that supports habitat creation, quality and maintenance is needed.

Adult Passage During Base Flows

Adult fall-run will probably migrate into the Restoration Area between mid-October and mid-December, based on Stanislaus River weir counts. Water temperatures are likely to be adequate for adult passage throughout the Restoration Area beginning in late October. However, it is unknown whether base flow releases will provide suitable water depths and velocities for adult passage throughout the Restoration Area. The Restoration

Hydrographs require 115 cfs in reaches 3 through 5 in October and a minimum of 155 cfs in November and December in all but critical water year types. There may be locations in reaches 3 through 5 that are too wide to provide suitable water depths for adult passage at these flows. Targeted research is needed to determine whether channel modifications will be necessary to provide adult passage during base flow releases.

2.3 Summary

Assuming that the 11(a) projects will provide hydrologic and morphological conditions suitable for passage of adult and juvenile salmon and suitable juvenile rearing habitat at the project sites, the conceptual model suggests that high springtime water temperatures, particularly in reaches 3 through 5, will need to be reduced by at least a few degrees Celsius to restore viable populations of spring-run and fall-run Chinook salmon in the Restoration Area. There are also many uncertainties about how salmon will respond to the habitat in the Restoration Area that can only be addressed after flow connectivity has been restored and substantial numbers of salmon have been reintroduced into the river. It should be possible to begin a population monitoring plan in winter 2013 and spring 2014 to assess the success of spawning, egg incubation, juvenile rearing, and downstream migration of fry and smolts. Monitoring of adult passage in reaches 4 and 5 should be able to begin in fall 2014. Another key research need will be to determine how best to manage flow releases, particularly in dry water year types, to balance the needs of all the life history stages of spring-run and fall-run salmon.

3.0 Themes

Each theme includes the actions identified in the Framework (SJRRP, 2012b), questions regarding uncertainties, and resulting studies to support further addressing the information needs. Additionally, the state of knowledge is provided for the three themes whose SIGs convened during 2013, which synthesizes existing information related to each theme. Prioritizing implementation of actions is driven by the ability of those themes to address uncertainties, and to meet the schedules for potential projects and actions described in the Settlement, Public Law 111-11, environmental compliance, and RA recommendations.

The questions presented in each subsection identify key uncertainties related to SJRRP implementation, and will be used to support Principal Investigators in developing studies and testable hypotheses. The questions are categorized as being related to either core, secondary, improvement, or other actions (C/S/I/O) in Tables 3-1, 3-4, and 3-6. Core, Secondary, and Improvement actions were defined in the Framework (SJRRP, 2012b) and are defined in Section 1. Questions identified in Tables 3-7 through 3-13 were developed through discussions and coordination with members of the SJRRP Technical Advisory Committee (TAC) and the Fish Management Workgroup in 2012. These questions will be revised with input from technical experts participating in future SIG meetings focused on the related themes.

The studies presented under each theme define hypotheses, which provide rationale for why data are needed to support implementation of the Settlement. The studies also describe the methodology for collecting these data. Studies may span multiple years and typically consist of monitoring or data gathering to address a specific uncertainty existing within the Restoration Area.

3.1 Rearing Habitat

The following section describes the state of knowledge, questions, and studies associated with the rearing habitat theme. Figure 3-1 illustrates the schedule related to actions and studies that will be implemented under this theme.

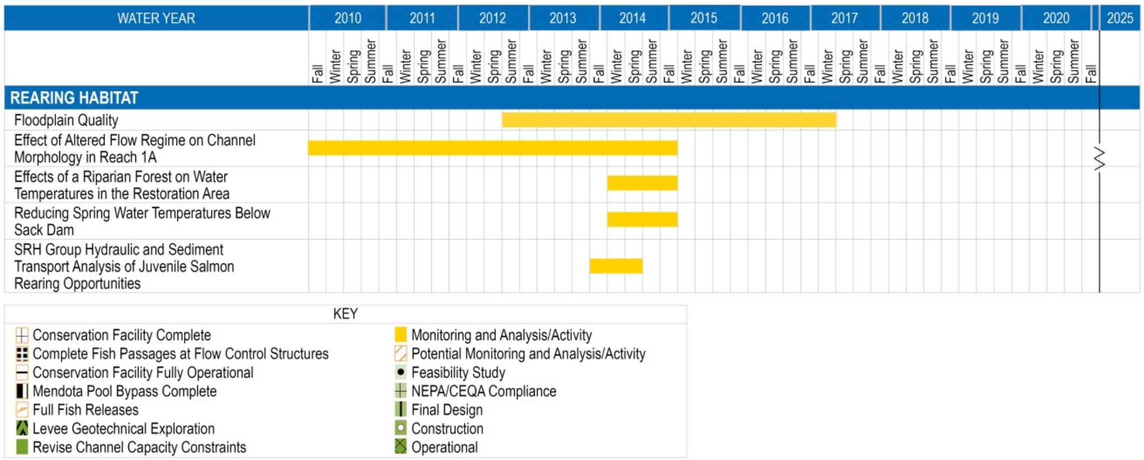


Figure 3-1.
Rearing Habitat Schedule

3.1.1 State of Knowledge

The purpose of the rearing habitat state of knowledge is to synthesize existing information about rearing habitat for Chinook salmon in the Restoration Area to guide the strategy and design for SJRRP studies and the implementation of actions.

Purpose and Objectives

To organize potential actions under the SJRRP, themes describing objectives for accomplishing the Restoration and Water Management goals were developed. Rearing Habitat is presented in the Framework as one of the themes to describe how Implementing Agencies may accomplish the Settlement Goals (SJRRP, 2012b). The core actions identified in the Framework (SJRRP, 2012b) for improving rearing habitat include levee setbacks, which allow grading of floodplains, and planting of riparian vegetation. As such, the Implementing Agencies are developing environmental documents and designs for site-specific actions that include the setback of levees and the establishment of floodplain vegetation. The Fisheries Management Plan (SJRRP, 2010a) identifies additional objectives that include high juvenile survival rates during base flow releases to be maintained at greater than 70 percent; suitable water temperatures throughout the Restoration Area when juveniles are present, water temperatures of less than or equal to 64°F, which are considered suitable in the Restoration Area; suitable water quality; and healthy macroinvertebrate communities (SJRRP, 2010a).

The objectives of the rearing habitat state of knowledge include:

- Link existing information to actions

- Organize existing information by rearing habitat component and information type
- Identify unanswered or follow-up questions for the rearing habitat questions section (Table 3-1)

Background

Juvenile rearing habitat in the Restoration Area has been significantly modified by agricultural development; hydrologic and sediment supply changes from operations of Friant Dam, Mendota Dam, and diversion systems; and the construction and operation of the Lower San Joaquin Flood Control Project. Land-use activities, such as road construction, urban development, gravel mining, agriculture, and recreation, are pervasive and have also significantly altered habitat quantity and quality for Chinook salmon.

Currently SJRRP studies have determined the number of acres needed for juvenile rearing habitat by reach. This is done for both the growth and long-term population targets. The Minimum Floodplain Habitat Area for Spring- and Fall-Run Chinook Salmon (SJRRP, 2012c) report also pulled together existing knowledge regarding depth, velocity, and cover appropriate for juvenile salmonids. Quantity of rearing habitat and quality of habitat are tradeoffs. The Minimum Floodplain Habitat Area for Spring- and Fall-Run Chinook Salmon (SJRRP, 2012c) report identified the quantity of rearing habitat required by reach based on the existing conditions habitat quality. Improved rearing habitat quality would improve conditions for fish and require less acreage. Program actions intended to restore or enhance rearing habitat include:

- Releasing flows and channel capacity
- Managing water temperature
- Construction of Mendota Pool Bypass
- Reach 2B channel capacity improvements
- Reach 4B/bypasses conveyance
- Floodplain revegetation
- Creation of habitat in reaches 1, 2A, 3, and 4A

The first four program actions identified above are core actions. The core actions were identified in the Framework (SJRRP, 2012b) as being necessary to meet the terms of the Settlement.

Key Characteristics of Rearing Habitat

The report on Minimum Floodplain Habitat Area for Spring- and Fall-Run Chinook Salmon (SJRRP, 2012c) defines habitat as the place where an organism lives (Odum, 1971; Baltz, 1990; Peters and Cross, 1992; Hayes et al., 1996) and as such, habitat that includes both main channel and floodplain habitat and provides physical parameters, such as food and shelter to support the development and growth of juvenile fish.

Additionally, the NMFS describes critical freshwater rearing sites as those with water quantity and floodplain connectivity to form and maintain physical habitat conditions and support juvenile growth and mobility; water quality and forage supporting juvenile development; and natural cover such as shade, submerged and overhanging large woody material, log jams and beaver dams, aquatic vegetation, large rocks and boulders, side channels, and undercut banks. Rearing habitat condition is strongly affected by habitat complexity, food supply, and presence of juvenile salmon predators.

All species have specific limits of tolerance to physical characteristics that directly affect their survival or reproductive success and this in turn may change in relation to age and development of a given organism (Keeley and Grant, 1995). The following describes key characteristics of rearing habitat for Chinook salmon.

- **Invertebrate Density –** Prey availability and density drives consumption rate which interacts bioenergetically principally with temperature and activity level to determine growth rate in a given habitat type. Research documenting improved salmon growth on Central Valley floodplains has attributed that growth to a combination of high prey densities driving improved consumption rates, and favorable temperature and flow conditions relative to habitat in the associated river channel (Summer et al 2001, Jeffres et al 2008.). Prey density tends to be driven by a range of physical and ecological factors including input from surrounding areas (terrestrial and aquatic), hydraulic residence time both as a component of in situ productivity and a driver of export rates, consumer densities and consumption rates, vegetative cover, and substrate type (Ahearn et al. 2006).

- **Vegetative Cover –** It is known that native riparian vegetation helps regulate stream temperatures (Moore et al., 2005), increase bank stability and channel complexity (Benda et al., 2004), promote biodiversity, improve water quality, and provides velocity refuge and food sources for juvenile salmon (Selheim et al., 2013; Andrews, 2012).

- **Channel Morphology** (e.g., undercut banks, connectivity) – Channel morphology affects the threshold at which flows inundate floodplains, threshold water temperature, sediment transport, hydraulics, habitat complexity, and the presence or absence of habitat for exotic predator species. Optimal in stream habitat conditions occur when channel morphology and flow schedule allow for the proper combination of timing, duration, and frequency of floodplain inundation. If inundation is too short, there is insufficient time for productive floodplain food webs to develop and little benefit to salmon is achieved (Humphries et al., 1999).

- **Substrate** (e.g., sediment grain size, organic content) – Substrate size and recruitment affects cover availability for young salmonids as well as macroinvertebrate species composition and abundance, which affects the availability of food for juvenile salmon (Suttle et al. 2004).

- **Water Quality** (e.g., temperature, salinity, turbidity) – Water quality has impacts on juvenile migration timing and speed, as well as overall health and survival. Growth and survivability in fish are optimum within a defined temperature range (Gadowaski and Caddell 1991). Water temperature outside this range may be related to increased stress, including vulnerability to disease and predation (Sylvester 1972; Dickerson and Vinyard 1999). Water temperature is important because many physical, chemical, and biological processes are significantly influenced by river temperatures, including the ability of water to carry dissolved oxygen (Piper et al. 1982).

- **Hydrology and Hydraulics** (e.g., flood patterns, inundation frequency, inundation duration, depth, and velocity) – For a stream to provide a productive rearing environment, the timing of flow pulses must coincide with appropriate temperatures and fish life stages (Junk et al., 1989; Bayley, 1991). If flows are decoupled from fish life cycles and physiological drivers (e.g., temperature), the advantage of floodplain inundation or prolonged rearing is largely lost (King et al., 2003). Juvenile Chinook salmon rear from approximately January until the physiological transformation to smolt begins. Flood pulses early in this period would provide opportunities for the greatest number of fish; however, temperatures may be too low to provide a growth advantage. Conversely, temperatures later in the rearing/migration period may be better for growth. The dispersal of flows onto floodplains also reduces velocity. The combination of reduced velocity (as a function of dispersed flows and velocity refuge in vegetative cover), prey density and optimal temperatures, creates the favorable bioenergetics conditions necessary to maximize growth.

Chinook Salmon Rearing in the Restoration Area

As described in the conceptual population model, elevated water temperatures after mid-April may substantially limit passage for both adults and juveniles. Water temperatures can impair juvenile salmon during smoltification and outmigration. When maximum daily water temperatures exceed 59°F, smoltification ceases, juvenile salmonids become highly stressed (U.S. Environmental Protection Agency 2003), and migration rates decline as observed in the Stanislaus and Tuolumne rivers (Mesick 2012). The ability of juvenile salmon to rear downstream of Reach 1 in the Restoration Area may depend on whether they can grow fast enough to complete smoltification before water temperatures exceed 59°F in late-February. Once juvenile salmon complete smoltification, they can tolerate higher temperatures (64.5°F) as they migrate downstream. However, water temperatures below Sack Dam are predicted to become stressful for smolts by mid-March under existing channel and riparian conditions. When water temperatures become stressful for juvenile salmon, disease, predation, and contaminants are likely to cause high rates of mortality.

Another concern is that the survival of fall-run juvenile salmon in the Stanislaus, Tuolumne, and Merced rivers is relatively low for those that attempt to rear in sand-bedded reaches during base flows compared to those that rear in gravel-bedded reaches even when water temperatures are highly suitable in winter. Studies have shown that the survival and growth of juvenile salmonids are low in sand-bedded habitats because the availability of food and cover are reduced in sand-bedded habitats (Suttle et al. 2004). In contrast, inundated floodplain habitats can provide an abundance of food and cover from predators (Sommer et al. 2001, Jeffres et al. 2008, Opperman 2008).

Restoration Strategies

The Rearing Habitat SIG suggested that water temperatures and floodplain functions could be simultaneously enhanced by taking the following actions:

- Minimizing the width of the base flow channel,
- Using the excavated substrate to create a "transition zone" within the main channel that could become inundated during modest increases in flow (e.g., 500 cfs), and
- Planting trees at high densities on all seasonally inundated habitats (Figure 3-1).

The following sections describe how the three actions identified by the group would relate to key characteristics. Only some of the key characteristics identified in the *Key Characteristics* section above, particularly those associated with elevated water temperatures and reduced floodplain inundation, are hypothesized as likely to limit the salmon populations in the Restoration Area. This section more fully describes the likely limiting factors associated with rearing habitat in the Restoration Area and links these limiting factors to key characteristics where applicable.

Vegetative Cover

A strategy to reduce water temperatures within the Restoration Area could be coupled with beneficial actions for floodplain productivity. Narrowing the base-flow channel and creating a dense forest canopy would potentially reduce both solar radiation and air temperatures after leaf-out in early spring and thereby reduce water temperatures. Prior to leaf-out of trees in late-winter, high levels of solar radiation may facilitate floodplain food production. Narrowing the low-flow channel, and/or planting riparian vegetation in the form of forest, perennial marsh, or riparian scrub across the floodway would reduce solar radiation reaching the river's flow.

There is also the potential that trees, could provide the added benefit of high levels of solar radiation in late winter, which would help increase food production for juvenile salmon, but also minimize solar radiation after the trees and shrubs gain their leaves in early spring while adult Chinook salmon are migrating and water temperatures are high. The presence of increased mature riparian forest would also attract beavers. The presence of beavers, given adequate woody material would likely result in ponding, creating areas of temperature refugia, as well as promoting increased channel dynamism, greater river-floodplain connectivity and greater habitat heterogeneity. A conceptual restoration design demonstrating several of these characteristics is provided below in Figure 3-2.

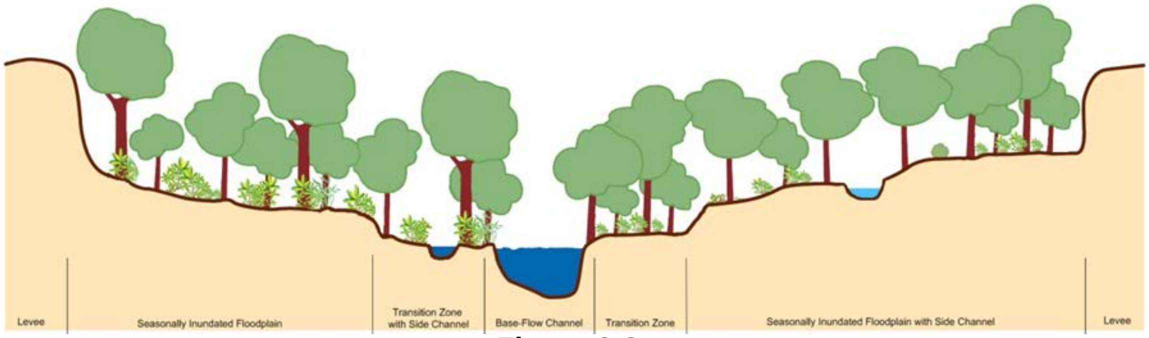


Figure 3-2.
Conceptual Restoration Design Showing a Narrowed Base-Flow Channel, Frequently Inundated Transition Zone, Floodplain Habitat, and a Dense Riparian Canopy

Channel Morphology

To maximize the benefit of habitat inundation with limited water resources, it is essential to understand the duration of flooding required to provide salmon growth and survival benefits. A major question is whether channel morphology can be resized to function with the Restoration Flow schedules and still provide productive floodplain ecology, a passage corridor with suitable water temperatures for both juvenile and adult salmon, and stable sediment transport processes. Using excavated substrate to create a “transition zone” within the main channel that could become inundated during modest increases in flow (e.g., 500 cfs) would create the opportunity to provide inundated habitats for prolonged periods of juvenile rearing. As a result of frequent inundation and a shallow groundwater table, the transition zone could support growth and recruitment of a riparian community that could also provide woody debris, bank stability, improved water quality, and other floodplain benefits. Increased riparian species within the Restoration Area would in turn help reduce water temperatures, increase food production, provide refuge from predators, provide channel stability, improve water quality, and provide large woody debris to the main channel.

Hydrology and Hydraulics

Reconnecting floodplain habitat in a regulated system presents unique challenges for creating conditions that mirror natural systems, particularly with limited water resources. Prolonged inundation of the entire floodway during wet years, which occurs about 20 percent of the time, is likely to provide high levels of natural juvenile production, which may be important to creating genetic diversity and facilitating adaptation to the Restoration Area. Flow management will have to be balanced between the need to provide suitable temperatures in the downstream reaches for passage and floodplain inundation for rearing. The greater the effectiveness of habitat restoration actions to reduce water temperatures (e.g., tree planting and channel narrowing), the more water will be available for floodplain inundation. However, actions that optimize water temperatures for passage may not provide optimal conditions for juvenile growth on inundated floodplain habitats. Inundation of floodplain habitats during the winter may result in low floodplain temperatures that inhibit food production and juvenile growth compared to conditions in the base-flow channel. However, winter inundation may still be beneficial because it provides cover from predators. Substantial food production would likely occur in March, April, and May, when air temperatures increase and floodplain inundation is likely to enhance the growth of smolts (Figure 3-3). However, it will be also necessary to reduce water temperatures beginning in March for migrating juveniles and adults. The Juvenile Habitat SIG postulated that if floodplain roughness was increased by planting riparian shrub species (e.g., sandbar willow), the exchange of flow between the base-flow channel and floodplain might be reduced enough to help keep the floodplain warm to enhance food production for rearing and keep the base-flow channel cool for juvenile and adult passage. If true, it may be necessary to plant both tree and shrub species to provide both temperature and floodplain growth benefits.

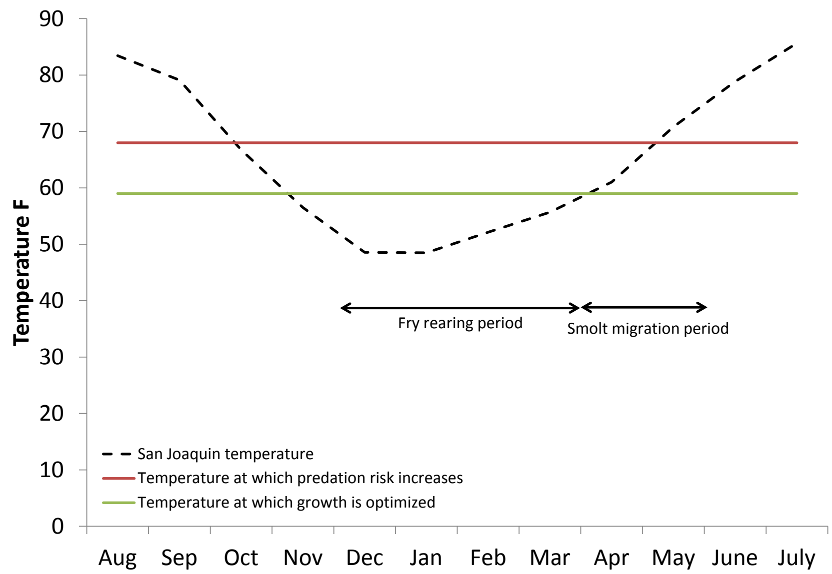


Figure 3-3.
Conceptual Model of Temperature and Fall-Run Salmon Life History in the San Joaquin River

The Juvenile Habitat SIG also suggested that it may be possible to provide floodplain productivity during dry water years with a series of short flow pulses rather than constant flow for floodplain connectivity (Ahearn et al., 2006) (Figure 3-4). This strategy would use an initial, early pulse to inundate floodplains. Flows would then be reduced and standing water would be allowed to initiate primary and secondary production on the disconnected but inundated floodplain (Andrews, 2012). A second pulse from Friant Dam could then be used to reconnect the floodplain, allowing juvenile salmon to access the productive waters of the floodplain. During the receding hydrograph, juveniles could return to the channel to complete their migration. However, once salmon smolt, their behavior changes from rearing to actively migrating toward the ocean and floodplain inundation during this period may be of less utility. Thus, it is essential to quantify the tradeoffs between early and late-season flow increases to maximize Chinook salmon productivity and emigration success from the Restoration Area (Figure 3-5). As presented in Figure 3-5, orange indicates the low-flow channel that provides minimal rearing habitat and green denotes habitat that provides optimal rearing conditions. Because little data are available to support these strategies, direct quantitative evidence is needed before consideration for implementation. Research would be needed to determine the best timing for the flow pulses; whether pools could be sustained on floodplains in the Restoration Area; whether juveniles would benefit from food produced from these intermittent brief pulses; and whether juveniles might be stranded in the floodplain pools as flows recede. This scenario seems promising because it could mimic conditions in the Sutter Bypass that greatly benefit spring-run salmon in Butte Creek.

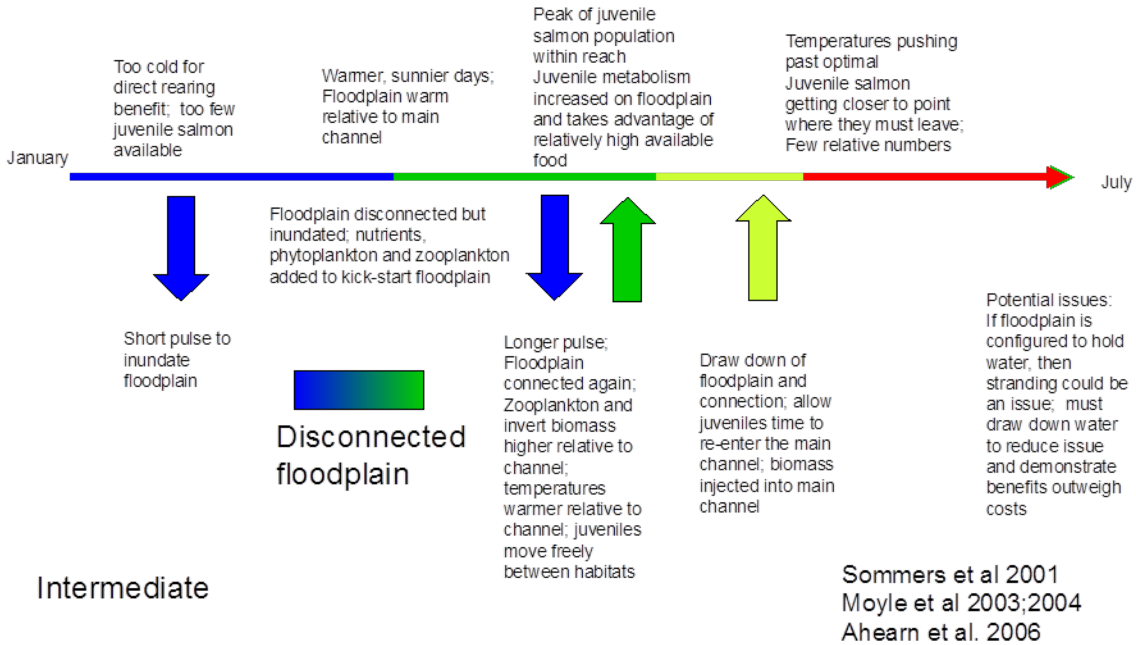


Figure 3-4.
Direct and Indirect Benefits of Floodplain Inundation to Juvenile Salmon

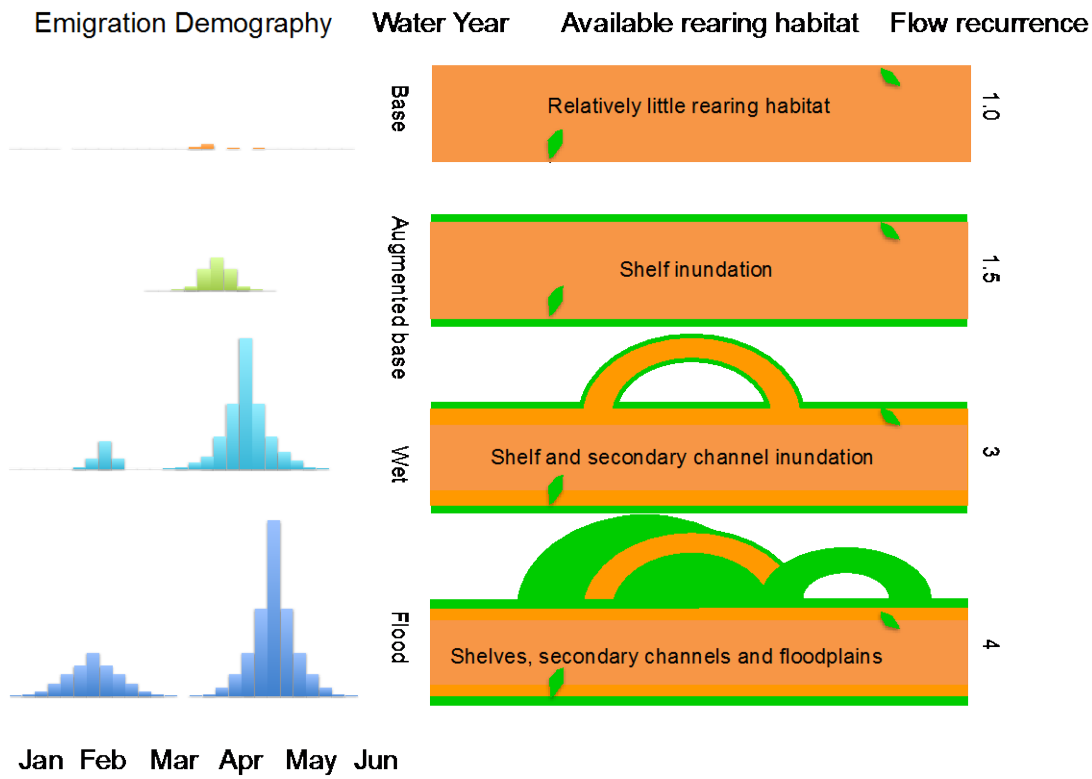


Figure 3-5.
Hypothesized Juvenile Chinook Salmon Behavior Associated with Water Year and Conceptual Habitat and Flow Recurrence

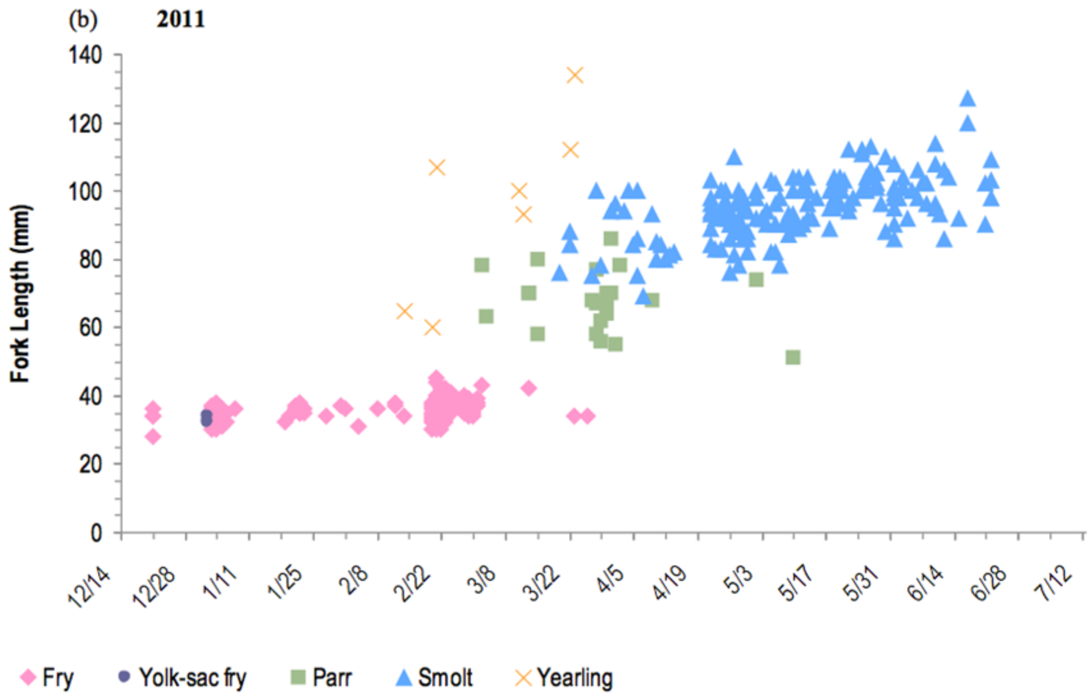
Substrate

It is known that a high sand content throughout most of Reach 1 creates an embedded substrate, which reduces the amount of food and cover available for late migrants (Kaller and Hartman, 2004; Suttle et al., 2004). As channel narrowing and the planting of riparian vegetation are considered strategies to enhance rearing habitat, studies may be needed to evaluate whether these activities throughout the floodplain would cause channel incision and excessive sediment deposition on floodplain margins. Conversely, if floodplain roughness was not an issue for channel incision and sand deposition, riparian shrub species (e.g., willows) could be planted to help confine the flow to a narrow channel and also provide high-quality cover for juvenile salmon. Another benefit of restoring a community of riparian vegetation is that it could help reduce the sand load. One concern is that there may be large stores of fine sediments in the main channel (e.g., mine pits) that may require other remedies. Lastly, studies would be needed to determine the optimum width of the low-flow channel.

A transition zone could be created at mine pits in Reach 1 as a cost-effective means of reducing predation risk in the pits. A more cost effective method of reducing substrate embeddedness in other areas in Reach 1 may be to revegetate riverbanks and terrestrial sources of sand to reduce sand loading as well adding coarse sediment where needed.

A key element of this restoration strategy is to preserve and sustain a diversity of salmon life history stages. Ideally, restoration actions would facilitate the success of early and late migrants for juvenile salmon to the greatest extent possible (Ruckelshaus et al., 2002; Beechie et al., 2006). Figure 3-6 below represents the distribution of fall-run Chinook salmon life stages within the Stanislaus River that can be used as a model for Chinook salmon behavior in the Restoration Area. In the Stanislaus River, late migrants tend to survive well by rearing in gravel-bedded reaches and then initiating their downstream migration after they have reached a length of at least 55 millimeters (Sturrock et al., 2013). Their survival is primarily dependent on the duration of the migratory window when water temperatures are suitable. The survival of early migrants tends to be highest during prolonged flood-controlled releases that provide access to floodplain habitats, particularly when inundation extends into the warmer spring months (Mesick, 2012). Therefore, preserving and sustaining juvenile life history diversity will require Restoration Actions that can:

- Reduce water temperatures in the base-flow channel from March through May;
- Provide prolonged inundation of the transition zone in all water year types, particularly in the sand-bedded reaches 2-5 to provide refuge, particularly for fry;
- Enhance the productivity of seasonally inundated habitats by increasing both flow retention (e.g., floodplain roughness) and inundation duration (e.g., create transition zones), and extend the duration into the spring when increasing temperatures would promote food productivity, if possible;
- Reduce substrate embeddedness in Reach 1, and if possible increase the productivity and carrying capacity of floodplain habitats.



Source: Watry et al. 2011.

Figure 3-6.
Distribution of Juvenile Chinook Salmon Life Stages by Size and Timing at Outmigration from the Lower Stanislaus River, California

Water Quality

Water temperature issues within the Restoration Area make it likely that the bulk of Restoration Flows allocated to the river will be needed to meet temperature targets for adult passage in the months of April and May. In certain water year types, very little, if any, water would be available for prolonged inundation of floodplain habitats outside of the April/May window unless actions are implemented to reduce water temperatures in the Restoration Area. Inundation of floodplain habitat outside the channel to create and benefit juvenile rearing habitat may therefore be most likely to occur during April and May as well as in years when flood releases occur.

3.1.2 Questions

Table 3-1 lists the questions associated with addressing uncertainties related to rearing habitat. These questions were developed and refined by the Rearing Habitat SIG, which convened during 2013.

Table 3-1.
Rearing Habitat Questions

No.	Questions	Type of question	Relevant Action Identified in Draft Framework for Implementation	Action Category (C/S/I/O)	Related Study
General					
RH-001	What levee alignments are needed to provide the mature riparian vegetative growth needed to reduce water temperatures and provide productive rearing habitats?	Creating Conditions	Other	O	model temperature and food production, then field experiment to validate
Rearing Habitats					
	How should rearing habitats be designed to maximize juvenile production?	Creating Conditions			
RH-002	What native vegetation community in the riparian corridor would help reduce water temperatures, augment food production, and be self-sustaining? What vegetative cover structure types maximize shade benefits, velocity refuge, and carrying capacity?	Existing Condition	Planting riparian vegetation	C	define vegetation classifications that would "support" rearing; then perform field surveys
RH-003	How does the timing of rearing habitat inundation affect the production of parr- and smolt-sized outmigrants? Is it necessary to provide inundation throughout the entire rearing period or just when parr and smolts are present? How does the timing of inundation affect life history diversity?	Creating Conditions			
RH-004	How can floodplain topography and soil type be optimized to maximize in-situ productivity and food export with the least amount of water (flow)?	Existing Condition	Channel and Structural Improvements	C	requires field surveys; habitat type soils; pump water onto soils and measure residence time as it relates to temperature
RH-005	Would the creation of transition zones (narrow rearing habitat benches within the main channel) provide refuge for juvenile salmon and augment food production? How do the potential relative benefits of transition zones vary across reaches and water year types?	Creating Conditions			
RH-006	Is it possible to have a dense riparian growth without the deposition of sand berms along the riverbank or accelerated channel incision?	Creating Conditions			

Table 3-1.
Rearing Habitat Questions (contd.)

No.	Questions	Type of question	Relevant Action Identified in Draft Framework for Implementation	Action Category (C/S/I/O)	Related Study
Flow Management					
RH-007	How long are fish rearing in reach 1 prior to migrating? Is this flow, temperature, or food dependent? Does residence time influence survival rates, both to the bottom of the river and smolt to adult return rates?	Existing Conditions; fish need	Flow Management	C	Could make inferences from other systems
RH-008	Should Friant pulse flow releases be timed with releases in the Stanislaus, Tuolumne, and Merced rivers?		Other	O	
RH-009	Would control of Friant release temperatures improve juvenile growth rates?	Creating Conditions; fish need	Flow Management	C	modeling effort
Low Flow					
RH-010	**How can we optimize low flow rearing habitat?**	Creating Conditions	Channel and Structural Improvements	C	
RH-011	Does sand accumulation limit food supply and cover in Reach 1? If so, how can the sand load be reduced?	Existing Conditions	Flow Management	C	field survey; use Suttle et. al, as a template: http://www.esajournals.org/doi/abs/10.1890/03-5190
RH-012	Do transition zones function as migration corridors during low flow releases?	Creating Conditions	Channel and Structural Improvements	C	tagging study (radio or acoustic); channel would need to be manipulated
RH-013	Can juvenile production and/or carrying capacity be increased through the placement of cover?	Creating Conditions	Channel and Structural Improvements	C	
RH-014	Would adding coarse organic matter (e.g., salmon carcass pellets) to the river increase juvenile growth and/or production or available prey?	Creating Condition; Fish Need	Flow Management	C	
RH-015	Could managed wetlands (e.g., wildlife refuges, dikes) be used to augment food production in dry years indirectly or by providing off channel rearing habitat?	Creating Conditions	Channel and Structural Improvements	C	field experiment

Table 3-1.
Rearing Habitat Questions (contd.)

No.	Questions	Type of question	Relevant Action Identified in Draft Framework for Implementation	Action Category (C/S/I/O)	Related Study
RH-016	Do capture mine pits limit food supply or act as false pathways and predator traps?	Existing Conditions	Gravel Pit Filling and Isolation	S	model and validate with food surveys
RH-017	Are water quality conditions (e.g., turbidity and contaminants) suitable for Chinook salmon and other native fishes to allow for successful completion of life cycles?	Existing Conditions	Other	O	monitoring is ongoing
Temperature					
RH-018	**What can be done to reduce daily maximum water temperatures in Reaches 4 and 5 in April and May?**	Creating Conditions			
RH-019	What is the effect of riparian vegetation canopy height, density, and width on daily maximum water temperatures in Reaches 4B and 5? Where would riparian forests have to be restored to reduce temperatures in Reaches 4B and 5, and provide juvenile and adult passage through mid-May?	Creating Conditions	Planting riparian vegetation	C	An informative river temperature modeling program: http://www.fort.usgs.gov/products/software/sntemp/
RH-020	What are the temperature benefits of narrowing the low flow channel? What reaches would have to be narrowed to reduce temperatures in Reaches 4B and 5 and provide passage for juvenile and adult salmon through mid-May?	Creating Conditions	Channel and Structural Improvements	C	An informative river temperature modeling program: http://www.fort.usgs.gov/products/software/sntemp/
RH-021	How does roughness provided by riparian vegetation affect residence time on the floodplain and temperature in the main channel? How does floodplain roughness affect juvenile usage and carrying capacity?	Creating Conditions	Channel and Structural Improvements	C	modeling effort
RH-022	How do tree species and leaf-out timing affect temperatures in the low-flow, migration channel?	Creating Conditions	Flow Management	C	An informative river temperature modeling program: http://www.fort.usgs.gov/products/software/sntemp/

Table 3-1.
Rearing Habitat Questions (contd.)

No.	Questions	Type of question	Relevant Action Identified in Draft Framework for Implementation	Action Category (C/S/I/O)	Related Study
RH-023	What are the effects of channel narrowing and a mature riparian forest on channel stability and flood capacity/safety?	Creating Conditions			

Key:
AM = Adult migration
C = Core action
S = Secondary action

3.1.3 Studies

The studies planned for implementation in 2014 focus on addressing uncertainties associated with rearing habitat. Results from these studies will inform the Implementing Agencies on whether sufficient rearing habitat is available for a successful program. The studies include the following:

- The Effects of a Riparian Forest on Water Temperatures in the Restoration Area (Study 31, Appendix A)
- Floodplain Production (Study 35, Appendix A)
- Effect of Altered Flow Regime on Channel Morphology in Reach 1A (Study 26, Appendix A)
- Reducing Spring Water Temperatures Below Sack Dam (Study 33, Appendix A)
- Sedimentation and Review Hydraulics (SRH) Group Hydraulic and Sediment Transport Analysis of Juvenile Salmon Rearing Opportunities (Study 39, Appendix A)

The rearing habitat studies are summarized below. The complete study descriptions are available in Appendix A.

The Effects of a Riparian Forest on Water Temperatures in the Restoration Area

The effects of a Riparian Forest on Water Temperatures in the Restoration Area study seeks to gather data on solar radiation, air temperature, wind speed, and relative humidity in areas along the San Joaquin River with and without mature riparian forest. These data will be used to calibrate the SJRRP HEC-5Q temperature model with site-specific data for the river. The data previously used for calibration of the model were from published studies done on small headwater streams, which may not be reflective of the conditions existing in the Restoration Area.

The information from the combination of these studies would allow informed calibrations of water temperature models, which would reflect restored riparian conditions in the Restoration Area. Greater accuracy of the water temperature models will aid in the development of effective riparian vegetation restoration actions to lowering water temperatures in reaches 4B and 5 below lethal thresholds. The lethal threshold for adult salmon is a 7-day mean daily maximum temperature of 68°F.

Solar radiation, air temperature, wind speed, relative humidity, and soil moisture will be measured at weather stations placed in study sites representing both vegetated and vegetation degraded sites of varying widths. Botanical surveys will be conducted twice per year at these sites to record seasonal vegetation variation and canopy cover within the sites. This is the first year of the study. This study may continue to repeat annually until the Implementing Agencies conclude that sufficient information has been collected to propose and implement riparian vegetation restoration actions.

Floodplain Production Study

In 2012, a modeling exercise using the Emigrating Salmonid Habitat Estimation model and a two-dimensional (2D) hydraulic model (SRH-2D) was undertaken to estimate the range of habitat area required to support Chinook salmon rearing and emigration through the Restoration Area. However, several key uncertainties still exist as they relate to the flow regime and configuration of floodplain habitat. The purpose of this study will be to identify habitat characteristics and floodplain inundation regimes that can best support SJRRP salmon rearing objectives through further understanding of the following:

- Identify when and how ephemeral floodplain habitat can be developed and managed to maximize benefits to juvenile Chinook salmon in support of the Restoration Goal.

- Define and identify suitable rearing habitat considering connectivity with the channel, seasonal temperature, and inundation (timing, duration, pulsing) as criteria.

- Develop and prioritize cover types as habitat criteria.

- Evaluate invertebrate (or other food) production specific to the San Joaquin River to better understand biological processes that will contribute to food supply (April through March time frame), ecosystem processes, and incremental contribution of floodplain inundation on downstream water temperatures (March through April time frame).

Figure 3-7 illustrates the expected trade-offs in juvenile salmon benefits over the entire rearing period. Because juvenile Chinook salmon tend to migrate at two distinct stages (Figure 3-7), changing floodplain conditions over this time may have significantly different population effects (Figure 3-8). Figure 3-8 presents examples of variable timing for fry and smolt emigrant pulses estimated from daily catch estimates at two rotary screw traps (RST) on the lower Mokelumne River for two different periods: (1) the 2005 – 2006 emigration period, and (2) the 2001 – 2002 emigration period.

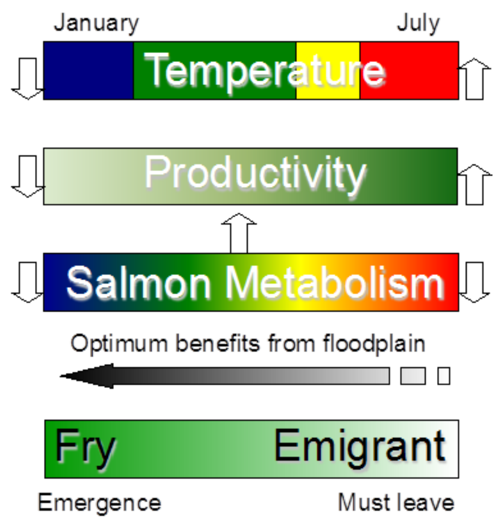
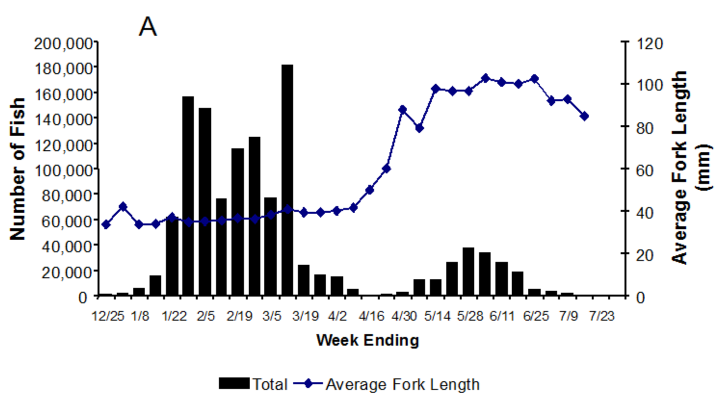


Figure 3-7.
Expected Trade-offs in Juvenile Salmon Benefits over the Entire Rearing Period



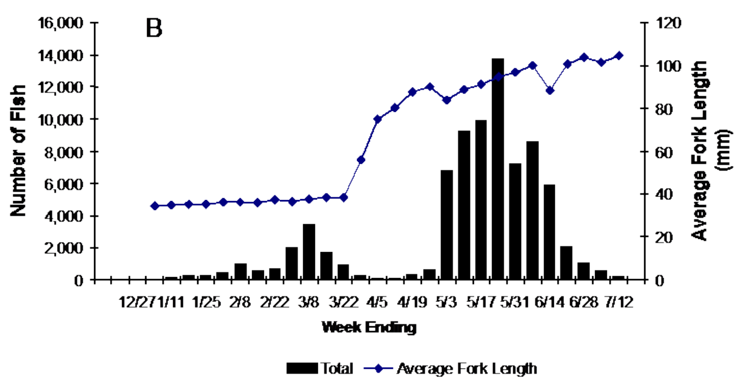


Figure 3-8.
Examples of Variable Timing for Fry and Smolt Emigrant Pulses

Beginning in 2014, five studies will be conducted to better understand the influence of floodplain inundation timing, the periodicity of floodplain hydrology, floodplain habitat attributes and floodplain food webs, and a greater understanding of the energy pathways to salmon through floodplain production. These studies were designed to use sound statistical and experimental design principles to guide SJRRP management, and plans for monitoring and experimental designs that strive for high replication and strong treatment effects.

Effect of Altered Flow Regime on Channel Morphology in Reach 1A

The Effect of Altered Flow Regime on Channel Morphology in Reach 1A Study will inform the Implementing Agencies on habitat quality, specifically by collecting data and developing modeling predictions of the availability of specific habitat types based on flow conditions. Deep pools, which provide temperature and predation refuge, holding habitat, and overhanging banks that provide protection from predation, will be evaluated as part of this study.

This study will also provide information relevant to the rearing habitat and spawning and incubation themes. The channel evolution model associated with this study is currently under development. Topographic resurveys of riffles and pools are planned for summer 2014 in Reach 1A if flows are high enough to cause observable bed geometry changes.

Reducing Spring Water Temperatures Below Sack Dam

Predictions from water temperature modeling for the San Joaquin River suggest that the daily maximum water temperatures in reaches 4B and 5 will exceed the lethal threshold for adult spring-run Chinook salmon when the upstream Friant Dam is releasing 4,500 cfs by April 28 each year. If the model reflects current conditions, then only up to 30 percent of the adult Chinook salmon moving upstream will be able to migrate to Reach 1, based on migration timing data from Mill and Butte creeks (Johnson et al., 2006). During the same period, juveniles are also experiencing critical temperatures and few could be expected to survive.

If no more than 30 percent of the adults can successfully migrate to Reach 1 where they could spawn, restoration actions to cool river water temperatures may be needed to reach the population viability target for the Restoration Program. The objective of this study is to determine which restoration actions will be necessary to reduce spring water temperatures in reaches 4B and 5 to the extent necessary to provide passage for adult spring-run through early May at flow releases of 4,500 cfs or less.

This study will inform as to whether restoration projects should consider adding wide riparian forests, and potentially trigger subsequent studies to determine if levee setbacks would be needed to allow a sufficiently wide riparian forest to mature without impeding flood flow releases or Restoration Flow releases. The project will be conducted in two phases: (1) will be to modify the existing water temperature model (SJRRP HEC-5Q), and (2) to develop 2D water temperature model to evaluate temperature differences between floodplains and the main channel.

SRH Group Hydraulic and Sediment Transport Analysis of Juvenile Salmon Rearing Opportunities

The first phase of this analysis will be an assessment of potential opportunities in Reaches 1, 2a, 3, and 4a for increasing the area’s likelihood for successful salmon rearing. The second phase will include a detailed analysis of a select number of other locations. These will include hydraulic analysis with depth and velocity analysis of with and without project alternatives using SRH-2D modeling, and a site-specific sediment transport analysis that could include a geomorphic assessment, or an SRH-1D and/or SRH-2D modeling assessment, depending on site conditions.

This project is part of the Sedimentation and River Hydraulics Group (SRH) San Joaquin River Restoration Program Hydraulic and Sediment Support program.

3.2 Spawning and Incubation

The following section describes the state of knowledge, questions, and studies associated with the spawning and incubation theme. Figure 3-9 illustrates the schedule related to actions and studies that will be implemented under this theme.

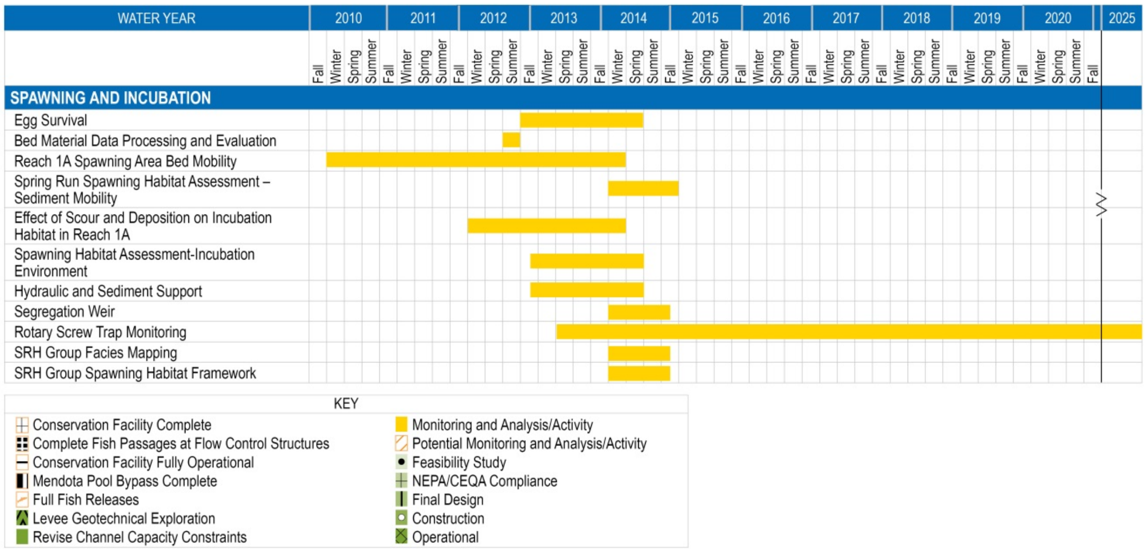


Figure 3-9.
Spawning and Incubation Schedule

3.2.1 State of Knowledge

Purpose and Objectives

The Framework describes themes encompassing potential actions to accomplish the Restoration and Water Management goals under the SJRRP, including Spawning and Incubation as a theme. The Fisheries Management Plan (SJRRP, 2010a) identifies spawning and incubation as a life stage to be supported for successful completion of the salmon life cycle. The SJRRP Spawning and Incubation SIG agreed on a strategy for ensuring that adequate spawning habitat is available to support fish populations, and a central effort in that strategy involves identifying the quality and quantity of spawning habitat.

The purpose of this document is to synthesize existing information on spawning habitat for spring- and fall-run Chinook salmon in the San Joaquin river system to guide research actions. Objectives include:

- Synthesize existing scientific knowledge relevant to spawning and incubation on the San Joaquin River.
- Identify data gaps and study questions to target additional studies; and

- Outline a process for investigating current habitat conditions in the Restoration Area for the purpose of:
  - Quantifying existing spawning habitat, and
  - The identification of critical limiting factors (i.e., habitat quality parameters) that may be more cost effective to manage than channel redesign and/or gravel augmentation strategies.

Key Characteristics of Spawning and Incubation

Spawning and incubation habitat must meet the needs of both spawning adults and incubating eggs and alevins. Adult Chinook salmon prefer to spawn in areas with appropriate flow depth and velocity, substrate size and mobility for constructing redds, water temperature, and nearby refuge (Bjornn and Reiser 1991). Additionally, spring-run Chinook adults require cool, safe pools for holding over summer before spawning in the fall. The successful incubation of embryos and emergence of fry, however, depend on many extragravel and intragravel chemical, physical, and hydraulic variables (Bjornn and Reiser 1991).

The following describes in detail the “key characteristics” of successful spawning and incubation habitat in the Restoration Area, and the preferred conditions of each for Chinook salmon spawning and incubation. These attributes include appropriate flow depths and velocities, substrate composition, sufficient transport of fine sediment, adequate hyporheic and surface water exchange (hydrodynamics) and water quality, and cover.

- Water depths and velocities
- Substrate composition
- Hydrodynamics and water quality
- Fine sediment transport
- Cover

The channel area that currently contain and is expected to maintain each of these attributes in high quality may be used to quantify the amount of suitable spawning habitat in the Restoration Area. Therefore, the gravel substrate content of a stream is not necessarily sufficient as a measure to determine suitable spawning and incubation habitat (Bjornn and Reiser 1991).

Water Depth and Velocity

For spawners, water depth must be enough to cover the fish during spawning, and velocity must be adequate to flush finer particles downstream during redd-building, but not so great that eggs do not remain in the egg pocket or adults have to expend too much energy holding position in the water column. For incubating eggs, the downwelling of water at sufficient velocities into the gravel is necessary to provide oxygen. Therefore, streamflow regulates the amount of spawning area available in any stream by regulating the area covered by water and the velocities and depths of water over redds (Bjornn and Reiser, 1991).

Substrate Composition

The suitability of gravel substrate for spawning depends mostly on fish size; large fish can use larger substrate materials than can small fish. Fish may also be able to utilize larger substrate if higher velocities are present to assist in mobilization (Moir and Pasternack 2010). For incubation, the particles from the streambed, as well as the organic and inorganic particles that settle into the redd and surrounding substrate during incubation affect the rate of water interchange between the stream and the redd, the amount of oxygen available to the embryos, the concentration of embryo wastes, and the movement of alevins when they are ready to emerge from the redd (Bjornn and Reiser 1991).

Hydrodynamics and Water Quality

During incubation, sufficient water must circulate through the redd as deep as the egg pocket to supply the embryos with oxygen and carry away waste products. Circulation of water through a redd is a function of the permeability of the particles in the redd, hydraulic gradient at the redd, and temperature of the water.

The permeability (ability of the spaces between particles in the redd to transmit water per unit of time) and apparent velocity (volume of water passing through a given area of redd per unit of time) are two commonly used measures of the suitability of a redd for successful incubation of salmonid embryos (Bjornn and Reiser 1991).

Many salmonids prefer to spawn in the transitional area between pools and riffles. This is due to a preference for accelerating flow, such as that found at a pool-riffle transition where downwelling currents exist. In these areas of downwelling, it is easier for salmon to excavate the redd as it is relatively free of silt and debris (Bjornn and Reiser, 1991). Additionally, the downwelling current brings oxygen to the eggs and removes metabolic wastes (Bjornn and Reiser 1991).

The minimum DO recommended for spawning fish is at least 80% of saturation and not dropping below 5.0 mg/L, even temporarily (Bjornn and Reiser, 1991). Hatching is delayed at low DO concentrations (Bjornn and Reiser, 1991). Larval development during the early stage of development depends wholly on diffusion for satisfying oxygen requirements. Once the circulatory system of the embryos is functional, oxygen transfer to the embryo becomes more efficient. Therefore, DO is a key factor in determining embryo health during incubation.

Water temperatures before and during spawning must allow the spawners to survive and deposit their eggs. Temperature during incubation regulates the timing of juvenile emergence from the redd. Water temperature during incubation affects the rate of embryo and alevin development and the capacity of water to hold dissolved oxygen. Table 3-2 demonstrates the upper and lower temperature limits for successful incubation of salmonid eggs in the Restoration Area.

Table 3-2.
Temperature Requirements for Spawning and Incubation (from SJRRP 2010b)

	Spawning	Incubation and Emergence
Optimal	≤ 57°F (13.9°C)	≤ 55°F (13°C)
Critical	60-62.9°F (15.6-17°C)	58-60 °F (14.4-15.6°C)
Lethal	≥ 62.6°F (17°C)	≥ 62.6°F (17°C)

Key:
°C = degrees Celsius
SJRRP = San Joaquin River Restoration Program

Fine Sediment Infiltration

Redds are susceptible to fine sediment infiltration, and the presence or absence of fine sediment in a redd is an important factor in egg survival and fry emergence. If fine sediments are being transported in a stream either as bedload or in suspension, some are likely to be deposited in the redd. The amount of fine sediment being transported and the depth to which it intrudes depend on the size of substrate in the redd, flow conditions in the stream, and the amount and size of sediment being transported.

If fine sediments are large relative to the spaces (pores) between gravel particles in the redd, they may only settle into the surface layer of the redd, where they can block other sediments from the deeper egg pockets. Under certain conditions, a layer of fine sediments can be beneficial if it prevents deposition of fine organic or inorganic materials in the pocket, but detrimental if it impedes the emergence of alevins or alters the embryos ability to take up oxygen (Bjornn and Reiser 1991).

Cover

Cover is important for Chinook salmon, which spend weeks or even months at the spawning grounds before they spawn (Bjornn and Reiser, 1991). Cover for salmonids waiting to spawn or in the process of spawning can be provided by overhanging vegetation, undercut banks, submerged vegetation, submerged objects such as logs or rocks, floating debris, deep water, turbulence, and turbidity (Bjornn and Reiser, 1991). If the holding and spawning areas have little cover, such fish are vulnerable to disturbance and predation over a long period. The nearness of cover to spawning areas may be a factor in the selection spawning sites by some species. (Bjornn and Reiser, 1991).

Background and Existing Study

This section discusses the background information and Restoration Area specific existing information and research that are relevant to the spawning and incubation theme.

Background

After the completion of Friant Dam, salmon were observed holding and spawning in Reach 1A until runs disappeared circa 1950 (McBain and Trush 2002). From historical anecdotal accounts, the SJRRP believes that the streambed downstream of Friant Dam was composed of mixed sand and gravel. The completion of Friant Dam has since resulted in the streambed being primarily a coarsened bed texture with significant amounts of sand, and incision from pre-dam bed elevations, all occurring under a significantly reduced flow regime (Cain 1997).

Some of this incision may have been the result of dredging activities as well as quarrying in locations close to engineered structures (i.e., the Dam and Friant's North Fork Bridge). Field observation of modern banks throughout the reach incised into the pre-Dam stream bed suggests incision is not solely related to mining and dredging operations. Reclamation suggests that the incision phase of channel adjustment to post-Dam conditions may be transitioning to a channel widening phase, which is driven by collapsing over steepened banks (see USBR 2013 Preliminary Sediment Budget Analysis of the San Joaquin River, in press).

Therefore, in addition to bed erosion, other processes such as erosion of stored bank deposits, floodplains, and fine sediment contributions during tributary flow events have, to some extent, maintained a supply of mobile sand in Reach 1A. The proportion of fine sediment (e.g., sand and finer) is inversely related to egg survival (Tappel and Bjornn 1983, SJRRP 2010c, and many others).

Existing Study

Egg Survival in Artificial Redds

In Fall 2012, USFWS conducted the second year of an egg survival experiment where eggs tubes were buried in artificial redds, and excavated following the incubation period for observation of the egg hatching success. Preliminary results presented at SJRRP's Fisheries Technical Feedback meeting highlighted 2012 egg survival rates varying from 20-54 percent at the five study sites. In 2011 survival rates at these sites varied from approximately 13-50 percent. These results were generally lower than predicted survival using the Tappel and Bjorn index. One exception was near Highway 41 (Site 5 at RM 255.5), where no survival was predicted but USFWS observed egg survival of approximately 35 percent in both study years.

Fine Sediment Accumulation in Artificial Redds

In 2011, DWR began a spawning-gravel, sand accumulation study in collaboration with the precedent USFWS egg survival study. Results indicate variable egg survival that correlates well with sand transport and accumulation. Sand transport was observed to vary across the five study sites, which were evenly spaced between Friant Dam and Highway 41. The upstream most site (Site 1 at RM 266.7) experienced the least sediment transport and deposition, while these attributes generally increased with distance downstream. The greatest transport and deposition of fine sediment occurred at the Site 4 (at RM 258.6). Transport and deposition of sand decreased at the Site 5 relative to the Site 4. These results suggest local sources supplying sand, a translating sand pulse, and/or differential sand storage within the channel and are supported by sand mapping efforts by Tetra Tech (2012a,b) and bed sample results collected by DWR (SJRRP 2013b). Furthermore, during fall pulse flows, the amount of sand being transported and deposited within the artificial redds was sufficient to inhibit egg survival.

Hyporheic Water Quality

Multiple studies are currently underway or have been completed to help identify the quality of the hyporheic environment as it relates to successful spawning, incubation, and fry emergence (see SJRRP, 2013).

One of these studies was developed by building on experience on the Yakima and Cle Elum Rivers in Washington (Nelson and Bowen, 2003, unpublished). Reclamation focused the study on the hyporheic water quality elements of egg survival. On the Cle Elum river, Reclamation observed egg survival ranging from 15-100% on egg plates containing 20 young eggs and installed in or adjacent to hyporheic pot samplers. When similar samplers with egg plates of young trout eggs were installed in the San Joaquin River in 2010, the observed survival rates at three sites were 28%, 88%, and 27%. In 2011-12, multiple parameters of water quality data were collected, including continuous DO and conductivity data, in and adjacent to the USFWS artificial redds. The 2012 hyporheic water sampling data revealed toxic levels of Fe, Al, and other metals in some of the sites.

Mesohabitat Mapping

CDFW conducted mesohabitat surveys in Reach 1A, to document the longitudinal distribution of habitat types and inform additional, more refined habitat studies. Field crews mapped habitat units (i.e., relatively homogenous areas with similar characteristics) throughout the potential spawning reach based on visual observation of depth, velocity, and substrate at a coarse scale (i.e., habitat unit length greater than or equal to one channel width). Habitat units were mapped utilizing a classification system based upon those developed by Flosi and Reynolds (1998) and P.A. Bisson, et al. (1982), and average wetted width, length, depth, and habitat type were recorded for each habitat unit. In Reach 1A, 378 distinct habitat units were recorded of 21 different habitat types. Twelve percent of Reach 1A, or approximately 37,140 square meters, was mapped as riffle habitat, while 28 percent of the reach was classified as pool habitat and 54 percent was classified as glide habitat.

Substrate Surveys

Efforts have been made to characterize the texture of the river bed within the spawning reach (SJRRP 2013b). Results suggest a general decreasing gravel grain size trend with distance downstream (SJRRP 2010c). However, sand storage within the channel suggests local sources as opposed to continuity of sand storage and transport in the reach (Tetra Tech 2012a, b).

In 2009, DWR began a study designed to evaluate bed mobility within Reach 1A at two riffles approximately midway between Friant Dam and Highway 41. The result of this study will include a measured critical shear stress for incipient entrainment of coarse bed material (i.e., gravel and cobble). With this primary input parameter for sediment transport formulae (e.g., Yalin 1972) and calibrating with bedload sampling data (from Graham Matthews and Associates 2011; SJRRP 2012c), the sediment transport rate for specified discharges can be predicted and, aided by a two dimensional (2D) hydraulic model, the area of mobilization can be delineated and quantified. Additional information is gained from tracer transport distance and storage loci of mobilized particles that can be used to provide insight on differential transport rates with longitudinal position and predict channel geometry evolution, respectively.

Channel net scour and deposition is being monitored with scour chains across two riffles at RM 260.7 and 261.6, designated Riffles 38 and 40, respectively. Results will be used to assess the active layer depth which will be used for quantifying bed flushing and transport.

In 2012, the U.S. Geological Survey (USGS) began monitoring the contribution of sediment provided by two intermittent tributaries within upper Reach 1A called Cottonwood Creek and Little Dry Creek. Though little, if any, coarse sediment is likely being supplied by these ephemeral streams, it is quite possible that they are providing sand-sized sediment to the main stem San Joaquin River. Future monitoring results will provide information to quantify their contribution.

Between 2008 and 2011, Tetra Tech (2011) assessed sand storage and sources within Reach 1A. The amount of sand within the channel and the location of other sources are useful for understanding which areas are more susceptible to deposition. Sand transported on the bed surface is much more likely to deposit between larger particles where it is sheltered from the force exerted by the flowing water. Such transport and resulting deposition can clog gravel interstices in redds, reducing hyporheic ventilation, as observed during the egg survival/sand accumulation study. Several sand source areas were noted in Tetra Tech (2012), including eroding banks, bluffs, floodplain, and side channels. However, flows capable of accessing and eroding these storage sites are not known, and therefore, the change in sand storage and the rate of contribution to the channel from these sources are also presently unknown.

Spawning Use Surveys

DFW in 2012 collaborated with Reclamation to trap and transport fall-run Chinook from Reach 5 to Reach 1A. After releasing the adult spawners, DFW tracked them with mobile acoustic equipment and observed use of existing spawning habitat. There were 11 potential redds identified during the mobile tracking. Some additional sites that showed evidence of bed disturbance were recorded, but the cause (e.g., salmon, trout, human) of disturbance was unclear. In addition to the visual observation, mobile tracking data indicated that there may have been other locations where females may have spawned, but were not observed due to water depth and clarity. Nine of the eleven potential redds observed were upstream of HWY 41 Bridge. Two riffles had clusters of what were presumed to be multiple redds. One cluster was near the Wildwood mobile home park upstream of Hwy 41 Bridge (RM 256) and the other was at the riffle downstream of the lower rock weir at Lost Lake Park (RM 264.6). The downstream-most observed spawning activity was at the riffle immediately below the State Route 99 Bridge (RM 243.1).

Conceptual Model for Assessing Existing Spawning Habitat

While initial estimates have suggested that the current amount and quality of spawning and incubation habitat in Reach 1 of the Restoration Area may be insufficient to support self-sustaining populations of spring- and fall-run Chinook salmon (SJRRP, 2010b;

Stillwater Sciences, 2003), the deficit between the amount of existing suitable habitat and the amount necessary to support a sustainable population is currently unknown. This creates significant uncertainty as to how much habitat needs to be constructed or improved through gravel augmentation, artificial riffle construction, enhancement efforts, or other actions to meet the Restoration Goal.

Implementation of spawning habitat creation or enhancement projects will require SJRRP resources. Therefore, the Program should determine both the quantity of existing high quality habitat and how much additional high quality habitat is needed before projects are implemented to improve it. Initial evaluation efforts are underway, but there is a need to document the larger process to allow the SJRRP to plan for eventual project implementation. Figure 3-10 presents a conceptual model of this process.

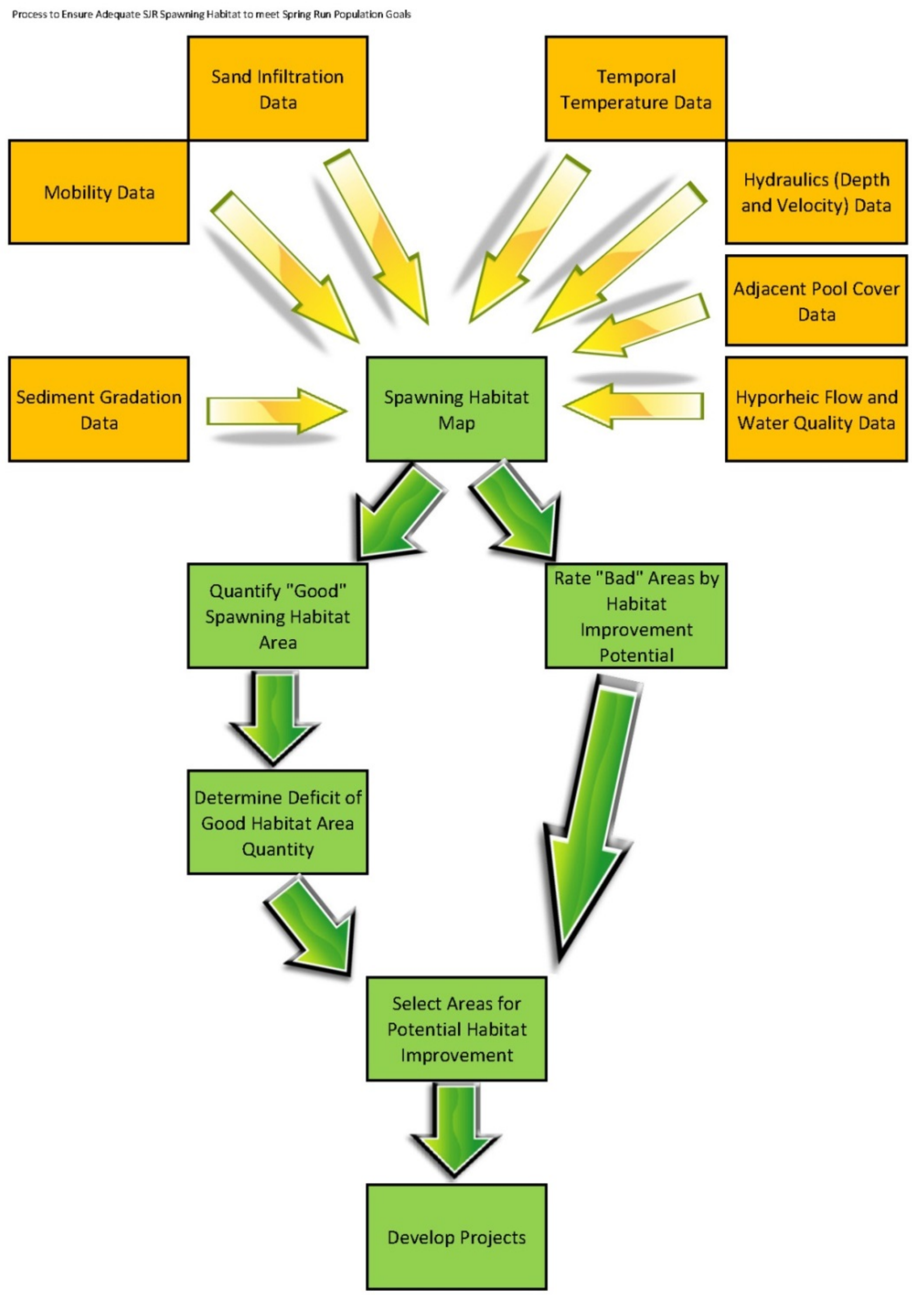


Figure 3-10.
Spawning Habitat Assessment and Needs Process

The overall process begins with data collection and studies that will feed into development of a map of existing potential spawning habitat. The map would delineate areas that have the physical attributes (e.g., depth, velocities, substrate, gravel permeability, water quality) necessary for spawning and incubation, and will be used to identify areas of good quality habitat areas so that location and quantity can be estimated and further study can be planned, if necessary. If the Program then determines there is a deficit in the quantity of good quality spawning habitat, potential projects can be identified to improve or create habitat.

The Spawning and Incubation SIG developed a flow diagram that identifies each habitat factor that should be included in the habitat assessment and how each of those factors should be evaluated (Figure 3-11). This diagram is still being refined, and it is not known yet how each suitability assessment would affect the area of mapped “potential” spawning habitat, but the initial version shown provides an indication of the number of physical characteristics that impact spawning and incubation habitat and how they might be incorporated into a habitat suitability evaluation. Studies identified in Table 3-3 and questions included in Table 3-4are based on needs identified in this diagram.

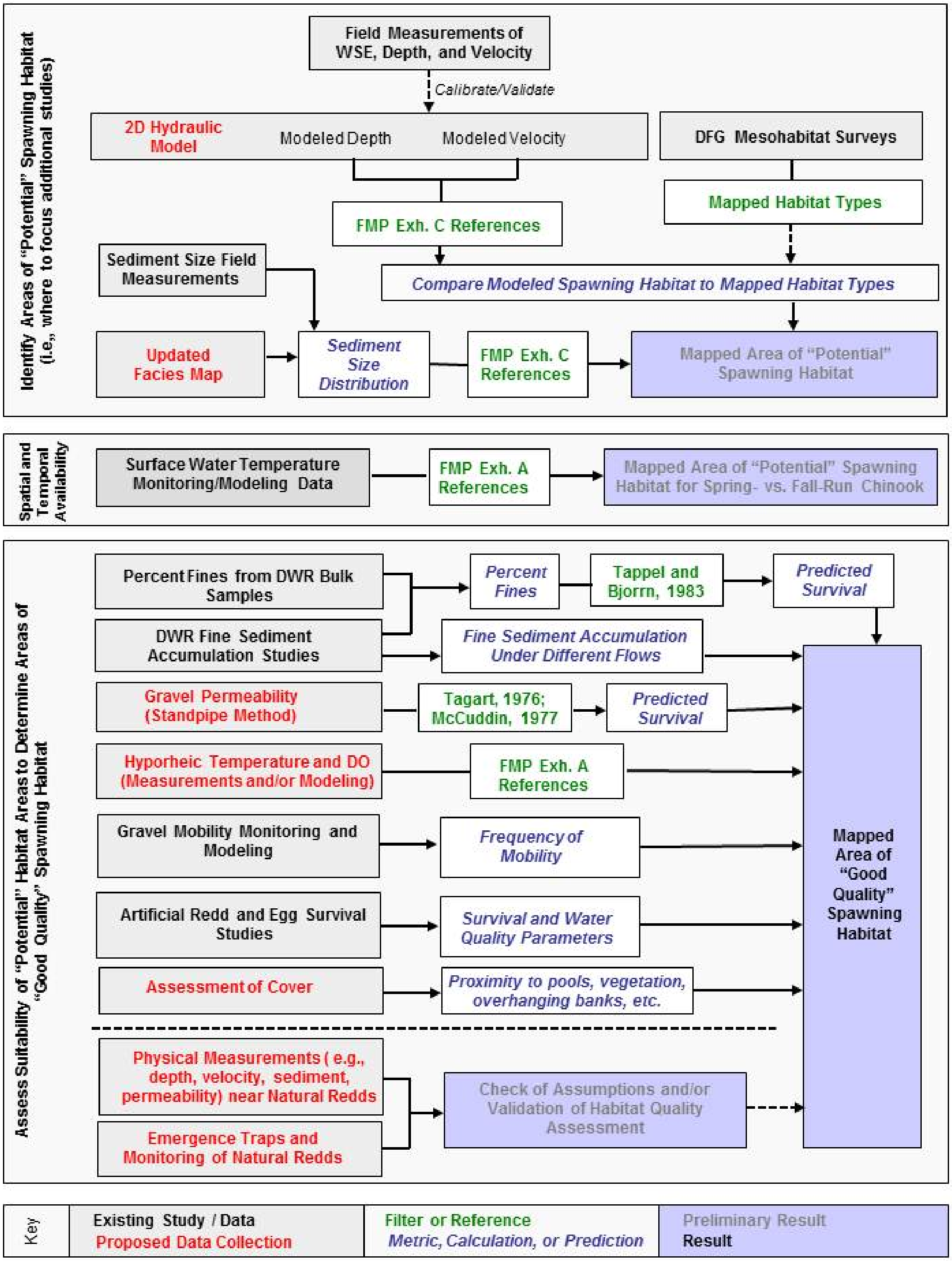


Figure 3-11.
Breakdown of the Detailed Data Collection and Analysis Steps

3.2.2 Data Gaps and Strategy

The data gaps remaining after specific areas of study regarding spawning and incubation, as well as strategies for each of the key characteristics were developed by the Spawning and Incubation SIG during 2013.

Table 3-3 discusses the existing studies surrounding spawning and incubation, the data gaps remaining after completion of the studies, and the strategies developed through the research process for further study.

Table 3-3.
Summary of Existing Spawning and Incubation Studies, Conclusions, Data Gaps, Strategy for Further Study

Key Characteristic of Spawning Habitat	Study Title	Objective	Conclusion	Data Gaps and Strategy
Water Quality and Intragravel Flow	Hyporheic Water Quality	Evaluate DO, water temperature, and fine sediment accumulation	Survival rates of trout eggs ranged between 27 and 88% at three study sites	Delineate attributes throughout the spawning reach
Water Quality and Intragravel Flow	Egg Survival Studies	Assess spawning habitat quality at five riffles in Reach 1A	Survival rates varied from 13 to 54% in the five riffles studied over 2 years	Egg survival in naturally produced redds
Fine Sediment Accumulation	Fine Sediment Accumulation in Artificial Redds	Quantify the potential for fine sediment to accumulate longitudinally and relationship with egg survival	Fine sediment transport and accumulation correlate with egg survival. Sand transport appears to be discontinuous with local differences with longitudinal position	Sand sources, depletion rates, and supply rates. Can supply be controlled? Delineate areas more prone to sand supply than others (temporally and spatially)
Habitat availability	Mesohabitat Characterization	Document distribution of habitat types (e.g., pool, run, glide, riffle) at channel width scale	Mapped polygons of habitat types in the Restoration Area	No data gaps for spawning habitat as all of Reach 1 has been mapped,
Habitat use	Spawning Habitat Use Monitoring/ Spawning Ground Surveys	Monitor spawning activity and habitat use of fall-run Chinook transported through the trap-and-haul activities	Eleven potential redds were identified, nine upstream from Highway 41	Habitat quality at redd sites, survival to emergence

Table 3-3.
Summary of Existing Spawning and Incubation Studies, Conclusions, Data Gaps, Strategy for Further Study (contd.)

Key Characteristic of Spawning Habitat	Study Title	Objective	Conclusion	Data Gaps and Strategy
Substrate	Bed Material Size and Mobility, Scour and Deposition	Quantifiably measure the transport potential of bed material locally	Critical shear stress measured at two sites is at the lower end of the expected range	Other sites, especially those with significant differences in the finer mode of the GSD or bed material reinforcing
Hydrodynamics and Water Quality	Stream Temperature Monitoring	Monitor hourly stream temperatures at 50+ sites in the Restoration Area (long-term monitoring)	Extent of habitat suitable for egg incubation depending on timing. Data also inform water temperature models and other studies	Additional monitoring maybe conducted to answer specific questions or provide data for related studies
Substrate	Sand storage studies (Tetra Tech)	Quantify sand storage and monitor. Define sources	Identified several discrete sand source areas. Volumetric estimates of in-channel sand storage	Whether or not sand sources are entrained at normal restoration flows has yet to be determined. Additional information is needed to understand if gravel pits are sediment sinks for available sand.
Substrate	Bedload and Suspended Sediment Load Monitoring (USGS)	Define sediment contribution from tributaries. Calibration data for predicting the reach's sediment transport rate.	From Ledger Island site, gravel transport (>2mm) and sand transport (<2mm) increases between 7,000-8,000 cfs, but still low transport rates.	Need a sampling site much further upstream of HWY 41

Key:
DO = Dissolved Oxygen
GSD = grain size distribution
N/A = not available
USGS = U.S. Geological Survey

3.2.3 Questions

Table 3-4 lists the questions addressing spawning and incubation uncertainties in the Restoration Area. These questions were developed and refined by the Spawning and Incubation SIG, which convened during 2013.

Table 3-4.
Spawning and Incubation Questions

No.	Questions	Type of question	Relevant Action Identified in Draft Framework for Implementation	Action Category (C/S/I/O)	Related Study
Spawning Habitat Quantity and Quality					
SI-001	Is spawning habitat quality in Reach 1A sufficient to support adequate egg survival and healthy emergent fry for both spring- and fall-run?				• Bulk sampling analysis • Distribution of gravel relative to pool tails and riffle crests • Permeability study • Bed mobility study • Fine sediment accumulation study
SI-001b	b. Is permeability sufficient for natural egg survival rates?	Existing Conditions	Habitat Enhancement	O	Completed egg survival studies and proposed emergence trap studies
SI-001c	c. Will fine sediment accumulation rates during incubation impair egg survival and/or alevin emergence for fall-run and spring-run redds?	Existing Conditions, Spawning Needs	Habitat Enhancement	O	• Completed sand accumulation and proposed sediment mobility SOW. • Existing and Proposed DWR Sand Studies • USGS tributary study and 2D hydraulic modeling results • bedload sampling upstream of Hwy 41 (Study 47 in the 2014 MAP) • acoustic studies
SI-001d	d. Is the gravel surface capable of being mobilized? Or are they sufficiently reinforced or embedded such that a loose and permeable bed is not available?	Existing Conditions, Spawning Needs	Habitat Enhancement	O	Bed Mobility Study
SI-002	Where do spring- and fall-run Chinook choose to spawn? What is the spawning gravel quality in those locations?	Existing Conditions	Other	O	• Redd surveys in the Restoration Area • Overlay redd surveys on top of the model results, the bed material maps, the fine sediment maps, etc. to begin to isolate the range of conditions being selected or even considered for spawning.

**Table 3-4.
Spawning and Incubation Questions (contd.)**

No.	Questions	Type of question	Relevant Action Identified in Draft Framework for Implementation	Action Category (C/S/I/O)	Related Study
SI-003	Given the current and/or potential future habitat quality in Reach 1A, is the amount and distribution of spawning habitat sufficient to support spring run Interim (2,500 adults) and Growth population Goals (30,000 adults) in the first four miles downstream of Friant Dam, as well as a self-sustaining population of fall-run spawners further downstream of the dam?	Existing Conditions	Habitat Enhancement	O	Habitat quality studies need to be related to observations of where adult salmon spawn in the uppermost 4-mile reach and the condition of the egg incubation habitat. This can be accomplished by monitoring the adult fall-run that will be transferred to Reach 1 in fall 2013 as well as the locations and quality parameters found at the spawning locations. • Completed egg survival studies and proposed emergence trap studies • Proposed emergence studies.
SI-003a	a. Are there sufficient spawning-sized gravels, and where are they located?	Existing Conditions	Habitat Enhancement	O	Facies mapping and grain size sampling
SI-003b	b. Is gravel recruitment sufficient?	Existing Conditions	Habitat Enhancement	O	• Bed Mobility Study • Bedload Monitoring Studies • Existing and Proposed DWR Sand Studies • USBR sediment budget Study • USGS Tributary study • Ongoing USGS sediment load and bed material monitoring in Little Dry and Cottonwood
SI-004	How do cumulative stresses (e.g., temperature, water quality, etc.) affect egg viability?	Existing Conditions	Other	O	Completed egg survival studies and proposed emergence trap studies
SI-006	Will pulse flows for fall-run attraction increase sand accumulation in spring-run redds?	Spawning Needs	Other	O	• Existing and Proposed DWR Sand Studies • USGS tributary study and 2D hydraulic modeling results

Table 3-4.
Spawning and Incubation Questions (contd.)

No.	Questions	Type of question	Relevant Action Identified in Draft Framework for Implementation	Action Category (C/S/I/O)	Related Study
SI-007a	What percentage of fry emerge from redds in Reach 1A and what is their condition?	Existing Conditions	Other	O	Completed egg survival studies and proposed emergence trap studies
SI-007a, 1	Does sand accumulation in spawning gravels produce “weak fry” that have a low probability of survival? What are mortality rates for newly emerged fry in Reach 1? Do current spawning habitat conditions result in "weak fry" that would have higher mortality than healthy fry?	Existing Conditions	Other	O	Hyporehic study; Completed egg survival studies and proposed emergence trap studies
SI-008	How important is cover in the Restoration Area to provide sufficient spawning habitat?	Spawning Needs	Other	O	Redd mapping
Sand Storage					
SI-009	If new spawning habitat is created, or existing spawning habitat rehabilitated, will future sand (fine bedload) quickly infiltrate spawning habitat, and reduce the quality (longevity) of spawning habitat? How frequently will gravel improvements be needed?	Creating Conditions	Other	O	• Existing and Proposed DWR Sand Studies • USBR sediment budget Study • USGS Tributary study • Ongoing USGS sediment load and bed material monitoring
SI-009a	Is Cottonwood Creek supplying substantial volumes of sand (fine bedload) to the high priority spawning reach?	Existing Conditions	Other	O	• Existing and Proposed DWR Sand Studies • USBR sediment budget Study • USGS Tributary study • Ongoing USGS sediment load and bed material monitoring
SI-009b	Is existing sand storage contributing to infiltration into gravels in the priority spawning reach?	Existing Conditions	Other	O	• Existing and Proposed DWR Sand Studies • USBR sediment budget Study • USGS Tributary study • Ongoing USGS sediment load and bed material monitoring

Table 3-4.
Spawning and Incubation Questions (contd.)

No.	Questions	Type of question	Relevant Action Identified in Draft Framework for Implementation	Action Category (C/S/I/O)	Related Study
SI-009c	Will future Restoration Flows increase or reduce sand storage and infiltration frequency via altering the fine sediment budget?	Existing Conditions	Other	O	• Existing and Proposed DWR Sand Studies • USBR sediment budget Study • USGS Tributary study • Ongoing USGS sediment load and bed material monitoring • Sampling location further upstream of HWY 41 needed to address question
SI-009d	What strategies are available to reduce sand impact to spawning (sedimentation basins, sediment removal, watershed rehab, etc.)?	Strategy/Action	Sand infiltration control projects	O	• Existing and Proposed DWR Sand Studies • USBR sediment budget Study • USGS Tributary study -Ongoing USGS sediment load and bed material monitoring
Redd Superimposition					
SI-010a	What is the differentiation of habitat use between spring- and fall-run? Is separating spring- and fall-run necessary?	Existing Conditions	Other	O	Redd mapping from spawning surveys
SI-010b	If there is substantial overlap of spring- and fall-run spawning habitat, will redd superimposition and/or genetic introgression by fall-run impair the viability of the spring-run population?	Existing Conditions	Other	O	This would require an assessment of spring-run and fall-run phenotype escapement trends over time.
SI-010c	What management strategies are possible to reduce competition for spawning habitat?	Strategy/Action	Other	O	2-D modeling

Table 3-4.
Spawning and Incubation Questions (contd.)

No.	Questions	Type of question	Relevant Action Identified in Draft Framework for Implementation	Action Category (C/S/I/O)	Related Study
SI-011	Are devices, such as a segregation weir necessary to prevent genetic introgression or redd superimposition between spring- and fall-run Chinook salmon? Can a segregation weir be placed in a strategic location reduce or to avoid this redd superimposition? Can quantity of fish be enhanced with a segregation weir?	Strategy/Action	Other	O	This would require an analysis of the quantity and quality of spawning and egg incubation habitat in the fall-run spawning reach (4-10 miles below Friant Dam). It also requires a study of the distribution of spring-run and fall-run spawners. If there's substantial overlap, then a segregation weir would be necessary. Pilot studies would be needed to determine where and how to install a weir.
Friant Dam Release Temperatures					
SI-012	What are the effects of the Restoration Flow releases on the suitability of the release temperatures for spring-run spawning habitat?	Existing Conditions	Other	O	• Existing HEC-5Q model and ongoing stream temperature monitoring. Although the temperature model analysis suggests that possible actions would have minimal effect on release temperatures, we should monitor the effect of elevated release temperatures on spawning and incubation. • Reservoir temperature modeling; Millerton Temperature Study • Temperature modeling and egg survival studies

Table 3-4.
Spawning and Incubation Questions (contd.)

No.	Questions	Type of question	Relevant Action Identified in Draft Framework for Implementation	Action Category (C/S/I/O)	Related Study
SI-013	Is river temperature sufficient both spatially and temporally for spawning and incubation?	Existing Conditions	Other	O	• Existing HEC-5Q model and ongoing stream temperature monitoring. Although the temperature model analysis suggests that possible actions would have minimal effect on release temperatures, we should monitor the effect of elevated release temperatures on spawning and incubation. • Reservoir temperature modeling; Millerton Temperature Study • Temperature modeling and egg survival studies
Other					
SI-014	Will poaching reduce the abundance of spawners?	Existing Conditions	Other (Anti-Poaching measures)	O	
SI-015	In the context of considering spawning gravel alternatives, if new spawning habitat is created, or existing spawning habitat rehabilitated, will future coarse bedload transport (spawning gravel) be quickly routed downstream, reducing the quantity (longevity) of spawning habitat, requiring more frequent augmentation (need to quantify rates)? a. Is Cottonwood Creek supplying useful spawning gravels to the high priority spawning reach (Input)? b. What is existing spawning gravel quantity (Storage) c. At what flows do spawning gravels begin to mobilize in riffles in the high priority spawning reach? d. What is the gravel transport rate out of the priority spawning reach (Output)?	Creating Conditions, Spawning Needs	Gravel augmentation	C	Tracer Studies and Hydraulic Modeling. Bedload transport measurements in upstream reach to quantify existing conditions, transport modeling to game future conditions under different grain size and sand (mixed load) scenarios

Table 3-4.
Spawning and Incubation Questions (contd.)

No.	Questions	Type of question	Relevant Action Identified in Draft Framework for Implementation	Action Category (C/S/I/O)	Related Study
SI-016	How can spawning habitat be created and/or improved below Friant Dam? Are there problems or restrictions that would prevent working in certain areas, or opportunities for working in certain areas?	Creating Conditions	Other	O	Feasibility study: Review bathymetry and topography and gradient and bedrock exposures, access, ownership, costs, permitting constraints, hydraulics of reach and identify potential project locations

3.2.4 Studies

The following studies were developed for 2014 to address uncertainties within the Restoration Area regarding spawning and incubation:

- Egg Survival and Emergence in Reaches 1A and 1B of the San Joaquin River (Study 8, Appendix A)
- Segregation Weir – Placement, Monitoring and Objective (Study 36, Appendix A)
- Rotary Screw Trap Monitoring (Study 45, Appendix A)
- San Joaquin River Spawning Habitat Assessment – Incubation Environment (Study 30, Appendix A)
- SRH Group Facies Mapping (Study 37, Appendix A)
- SRH Group Spawning Habitat Framework (Study 40, Appendix A)
- Spring Run Spawning Habitat Assessment – Sediment Mobility (Study 47, Appendix A)

The 2014 spawning and incubation studies are summarized below. The complete study descriptions are available in Appendix A.

Egg Survival and Emergence in Reaches 1A and 1B of the San Joaquin River

The Restoration Goal of the SJRRP includes the return of viable, long-term, and sustainable populations of naturally reproducing spring- and fall-run Chinook salmon. To realize restoration of lower San Joaquin River salmon populations, successful completion of the freshwater portion of the salmon life-cycle must occur. However, the availability of high-quality spawning habitat is limited in the Restoration Area due to a lack of appropriately sized gravel for spawning, insufficient flows for flushing fine sediments that impede nest suitability, and elevated water temperatures that compromise the egg incubation period. The information from this study, paired with studies conducted by Reclamation and DWR on hyporheic water quality conditions, substrate composition, depth/velocity profiles and fine sediment accumulation will help determine the deficit of suitable spawning habitat and evaluate options for habitat restoration.

In 2011 and 2012, as part of this study, egg survival studies were conducted in Reach 1A in an effort to assess existing egg survival in existing spawning habitat in a longitudinal gradient from Friant Dam to Highway 41. The 2014 Egg Survival and Emergence in reaches 1A and 1B of the San Joaquin River study will evaluate the survival to emergence, as well as the overall condition at and timing of emergence for alevins from naturally placed fall-run Chinook salmon redds and artificial placements in the San Joaquin River as an element of the tasks identified by the Spawning and Incubation SIG as important for describing the overall suitability of spawning gravel from Friant Dam to Skaggs Bridge.

Segregation Weir – Placement, Monitoring and Objective

This study involves the construction of a segregation weir in Reach 1A above the Highway 41 Bridge to keep fall-run Chinook salmon separate from threatened spring-run Chinook salmon during spawning. The objective is to prevent hybridization between the two species. The segregation weir would allow both runs of Chinook salmon to exist in the Restoration Area. Similar methods have been used successfully in other Central Valley streams to enhance the production of both species.

An adequate segregation of spring-run Chinook salmon from fall-run Chinook salmon in accordance with the Settlement may be necessary to allow both species to reestablish in the Restoration Area. Data collected from the post-placement monitoring of the segregation weir will aid in understanding the potential for success of both species in the system given uncertainties about whether or not redd superimposition or genetic introgression by fall-run spawners will affect the success of spring-run production by keeping the species spatially separate.

Rotary Screw Trap Monitoring

An RST is a trapping method used for evaluating live fish. The trap is floated in the water on pontoons, which support interior baffles to trap and transfer fish into a live-box where the fish can be studied and then released. Monitoring Chinook salmon with an RST gives descriptive information on the abundance, timing, size, and condition of fish with a given system. In the Restoration Area, data collected from RST trapping may be used to make inferences about spawning success of released study fish during pilot-scale reintroduction efforts (i.e., trap and haul), while also providing a means to better inform future large-scale salmon reintroduction efforts.

Preliminary, pilot-scale RST monitoring on the San Joaquin River began in the spring of 2013 (March through June), with one RST operated near the State Route 99 Bridge. In 2014, the primary purpose of the study is to evaluate the feasibility of using RSTs while optimizing RST efficiencies in the San Joaquin River.

San Joaquin River Spawning Habitat Assessment – Incubation Environment

The current understanding within the SJRRP is that a sufficient availability and quality of spawning habitat within Reach 1 of the San Joaquin River is imperative to sustaining populations of Chinook salmon in the Restoration Area. Successful salmon spawning survival-to-emergence is often dependent on the physical habitat quality of the incubation environment for eggs, which is largely determined by the size of gravel available for nest (redd) building on the streambed, and the presence and accumulation of fine sediment on those gravels, which inhibit egg survival.

Past studies conducted in the river system conclude that the amount of sand being transported and deposited in the San Joaquin River is sufficient to inhibit egg survival, and that much is unknown as to whether the existing streambed incubation environment is suitable for successful salmon spawning survival-to-emergence habitat within Reach 1A (Stillwater Sciences, 2003).

The 2014 San Joaquin River Spawning Habitat Assessment will provide necessary insight into the spawning habitat available for naturally created redds. As it is unknown whether or not sufficient habitat exists to meet the restoration objective for survival-to-emergence, this assessment will aid in determining the factors that may be detrimental to suitable incubation habitat quantity and quality within the system. Data collection for 2014 includes the mapping of salmon incubation habitat by measuring gravel permeability, intragravel flow, fine sediment bedload, and percent of fines in bed material at naturally created Chinook salmon redds and their surrounding areas of potential spawning habitat.

SRH Group Facies Mapping

Facies mapping attempts to reconstruct the paleogeography of a given area using maps that show the thicknesses and kinds of sediments that were being deposited during a particular time interval. Facies maps plot the areal distribution of different sedimentary rock types existing throughout an area. In 2013, data on the sediment facies existing between Reach 1A to Friant Dam to Sycamore Island were collected. In 2014, the 2013 data will be compared to data collected for the same area in 2002 to distinguish changes in sedimentary rock in the area over time.

This project is part of the Sedimentation and River Hydraulics Group (SRH) San Joaquin River Restoration Program Hydraulic and Sediment Support program.

SRH Group Spawning Habitat Framework

In 2014, the SRH Group will develop a spawning habitat framework that will include a characterization of existing bed material and hydraulic conditions as they relate to spawning habitat; a conceptual plan for improving and increasing spawning habitat using data from the Spawning and Incubation SIG; and a plan for monitoring the change and success of the proposed improvements to spawning habitat within the system.

This project is part of the Sedimentation and River Hydraulics Group (SRH) San Joaquin River Restoration Program Hydraulic and Sediment Support program.

Spring Run Spawning Habitat Assessment – Sediment Mobility

The objective of this study will be to characterize gravel, sand mobility, and bedload transport measurements (upstream reach) in potential spawning habitat, and to map mobility characteristics at each site. These maps will be used as layers that will be joined with other habitat characterizing efforts to provide a habitat suitability index (HSI) throughout the spring-run salmon spawning habitat. With the HSI maps, the amount of spawning habitat deemed to fall within suitable characteristics will be delineated, quantified, and compared to the project's goals. In addition, the mobility characteristics will be used to consider methods of expanding spawning habitat through enhancement strategies if it is determined that there is a deficit in spawning habitat.

3.3 Adult Migration

The following section describes the state of knowledge, questions, and studies associated with the adult migration theme. Figure 3-12 illustrates the schedule related to actions and studies that will be implemented under this theme.

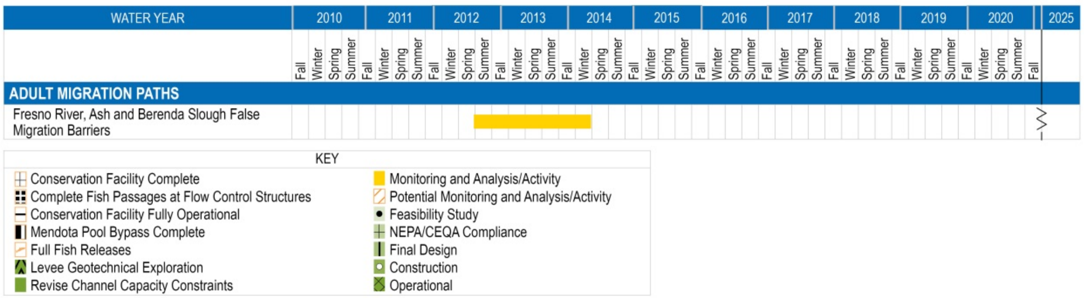


Figure 3-12.
Adult Migration Schedule

3.3.1 State of Knowledge

Purpose and Objectives

The purpose of the adult migration state of knowledge is to synthesize existing information the adult migration of Chinook salmon in the Restoration Area to guide the strategy and design for SJRRP studies and the implementation of actions.

Background

False migration paths are pathways that attract adult migrating salmon but do not lead to suitable spawning habitat. Adults traveling into these false pathways often become trapped or die in the false pathway. Even if a pathway does not lead to mortality, the delay to migration can prohibit fish from traveling to suitable habitat in time to reproduce. The Implementing Agencies identified actions to construct the Salt Slough and Mud Slough barriers to prevent false migration pathways for adult anadromous fish, and are currently developing plans for implementing these actions. An additional potential action identified in the Framework (SJRRP, 2012b) as an improvement is to include an evaluation of Fresno River, Ash, and Berenda Slough false migration barriers (Chowchilla Bypass).

In 1988, the California State legislature issued a doubling goal for Chinook salmon natural production in the state by creating Fish and Game Code Sections 6901 and 6902, The Salmon, Steelhead Trout, and Anadromous Fisheries Program Act (1988) (The Act). The Act focuses on the protection of naturally spawning salmon and steelhead resources of the state, primarily through the improvement of stream habitat. The focus of this legislation is more on natural production of the fish than hatchery production.

Fall-run Chinook salmon populations in the San Joaquin River Basin declined to seriously low levels in the late 1980s and early 1990s. In the fall of 1991, there were fewer than an estimated 650 fish compared to historic high levels of 70,000 fish in 1985, 80,500 fish in 1953, and 125,900 fish in 1940.

Agricultural drainage practices in western Merced County and release patterns from the eastside tributaries of the San Joaquin River (i.e., Stanislaus, Tuolumne, and Merced rivers), have resulted in significant numbers of adult Chinook salmon in the San Joaquin River Basin to stray into westside agricultural drains and canals during their upstream migration. These fish therefore do not enter the tributary streams, but rather continue up the main stem San Joaquin River into Salt and Mud sloughs; areas largely dominated by agricultural drainage water and unsuitable salmon spawning habitat.

As spawning runs declined in the tributaries, the proportion of San Joaquin River Basin salmon entering the westside drains increased. Significant numbers of adult Chinook salmon were straying into westside agricultural drains and canals during their upstream migration, leading them to areas largely dominated by agricultural drainage water and unsuitable spawning habitat instead of tributary streams.

The following are estimated Chinook salmon spawning escapements in the basin for the 4 years from 1988 to 1991, by tributary stream (Table 3-5). In the fall of 1991, an estimated 31 percent of the basin's spawning run strayed into westside canals.

Table 3-5.
Estimated Chinook Salmon Spawning Escapements for 1988 Through 1991

Year	Stanislaus	Tuolumne	Merced	Westside (LBWA)	Total
1988	12,300	6,300	3,200	2,300	24,100
1989	1,543	1,274	211	322	3,350
1990	492	96	73	280	941
1991	282	53	99	200	634

Key:
LBWA = Los Banos Wildlife Area

In an effort to salvage fish straying into the westside canals, the DFW began an adult trapping and salvage effort in 1988. Makeshift electrical barriers were installed on Salt Slough which shunted the majority of the strays into South End Mud Slough and the San Luis Canal. A guide fence, steppass fish ladder, and trap box were installed on an irrigation drop on the San Luis Canal near the Los Banos Wildlife Area headquarters. During the spawning season, trapped fish were spawned and the eggs transported to the Merced River Fish Facility for incubation and rearing.

Although DFW had some success in salvaging eggs from fish straying into westside canals, it became evident that a more permanent solution to the straying problem was necessary. DFW decided to construct the HFB in 1993, a physical barrier. This, and other barrier projects were funded by mitigation money obtained through the Delta Pumps Fish Protection Agreement (DPFPA).The primary purpose of the Hills Ferry Barrier (HFB) is to redirect upstream-migrating adult fall-run Chinook salmon to suitable spawning habitat in the Merced River and prevent migration into the main stem San Joaquin River upstream, where conditions are currently considered unsuitable for Chinook salmon and steelhead.

DFW operates the HFB under the Delta Fish Agreement with the DWR as a mitigation action for impacts to fish caused by water diversions at the Harvey O. Banks Pumping Plant. It is unclear at this time whether the operation of the HFB will continue.

The Merced River Fish Facility began operation in 1970 with funding provided by the Merced Irrigation District (MID) by means of the Davis-Grunskey Act. The facility consisted of a 4,300-foot-long by 40-foot-wide spawning channel and two 275- by 30-foot rearing ponds. Fish were naturally spawned in the spawning channel until 1980 when a spawning shed was erected and artificial spawning occurred with eggs held in incubator trays. The facility is still operational.

To date, fish capture and relocation programs in Restoration Area attempt to move individuals above obstructions to continue their spawning migration and provide access to suitable habitat. These programs have been a management concern due to their limited success (Schroeder et al., 2007; Keefer et al., 2010; Mosser et al., 2012) and provide challenges for recovery efforts.

Key Characteristics for Adult Migration Paths

The following describes how water temperature, false migration pathways, barriers, and hydraulics in the Restoration Area may impede or prevent some adult Chinook salmon from completing their upstream migration.

The “key characteristics” contributing to functioning adult migration paths are:

- Temperature
- False migration paths
- Hydraulics
- Barriers

Temperature

High water temperatures in the Restoration Area may impede or prevent some adult Chinook salmon from completing their upstream migration. Predictions from the initial HEC-5Q water temperature model (SJRRP, 2008) suggest that the daily maximum water temperatures in reaches 4B and 5 will exceed the lethal threshold for adult spring-run Chinook salmon at a Friant Dam release of 4,500 cfs by April 24 during median (0.52 exceedance probability) meteorological conditions.

When the HEC-5Q model was recalibrated with 2009 – 2010 interim flow data, the lethal threshold of 68°F (20 degrees Celsius) was exceeded by April 28 (SJRRP, 2012). If the recalibrated model reflects current conditions, then only up to 30 percent of the adults may be able to migrate to Reach 1 based on migration timing data from Mill and Butte creeks (Johnson et al., 2006). If no more than 30 percent of the adults can successfully migrate to Reach 1 where they could spawn and flow for juvenile passage must be limited to brief pulses, restoration actions to cool temperatures may be needed to reach the population viability target.

To create suitable water temperatures for adult migration in the Restoration Area, it is highly likely that it will be necessary to implement a combination of actions to achieve the Restoration Goal, including narrowing the low flow channel and planting a riparian tree canopy on both sides of the low flow to reduce air temperatures and provide shade.

Riparian Shading

Shading from riparian tree species reduces solar radiation and air temperatures in the river corridor, thus reducing water temperatures. Maintenance or enhancement of a vegetated riparian corridor creates riparian shading.

Sensitivity analyses, called the Sets 4 and 5 Sensitivity Analyses (SJRRP, 2008) evaluated the effects of riparian shading and channel narrowing on daily maximum water temperatures primarily upstream from Mendota Pool. The riparian shading study (Set 4) used solar radiation measurements from a Stanislaus River site that was shaded for approximately half the day and those data were used in a conceptual analysis of the median of the maximum daily temperatures in 5-foot-deep pools at four sites: Gravelly Ford, below Chowchilla Bypass, Sack Dam, and above Mendota Pool. There was uncertainty in the results due to a lack of data on the effects of shade trees on wind speed and humidity, both of which would partially negate the benefits of providing shade and were not included in the sensitivity study.

The results from Set 4 suggested that a half day of heavy riparian shade could reduce daily maximum water temperatures by about 2°F at Gravelly Ford in late spring and summer at a flow release of 1,500 cfs, assuming there were no negative effects of reduced wind speed and increased humidity. Based on this information, it has been deduced that the temperature reductions that could result in the San Joaquin due to riparian shading would likely decline as flows increase above 1,500 cfs.

Furthermore, the results for the Sack Dam site, which was only conducted at a flow of 350 cfs, suggest that the effects of riparian shading would be less at Sack Dam than at Gravelly Ford. However the Set 4 analysis did not fully address the effect of riparian shading on both banks of the river below Sack Dam. The reaches below Sack Dam are particularly important for further study, because the effects of riparian shading would be less in channels flowing toward the north (Restoration Area below Mendota Pool) compared to channels flowing toward the west (Restoration Area above Mendota Pool). Second, the study does not consider the cumulative effect of providing shade throughout the Restoration Area. Presumably, water temperatures in reaches 4B and 5 are partially dependent on the temperature of the water flowing in from upstream reaches.

Channel Narrowing

Narrowing and deepening of the base-flow channel reduces heating from solar radiation and decreases water temperature within the base-flow channel. Solar radiation may still heat overbank flows.

The channel narrowing analysis (Set 5 of Sensitivity Analyses (SJRRP, 2008b)) evaluated the effects of three channel modifications on the median of the maximum daily water temperatures in conceptual 5-foot-deep pools at Gravelly Ford, below Chowchilla Bypass, and above Mendota Pool at flow releases of 350 and 700 cfs.

- A 25 percent width reduction and no change in depth
- A 25 percent width reduction and a 33 percent depth increase
- A 50 percent reduction in width and depth

The results suggest that 50 percent reductions in channel width and depth might reduce daily maximum temperatures in the month of May to about 6°F at a flow of 700 cfs at Gravelly Ford. Flow magnitude had no effect on the temperature reduction as long as flows remained in the low flow channel (less than 700 cfs).

The benefits of channel narrowing and deepening were smaller at the Below Chowchilla and Above Mendota Pool sites, compared to the Gravelly Ford site, presumably because the existing channel was wider at these sites than at Gravelly Ford. No analysis was done for the reaches below Mendota Pool where shading may affect daily maximum water temperatures in the northerly flowing channel differently from those modeled at Gravelly Ford and above Mendota Pool, which flow toward the west.

Wide Riparian Canopy
'Wide riparian canopy,' as a stream cooling action, is the use of wide bands of trees to shade the river, as opposed to narrow bands. Wide riparian canopies reduce air temperatures at the river's edge and reduced air temperatures may reduce water temperatures (Moore et al., 2005). This action that has not yet been studied for the Restoration Area.

Studies in upper watersheds in northern California indicated that the rate of decline in air temperature due to riparian tree canopies is highest up to a width of 30 meters and only 0.36°F for each additional 10 meters of width. A 30-meter-wide riparian tree canopy reduced above stream air temperatures by 8.6°F, compared to sites without riparian trees (Moore et al., 2005). It would be possible to use estimates of air temperature reduction, increases in humidity, and reduction in wind speed in a conceptual modeling analysis based on the data provided in Moore et al. (2005). However, there is a lack of meteorological data that could be used to quantify the effects of riparian canopy width along the San Joaquin River below Mendota Pool where the river flows toward the north.

Hydraulics
Adult salmon passage can be impaired by water depths that are too shallow (less than 1.2 feet), excessive velocities (greater than 4 feet/second), and excessive jump heights (greater than 1.5 feet at structures (SJRRP, 2010a).

DWR has identified 11 structures in the main stem river that would be either a partial or full barrier to adult salmon during part of the restoration flow hydrograph (Annual

Technical Reports, 2010, 2012). All of the identified barriers occur within the Reach 2B, Reach 4B, and Sack Dam project sites, where modifications are planned to provide adult passage. DWR has just completed an adult passage analysis in the upper Eastside and Chowchilla bypasses, where adult salmon may migrate during flood control releases. The analysis is to be distributed in late 2013. USGS plans to conduct a nonstructural adult passage analysis at sites where the channel may be too wide and the flow too shallow to permit adult passage. Completing the analysis may require that flows are released below Sack Dam to help calibrate the hydraulic models.

False Migration Paths

False migration paths are pathways that may attract adult migrating Chinook salmon but do not lead to suitable spawning habitat. Adults traveling into these false pathways often become trapped or die in the false pathway. Even if a pathway does not lead to mortality, the delay to migration can prohibit fish from traveling to suitable habitat in time to reproduce. Paragraph 11 of the Settlement and the Framework (SJRRP, 2012b) identify Mud and Salt sloughs as false migration pathways that will require seasonal barriers to block adult migration. Another false pathway that may require a barrier is the James Bypass in Mendota Pool, which may affect spring-run adults during wet year flood control releases. Other false pathways may exist in the main stem and bypasses.

It is possible that salmon produced in the Restoration Area will be able to follow olfactory and other orientation cues to navigate to Reach 1 and avoid false migration paths. Homing to natal sites is a characteristic behavior pattern in all salmon, though roughly 1 percent to 5 percent of fish that reach adulthood stray to other locations (Quinn, 2005). Straying occurs naturally and increases the likelihood of persistence during periods of fluctuating habitat suitability (Quinn, 1984; Milner and Bailey, 1989). Excessive straying in the San Joaquin River can lead to migration of adult fish into waterways with inferior habitat quality. From a mechanistic perspective, homing is largely directed by olfactory imprinting of natal stream at one or more stages before and during seaward migration (Quinn, 2005). Disruption to this stream odor imprinting process may partially explain the number of strays observed at the HFB.

False migration paths for adults can reduce the effectiveness of salmon reintroduction. The most common false migration paths in the Restoration Area are diversions and outplanting, discussed below.

Diversions

The complex system of long-distance water diversions and transportation throughout California may disrupt the natural imprinting process for salmon. In the San Joaquin River Basin, diversions and transportation of water includes 15,000 acre-feet per year of water conveyed through Merced Irrigation District to the Merced National Wildlife Refuge to sustain local habitats. It also includes water transfers provided by Merced Irrigation District to local refuges such as the East Bear Creek Unit of the San Luis Wildlife Refuge when surface water is available (RMC, 2013). These waters, along with additional Merced River water supplied via Merced Irrigation District canals, sloughs, and creek, discharge Merced River water into Salt Slough and the Eastside Bypass and could falsely attract fall-run Chinook salmon to these locations. In addition, the Delta

Mendota Canal delivers water to Mendota Pool, which may then be released downstream or conveyed to various irrigation districts that ultimately discharge its water to Mud and Salt sloughs. This may be another potential cause of straying due to the potential for out-of-basin water that could be conveyed by these sloughs exacerbating the issue by falsely attracting out-of-basin fish.

Outplanting

Further disruption to the natural imprinting process may come from outplanting procedures common among salmon hatcheries. Chinook salmon produced at the Merced River Fish Hatchery are not released in the San Francisco Bay, but large numbers of fish are trucked downstream and released at sites within the Delta. Releases from the hatchery are being used as part of a long-term experimental program designed to protect juvenile Chinook salmon from migrating from the San Joaquin River through the Delta (this program is called the Vernalis Adaptive Management Plan or VAMP). The VAMP is evaluating how salmon survival rates change in response to flow management. From 2001 to 2006, the annual release of Merced River Fish Hatchery fall-run Chinook salmon was approximately 1.1 million fish, of which about 35 percent were released annually within the Delta. Recoveries of coded wire-tags (CWT) for Merced River Fish Hatchery fish (expanded for sampling) show that Delta releases resulted in much higher stray rates than for fish released into the Merced River (both on- and off-station releases) (ICF Jones & Stokes, 2010), a pattern consistent with what has been seen elsewhere in the Central Valley system for Delta releases. While it is generally believed that the extent of straying increases the farther downstream fish are released from Central Valley hatcheries (e.g., San Francisco Bay versus Delta), this matter is still being evaluated.

Barriers

Barriers within the river system impede adult migration. Strategies to allow for adult migration within the Restoration Area have been developed and are discussed herein.

Restoration Strategies

Strategies for each of the adult migration key characteristics were developed by the Adult Migration SIG during 2013, and are discussed herein.

Temperature Strategy

The Adult Migration SIG suggested that water temperatures could be reduced by minimizing the width of the base flow channel, using the excavated substrate to create a “transition zone” within the main channel (e.g., 500 cfs), and by planting trees at high densities on all seasonally inundated habitats (Figure 3-1). It may be necessary to implement these actions in all reaches to improve temperatures below Sack Dam.

Riparian Shading Strategy

The reaches below Sack Dam are particularly important for further study because the effects of riparian shading would be less in channels flowing toward the north (Restoration Area below Mendota Pool) compared to channels flowing toward the west (Restoration Area above Mendota Pool). Consideration should be made of the cumulative effect of providing shade throughout the Restoration Area. Presumably, water temperatures in reaches 4B and 5 are partially dependent on the temperature of the water flowing in from the upstream reaches.

Another issue is whether dense riparian growth adjacent to the river will exacerbate channel incision and sand deposition on the floodplain margins. An assessment may be necessary to determine whether large tree species (e.g., cottonwoods) would minimize fluvial geomorphic impacts compared to shrub species (e.g., sandbar willow).

Base-Flow Channel Narrowing Strategy

The lower section of Reach 1 between Skaggs Bridge and Gravelly Ford has a base-flow channel that is approximately 50 feet wide with heavy riparian shrub growth on both banks. The base-flow channels in reaches 2A, 3, and 4A have a mean width of 136 feet, a maximum width of 280 feet (Reach 3, RM 187), and sparse riparian growth, primarily along the riverbanks. Studies will be needed to determine whether the base-flow channel can be narrowed to less than a 50-foot width without exacerbating channel incision.

Reducing Overbank Flow and Air Temperatures

Air temperatures and overbank flow temperatures could be reduced in two ways. First planting trees over all seasonally inundated habitats (transition zone and floodplain) to form a dense canopy would reduce both solar radiation and air temperatures (Moore et al., 2005). Creating a seasonally inundated transition zone within the main channel would increase the tree canopy area and thereby reduce heating from solar radiation and reduce air temperatures at the base-flow channel. The second method would be to increase floodplain roughness by densely planting riparian shrub species. Maximizing floodplain roughness may help keep warm floodplain flows from mixing with cool flows in the base-flow channel. If true, it may be necessary to plant both tree and shrub species to provide both temperature and floodplain growth benefits. The effects a wide riparian tree canopy or high floodplain roughness has not been studied on air temperatures or overbank flow temperatures in the Restoration Area.

Hydraulics Strategy

The SJRRP will be able to gradually increase flows in the Restoration Area with completion of flowage easements in the Eastside Bypass, seepage easements, and construction of physical seepage control projects. Increased flows below Sack Dam will enable the SJRRP to observe migration patterns under a broader range of mixed San Joaquin River, Salt Slough, Mud Slough, and other water sources in Reach 5. Reintroduction of spring-run salmon will eventually result in returning adults of San Joaquin River origin, which may have different behavior than the fish currently migrating past HFB. San Joaquin origin fish will not be expected to return until 1-3 years after the first group of juveniles are able to migrate from the Restoration Area.

False Migration Paths Strategy

Adult salmon might that enter false pathways because of the complex system of long-distance water diversions and transportation, presence of out-of-basin waters, or from hatchery strays that were released as juveniles in the Delta. Studies may be needed to determine the effects that false migration pathways may have on salmon within the Restoration Area.

The SJRRP does not currently have the benefit of prioritizing improvements through observing an established population migrate through a restored system. Historically the fisheries agencies and program staff has observed fall-run salmon of unknown origin in the Restoration Area with limited or no flows below Sack Dam. SJRRP has continued these observations through trap and haul, but it still provides a limited picture of future adult migration issues in the Restoration Area. If technique and protocol could be developed ahead of restoration flows, the SJRRP's ability to understand adult migration issues and develop solutions will improve with experience managing fish within the restored system.

Additionally, potential adult migration pathways may exist at the Newman Wasteway and locations within the Chowchilla Bypass (e.g., Ash and Berenda sloughs). Adult migration monitoring should be at a resolution that will allow the SJRRP to identify the source of losses within the migration corridor.

Adult fall-run salmon that bypassed the HFB were captured and successfully relocated to Reach 1 of the Restoration Area in fall 2012. These trap-and-haul efforts will help evaluate the feasibility of transporting adult Chinook salmon around existing barriers in the San Joaquin River to suitable holding and spawning habitat. Released fish will provide the means to evaluate preferred spawning habitats and spawning habitat quality.

There are no established best management practices for capture and relocation of salmon with blocked migration corridors that have prolonged, sub-lethal thermal exposure. The relationships between spring-run survival, temperature, and discharge, are poorly understood on most rivers and studies will needed in the Restoration Area with adult spring-run. Adult spring-run may be particularly susceptible to trap-and-haul stresses because they must hold throughout the summer before spawning in September and October. In contrast, adult fall-run spawn within a few weeks after arriving in Reach 1. Acoustic telemetry can be used to observe individual fish movements after transport and release with what is assumed to be little additional stress. It can determine survival and movement of relocated fish as well as temperature data to determine thermal exposure and time of death.

Special consideration should be made when tagging and releasing fish as a balance of proper environmental conditions, such as water temperature, flow, and dissolved oxygen (DO) are critical to fish survival and therefore must be taken into account at release locations. Relocated salmon should be released into upstream waters that are cooler than the capture location, not exceeding 68°F. Successfully relocating salmon under these conditions may be challenging and uncertain, but mortality of spring-run Chinook salmon without intervention is likely.

Barriers Strategy Hills Ferry Barrier

An evaluation of the capacity of the HFB to redirect migrating adult Chinook to the Merced River and away from unsuitable habitat in the San Joaquin River was conducted in 2010. It was determined that the barrier was not effective in blocking all salmon, but did act to deter most fish. Fish that were found upstream from the barrier were tagged and released downstream from the San Joaquin and Merced rivers' confluence for further study.

The following year, no efforts were made to trap and transport salmon at the HFB, but the effectiveness of the barrier as a stand-alone project was investigated. Again, it was found that the barrier was not effective in blocking all adult salmon, and some monitored fish passed the barrier freely through scour holes and small barrier openings. Of the fish that passed the barrier and were tagged, unique tracks of each were detected, providing valuable information on fish movement during migration after capture.

In 2012, efforts were made to capture as many fish having made their way above HFB. In total, 119 salmon were successfully captured and transported to Reach 1. There they were either placed in the river or used in an artificial spawning operation.

Based on the data and processes discovered during the HFB evaluation, the following strategies were developed regarding the study of barriers within the Restoration Area.

- While 2011 proved to be a successful year for gathering migration information and observations about adult salmon behavior, larger sample sizes are needed to obtain a more realistic sense of salmon migration behavior within the Restoration Area. A larger sample size would give insight to the migratory choices made by the fish at the San Joaquin-Merced River confluence.

- Receivers upstream on the sloughs and canals adjoining the HFB could provide additional information as to the fates of the tagged fish further outside of the area monitored.

- Because fish were not released in the Restoration Area after their capture at the HFB, no information was collected relating to migration routes upstream from the barrier. Capture data was limited to the HFB locations as there were no upstream collection points upstream. There would be value in releasing fish in the Restoration Area after capture at the HFB and establishing collection points upstream.

- Additional rearing and holding habitat information is needed in Reach 1. Monitoring in the fall of 2013 is anticipated to include tagging 50 adult female Chinook with acoustic tags and all males and additional females with disc tags for identification.

Kings River Barrier

Flood flows from the Kings River that are conveyed through the James Bypass into Mendota Pool represent an adult pathway that may attract adult salmon from the San Joaquin River. This is a particular concern, because when the James Bypass flows are near the maximum of 4,500 cfs, San Joaquin River flows in Reach 2B must be reduced to very low levels. When the proportion of San Joaquin flows in Mendota Pool are very small (e.g., <5%) compared to the total inflow from the James Bypass, the risk of adult salmon straying into the James Bypass may be high. A study may be needed to determine the frequency that Kings River flood flows may attract adult salmon from the Restoration Area and the need for a barrier in Mendota Pool.

3.3.2 Questions

Table 3-6 lists the questions associated with addressing uncertainties related to adult migration. These questions were developed and refined by the Adult Migration SIG, which convened during 2013.

Table 3-6.
Adult Migration Questions

No.	Questions	Type of question	Relevant Action Identified in Draft Framework for Implementation	Action Category (C/S/I/O)	Related Study
Hydraulics					
AM-001	Will existing or future structures impede passage when temperatures are near the critical maximum?	Near-term	Structural Barriers	C	
AM-002	Does the existing geomorphology of the river provide sufficient passage (e.g., depth, velocity, resting pools, large woody debris, thermal refugia, stable morphology, sediment transport) for adult migrants?	Near-term			Field data and modeling exercise. Use USGS inundation maps.
False Migration paths					
AM-003	Are there false migration paths other than Mud and Salt sloughs that need to be considered?	Long-term	Structural Barriers	C	
Temperature					
AM-004	What actions are needed and where to reduce daily maximum water temperatures in Reaches 4B and 5 to provide suitable temperatures for adult passage? Would these actions be compatible with flood safety?	Near-term			
AM-005	Subquestion: How much riparian vegetation is acceptable for flood control and has to be restored to reduce temperatures in Reach 4B to provide suitable temperatures for adult passage?	Near-term			
AM-006	Can trap-and-haul be used to transport adults after water temperatures in Reaches 4B and 5 exceed maximum thresholds? Will transported spring-run fish survive through spawning?	Near-term			

Table 3-6.
Adult Migration Questions (contd.)

No.	Questions	Type of question	Relevant Action Identified in Draft Framework for Implementation	Action Category (C/S/I/O)	Related Study
Timing					
AM-007	Is there enough difference in migration run-timing and spatial separation between mature spring-run Chinook salmon and fall-run Chinook salmon in the Restoration Area to limit genetic introgression of the two populations?	Near-term			
AM-008	Will the Mill Creek migration timing data for spring 2006 reflect the migration timing for SJRRP source fish? Are there other data that can supplement migration timing?	Near-term			
Long-Term Questions					
AM-009	When will adults begin to migrate into the Restoration Area?	Long-term			
AM-010	What is the source (origin) and contribution/risk of fish that are found at the barriers?	Long-term	Structural Barriers	C	

Key:
AM = Adult migration
C = Core action
S = Secondary action

3.3.3 Studies

Studies were not developed for 2014 to address uncertainties within the Restoration Area regarding adult migration.

3.4 Flow Scheduling

The following section describes the state of knowledge, questions, and studies associated with the flow scheduling theme. Figure 3-13 illustrates the schedule related to actions and studies that will be implemented under this theme.

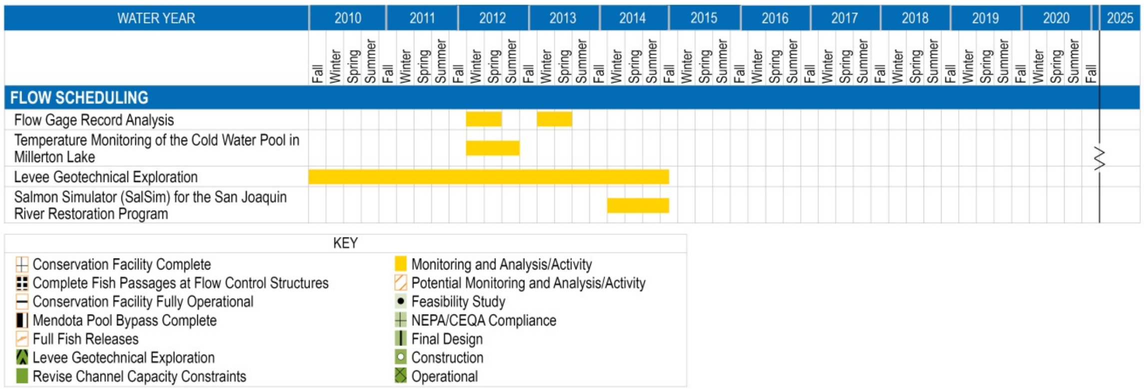


Figure 3-13.
Flow Scheduling Schedule

Flow scheduling encompasses all actions under Paragraph 13 of the Settlement. Actions under Paragraph 13 include operational actions at Friant Dam, compliance with hydrographs defined in the Settlement, recapture accounting, scheduling, water acquisitions, banking, and permit requirements. Reclamation currently implements these actions through a program of Interim Flows, development of Restoration Flow Guidelines, and the MAP and biannual reporting process.

3.4.1 Actions

Actions associated with flow scheduling, identified in the Framework (SJRRP, 2012b) include the following:

- Stream gage monitoring of releases from Friant Dam and locations specified in Exhibit B of the Settlement
- Monitoring of unexpected seepage losses and unreleased Restoration Flows

A long-term question to be addressed for successful implementation is the concept of flow scheduling to facilitate fish survival and migration. This is one of the key questions for SJRRP because flow scheduling provides a potentially powerful tool for influencing fish survival and migration. The Interim and Restoration flows' flexible flow period allows managing of releases to meet SJRRP objectives. Implementing Agencies have the ability to manage the timing, magnitude, and duration of water releases. However, the trade-offs of flow flexibility for temperature management; providing floodplain habitat; or providing pulse flows to initiate fish migration needs to meet SJRRP goals are not well understood. Additional actions that have been identified by Implementing Agencies to understand these trade-offs include the following:

- **Acquire Water for Unexpected Seepage Losses –** Acquisition of water or options on water to meet flow targets consistent with the Restoration Flow Guidelines and Paragraph 13(c) of the Settlement.

- **Bank or Store Unreleased Restoration Flows –** Use of water not released for any reason consistent with the Restoration Flow Guidelines and Paragraph 13(j) of the Settlement.

3.4.2 Questions

Table 3-7 lists the questions associated with addressing uncertainties related to flow scheduling. These questions are organized by actions identified in the Framework (SJRRP, 2012b).

Table 3-7.
Questions Related to Flow Scheduling

Action	Questions
Stream gage monitoring of releases from Friant Dam and locations specified in Exhibit B of the Settlement.	What are the benefits versus consequences of releasing water under different flow schedules?
	How conservative should the program be with releasing flows to maximize benefits for fish and avoid potential impacts of using water too early?
	What are the strategic goals for changing the flows? Are there questions that would not be addressed at 350 cfs?
	What is needed in Reach 1 to trigger response we are looking for in the salmon? Is 350 cfs or 500 cfs sufficient flow? Also, what is needed downstream in reaches 2B and 4B?
Stream gage monitoring of releases from Friant Dam and locations specified in Exhibit B of the Settlement. (contd.)	What is the flow relationship with turbidity? How do changes in reservoir releases change turbidity in the river?
	What is the relationship between high flows and temperature? High flows and floodplain? High flows and transit time?
	What is the relationship between base flows and temperature? Base flows and floodplain? Base flows and transit time?
	What is the minimum adjustment on valves and on power plant to physically change flows? How important is an additional 5 cfs? What is the impact of the lack of sensitivity of cfs releases (connectivity of river)?
	What are the thresholds for ramping rates in different times of year, in terms of flood, to manage pulse flows, biological issues, safety issues, and structural issues (i.e., don't want to reduce releases too fast resulting in sloughing, erosion, turbidity, etc.)?
	How can the reservoir be operated to mimic the natural hydrology of the river system? How can the reservoir releases be used to fill in the gaps of where minimum flows might not be met?
Monitoring of unexpected seepage losses and unreleased Restoration Flows.	What are the flow losses and gains?
	What are the seepage return flows in the lower San Joaquin River in terms of quantity and quality and temperature?
	What is the linkage between seepage and Restoration Flows?
Acquiring water for unexpected seepage losses.	What are the flow losses and gains?
Banking or storing unreleased restoration flows.	How should the SJRRP manage unreleased Restoration Flows?
	Can we use Restoration Flows to improve the suitability of rearing habitat?

Table 3-7.
Questions Related to Flow Scheduling (contd.)

Action	Questions
Other	What are the biological priorities (preferred conditions) for the next year to guide flow schedule? How do these conditions fit within the outlined SJRRP flow schedule?
	What is the flow we need to define suitable habitat? How does that affect carrying capacity?
	What are the minimum flows to achieve life history?
	How can we characterize the flow to habitat relationship in each reach? What is the foundation for the number?
	What is the relationship between flow and spawning quantity and quality in Reach 1? Does the flow regime maximize the duration and downstream extent of suitable rearing and outmigration temperatures for Chinook salmon and other native fishes?
	What discharge would foster riparian habitat recruitment? What is the timing for riparian recruitment (seed release for germination)?
	What triggers fall migration and the duration as it relates to migration rates?
	What is the interaction between flow and potential to stimulate juvenile movement?
	Does the flow regime maximize the duration and downstream extent of suitable rearing and outmigration temperatures for Chinook salmon and other native fishes?
	Can flow scheduling be used to trigger juvenile migration, and the speed and success of migration? How can the program time flow patterns with other tributaries to improve fish survival through the system?
	What are the minimum flows for connectivity? Does the flow regime provide year-round river habitat connectivity throughout the Restoration Area?
	What is the flow scheduling strategy for fish survival and performance? Is there trade-offs associated with releases later in the year?
	What is the relationship between flow and survival, from Reach 5 downstream?
	Will recapturing water in the Delta or lower San Joaquin River affect other species in the river? Is there an optimal location for recapture in consideration of all species? How far downstream can water reasonably be recaptured to benefit fish species?
	How long do high flows inundate habitat? How long do base flows inundate habitat?
	How does this relate to floodplain inundation? What can be adjusted to change conditions that will improve survival in different reaches?
	What is the temperature impact of floodplain inundation? How much affect does inundation of floodplain have on river temperature?
	What is the need for isolating gravel pits? How does isolation of gravel pits affect river temperature (attenuation of water into pits reducing peak temperatures, heating effect of the pits)? Can we develop a prioritization of gravel pit isolation based upon temperature affects?
	How are we addressing cold water refugia?
	What are the effects of the Restoration Flow releases and water diversions on the size of the cold water pool in Millerton Lake? How are we addressing cold water pool management?

Table 3-7.
Questions Related to Flow Scheduling (contd.)

Action	Questions
Other (contd.)	How do subsidence and climate change factor in to flow scheduling? How does the program deal with these issues?
	What is the accommodation space, when designing a floodplain? How should the floodplain be designed to provide a buffer to account for climate change and other factors? What scientific approach can be used to determine the buffer?
	What are the uncertainties associated with each component of the hydrograph? What summer baseflows are needed?
	How should flow releases be scheduled to maximize escapement? How might flow schedules change as projects are implemented and riparian plantings mature? Can flow schedules be developed that achieve viable populations (minimum escapement of 500 adults) for both spring-run and fall-run?
	Are there restoration opportunities that provide benefit through flow scheduling outside of the major construction projects (e.g., side channel creation in Reach 1, mini-floodplain concepts)? How do these features improve survival through growth opportunities in the upper reach?

Key:
cfs = cubic feet per second
SJRRP = San Joaquin River Restoration Program

3.4.3 Studies

The following studies were developed for 2014 to address uncertainties within the Restoration Area regarding flow scheduling:

- Salmon Simulator Model (SalSim) for the SJRRP (Study 32, Appendix A)
- Temperature Monitoring of Cold Water Pool in Millerton Lake (Study 5, Appendix A).

Salmon Simulator Model (SalSim) for the SJRRP

CDFW has developed a full life-cycle salmon population model, called SalSim (Version 2), for the San Joaquin River Basin that estimates fall-run Chinook salmon escapements relative to flow management, water temperatures, hatchery management, irrigation diversions, Head of Old River Barrier (HORB) operations, Delta exports and ocean sport and commercial harvest effort, along with other environmental factors. In stream flows, irrigation diversions, HORB operations, Delta exports and Merced River Hatchery operations are user-modifiable variables. SalSim does not currently have a functional salmon production sub-model for the SJRRP Restoration Area.

SalSim is composed of three sub-models: a water operations model, a water temperature model, and a salmon production model. For the Restoration Area, the model would simulate flows between Friant Dam and the confluence with the Merced River, water temperatures throughout the Restoration Area based on the San Joaquin River Basin HEC-5Q calibration results for data from 1980 to 2010, and simulate salmon abundance from the egg throughout their entire life cycle to adults returning inland to spawn 2 to 4 years later.

In 2014, SalSim will be modified to develop a salmon production model with modifiable salmon production parameters for the Restoration Area. The model modification would include the San Joaquin River from Friant Dam to the Merced River confluence and divides this portion into seven sub-reaches the same as the Stanislaus, Tuolumne and Merced rivers, with the upper four reaches containing suitable spawning habitat. This layout will need to be reconciled with the location of available spawning habitat in the Restoration Area. SalSim currently does not allow changes to fisheries growth, survival, timing, movement or spawning distributions, which would be added as a result of the proposed work.

SalSim would inform flow scheduling, and could be used to evaluate reintroduction scenarios and some restoration or population management actions. With the proposed updates to the salmon production model, input data on salmon biology, such as adult migration timing, spawning distribution, juvenile migration timing, and loss rates at unscreened channels, could be modified in the future as empirical data are obtained from field studies in the Restoration Area.

Millerton Lake Cold Water Pool Monitoring

Temperature monitoring of the cold water pool in Millerton Lake will provide data to support consideration of management actions to release flows from higher in the water column as a potential solution to improve temperature conditions for fisheries. Because water temperatures affect all life stages of Chinook salmon, it is critical to address the key question of whether the temperature of inflows to the San Joaquin River from Millerton Lake will provide a suitable fisheries habitat. The availability and the effect that the Millerton Lake cold water pool has on in stream river temperatures are not well understood. Water temperature in the lake is being monitored to evaluate how releases from Millerton Lake's cold water pool relate to in stream San Joaquin River temperatures.

This is the third year of the Millerton Lake cold water pool management study. The study will take place again in 2014 and may repeat annually until Implementing Agencies conclude that sufficient information has been collected for proposing and implementing flow scheduling to support temperature management.

While 2012 was successful for monitoring in-stream juvenile Chinook migration, more technology development and emphasis is necessary for flat plate PIT tag array designs and detection at in-river structures (i.e., dam and bypass passage). Continued efforts are needed to assess migration and survival over a variety of operations scenarios and flow conditions to detect the success of migrating adults in the Restoration Area. The San Joaquin River PIT Tag Monitoring and Site-specific Technology Development will monitor the basin-wide escapement, entrainment, or entrainment of returning adults to determine survival estimates. The study is intended to design PIT tag arrays to determine migration scenarios with the greatest survival rates for a variety of conditions.

3.5 Conveyance

The following section describes the state of knowledge, questions, and studies associated with the conveyance theme. Figure 3-14 illustrates the schedule related to actions and studies that will be implemented under this theme.

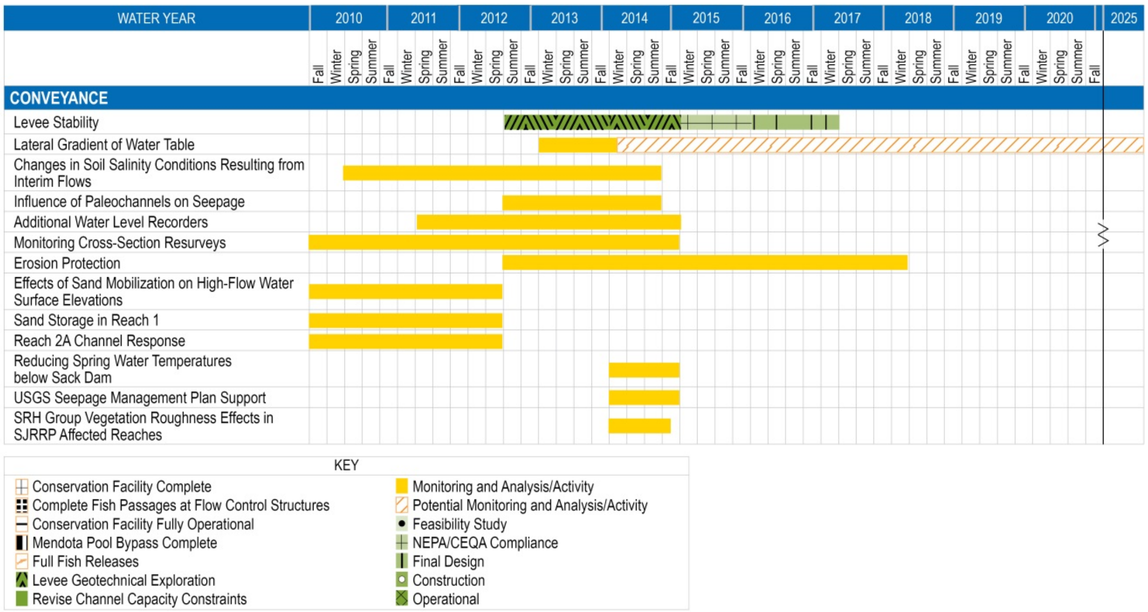


Figure 3-14.
Conveyance Schedule

Conveyance involves establishing nondamaging channel capacities to allow releases that provide for fish movement and to maintain acceptable water temperatures. The PEIS/R calls for Restoration Flows to be limited to then-existing channel capacity based on U.S. Army Corps of Engineers criteria for levee through- and under-seepage. Potential actions to increase channel capacity and thereby establish additional conveyance include constructing levee setbacks for physical capacity, improving levee stability to maintain the flood control project, and constructing new seepage projects to reduce or avoid material adverse impacts from groundwater seepage.

Reclamation and other Implementing Agencies are currently completing site-specific environmental compliance documentation for actions under the Reach 2B Channel Capacity Improvements and Mendota Pool Bypass Improvements, and Reach 4B, Eastside Bypass, and Mariposa Bypass Conveyance Improvement projects, consistent with Paragraph 11 of the Settlement. Environmental documentation for these actions is anticipated on the following schedule:

- Draft Environmental Impact Statement/Report (EIS/R) for Reach 2B Channel Capacity Improvements and Mendota Pool Bypass Improvements is under development

- Final EIS/R for Reach 2B Channel Capacity Improvements and Mendota Pool Bypass Improvements is under development
- Draft EIS/R for Reach 4B, Eastside Bypass, and Mariposa Bypass Conveyance Improvements is under development

Collecting data on levee materials is used to determine levee stability risks. In the absence of sufficient data to evaluate levee stability, Reclamation is dedicated to maintaining flows below the outside toe. Levee constraints currently limit flows at the following locations:

- Upstream from the Mendota Pool to 810 cfs in Reach 2B
- Below Sack Dam to 600 cfs in the Eastside Bypass

Other current efforts to support evaluation of levee stability include geotechnical investigations underway by DWR to collect relevant data to identify and prioritize bottleneck areas for levee remediation.

Reclamation developed a *Seepage Management Plan* (SJRRP, 2011) in coordination with the landowners, last updated in March 2011, which lays out a groundwater monitoring network and identifies thresholds in wells within the monitoring network. Reclamation limits the release of Interim Flows to flow rates that do not cause groundwater levels to rise above thresholds. Reclamation can sometimes recapture a portion of the releases from Friant Dam to reduce or avoid downstream impacts from groundwater seepage. Seepage constraints currently limit flows upstream from the Mendota Pool to 2,100 cfs in Reach 2A. Seepage constraints vary seasonally and by hydrology below Sack Dam, and currently limit flows to between zero and 140 cfs in the Eastside Bypass between the Sand Slough Control Structure and the Mariposa Bypass Bifurcation Structure.

The PEIS/R also calls for addressing seepage effects through easements and/or compensation for seepage effects to landowners. Implementing physical or real estate-related seepage projects will allow higher flow rates without groundwater levels rising above thresholds. Reclamation, in coordination with landowners, has nearly completed developing a *Seepage Project Handbook* (SJRRP, 2012h), which specifies the process for working with landowners, and timelines for implementing seepage projects. Reclamation has initiated several seepage projects to increase nondamaging conveyance capacity.

3.5.1 Actions

Several actions have been identified by the Implementing Agencies as part of the Framework (SJRRP, 2012b) related to the conveyance theme. These include the following:

- Levee improvements for lengths impacted at 2,000 cfs conveyance in reaches 2A, 3, 4A, and 5 by 2018.

- **Up to 2,000 cfs of conveyance by 2016 –** This action suggests that seepage improvements be made for parcels impacted at 2,000 cfs conveyance in reaches 2A, 3, 4A, and 5.

- **Reach 2B Channel Capacity Improvements –** This would include construction of levees for 4,500 cfs capacity without engineering floodplain habitat through grading or planting of vegetation. Temperature criteria identified a conveyance of 2,000 cfs as a core need. Although construction of the Mendota Pool Bypass may accomplish nondamaging conveyance near 2,000 cfs, the Implementing Agencies included this as an action to meet requirements in Paragraph 11(a) of the Settlement. Conveyance levels from seepage and levee stability actions show incremental improvements to existing levees as an alternative to constructing the 4,500 cfs Settlement project. Construction would include relocations, levee construction, partial removal of existing levees, and riprap bank protection on Bend 10.

- **Reach 4B, Eastside Bypass, and Mariposa Bypass Conveyance –** This would include constructing flow routing facilities at the Sand Slough Control Structure, levee construction or repair, low-flow channel excavation, and transportation crossing improvements in either the old river channel or the flood bypass system. A series of channel capacity constraints in these areas prevent the conveyance of 2,000 cfs.

Another action for seepage was identified by the Implementing Agencies in the Framework (SJRRP, 2012b) that suggests seepage improvements be made between 2019 and 2023 for parcels impacted at greater than 2,000 cfs.

3.5.2 Questions

Table 3-8 lists the questions associated with addressing uncertainties related to conveyance. These questions are organized by actions identified in the Framework (SJRRP, 2012b).

**Table 3-8.
Questions Related to Conveyance**

Action	Questions
Increase channel capacity by: Levee improvements for lengths impacted at 2,000 cfs conveyance in Reaches 2A, 3, 4A, and 5. Increase conveyance to 2,000 cfs by 2016. Reach 2B Channel Capacity Improvements. Reach 4B, Eastside Bypass, and Mariposa Bypass Conveyance.	Given conveyance constraints, how can we proceed with restoration?
	How do subsidence and climate change factor in conveyance? How does the program deal with these issues?
	What are the alternatives for addressing levee stability uncertainty (not replacing levees, ramping rates, duration of inundation at certain elevation in channel, or flow scheduling options)?
	What are the differences in roughness associated with different riparian vegetation?
	What is the role of riparian recruitment on channel capacity? How does riparian vegetation affect rates of evapotranspiration?
	In Reach 2A, what are the different strengths of bank and bank treatment options to prevent or slow erosion?
	What are the dynamics of bank erosion and time scales of erosion?
Other	What is the linkage between seepage and Restoration Flows?
	If reaches are not connected, what is the role of groundwater pumping? How does it affect the rate of delivery and how will it change over time?
	What is the ability of the existing temperature model to be used on real-time basis to make flow decisions? How can it be used to link to cold-water pool and other aspects?
	How does the SJRRP address integrated flood management?
	What are project outcomes and uncertainties that would be addressed by an integrated approach?

Key:
cfs = cubic feet per second
SJRRP = San Joaquin River Restoration Program

3.5.3 Studies

The following study was developed for 2014 to address uncertainties within the Restoration Area regarding conveyance:

- Reducing Spring Water Temperatures Below Sack Dam (Study 33, Appendix A)
- USGS Seepage Management Plan Support (Study 41, Appendix A)
- Levee Geotechnical Exploration (Study 13, Appendix A)
- Additional Water Level Recorders (Study 24, Appendix A)
- Monitoring Cross-Section Resurveys (Study 25, Appendix A)
- Changes in Soil Salinity Conditions Resulting from Interim Flows (Study 3, Appendix A)
- Influence of Paleochannels on Seepage (Study 4, Appendix A)

- SRH Group Vegetation Roughness Effects in SJRRP-Affected Reaches (Study 38, Appendix A)

The studies are summarized below. The complete study description is available in Appendix A.

Reducing Spring Water Temperatures Below Sack Dam

A summary of this study is provided above in Section 3.1.

USGS Seepage Management Plan Support

The USGS role in the seepage management component of the SJRRP focuses on supporting the continued development of a Seepage Management Plan. In 2014, the emphasis is on development, calibration, and documentation of groundwater flow models in support of multiple aspects of the Plan. Other tasks include continued development and maintenance of a groundwater database and associated products, and technical support on SJRRP-related groundwater issues, including evaluation of data associated with damage claims.

Levee Geotechnical Exploration


Drill Rig and support vehicle for HSA/SPT Borings

The Levee Geotechnical Exploration Study will evaluate the potential risk impacts of Interim and Restoration flows under the SJRRP. As an early step in the process, obtaining geotechnical information on existing levees in the San Joaquin River and flood bypasses will help evaluate the geotechnical integrity of levees. The plan is to focus the exploration on the highest priority reaches and will include Lower San Joaquin River Flood Control Project (Project) levees and non-Project levees on the San Joaquin River from the top of Reach 2A to the end of Reach 5 at the Merced River confluence. The current study work excludes sub-reaches 2B and 4B1 until SJRRP makes the decision to use the existing levees for long-term conveyance of the restoration flows.


Typical CPT Rig

Results of this data collection and analysis task will allow DWR and the SJRRP to catalog reconnaissance-level geotechnical characteristics for 75 miles of levees within the flood system and allow Reclamation to make more informed decisions on release of restoration flows. This information will allow for the evaluation and design of potential remediation measures required to safely convey Restoration flows.

The Department of Water Resources (DWR) Non-Urban Levee Evaluations Program will prepare a technical memorandum (TM) to assist SJRRP in assessing flood risks and identify potential mitigation strategies to maintain acceptable flood risk management. DWR is continuing the review of geotechnical data and is preparing the Draft geotechnical Evaluation Report which will be complete in the summer 2014.

Additional Water Level Recorders

The Additional Water Level Recorders Study involves collecting data to inform hydraulic models being used to assess channel capacity, fishery habitat, channel stability, and many other aspects of SJRRP planning and design. This study was initiated in 2009 and data collection is ongoing. The current plan is to analyze data and determine if more or alternative locations should be installed. The analysis will extend through 2014. The effectiveness of the recorders and whether recorders should be added or moved will also be periodically evaluated.

Monitoring Cross-Section Resurveys

The Monitoring Cross-Section Resurveys Study involves collecting data to inform the Implementing Agencies about whether Interim and Restoration flow releases are causing systematic changes in channel geometry that could lead to a reduction in channel capacity and stability. This study will continue to provide data that can be used to assess mid- and long-term changes in channel geometry and substrate characteristics in the sand-bed portions of a reach in response to the Interim and Restoration flow releases.

This study was initiated in 2009 and will continue through 2014 if flows occur during flood season. Analysis of past surveys, including the rate of change and identification of flow triggers for future surveys, should be complete in 2014.

Changes in Soil Salinity Conditions Resulting from Interim Flows

The Changes in Soil Salinity Conditions Resulting from Interim Flows Study will establish baseline salinity levels for seepage-prone areas, and quantify salinity changes over time so that the presence of shallow groundwater during Interim Flows may be understood in relation to existing conditions. This study will also inform the key question of identifying where seepage concerns exist, and improve SJRRP understanding to support updates to the *Seepage Management Plan* (SJRRP, 2011).

This is the third year of the Changes in Soil Salinity Conditions Resulting from Interim Flows Study. This study may continue to repeat annually until the Implementing Agencies conclude that sufficient information has been collected to propose and implement seepage management actions.

Influence of Paleochannels on Seepage

The Influence of Paleochannels on Seepage Study will address whether (1) paleochannels exist along the San Joaquin River; (2) if the paleochannels exist, the extent of paleochannel influence on seepage extent; and (3) if the paleochannels exist, changes to project design necessitated by existence of paleochannels at a site.

SRH Group Vegetation Roughness Effects in SJRRP-Affected Reaches

SRH-2D modeling will be used to quantify potential increases in river stage given increases in riparian vegetation growth in the reaches affected by Restoration Flows. It is anticipated that the analysis will be performed in reaches 2A and 4A. Any potential increase in vegetation will be estimated using analogs to surrounding reaches. Various methods will be used to predict the increase in river stage due to increasing vegetation density. The end product will be a technical report documenting the effect of vegetation roughness in reaches 2A and 4A.

This project is part of the SRH San Joaquin River Restoration Program Hydraulic and Sediment Support program.

3.6 Entrainment Protection

The following section describes the state of knowledge, questions, and studies associated with the entrainment protection theme. Figure 3-15 illustrates the schedule related to actions and studies that will be implemented under this theme.

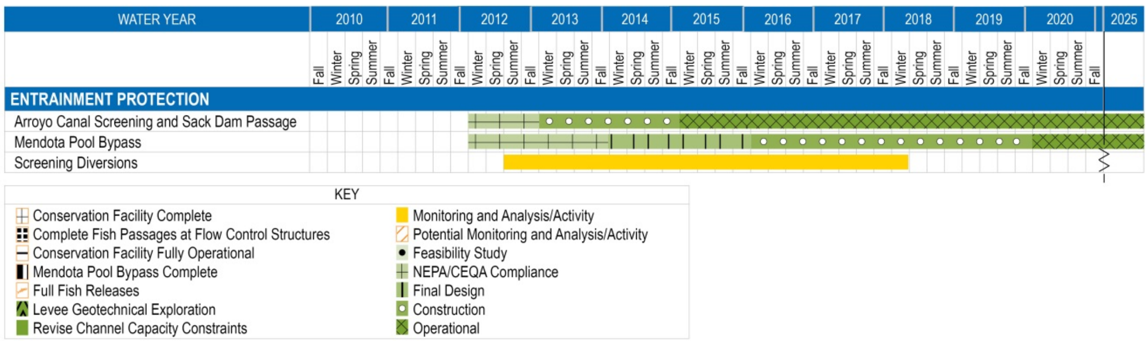


Figure 3-15.
Entrainment Protection Schedule

Entrainment protection includes actions to screen diversion facilities to prevent the loss of juvenile salmon. Major known locations for juvenile salmon entrainment have been identified, but questions remain about whether other diversions will entrain large numbers of emigrating juveniles. The Implementing Agencies are currently developing plans for implementing these actions to screen Arroyo Canal and bypass the Mendota Pool. Diversions that were not identified as a known major entrainment problem have been noted and include riparian diversions and the diversion at Lone Willow Slough. Additional potential actions described in the Framework (SJRRP, 2012b) would address entrainment at these locations pending further evaluation of the level of loss and need. These diversions are not expected to entrain large number of juvenile salmon, but fish monitoring and studies for juvenile losses will track reach-specific losses.

3.6.1 Actions

Actions associated with entrainment protection include screening the Arroyo Canal and constructing a bypass at the Mendota Pool. Evaluations of expected diversion rates and field studies on fish survival identified the Mendota Pool as a potential major source of juvenile salmon loss through entrainment into water diversions in most years. Bypassing fish around the Mendota Pool or moving the Mendota Pool into Fresno Slough would resolve this concern.

3.6.2 Questions

Table 3-9 lists the questions associated with addressing uncertainties related to entrainment protection. These questions are organized by actions identified in the Framework (SJRRP, 2012b).

Table 3-9.
Questions Related to Entrainment Protection

Action	Questions
Screening the Arroyo Canal and constructing a bypass at the Mendota Pool.	Are there adequate flows or any structural modifications needed to ensure juvenile passage during the migration periods of both spring- and fall-run Chinook salmon?
	Do modifications need to take place to limit entrainment rates at pumps and weirs, or other structures not already identified in the *Working Draft Framework for Implementation* (SJRRP, 2012b) or Settlement (e.g., small diversions)?
	How can information collected from monitoring juvenile losses in the system be used to help identify entrainment risks (e.g., potential risks at Chowchilla Bypass, Reach 4B depending on flow split)?
	If entrainment is an issue, what are the metrics for prioritizing, (e.g., volume, seasonality)?
	What is the entrainment potential for Mendota Pool? Does there need to be a screen on flows going into Mendota pool? What is the likely loss?
Other	How does the program take into account potential entrainment from mine habitat?
	Is it necessary to put a screen on Chowchilla Bypass? What is the likely entrainment potential and impact on juvenile survival? Or is there a benefit of letting fish down the Chowchilla Bypass?
	How can actions of SCE and PG&E for different climate change scenarios benefit the SJRRP? Are there opportunities associated with upstream projects to support cold water pool management? Could they evacuate space in November? Does it make a measureable difference to SCE and PG&E when they move water?
	Will unscreened diversions in Reach 1 affect juvenile for a long period?
	Are there unscreened diversions that may result in high rates of entrainment?

Key:
PG&E = Pacific Gas and Electric Company
SCE = Southern California Edison
SJRRP = San Joaquin River Restoration Program

3.6.3 Studies

No studies related to flow scheduling were proposed for 2014.

No studies are currently underway to directly screen smaller diversions, but the fish survival studies (Juvenile Survival and Migration (Study 10, Appendix A) and San Joaquin River PIT Tag Monitoring and Site-Specific Technology Development (Study 15, Appendix A)) will help determine the location of losses and guide targeted studies. Flow levels comparable to anticipated Restoration Flows and a complete migration corridor for juvenile salmon will help further understand potential losses from smaller diversions. Juvenile survival monitoring will identify reach-specific losses of juveniles, and any areas of large losses can be further investigated with targeted studies. The PIT tag feasibility study is also a step in developing a system to monitor for losses by reach and at specific structures. Future fish releases and monitoring efforts will inform the program on potential losses from these diversions.

3.7 Predation

The following section describes the state of knowledge, questions, and studies associated with the predation theme. Figure 3-16 illustrates the schedule related to actions and studies that will be implemented under this theme.

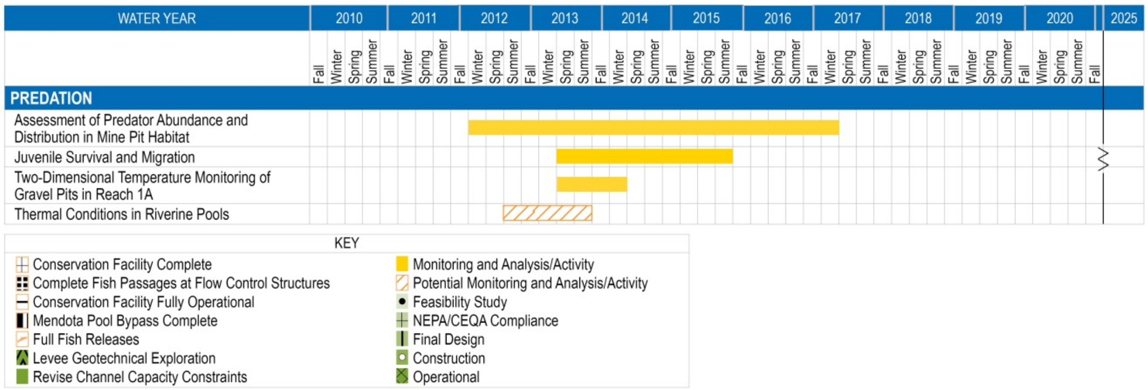


Figure 3-16.
Predation Schedule

Predation of juvenile salmon can have a large effect on migration survival and impede the SJRRP from meeting fish population targets. The Settlement calls for addressing gravel mine pit habitat in the San Joaquin River, but other areas have also been identified as predator habitat that overlaps with the juvenile salmon migration corridor. Given the potential high level of loss from predation, the expense of remedial actions as integrated approach to predation management is warranted.

Given the cost and difficulty of predator control actions, the SJRRP will likely investigate actual losses from predation. If these losses are deemed significant, the SJRRP will consider methods to reduce the predation pressure on migrating salmon and evaluate the potential for these actions to reduce losses from predation and increase the probability of meeting fishery objectives.

The San Joaquin River has been impacted historically by in channel and floodplain sand and gravel mining, leaving both off-channel mine pits and captured mine pits in the channel. The gravel mine pits and lower San Joaquin River reaches (4 and 5) have been identified as areas suitable for predator populations that should be evaluated. Any structure in the system can also provide predator habitat; therefore, existing structures should be evaluated for predation threats and new structures should be designed to not provide habitat for predators.

3.7.1 Actions

Actions associated with this theme include filling and isolating gravel mine pits, and other predator avoidance and predator management actions. The gravel mine pits in the Restoration Area have been identified as a potential contributor to juvenile salmon loss. The gravel pits provide habitat for predatory fish, and the slow current through these pools can expose juvenile salmon to high predation mortality. The SJRRP is currently studying predator populations in these gravel mine pits, and the likelihood of survival for juvenile salmon migration through them. These studies will advise future actions.

Gravel mine pit filling and isolation actions have not yet been implemented, but the Implementing Agencies are developing plans for these actions.

3.7.2 Questions

Table 3-10 lists the questions associated with addressing uncertainties related to predation. These questions are organized by actions identified in the Framework (SJRRP, 2012b).

Table 3-10.
Questions Related to Predation

Action	Questions
Filling and isolating gravel mine pits.	Where are the hotspots for predation in the system?
	What are the expected predation rates in mine pit habitats? What can be done to minimize predation and what mine pits should be prioritized? What design measures can be taken to minimize predation at structures? How can the program modify structures to make the habitat unsuitable for predators (e.g., raise velocity, create shallow depths)?
	What is the comparative effect of predation in different gravel pits?
	What is the need for isolating gravel pits? How does isolation of gravel pits affect river temperature (attenuation of water into pits reducing peak temperatures, heating effect of the pits)? Can we develop a prioritization of gravel pit isolation based upon temperature affects?
Other	Is predation risk expected to be detrimental to restoration? If so, what measure can be taken to minimize predation?
	What is the relationship between predation risk, temperature, size of juveniles, and timing of outmigration in different reaches, turbidity, velocity and different release strategies?
	How will predation affect survival downstream from the Merced River confluence?
	What is predator populations' diet composition?
	What modifications can be made to the system to minimize delays in juvenile fish migration?
	Is predator population resident or migratory? If migratory, it may create a downstream issue?
	Is there benefit from large-scale short releases from the hatchery? What are the release strategies and predator management strategies?
	If migratory or resident predators, what is the response of predator populations to high flows? What is the driving factor?
	What are the predator population dynamics?
	What is the risk of avian predation on floodplains and bypasses?
	What are the trophic dynamics of the system and how are they affected by other fish (e.g., suckers, carp)?
	Are predators coming out of Millerton Lake during flood spills?
	How does poaching impact the abundance of spring-run Chinook salmon spawners in the San Joaquin River?
	What is the relationship between habitat type, design, and predation risk on floodplain habitat? Can information from Yolo and Consumes rivers be used to understand predators' preferences?
	Do captured mine pits, flow control structures, and diversion structures increase predation risk for juvenile salmon? Would predator management improve juvenile passage rates?
	Do predators substantially reduce juvenile survival in Reach 1? Can habitat restoration increase predator refuge or provide more suitable space in Reach 1?

3.7.3 Studies

The following studies were developed for 2014 to address uncertainties within the Restoration Area regarding predation:

- Assessment of Predator Abundance and Distribution in Mine Pit Habitat in the San Joaquin River Restoration Area (Study 11, Appendix A)

- Juvenile Survival and Migration (Study 10, Appendix A)
- Two-Dimensional Temperature Modeling of Gravel Pits in Reach 1A (Study 19, Appendix A)
- Effect of Altered Flow Regime on Channel Morphology in Reach 1A (Study 26, Appendix A)

The studies are summarized below. The complete study descriptions are available in full in Appendix A.

Assessment of Predator Abundance and Distribution in Mine Pit Habitat in the San Joaquin River Restoration Area

The Assessment of Predator Abundance and Distribution in Mine Pit Habitat in San Joaquin River Restoration Area Study is an ongoing study and is anticipated to be a 5-year effort with completion in 2017. The study evaluates population composition, relative abundance, and habitat use of fish that prey on spring-run and fall-run Chinook salmon within the San Joaquin River system. Largemouth bass, among other predatory species, are adapted to the high water temperatures existing in gravel mine pits. This study will improve understanding of predator populations in gravel mine pits, and the information collected will allow the Implementing Agencies to identify the highest priority pits to be filled.

External marks were placed on predators in 2013, and results of recapture data will be used to assess source-versus-sink habitats for predators, and large-scale predator movements. These data are to be processed before the 2014 spring sampling to guide levels of effort and juvenile Chinook releases in gravel mine pits to assess mortality rates. These data will also guide reintroduction scenarios for Chinook salmon in the Restoration Area to help focus efforts to reduce or control predation, while also maximizing salmon imprinting ability within the river system. This information is critical to informing the Adaptive Management approach as described in the Draft Fisheries Management Plan (SJRRP, 2010a).

Juvenile Survival and Migration

Evaluation of the gravel mine pits in the Restoration Area for prioritization for restoration is identified Paragraph 11(b) of the Settlement, and studies are needed to help quantify predation risk and assess the habitats that pose the greatest risk of predation. Results from this study will inform the Implementing Agencies on predaceous species of fish that are associated with different river features, including gravel mine pits, and identify habitats associated with the greatest risk of predation.

Two components are critical in designing and implementing reintroduction actions for Chinook salmon in the near and long term:

- Juvenile survival rates
- Where in the river threats to juveniles may occur

The 2014 acoustic tagging study will help quantify predation and entrainment potential and fish movement around and through existing impoundments, including the Mendota Pool and Sack Dam, as well as continue monitoring near Friant Dam and in Reach 5. These data will build upon data collected in 2011 through 2013. Collectively, these multi-year comparisons of migration rates, routes, and survival estimates can be used to inform reintroduction strategies, and to aid in estimating project-wide smolt survival rates allowing for refinement of existing fish population models.

As in past years, receivers will be placed throughout the Restoration Area, and through the downstream tributary reaches through the Stanislaus River. Receivers will be interrogated on a standard schedule, and additional mobile tracking with a handheld tag detector will be conducted within the mine pits/Mendota Pool area to assess predation/entrainment.

Specific release locations will be confirmed through DFG access agreements. Releases of fish in mine-pit complexes will be coordinated with mine-pit predation assessment scheduling to validate predation losses through diet analysis.

Two-Dimensional Temperature Modeling of Gravel Pits in Reach 1A

This project is part of the Sedimentation and River Hydraulics Group (SRH) San Joaquin River Restoration Program Hydraulic and Sediment Support program.

In 2014, a temperature analysis using SRH-2D modeling of two different areas will be completed. The first area will be the gravel pits in the Sycamore Island Reach of Reach 1A. Several temperature sensors in this area have been recording water temperatures for the last few years and these will be used to calibrate and/or verify model results. The second area will be in the location of the proposed floodplain study being conducted by Fresno State. The end product will be a report summarizing both cases.

An improved understanding of the interactions between the river and gravel pit water temperatures may help to identify the most effective mechanisms to reduce predation potential. An assessment of predator abundance and distribution was conducted within gravel pits present in the study area in 2013 (SJRRP, 2012e). In addition, ongoing temperature monitoring of the gravel pits and river within the study area took place in 2013 and will likely continue in the future (SJRRP, 2012e). Data collected from these studies can be combined with results from the 2D temperature model to examine interactions among hydraulic conditions, temperature, and predation.

The primary goal of the 2D temperature model is to offer insight for controlling water temperatures during critical life stages. In addition, the modeling effort may also assist in determining which gravel mine pits may be most favorable to certain predator species, and in evaluating restoration techniques to promote hydraulic and temperature conditions that would suppress specific predator species during critical life stages for juvenile salmon.

Effect of Altered Flow Regime on Channel Morphology in Reach 1A

A summary of this study is provided above in Section 3.1.

3.8 Fish Passage

The following section describes the state of knowledge, questions, and studies associated with the fish passage theme. Figure 3-17 illustrates the schedule related to actions and studies that will be implemented under this theme.

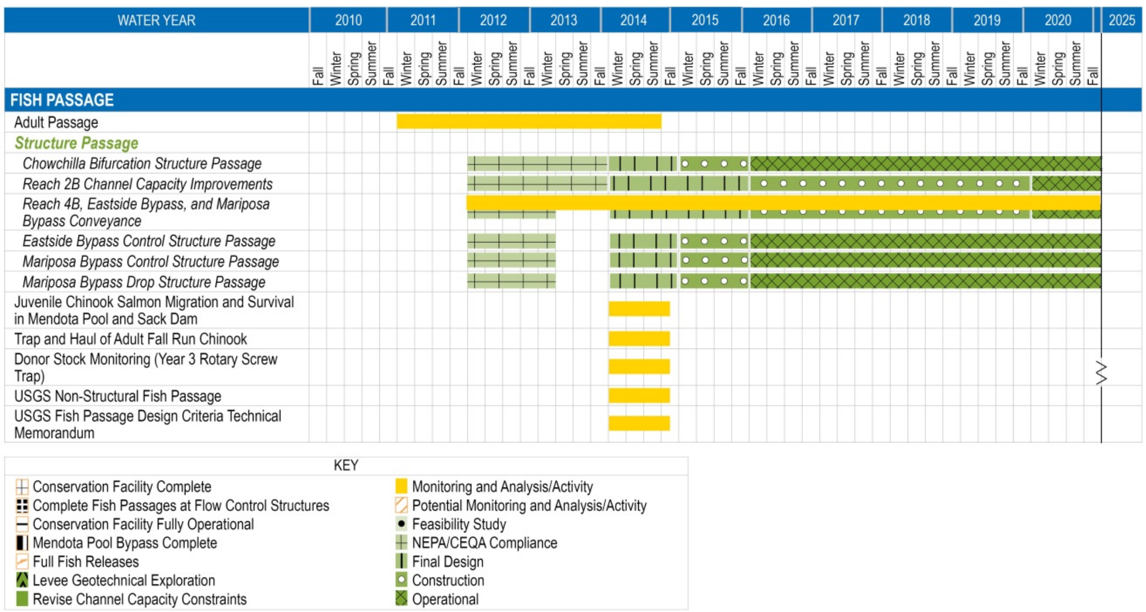


Figure 3-17.
Fish Passage Schedule

One of the actions identified by the Implementing Agencies is to meet structural and channel improvements as described in Paragraph 11(a) of the Settlement. Therefore, a number of specific actions were identified for 2014.

For the purpose of planning, the Implementing Agencies assumed that adult salmon will enter the flood bypasses during wet years.

Adult fish must be able to return to an area in the river to spawn for reintroduction to be successful. As such, the creation of a reliable passage corridor was identified as a means to help fish move down and up the San Joaquin River to complete their life cycles. Actions to reduce juvenile entrainment were included as actions where the Implementing Agencies expect a high degree of juvenile loss.

Adult passage impediments include things that can be a complete barrier that blocks salmon from being able to migrate to spawning grounds. Major losses through juvenile entrainment can also preclude restoring salmon populations to the San Joaquin River.

Actions associated with this theme include establishing acceptable depths, velocities, and jump heights at structures and road crossings, modifying structures, and maintaining access across the river, for fish passage. The Implementing Agencies identified numerous fish passage actions that would have the highest priority for implementation. These actions include the Chowchilla Bifurcation Structure Passage, San Joaquin River Control Structure Passage, Mendota Pool Bypass, Arroyo Canal Screening and Sack Dam Passage, Eastside Bypass Control Structure Passage, Mariposa Bypass Control Structure Passage, and Mariposa Bypass Drop Structure Passage. The Implementing Agencies identified additional actions that would be prioritized after the actions above that include increased conveyance in reaches 2A, 3, 4A, and 5; San Mateo Road Crossing; Chowchilla Bypass Passage at Crossings (Avenue 18 ½ and Avenue 21); and Eastside Bypass Passage at Crossings and structures (Dan McNamara Road, Merced National Wildlife Refuge weirs).

Reclamation and other Implementing Agencies are currently completing site-specific environmental compliance documentation for the above actions consistent with Paragraph 11 of the Settlement. The environmental documentation for these actions is anticipated on the following schedule:

- Draft Environmental Assessment/Initial Study (EA/IS) for Arroyo Canal Screening and Sack Dam Passage was released on June 1, 2012.

- Final EA/IS for Arroyo Canal Screening and Sack Dam Passage is anticipated to be released in October 2012.

3.8.1 Actions

Specific actions identified in the Framework (SJRRP, 2012b) associated with the structural improvements identified above include the following:

- **Chowchilla Bifurcation Structure Passage –** This would include constructing a fish ladder or ramp. Water velocities at the existing structure are expected to exceed fish passage criteria during flood flows and create an impediment to adult passage.

- **San Joaquin River Control Structure Passage –** This would include constructing a fish ladder or ramp on the existing structure or replacing the structure as part of water supply facilities for the Mendota Pool. Hydraulic analysis indicates that water velocities during flood flows would exceed criteria for adult Chinook salmon passage at the existing structure.

- **Arroyo Canal Screening and Sack Dam Passage –** This would include constructing a fish screen on the Arroyo Canal and passage facilities at Sack Dam. Arroyo Canal was identified as very likely to entrain a large proportion of juvenile salmon. Screening the canal would prevent this loss. Sack Dam has been identified as a passage barrier for adult salmon when the boards are in place. The drop height of over 2.5 feet in the spring would impede upstream passage.

- **Eastside Bypass Control Structure Passage –** This would include constructing a fish ladder or ramp. Excessive velocities at the existing structure during flood flows exceed the fish passage criteria and impede adult upstream migration.

- **Mariposa Bypass Control Structure Passage –** This would include constructing fish passage in coordination with a drop structure and low-flow channel modifications. Excessive velocities at the existing structure exceed fish passage criteria maximums and would impede upstream adult migration.

- **Mariposa Bypass Drop Structure Passage –** This would include constructing passage in coordination with a control structure and low-flow channel modifications. This drop structure is an adult fish passage impediment at all flow levels. Modification or removal will allow fish to pass.

- **Mendota Pool Bypass –** The Mendota Pool is a potential major source of juvenile salmon loss through entrainment into water diversions in most years. Bypassing fish around the Mendota Pool, modifying the structure, or moving the Mendota Pool into Fresno Slough would resolve this concern.

Additional actions identified in the Framework (SJRRP, 2012b) by the Implementing Agencies that have not been implemented include the following:

- **San Mateo Avenue Road Crossing –** The San Mateo Avenue road crossing was identified as a potential adult migration impediment, but it is uncertain how significant this barrier is for adult passage. At high flows, adult passage is not expected to be impaired, but it uncertainty exists regarding passage impacts and how monitoring should be implemented to determine the degree to which the existing crossing would delay or impede fish passage.

- Chowchilla Bypass Passage at Crossings

  - **Avenue 18 ½ –** Fish are expected to migrate up the Chowchilla Bypass during flood flows, and may encounter this crossing. Hydraulic analysis indicates a high elevation drop. Modifying this crossing would increase confidence about the ability of fish to migrate through the bypass under flood conditions.

  - **Avenue 21 –** Fish are expected to migrate up the Chowchilla Bypass during flood flows, and may encounter this crossing. Hydraulic analysis indicates a high elevation drop. Modifying this crossing would increase confidence about the ability of fish to migrate through the bypass under flood conditions.

- Eastside Bypass Passage at Crossings and Structures

  - **Dan McNamara Road –** This road crossing could potentially impact adult migration, but it is not believed to completely impede upstream passage.

  - **Merced National Wildlife Refuge Weirs –** The Merced National Wildlife Refuge Weir can present a vertical drop barrier for upstream migrating salmon under low- to moderate-flow conditions. This barrier is expected to be more of a passage impediment for fall-run Chinook salmon because they will migrate at lower flows than spring-run Chinook salmon in most years.

Operation of the weir, such as removing the flashboards, may resolve this impediment.

The schedule for implementing the actions is presented in Figure 3-1. The Implementing Agencies identified other actions as potential improvements:

- King's River Fish Barrier (Reach 2B)
- Washington Avenue Bridge Replacement (Reach 4B)
- Turner Island Road Bridge Replacement (Reach 4B)
- El Nido Road Crossing Passage (Eastside Bypass)
- Chamberlain Road Crossing (Eastside Bypass)
- Mariposa Bypass Road Crossing (Bypass)
- Newman Wasteway Barrier (Reach 5)
- Other Barriers (Reach 5)

3.8.2 Questions

Table 3-11 lists the questions associated with addressing uncertainties related to fish passage. These questions are organized by actions identified in the Framework (SJRRP, 2012b).

Table 3-11.
Questions Related to Fish Passage

Action	Questions
Structural and Passage Improvements	What species need to pass at individual structures?
	In addition to the core actions on adult fish passage, are there other structural adult fish passage concerns that need to be addressed? a. fall-run salmon vs. spring-run salmon b. core vs. secondary actions
	Do structures need further evaluation? Should these drive whether projects are built there or not?
	What is the passage effectiveness of structures at different flows? Given uncertainties with the water supply forecast, how will pulse flows be scheduled for fry in January without endangering adult passage in April and May if the water year becomes drier than forecasted in January?
	How does the design of facilities take predation into account?
	How is fish passage influenced by local operations (e.g., changes in localized water quality)?
	Will flood operations constrain fish passage?
	What is minimum flow needed for fish passage and connectivity for adult and juvenile?
	Will flow control structures impede passage when water temperatures are near the critical maximum?
	Will it be necessary to modify the channel and/ or in stream structures (e.g., road crossings and culverts) to provide passage during base flows? Can the channel be modified to simultaneously reduce water temperatures and increase the frequency of floodplain inundation?
Other	What are the passage goals or objectives for different fish (e.g., sturgeon, lamprey)?
	Is ponding or stranding significant to overall adult fish passage?
	What does the survival rate need to be to have enough adults to return?
	Is it feasible and/or possible to move juvenile fish in a manner to resolve issues in the system? Is it feasible to trap juveniles in the river?
	Can we implement and trap and haul program to create a migration corridor before completion of adult fish passage improvements?
	In addition to physical barriers, are there other adult fish passage concerns (e.g., water temperatures, Delta exports, groundwater inflow, and water quality, including organic contaminants and dissolved oxygen)?

**Table 3-11.
Questions Related to Fish Passage (contd.)**

Action	Questions
Other	Is there adequate holding habitat in quantity and quality for spring-run adult Chinook salmon? Are there adequate depths and velocities under baseflows?
	Does disease affect adult holding for spring-run Chinook salmon?
	What is the adult migration rate as it is influenced by pulse flows, seasonally?
	What are the cues of fish on other fish downstream? When do we expect to see fish? How can this information be used to help schedule pulses?
	Can we manage survival rates by release? Do we have a model by reach? How will information gained with acoustic and PIT tags monitoring identify sinks for population?
	What are the cumulative energetic costs of combined passage through SJRRP designs in different water year types?
	How can the SJRRP integrate flood management and fish passage with flow measures? How can the SJRRP integrate flood management with rearing habitat?
	How can models be used to provide a quantitative assessment of the results the SJRRP would like to achieve?
	How does the SJRRP address a migration delay? How does the SJRRP manage critical riffles?
	What is the passage for non-spring-run salmon or fall-run salmon? Will the striped bass and steelhead attracted? What are incidental effects? What are benefits of structures downstream?
	Would habitat restoration (e.g., creation of shallow water refugia in predator habitats) improve juvenile passage rates during base flows, particularly for fry-sized juveniles?
	Will depths and velocities in Reaches 3 – 5 be adequate for adult passage during base flow releases?
	What are the effects of flow, turbidity, and water temperature on the survival of fry-, parr-, and smolt-sized juveniles in the Restoration Area? Does floodplain inundation affect passage rates? Do flow increases and/or reductions trigger juvenile migration? If so, in what direction? Is there a benefit of timing Friant Dam releases to match flow releases from the Stanislaus, Tuolumne, and Merced rivers?
	How do growth rates and smoltification timing in Reach 1 compare with those in Reach 5? Do contaminants affect growth and/or survival rates, particularly in Reaches 3 – 5?
	Do captured mine pits, flow control structures, and diversion structures increase predation risk for juvenile salmon? Would predator management improve juvenile passage rates?
	Are there unscreened diversions that may result in high rates of entrainment?
	Is it possible to trap and haul juvenile salmon when conditions in the lower Restoration Area are not conducive to unassisted passage (e.g., before completion of the Reach 2B project)?

Table 3-11.
Questions Related to Fish Passage (contd.)

Action	Questions
Timing	When will spring-run adults migrate into the Restoration Area? a. Will the Mill Creek migration timing data for spring 2006 reflect the migration timing for SJRRP source fish? b. How does the San Joaquin River tributary 'spring running' fish timing compare to extant spring runs from donor streams? c. How does the spring Feather River fish timing match (halfprinting of fish as they enter the hatchery in the spring)?
Adult Passage	Can trap and haul be used to transport adults after water temperatures in Reaches 4B and 5 exceed maximum thresholds? Will transported fish survive until spawning? If adults survive, will egg viability be high enough to support trap-and-haul operations at sustainable production levels?
	Are there an adequate number of resting pools below Sack Dam for adult migrants?
Juvenile Passage	What are the effects of flow, turbidity, and water temperature on the survival of fry-, parr-, and smolt-sized juveniles in the Restoration Area? a. Does floodplain inundation affect passage rates? b. Do flow increases and/or reductions trigger juvenile migration? If so, in what direction? c. Is there a benefit of timing Friant Dam releases to match flow releases from the Stanislaus, Tuolumne, and Merced rivers?
Juvenile Passage	Would habitat restoration (e.g., creation of shallow water refugia in predator habitats) improve juvenile passage rates during base flows, particularly for fry-sized juveniles?
Juvenile Passage	How do growth rates and smoltification timing in Reach 1 compare with those in Reach 5? Do contaminants affect growth and/or survival rates, particularly in Reaches 3 through 5?
Juvenile Passage	Do captured mine pits, flow control structures, and diversion structures increase predation risk for juvenile salmon? Would predator management improve juvenile passage rates?
Juvenile Passage	Are there unscreened diversions that may result in high rates of entrainment? Under what flow/timing scenarios are these diversions the greatest risk? Can juvenile holding/release patterns reduce this impact?
Juvenile Passage	Is it possible to trap and haul juvenile salmon when conditions in the lower Restoration Area are not conducive to unassisted passage (e.g., before completion of the Reach 2B project)? Are the levels we can transport enough to sustain the population?

Key:
SJRRP = San Joaquin River Restoration Program

3.8.3 Studies

Studies planned for implementation in 2014 addressing fish passage issues include the following:

- Juvenile Chinook Salmon Migration and Survival in Mendota Pool and Sack Dam (Study 34, Appendix A)
- Donor Stock Monitoring (Study 46, Appendix A)

- Trap and Haul of Adult Fall-Run Chinook (Study 6, Appendix A)
- USGS Non-Structural Fish Passage (Study 43, Appendix A)
- USGS Fish Passage Design Criteria Technical Memoranda (Study 44, Appendix A)
- Adult Passage (Study 20, Appendix A)

The studies are summarized below. The complete study descriptions are available in full in Appendix A.

Juvenile Chinook Salmon Migration and Survival in Mendota Pool and Sack Dam

To complete their life cycle, juvenile Chinook salmon must be able to successfully navigate the gauntlet of predators and diversions, and pass both irrigation dams on their trek from San Joaquin River to the Pacific Ocean. Juvenile Chinook salmon emigrating from spawning and rearing habitat in the Restoration Area must negotiate two structures and the lacustrine habitats created by impounded water on the San Joaquin River (1) Mendota Pool formed by Mendota Dam at the confluence San Joaquin River and Fresno Slough, and (2) Sack Dam, which was created as a check structure and diversion for the Arroyo Canal. The diversions at these two sites are screened and do not meet NMFS and DFW screening criteria for salmon species.

High entrainment losses for experimental salmon populations are anticipated at these diversions and excessive predation has been identified as a potential limiting factor for their ocean-ward migration at these locations. Data from this study will aid in understanding where losses occur and how operations at the two dams may be improved to foster effective downstream fish passage.

To determine the survival and movements of juvenile Chinook salmon above Mendota and Sack dams, monitoring using telemetry and PIT tag arrays via 12 new telemetry stations will be established at the Mendota Pool upstream from Mendota Dam to San Manteo Avenue on the San Joaquin River, in five major canals on the west side, and at the St. James Bypass, as well as at Sack Dam at the diversion of the Arroyo Canal.

Donor Stock Monitoring

This project is intended to provide baseline population information about Central Valley spring-run Chinook salmon from Butte Creek as a potential donor stock for the Restoration Area. Butte Creek currently has the largest of three sustaining populations of Central Valley spring-run Chinook salmon. The species is currently listed under the Endangered Species Act and the California Endangered Species Act.

There is a need to better understand the Butte Creek population as it is a potential donor population for the reintroduction of spring-run Chinook salmon for the Restoration Area. Incorporation of donor stocks with high genetic diversity has been identified as the reintroduction strategy most likely to succeed. However, due to the threatened nature of spring-run Chinook salmon in California, care must be taken to ensure that potential donor populations are not impacted by reintroduction efforts elsewhere. At no time would collection exceed a level that has been determined to be beyond a threshold that the potential for additive loss to the Butte Creek donor population is likely to occur.

The first year of study occurred during January and June of 2013; however, historical sampling efforts have documented fry emigrating as early as mid-November. To characterize the entire outmigration period and increase the likelihood of capturing yearling emigrants, the 2014 study will have an extended sampling period to include November and December. Outmigrating juveniles will be monitored through operation of one RST and one diversion fyke trap located at the Parrott-Phelan Diversion Dam located southeast of Chico, California.

Trap and Haul of Adult Fall-Run Chinook

The Trap and Haul of Adult Fall Run Chinook study involves the trapping of adult Chinook salmon which are lost upstream from HFB (a false migration pathway) and relocating the fish to more suitable habitat in Reach 1 of the Restoration Area. Field activities associated with this study will include transporting adult Chinook salmon around existing barriers in the San Joaquin River to suitable holding and spawning habitat and developing protocols to successfully trap and haul adult salmon with the intent of reintroducing salmon to the San Joaquin River system in a timely manner.

The objectives associated with this study in 2014 include assessing the viability of trapping and hauling adult salmon, assessing spawning site selection of adults transported to Reach 1, and establishing a long-term plan for using trap-and-haul activities. The study is expected to continue through 2020.

USGS Non-Structural Fish Passage

In 2014, USGS will evaluate various model outputs to identify areas of shallow and high-velocity water that may impede upstream or downstream migration of juvenile or adult Chinook salmon. Field studies will be conducted as needed to verify and record problem areas.

USGS Fish Passage Design Criteria Technical Memoranda

The Fish Passage Design Criteria Technical Memoranda will describe the upstream fish passage strategy for the SJRRP to guide engineering modifications to structures within the San Joaquin River and flood bypass between Friant Dam and the Merced River confluence.

Adult Passage

This study is working to develop conceptual alternatives to improve conditions on the river to allow for unimpeded fish passage for structures that are not already part of an existing project, and will recommend fish passage improvements for these by developing alternative solutions at structures that have been identified as potential fish barriers. This work will be completed during 2014. The focus fish for the evaluation will be adult Chinook salmon, but can include other fish species if there is evidence that they will be present at the structure and will need passage.

3.9 Fish Reintroduction

The following section describes the state of knowledge, questions, and studies associated with the fish reintroduction theme. Figure 3-18 illustrates the schedule related to actions and studies that will be implemented under this theme.

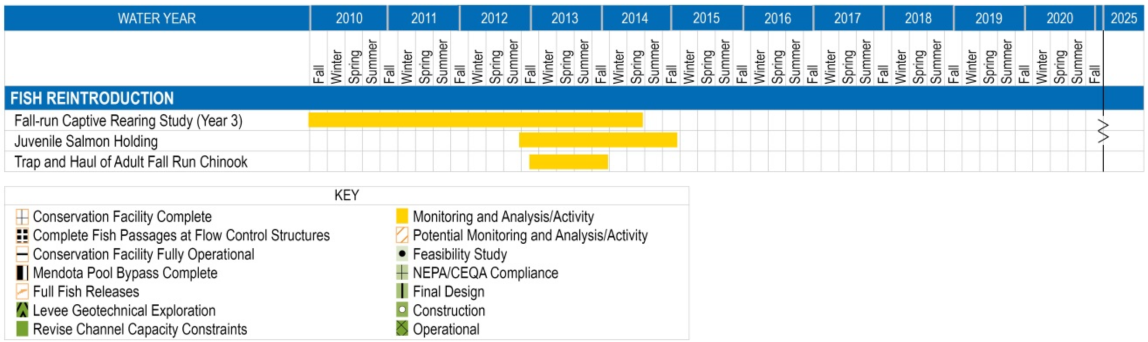


Figure 3-18.
Fish Reintroduction Schedule

The Implementing Agencies will conduct a series of efforts to further understand the Chinook salmon reintroduction process through the development of a captive broodstock, conducting expanded studies to address key uncertainties, and implementation of Chinook salmon pilot release efforts. Starting in 2010, fall-run broodstock were collected and raised in the Interim Facility to refine captive rearing techniques. In 2012, experimental studies were initiated with juvenile study fish from the Feather River Hatchery on the San Joaquin River.

Trap-and-haul programs have been used in other systems to allow fish passage before resolving all fish passage impediments (Zimmerman, 1996). Returning adults would be trapped and transported to upstream areas. Low numbers of adult returns are expected from the initial releases, which will allow fish to be actively captured and transported. The Implementing Agencies can begin testing a trap, haul, and release program before the return of SJRRP released fish by relying on fall-run Chinook salmon from San Joaquin River tributaries that stray into the Restoration Area.

3.9.1 Actions

Actions to improve understanding of the fish reintroduction process include preparing for a spring-run broodstock program, trap and haul of fall-run adults above the HFB, translocation of eggs or juveniles from the Feather River Hatchery to the San Joaquin River, and a continuation of a fall-run Chinook salmon broodstock experiment.

Trap-and-haul actions involve moving adult fish and eventually juvenile fish around passage barriers. A number of passage barriers exist within the Restoration Area. Trap-and-haul operations have been used in other systems to provide salmon passage around impoundments and other barriers to allow fish releases before resolving all passage issues.

3.9.2 Questions

Table 3-12 lists the questions associated with addressing uncertainties related to fish reintroduction. These questions are organized by actions identified in the Framework (SJRRP, 2012b).

Table 3-12.
Questions Related to Fish Reintroduction

Action	Questions
Preparing for a sping-run broodstock program.	How does the program move forward with fish reintroduction given policy issues with availability of spring-run fish?
	How can natural populations of spring-run and/or fall-run Chinook salmon be established?
	Is there enough difference in migration run-timing and spatial separation between mature spring-run Chinook salmon and fall-run Chinook salmon in the Restoration Area to limit genetic introgression of the two populations?
	What are the conditions needed for collecting spring-run salmon from other sources?

Table 3-12.
Questions Related to Fish Reintroduction (contd.)

Action	Questions
Preparing for a sping-run broodstock program. (contd.)	Is there a competition issues between fall- and spring-run? What is the differentiation of habitat use? What management strategies are possible to prevent competition for spawning habitat or rearing habitat?
Preparing for a trap-and-haul operation of fall-run adults above the Hills Ferry Barrier.	How will the use of Hills Ferry Barrier affect fish?
	Is there exclusion further upstream?
Preparing for a translocation of eggs or juveniles from the Feather River Hatchery to the San Joaquin River.	How does the program assess impacts of continued hatchery operations? Do we curtail and augment operations?
	What is the relative influence of hatchery-produced fish on the naturally spawning stock?
	How can substantial signs of hybridizing with nontarget hatchery stocks be avoided?
	What are the conditions and genetics questions associated with genetics of Feather River fish? Is there still value with moving forward with these fish?
	Does the SJRRP need hatchery management for different escapement years? Does the SJRRP follow recommendation to cut back when populations are high and supplement when populations are low?
Preparing for a translocation of eggs or juveniles from the Feather River Hatchery to the San Joaquin River. (contd.)	What is the hatchery capacity needed relative to targets (address when targets are established)?
	What life stage is best at point of release? Is it better to use egg incubators and pump out fry, smolt, etc.?
	What juvenile production is necessary to support long-term population? Will use of a population model help address uncertainty?
	In context of the floodplain model, what is the need for juveniles to meet population goals?
	How long do we need a hatchery? What is the level of production? What habitat is needed to have a sustainable population?
	What is the peak production to support population targets and annual expectations?
Preparing for a continuation of a fall-run Chinook salmon broodstock experiment.	How far forward should the program proceed forward with fall-run fish before considering spring-run salmon?
	How can natural populations of spring-run and/or fall-run Chinook salmon be established?
Preparing for a continuation of a fall-run Chinook salmon broodstock experiment.	Is there enough difference in migration run-timing and spatial separation between mature spring-run Chinook salmon and fall-run Chinook salmon in the Restoration Area to limit genetic introgression of the two populations?
	Is there a competition issues between fall- and spring-run salmon? What is the differentiation of habitat use? What management strategies are possible to prevent competition for spawning habitat or rearing habitat?
	What is the existing approach for fall-run salmon reintroduction? Does the SJRRP need genetic management, supplementation, etc.?

Table 3-12.
Questions Related to Fish Reintroduction (contd.)

Action	Questions
All actions	What are the consequences of using or not using different source stocks?
	Which life stage should be released and where (i.e., better genetics upstream, better homing downstream, etc.)?
	How can genetically diverse populations be established?
	How can demographically diverse populations be established?
	In addition to salmon, are other native fish reintroduction actions needed?
	What source population should be used for reintroduction?
	What are the reintroduction strategies to maximize survival and sustainability of source stock populations?
	What are the appropriate stocking targets for the SJRRP for different water years?
	Will fall-run Chinook naturally be reintroduced, or will a hatchery be needed?
	How can the program phase in reintroduction over time that accounts for changing conditions in the system and current time frames for project completion?
	How do we move fish out to the system with different connectivity scenarios?
	What are the considerations for passage under different conditions (truck and trap)?
	How are long-term trends of productivity being tracked? How can this be related back to fish passage?
	What are the inputs, information, uncertainties that are keeping SJRRP from making decisions on fish? How does the SJRRP move forward with making decisions on fish?
	What is the appropriate set of genetic traits for fish reintroduction?
	What are the remaining uncertainties related to the genetic management plan?
	What are the genetics most consistent with San Joaquin River? What genetics are most variable? How will natural selection affect them? How much needs to be considered in Conservation Strategy? How has the understanding changed from Moyle and Hanson assumptions from 2008?
	What are the impacts to existing fisheries from the reintroduction of salmon and how can those be mitigated?
	Is it possible to trap and haul juvenile salmon when conditions in the lower Restoration Area are not conducive to unassisted passage (e.g., before completion of the Reach 2B project)?

Key:
SJRRP = San Joaquin River Restoration Program

3.9.3 Studies

The following study is planned for implementation in 2014 to focus on addressing uncertainties associated with fish reintroduction:

- Fall-Run Captive Rearing Study (Study 12, Appendix A)
- Trap and Haul of Adult Fall-Run Chinook (Study 6, Appendix A)

The Fall-Run Captive Rearing Study is summarized below. The complete study plan is available in Appendix A.

Fall-Run Captive Rearing Study

The goal of the Captive Rearing Study is to investigate methods for the captive rearing of Chinook salmon from the spawning portion of their life cycle, through adulthood in an effort to be fully prepared to work with threatened spring-run Chinook salmon and to increase the chances for the successful development of a self-sustaining, self-reproducing population in the San Joaquin River. The San Joaquin Salmon Conservation and Research Facility is scheduled to be operational in February 2016. It is anticipated that this facility will provide much of the founding population for salmon restoration in the Restoration Area. During facility planning and construction, a modest Interim Facility and the Fall-Run Captive Rearing Study has been developed to refine techniques and protocols for captive rearing and to help meet reintroduction timelines during full-scale facility development.

The study, which began in 2010, has advanced the understanding of captive rearing practices during early stages of fish rearing for the San Joaquin River system. Data from the first years of the study indicate that spawning timing is not significantly altered by captive rearing, and the focus of the 2014 study is to test the effectiveness of captive rearing with and without environmental enrichment, a type of captive rearing methodology that could increase the likelihood of survival for captive broodstock. If results of the study are positive they will be incorporated into the hatchery practices at the San Joaquin Salmon Conservation and Research Facility.

Trap and Haul of Adult Fall-Run Chinook

This study is summarized above in Section 3.8.

3.10 Water Management

The following section describes the state of knowledge, questions, and studies associated with the water management theme. Figure 3-19 illustrates the schedule related to actions and studies that will be implemented under this theme.

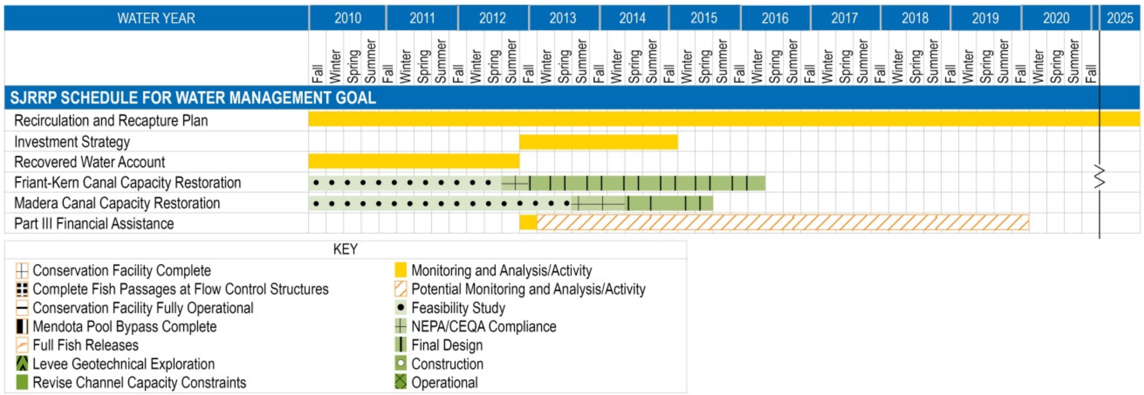


Figure 3-19.
Water Management Schedule

Water Management Goal actions include identifying, developing, and implementing projects and programs to reduce or avoid adverse water supply impacts to all of the Friant Division Long-Term Contractors. Adverse water supply impacts could result from the Interim and Restoration flows provided for in the Settlement. The reduction in water deliveries caused by the Interim and Restoration flows is monitored and recorded in the Recovered Water Account (RWA). The SJRRP prioritizes and measures the success of actions by their ability to reduce RWA balances of Friant Division Long-Term Contractors.

The Implementing Agencies identified actions in the Framework (SJRRP, 2012b) associated with water management to include Friant-Kern and Madera Canals Capacity Restoration; Part III, Recapture, Recirculation, and Other Projects; Outreach and Technical Support; and Investment Strategy Development. Reclamation, in coordination with appropriate Federal, State of California (State), regional, and local authorities, is authorized and directed to conduct feasibility studies on restoring the capacity of the Friant-Kern and Madera canals to such capacity as previously designed and constructed by Reclamation. After completion of, and consistency with the applicable feasibility study, Reclamation is authorized to construct improvements and facilities in accordance with Federal and State law. Initially, Reclamation jointly evaluated restoration of the capacities of the Friant-Kern and Madera canals. However, because of unique differences in the design and construction of the canals, Reclamation has since separated the evaluation into two separate feasibility studies.

3.10.1 Actions

- Identifying, developing, and implementing projects and programs to reduce or avoid adverse water supply impacts to all of the Friant Division Long-Term Contractors.

3.10.2 Questions

Table 3-13 lists the questions associated with addressing uncertainties related to water management. These questions are organized by actions identified in the Framework (SJRRP, 2012b).

Table 3-13.
Questions Related to Water Management

Action	Questions
Identifying, developing, and implementing projects and programs to reduce or avoid adverse water supply impacts to all of the Friant Division Long-Term Contractors.	Can water management provide flexibility to manage Restoration Flows?
	Can the release overlap to provide ecological benefit and water management?
	What is USACE's flood control flexibility? Is there potential to surcharge reservoir to gain water to offset water supply impacts?
	How should the SJRRP manage unreleased Restoration Flows?
Other	How can reservoir operations (e.g., cold water pool management) be managed to support fish needs?
	How should the SJRRP shape the flood release to meet needs of riparian recruitment?
	Can management of upstream reservoirs to improve cold water pool? Are there temporary management tools for Millerton to increase flexibility of flows, where more water can be stored?

Key:
SJRRP = San Joaquin River Restoration Program
USACE = U.S. Army Corps of Engineers

3.10.3 Studies

No studies related to flow scheduling are proposed for 2014.

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4.0 Monitoring Status and Trends

The SJRRP conducts long-term monitoring to meet Settlement requirements and to record status and trends for different physical and biological parameters. Long-term monitoring efforts can be used to inform the Implementing Agencies of how management actions relate to and affect conditions in the Restoration Area. Long-term monitoring may also be used to demonstrate effectiveness of actions implemented under the SJRRP. The SJRRP provides this data online on a biannual basis and the monitoring data is used to answer questions related to studies described in Section 3, Themes, and additional questions associated with addressing uncertainties related to long-term monitoring (Table 4-1).

Table 4-1.
Questions Related to Long-Term Monitoring

How well is the program meeting population targets?
How healthy is the population? What is the population performance?
What are the populations by reach? Where are problem spots identified in terms of population targets?
How many juveniles migrate out of the system? How many make it upstream?
What are the appropriate frequency and timing for long-term monitoring efforts? What are the short-term and long-term needs?
What are the minimum long-term U.S. Army Corps of Engineers monitoring elements? How will monitoring be used to measure biological monitors or response? What is the minimum we need to support and sustain?
Do the long-term monitoring efforts capture the signals of change in the system?
How can data collected be used to populate models and use as adaptive management tool?
How can the SJRRP use new technologies to better integrate data?
What is the riparian vegetation succession over time? How has it changed (aerial photography), general channel evolution (channel form), bed sediment distribution (gravel quantity and quality)? After 5 – 10 years? How sensitive is the system to flow triggers?
How is invasive vegetation tracked over time?
What are the approaches to vegetation planting? Do we plant in one clump or 25 small clumps? What are the experimental designs?
What is the river geometry? After 10 years? 20 years?
What type of systems needs to be maintained in the program (e.g., water quality conditions including temperature)?
What are the populations of other, non-vegetation invasive species (e.g., quagga mussels, New Zealand mud snail)? Should this be considered an issue?

Key:

SJRRP = San Joaquin River Restoration Program

Figure 4-1 illustrates the schedule related to actions and studies that will be implemented as related to monitoring status and trends.

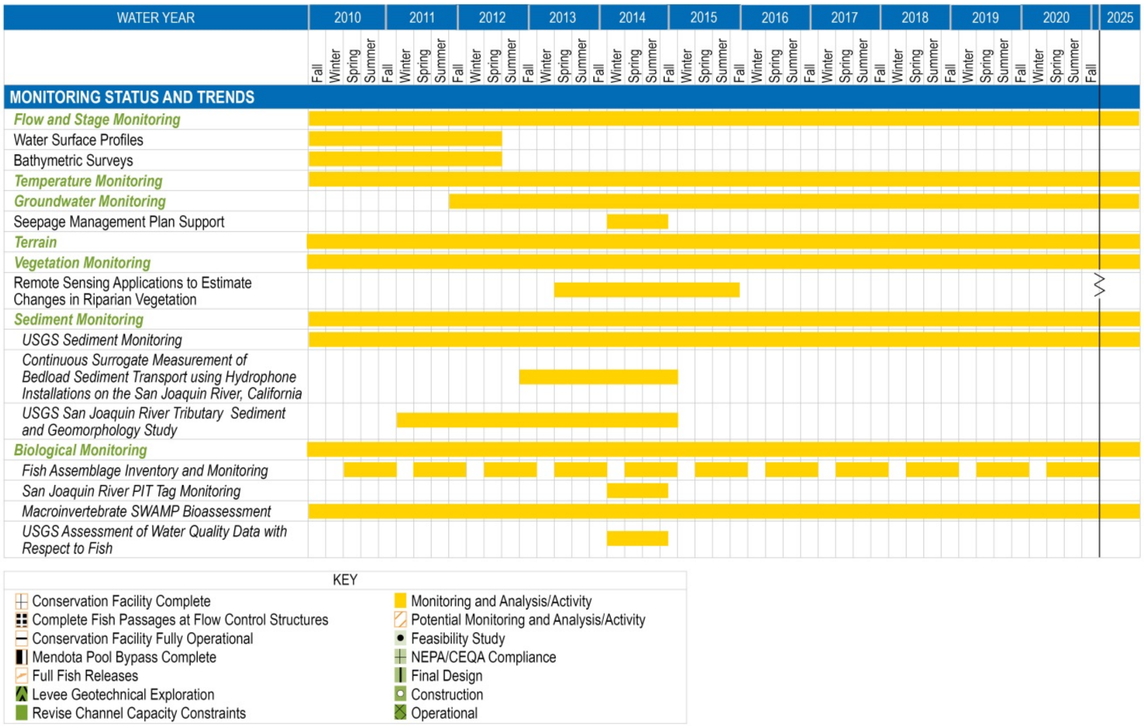

Figure 4-1.
Monitoring Status and Trends Schedule

4.1 Flow and Stage Monitoring

The Implementing Agencies conduct stream gaging to understand river conditions and collect information to address actions. In addition to flow gage monitoring, sensors at these sites also include a probe for detecting water temperature, DO, electrical conductivity, and chlorophyll.

Table 4-2 lists the stations that collect flow and stage data that undergo quality assurance/quality control (QA/QC). Flow data is available for other stations along the San Joaquin River that have not undergone QA/QC at the California Data Exchange Center (CDEC) at http://cdec.water.ca.gov/.

Table 4-2.
California Data Exchange Center Flow and Stage Measurement Stations

Stations
SJF – Below Friant Dam*
DNB – Donny Bridge
GRF – Gravelly Ford*
SJB – Below Chowchilla Bifurcation Structure*
SJN – San Mateo Ave.
MEN – Near Mendota Dam
SDP – Sack Dam near Dos Palos*
SWA – Washington Road*
ELN – El Nido
SJS – Stevinson
FFB – Fremont Ford Bridge
SMN – Merced Confluence*

Key:
* Settlement requires flow monitoring at these stations.

4.2 Temperature Monitoring

DFW and Reclamation collect surface water temperature data from sites along the San Joaquin River to monitor the status and track trends of the surface water temperature regime. The locations of temperature monitoring stations throughout the SJRRP reaches are presented in the *Temperature Atlas* at http://restoresjr.net/flows/WaterQuality (SJRRP, 2012f), which is updated annually.

4.3 Groundwater Monitoring

The SJRRP groundwater monitoring well network includes 182 wells installed by the program, excluding temporary wells. A single monitoring well atlas reports groundwater levels for 291 wells, including the SJRRP groundwater monitoring wells, temporary wells, and other wells in the vicinity of the San Joaquin River, and is published at http://www.restoresjr.net/flows/Groundwater (SJRRP, 2012g).

Reclamation collects groundwater elevation data from the SJRRP groundwater monitoring well network to inform seepage management. The *Seepage Management Plan* (SJRRP, 2011) describes monitoring and operating guidelines for reducing Interim Flows or Restoration Flows to address any material adverse impacts caused by Interim and Restoration flows in the San Joaquin River identified by the SJRRP groundwater monitoring program.

In support of the seepage management of the SJRRP, USGS will continue the development of the Seepage Management Plan with an emphasis on calibration, documentation of groundwater flow models, maintenance of a groundwater database, and evaluation of data associated with damage claims (see Study 41, Appendix A).

Terrestrial and bathymetrical light detection and ranging (LiDAR), and color infrared and/or hyperspectral aerial imagery will be collected as needed.

4.4 Vegetation Monitoring

Multiple studies associated with vegetation monitoring of status and trends are presented in this MAP, including the following:

- Vegetation Monitoring (Study 23, Appendix A)
- Remote Sensing Applications to Estimate Changes in Riparian Vegetation (Study 48, Appendix A)

4.4.1 Vegetation Monitoring

Riparian vegetation along the San Joaquin River between Friant Dam and the Mendota Pool has been significantly modified by agricultural development, hydrologic changes from operations of Friant Dam, and construction and operation of flood control levees and the bypass system.

Twenty permanent vegetation transects were established within reaches 1A, 1B, 2A, 2B, 3, 4A, and 4B2 (i.e., San Luis National Wildlife Refuge), and the Eastside and Mariposa bypasses (Study 23, Appendix A). Vegetation transects are monitored annually to monitor status and trends of plant cover, composition, overstory height, and stem density along each transect.

4.4.2 Remote Sensing Applications to Estimate Changes in Riparian Vegetation

In the SJRRP PEIS/R, Reclamation committed to invasive vegetation monitoring and management through 2020 as a condition of releasing Interim and Restoration flows, which have potential to spread invasive vegetation from upstream sites to newly wetted, unvegetated sites downstream. As such, a complete description of this study is provided under the Section 5, Environmental Compliance.

4.5 Sediment

The USGS will continue collecting sediment and bedload data in 2014 as part of an annual monitoring program (Study 21, Appendix A). Sediment data collected include suspended sediment, bedload, and bed material to monitor long-term changes in geomorphology. The primary objective of this study is to quantify the rate, timing, and grain size distribution of sediment entering the main stem San Joaquin River from Little Dry Creek and Cottonwood Creek. Potential continuity issues in the tributaries and mainstem will also be examined.

The USGS is also conducting a study to collect continuous surrogate measurements of bedload sediment transport using hydrophone installations on the San Joaquin River (Study 18, Appendix A). The objective of this study is to evaluate the use of hydrophone stations for estimating coarse bedload sediment transport dynamics at high temporal resolutions (e.g., hourly or finer) on the main stem San Joaquin River at existing bedload sampling locations, Ledger Island and Skaggs Bridge for Water Years 2013 and 2014. Three separate types of installations will be evaluated: two stereo hydrophone installations and one “Quadraphone” (double stereo) installation co-located at existing bedload sampling locations for measuring coarse bedload transport rates, and two stereo hydrophone installations located at riffle sites for estimating thresholds of coarse bedload mobilization and cessation. Each type of hydrophone installation will be evaluated for its accuracy in estimating coarse bedload transport rates and bed mobilization using data collected by other studies funded by the SJRRP. In particular, the hydrophone data will be evaluated for the ability to “tune” hydrophone response to the relatively low rates and low bedload grain sizes present on the San Joaquin River. In addition, the Quadraphone installation will be assessed for the potential to spatially locate bedload movement within the river using calibrated time-of-travel techniques.

The USGS is also continuing its San Joaquin River Tributary Sediment Transport and Geomorphology Study (Study 22, Appendix A). The purpose of this study is to quantify the sediment input from two major tributaries, Cottonwood Creek and Little Dry Creek, to the San Joaquin River downstream from Friant Dam. The amount and type of sediment contributed from the two major tributaries is not well understood but likely will play a substantial role in the sediment budget of the San Joaquin River, given the lack of upstream sediment supply due to Friant Dam. The amount and timing of fine and coarse sediment contributed by these tributaries can affect aquatic and riparian species, which are a focus of the SJRRP.

4.6 Biological Monitoring

Multiple studies associated with long-term biological monitoring of status and trends are presented in this MAP, including the following:

- Fish Assemblage Inventory and Monitoring (Study 9, Appendix A)
- San Joaquin River PIT Tag Monitoring and Site-Specific Technology Development (Study 15, Appendix A)
- Macroinvertebrate Surface Water Ambient Monitoring Program (SWAMP) Bioassessment (see Appendix A, Section 13, 2012 MAP, for the complete study plan)

Five Pikeminnows over 760 mm captured during October 2012 inventory

4.6.1 Fish Assemblage Inventory and Monitoring

To assess achievement of the Restoration Goal, an inventory and monitoring program is being conducted to identify fish abundance and diversity within the Restoration Area (Study 9, Appendix A). Describing a baseline fish assemblage within the Restoration Area during the beginning stages is useful for long-term monitoring. Information on chronological analysis of the temporal and spatial distribution, relative abundance, and diversity of fish species will help with the SJRRP Restoration Goal's success. This information can also be used to adaptively manage future efforts for a more effective implementation of the Restoration Goal.

4.6.2 San Joaquin River PIT Tag Monitoring and Site-Specific Technology Development

The San Joaquin River is highly regulated and water flow decisions may impact juvenile Chinook salmon downstream migration patterns. Data recorded from the San Joaquin River PIT Tag Monitoring and Site-Specific Technology Development Study can be used to determine areas that contribute to salmon mortality, migration rate, and emigration routes through the Restoration Area under a variety of flow conditions (Study 15, Appendix A). This information will be used to better inform management while making decisions regarding reintroduction timing and flows, and pathways through the system that provide the greatest chance for survival. These data will also be used to estimate reach-specific and Restoration Area-wide juvenile Chinook salmon survival rates, providing more accurate information for the ESHE model to predict the number of juvenile production to meet the SJRRP population goals. These data can be used to better understand the survival and migration paths of juvenile Chinook salmon while adaptively managing future decisions toward reaching the Restoration Goal.

The third year of the San Joaquin River PIT Tag Monitoring study will be 2014. A PIT tag is an electronic tag measuring 12 mm long by 2.1 mm in diameter, which will be inserted into stream-side spawned juvenile Chinook salmon progeny from the Trap and

Haul of Adult Fall-Run Chinook Study (Study 6, Appendix A). Tagged fish will be released in the river below Friant Dam and are monitored when they pass a permanent antenna located on the shore. In 2013, PIT tag arrays were constructed to determine the migration rates, residence areas, and behavioral changes of juvenile Chinook salmon as related to Friant Dam flow pulses of varying magnitude in Reaches 1 and 2 of the Restoration Area. The continued effort of this study in 2014 is needed to assess migration and survival of juvenile Chinook salmon over a variety of operations scenarios that include changing the migratory path of emigrating juvenile salmon by the use of managed flows, bypasses, or confining the fish to the river channel.

4.6.3 USGS Assessment of Water Quality Data with Respect to Fish

This water quality analysis will evaluate water quality data collected by Reclamation with respect to established criteria for Chinook salmon and interpret the results in terms of possible effects on salmon and other native fish species that live within the San Joaquin River (Study 42, Appendix A). The 2014 summary and assessment will consider the sampling frequency for adequate characterization of variability, sampling locations for sufficient characterization of the sampling reach, and sampling methods for appropriate media (water, sediment, tissue) and detection levels.

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5.0 Environmental Compliance

SJRRP actions are subject to environmental compliance. This section provides an overview of the environmental documents and permits that affect implementation of the SJRRP. These requirements are taken into consideration when developing and performing monitoring and analysis activities to support the SJRRP. The data collected through this mandatory monitoring and analysis may be used to address other SJRRP uncertainties. The SJRRP reports this data on an annual basis in the Annual Technical Report.

5.1 Final Program Environmental Impact Statement/Report

The Final SJRRP PEIS/R (SJRRP, 2012a) contains a Conservation Strategy with elements to be incorporated into projects to avoid or minimize adverse effects to listed species. To meet the Conservation Strategy goals of controlling and managing invasive species and conserving special-status species, monitoring and analysis will be performed to establish baseline species presence in the Restoration Area, and to design more specific protective measures.

In the SJRRP PEIS/R, Reclamation committed to invasive vegetation monitoring and management through 2020 as a condition of releasing Interim and Restoration flows, which have potential to spread invasive vegetation from upstream sites to newly wetted, unvegetated sites downstream. Reclamation entered into a grant with the San Joaquin River Parkway and Conservation Trust who began invasive vegetation monitoring and management activities in spring 2013. This agreement funds management actions for approximately 2 to 3 seasons. SJRRP needs to understand the extent and distribution of invasive vegetation in the Restoration Area and success of past invasive vegetation management on a Restoration Area-wide scale to determine if funding additional management is warranted.

Monitoring riparian vegetation at the species level to a spatial resolution that will meet project needs is often not realistic with traditional mapping approaches. New research is demonstrating that mapping and monitoring complex vegetation communities is improving through the use of hyperspectral imagery in combination with LiDAR data (Naidoo, 2012). This study proposes to investigate and determine classification approaches using Hyperspectral imagery with LiDAR that will produce the highest vegetation map accuracies, and establish mapping methodologies for future monitoring requirements. This tool will allow the SJRRP to more accurately map and quantify native riparian vegetation for mitigation credits as well as more precisely pin-point areas requiring invasive vegetation management and control, leading to program implementation and cost efficiencies.

5.2 Central Valley Steelhead Monitoring Plan

Dams have blocked access to historical spawning and rearing habitat upstream, thus forcing steelhead to spawn and rear in the lower portion of the rivers where water temperatures are often high enough to be lethal. Spring Interim Flows occurring from February 1 through June 1 could attract adult steelhead into the Restoration Area, but these steelhead would not have access to appropriate spawning habitat because of a number of impassable barriers. Reclamation, in coordination with the Fisheries Management Work Group, has developed a Steelhead Monitoring Plan to facilitate detection of steelhead on the San Joaquin River upstream from the Merced River confluence and to transport to suitable habitats downstream from the mouth of the Merced River.

This study is a multi-year study and will implement monitoring activities during 2014 for Central Valley Steelhead in the Restoration Area (Study 14, Appendix A).

5.3 State Water Resources Control Board Water Rights Orders

On October 1, 2009, the State Water Resources Control Board (State Water Board) issued Order 2009-058-DWR for the Water Year 2010 Interim Flows Project. Order 2009-058-DWR required explicit monitoring during implementation of Water Year 2010 Interim Flows. The State Water Board authorized the WY 2011-2013 Interim Flows Projects under subsequent Orders. The Orders required the SJRRP to monitor flow, water quality, seepage, invasive vegetation species, Millerton cold water pool, and other parameters. The SJRRP anticipates a long-term petition to be in place for WY2014 that may condition flow releases on ongoing monitoring.

Fyke net on Salt Slough

6.0 Monitoring Network

The SJRRP maintains a network of installed monitoring equipment and permanent survey locations to meet Settlement requirements and environmental commitments, and to collect relevant data during Interim Flows. This section presents changes to the monitoring network scheduled for 2014 to promote integration of all sensors and to disclose available data. Existing infrastructure is documented in resource-specific monitoring plans and atlases.

The monitoring network is continually refined to meet the evolving information needs of the SJRRP. For 2014, 23 new monitoring wells will be installed in Reaches 2B through 4A. Table 6-1 presents monitoring network surveys planned for 2014.

Data collected from the monitoring network are provided online biannually. Real-time data available from flow gage stations are available through CDEC and can be accessed through links on the SJRRP Web site (http://restoresjr.net). Groundwater levels from select wells and water quality measurements from telemetered stations are also available in real time and are accessible on the SJRRP Web site. The data collected from the SJRRP monitoring network will be analyzed in studies to support SJRRP implementation and management actions.

Table 6-1.
Monitoring Network Surveys

Survey Type	Purpose	2014 Plans	Relevant Study Name (Agency)
Bathymetric	Hydraulic model calibration	No bathymetric surveys planned for 2014.	Not applicable
Cross sections	Hydraulic model calibration	Resurveys to be conducted only if flows reach a range expected to significantly change bed topography.	Monitoring Cross-Section Resurveys (DWR)
Aerial	Inundation mapping, habitat assessments, vegetation mapping	No aerials planned for 2014.	Not applicable
Vegetation	Model calibration, detection of invasive species, riparian recruitment information.	Annual vegetation surveys planned for 2014.	Vegetation Monitoring (Reclamation)
Invertebrate studies	Habitat assessment	Final year of 3-year study.	Benthic Macroinvertebrate SWAMP Bioassessment (DWR, DFW) (Section 13, Appendix A, 2012 MAP)

Key:
DFW = California Department of Fish and Wildlife
DWR = California Department of Water Resources
Reclamation = U.S. Department of the Interior, Bureau of Reclamation
SWAMP = Surface Water Ambient Monitoring Program

7.0 Analytical Tools

This section discloses the analytical tools currently available or under development for the SJRRP (Table 7-1). These tools can be used to help meet study goals, and to simulate additional actions that need to take place to promote successful implementation of the Settlement.

Analytical tools provide a numerical representation of conceptual models. Monitoring data collection for the SJRRP can improve calibration and validation of these tools and fill in physical data gaps.

Table 7-1.
Analytical Tools for SJRRP

Model	Type	Purpose	Status	Model Application
DTM	Terrain	Digital terrain model of San Joaquin River	Complete with exception of incorporating 2011 gravel pit surveys for Reach 1A	Support other model development/updates
HEC-RAS	Hydraulic (1D)	Water surface (inundation mapping)	Complete	Developed for entire project reach. Support reaches 2B and 4B studies. Includes refined model with vertical N-values representing the main channel and a simplified model that includes a single representative N-value for the main channel.
SRH-2D	Hydraulic	Depth/velocity/habitat mapping	Existing conditions model available; some reaches modified to evaluate alternatives (Reclamation, 2008, 2012)	Support floodplain rearing study, spawning habitat study, and site-specific design
SRH-2D	Sediment	Transport/habitat mapping	Finishing modeling and analyzing results	Analyze sediment deposition dynamics at bypass in Reach 2A.
SRH-2D	Temperature	Habitat mapping	Temperature model will be updated (see Study 19)	Test temperature in model gravel pits in Reach 2B
SRH-1D	1D mobile boundary sediment	Transport	Geometry to be updated	Support reaches 2B and 4B study proposed alignments
HEC-5Q	1D hydraulic routing, temperature	San Joaquin River temperature	Complete (Reclamation, 2007)	Modeling for proposed hydrographs to aid flow scheduling
CE-QUAL-W2	Temperature (vertical 2D)	Millerton Lake cold water pool	Complete (Portland State University, 2012)	Simulate cold water pool in Millerton Lake

**Table 7-1.
Analytical Tools for SJRRP (contd.)**

Model	Type	Purpose	Status	Model Application
SRH-1DV	Cross section vegetation	Vegetation response to flow and sediment conditions	Geometry to be updated	Support design work on Reach 2B and Reach 4B site-specific projects
CVHM	Groundwater	Groundwater flow	Complete (USGS, 2012)	Run preliminary simulations related to Reach 2B proposed alignments; seepage projects
EDT	Fisheries	Population response to habitat conditions	Under refinement	Completed Reach 2B alternatives, modeling Reach 4B alternatives
ESHE	Fisheries	Floodplain habitat	Complete	Identified floodplain habitat needs for salmon
CalSim	Water resources	Flow scheduling and water management	Complete	Support flow scheduling and water management
RiverWare	1D hydraulic routing	Flow scheduling and water management	Complete	Support flow scheduling and water management
CVHM	Groundwater	Groundwater flow	Complete (USGS, 2012)	Run preliminary simulations related to Reach 2B proposed alignments
EDT	Fisheries	Population response to habitat conditions	Under refinement	Run preliminary simulations related to Reach 2B proposed alignments
ESHE	Fisheries	Floodplain habitat	Under development	Identify floodplain habitat needs for salmon

Key:
1D = one-dimensional
2D = two-dimensional
CVHM = Central Valley Hydrologic Model
DTM = Digital Terrain Model
EDT = Ecosystem Diagnosis and Treatment
ESHE = Emigrating Salmonid Habitat Estimation
HEC = Hydrologic Engineering Center
RAS = River Analysis System
SJRRP = San Joaquin River Restoration Program
SRH = Sedimentation and River Hydraulics

8.0 Monitoring Activities Summary

This section lists what type of monitoring activities are going to occur in 2014, and can be used to help coordinate efforts among agencies to efficiently collect relevant data to implement the SJRRP. Table 8-1 summarizes the schedule for monitoring activities in 2014. Study numbers below reference Appendix A study sections. The budget for the 2014 studies is presented in Appendix B. Attachment 1 presents a table identifying studies presented in the 2014 MAP and the status of those studies.

**Table 8-1.
Monitoring Activities Summary**

Study Number	Study	Monitoring	Schedule/Frequency
3	Changes in Soil Salinity Conditions Resulting from Interim Flows	Soil salinity	On as-needed basis
4	Influence of Paleochannels on Seepage	Seepage	Subject to landowner access and irrigation schedules
5	Temperature Monitoring of Cold Water Pool in Millerton Lake	Reservoir temperature	Continuous
6	Trap and Haul of Adult Fall-Run Chinook	Fisheries	October 2012 to 2020
8	Egg Survival and Emergence in Reaches 1A and 1B of the San Joaquin River	Water quality, sedimentation, and hydraulics	2 months during 2014
9	Fish Assemblage Inventory and Monitoring	Fisheries	Annual
10	Juvenile Survival and Migration	Fisheries	Start spring/early summer of 2014
11	Assessment of Predator Abundance and Distribution in Mine Pit Habitat in the San Joaquin River Restoration Area	Fish tagging and stomach analysis, surface temperature, DO, and turbidity	First 3 weeks of each month from February to June
12	Fall-Run Captive Rearing Study	DO, temperature, and feed quantity Fish weights, lengths, and condition factors will be measured	Daily Every 1 to 3 months
13	Levee Geotechnical Exploration	Field work	Summer 2012 through summer 2013
14	Central Valley Steelhead Monitoring Plan	Electrofishing Fyke nets with wing walls and traps Trammel nets	Monthly during December through March 2014 Mid-December through March 15, 2014 December through March 2014

Table 8-1.
Monitoring Activities Summary (contd.)

Study Number	Study	Monitoring	Schedule/Frequency
15	San Joaquin River PIT Tag Monitoring and Site-Specific Technology Development	PIT tag arrays	Maintain for 10 – 12 weeks in spring 2014
18	Continuous Surrogate Measurement of Bedload Sediment Transport Using Hydrophone Installations on San Joaquin River	Bed topography	Continuous
19	Two-Dimensional Temperature Monitoring of Gravel Pits in Reach 1A	Modeling	Not applicable
20	Adult Passage	Fisheries	On an as-needed basis
21	USGS Sediment Monitoring	Sediment	Every other week during February through June
22	USGS San Joaquin River Tributary Sediment and Geomorphology Study	Sediment and Geomorphic	Winter 2013 and spring 2014
23	Vegetation Monitoring	Vegetation	5 days between June and August
24	Additional Water Level Recorders	Surface water	Continuous
25	Monitoring Cross-Section Resurveys	Bed Topography	Only if flows are sufficient to move bed material
26	Effect of Altered Flow Regime on Channel Morphology in Reach 1A	Topography	Complete

Key:
DO = dissolved oxygen
MAP = Monitoring and Analysis Plan
PIT = passive integrated transponder
USGS = U.S. Geological Survey

9.0 Conclusions

At the end of 2014, the SJRRP expects to have progressed on addressing the uncertainties for actions within each theme through completion of study question and the development of new strategy to address uncertainties. The following section is organized by theme and summarizes anticipated outcomes of 2014 monitoring and analysis activities.

Rearing Habitat – Refinement of site-specific temperature models based on data gathered within the Restoration Area to inform actions for temperature management. Understanding of mechanisms to enhance water temperatures for juvenile salmon through riparian vegetation, transition zone and floodplain restoration strategies to improve food production and increase cover availability, and reduced fine sediments in Reach 1.

Spawning and Incubation – Detailed understanding of the availability and quantity of spawning habitat through assessment of substrate, sediment transport, spawning gravel, and stage. Determine whether eggs in redds constructed by fall-run adult salmon in Reach 1 can survive and produce healthy fry given the current spawning habitat conditions. Determine whether an adequate segregation of spring-run Chinook salmon from fall-run Chinook salmon can allow both species to reestablish in the Restoration Area.

Adult Migration – Assessment of adult passage in the bypass channels and at nonstructural sites in the natural channel that may be too shallow for unimpeded passage. Evaluation of the effects of water temperature on adult passage using the full life-cycle salmon population model SalSim.

Flow Scheduling – Refinement of site-specific temperature models based on data gathered within the Restoration Area to inform actions for temperature management, evaluate the effectiveness of modified flow schedules to sustain salmon escapements with the full life-cycle salmon population model SalSim, and use updated reports of fish studies (e.g., egg survival, juvenile tagging, adult fall-run spawning) to calibrate the SalSim model and revise temperature targets.

Conveyance – Completion of levee geotechnical evaluations and initiation of revisions to channel capacity constraints at the beginning of 2014; updated thresholds for *Seepage Management Plan* (SJRRP, 2011); additional groundwater, soil salinity, and soil texture data to inform design of seepage projects to improve SJRRP flow conveyance.

Entrainment Protection – Quantification of predation and entrainment potential and fish movement around and through Mendota Pool and Sack Dam to reduce the number of areas in the river where threats to juveniles occur, thereby increasing overall juvenile survival prior to the completion of the Reach 2B and Arroyo Canal projects.

Predation – Understanding of predation risk through measuring predator abundance near the gravel mine pits and juvenile survival in the Restoration Area. An improved understanding of the interactions between the river and gravel pit water temperatures may also help to identify the most effective mechanisms to reduce predation potential.

Fish Passage – Development of an upstream fish passage strategy. Evaluation of the potential viability of trapping and hauling fall-run adult salmon from Reach 5 to Reach 1. Identification of areas of shallow and high velocity water that may impede upstream or downstream migration.

Fish Reintroduction – Refined methodology for the captive rearing of Chinook salmon from the spawning portion of their life cycle, through adulthood in an effort to fully prepare professionals to work with threatened spring-run Chinook salmon and to increase the chances for the successful development of a self-sustaining, self-reproducing population. Provide juvenile spring-run production data for Butte Creek that will help determine whether donor broodstock could be collected for the Restoration Area without harm to the Butte Creek population.

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