Recommendations on Restoring Spring-run Chinook Salmon to the Upper San Joaquin River

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Executive Summary

The San Joaquin River Restoration Program Technical Advisory Committee (TAC) is required under the Stipulation of Settlement in NRDC v. Rodgers (CIV-S- 88-1658-LKK/GGH) (Settlement) to develop recommendations for interim and long-term population targets, goals and milestones for restoration of spring-run Chinook salmon, as well as recommendations on stock selection and strategies for reintroduction. These recommendations of the TAC are provided to the Restoration Administrator (RA) for consideration in preparing recommendations to the Secretary of the Interior for the targets, goals, and milestones as required under the Settlement.

Due to logistical and organizational issues, there was not sufficient time to prepare recommendations on both the spring-run and fall-run Chinook salmon. Therefore, as required by the Settlement, the TAC will prepare a follow up report for transmittal to the RA in the near future that will contain the same range of recommendations for interim and long-term population targets, goals and milestones for restoration of fall-run Chinook salmon. The subsequent TAC report will also provide recommendations required under the Settlement for coordinating releases from Friant Dam with fishery restoration actions on the Merced, Tuolumne and Stanislaus Rivers.

Initial Targets, Goals and Milestones for Spring-run Chinook Salmon

Considerable changes have occurred to the San Joaquin River in the 60 years since Friant Dam was completed and anadromous salmonids were extirpated from the river. The following recommendations are initial numeric targets, goals, and milestones for naturally reproducing spring-run Chinook salmon. They reflect the potential of the restored river's ability to support robust populations based on careful consideration of a variety of information, including: (1) historic population estimates; (2) sizes of runs immediately after Friant Dam was completed; (3) post-dam runs of fall-run Chinook salmon on the Merced, Tuolumne, and Stanislaus rivers below the lowest major dams; (4) estimates of the number of spring-run Chinook salmon spawners and juveniles that can be supported by existing and/or improved habitat (habitat carrying capacity); and (5) basic genetic and demographic models for minimum viable population sizes.

Review of population responses to restoration actions and favorable hydrology on other Central Valley rivers suggests that population improvements can be rapid (5-10 years). However, it is more likely that it will likely require multiple generations for San Joaquin River salmon to respond to levels that meet population goals because of a number of factors, including the time needed to complete restoration actions and potential drought years. Two principal milestones provided in the Settlement related to re-establishing Chinook salmon populations are December 31, 2012 (year of reintroduction), and December 31, 2024 (date by which a self-sustaining population should be re-established). In order to set goals and targets set by the Settlement, the TAC recommends that additional detail be incorporated into the milestones to include the following time periods:

Reintroduction Period: January 1, 2012, to December 31, 2019;

Interim Period: January 1, 2020, to December 31, 2024;

Growth Population Period: January 1, 2025, to December 31, 2040;

Long-term Period: Beyond January 1, 2041.

For each of these time periods, the TAC provides recommendations for naturally produced spring-run Chinook salmon population targets as follows:

<u>2012-2019 Reintroduction Period</u>

Recommendation 1: The Reintroduction Period should be defined as January 1, 2012, through December 31, 2019.

Recommendation 2: 500 spawners should be the minimum target for fish returning to spawning areas at the end of six years (2019). If returns fail to meet the annual 500 fish target by December 31, 2019, monitoring data should be reviewed, and restoration strategies and efforts should be assessed by the TAC in consultation with implementing agencies to recommend refinements in management actions to improve returns.

2020-2024 Interim Period

Recommendation 3: The Interim Period should be defined as January 1, 2020, through December 31, 2024.

Recommendation 4: The five-year running average target for escapement should be at least 2,500 fish, with allowable population fluctuation between 500 and 5,000 spawners (upper limit to guide maximum capacity of spawning habitat).

Recommendation 5: 500 spawners should be the minimum target for fish returning to spawning areas for any given year after 2019. If the number drops below 500 fish in any given year, or if the targets outlined in Recommendation 4 are not achieved, monitoring data should be reviewed, and restoration strategies and efforts should be assessed by the TAC in consultation with implementing agencies to recommend refinements in management actions to improve returns.

Recommendation 6: Assessment of success of achieving interim targets should take into account fluctuations of other salmon populations in the Central Valley, to serve as indicators of unfavorable conditions for survival of juvenile salmon outside the San Joaquin River system.

2025-2040 Growth Population Period

Recommendation 7: Between 2025 and 2040, the target for the 5-year running average of spawners should increase from 2,500 to 30,000 spawners, and the rate of increase of the number of spawners (cohort replacement rate) should be greater than 1.00.

Recommendation 8: During the Phase 1 and Phase 2 of the Restoration Actions, create in-river holding, spawning, and rearing habitat necessary to support the upper range of returns (45,000 spawners) for the Long-term Period.

2041+ Long-term Period

Recommendation 9: The Long-term Period should be defined as beyond January 1, 2041.

Recommendation 10: By 2040, the long-term target for annual escapement of spring-run Chinook salmon should be a 5-year running average of 30,000 spawners, providing for 50% range of fluctuation (15,000-45,000 spawners).

Recommendation 11: A major re-evaluation of population status should occur at a maximum every 15 years (in addition to routine annual population status assessment).

Initial Stock Selection for Spring-run Chinook Salmon

The primary objective of selecting an appropriate stock is to identify the stock(s) of spring-run Chinook salmon with the greatest likelihood of establishing a self-sustaining population in the San Joaquin River between Friant Dam and the mouth of the Merced River (“the Upper San Joaquin River”). The ‘best’ stock will have life history traits (e.g., adult and juvenile migration timing, habitat requirements, and environmental tolerance) that are compatible with anticipated future habitat conditions (e.g., seasonal hydrology, water temperatures, and physical habitat) within the upper San Joaquin River. The TAC developed the following criteria for considering the most appropriate stock(s) for reintroduction on the San Joaquin River: (1) stock should be of local or regional origin from the Central Valley; (2) stock should be genetically diverse; (3) stock should take into account the status of the source population; (4) stock should not jeopardize existing Chinook salmon stocks in the San Joaquin basin; (5) stock should have life-history characteristics that maximize probability of successful reintroduction into the San Joaquin River; (6) stock should have behavioral and physiological characteristics that fit conditions expected to occur on the San Joaquin River; and (7) stock should not be of hatchery origin, except under extreme circumstances.

Based on these criteria and review of potential stocks within the Central Valley, the TAC makes the following initial recommendations on stock selection:

Recommendation 12: The founding stock should be selected from currently existing stocks inhabiting the Central Valley to maximize the likely success of local adaptation to the San Joaquin River. Preliminary assessment of potential founding stocks indicate that the Butte Creek spring-run Chinook salmon has life history characteristics that may be most compatible with the anticipated future environmental conditions on the upper San Joaquin River. The TAC recommends that a more detailed analysis be conducted to further evaluate the potential use of the Butte Creek and other potential founding stocks as part of refining the San Joaquin River reintroduction strategy.

Recommendation 13: The founding stock should have adequate genetic material (i.e., population abundance and genotypic/phenotypic diversity) to allow San Joaquin River specific pressures to eventually produce a locally adapted stock.

Recommendation 14: Factors that should be considered when selecting the founding stock(s) include current trends in abundance of source spring-run Chinook salmon populations (e.g., Butte Creek population), whether existing habitat conditions within a source watershed are fully used (e.g., are "surplus" fish available for relocation with minimal or potentially beneficial effects), logistic conditions affecting the ability to successfully collect and transport adults, eggs, or juveniles, and the genetic characteristics of the founding stock. These recommendations are intended to inform the Secretary of Interior, as well as state and federal fishery biologists who are responsible for final identification and selection of the founding stock(s) for reintroduction on the San Joaquin River.

Recommendation 15: Measures to assure fidelity to the San Joaquin River spawning areas, such as juvenile imprinting, and marking programs, should be used to help reduce inter-basin movement of spring-run Chinook salmon from the upper San Joaquin River to downstream tributaries while establishing the initial population on the upper San Joaquin River.

Recommendation 16: A founding stock should be selected that has behavioral and life history characteristics most compatible with the anticipated conditions on the San Joaquin River.

Recommendation 17: Wild stocks should be evaluated from various Central Valley rivers as a founding stock with the goal of maximizing, to the extent possible, the genetic diversity of the founding stock to support the greatest degree of local adaptation to the San Joaquin River and to match the compatibility of life history characteristics with anticipated future environmental conditions.

Recommendation 18: A technical report should be developed that compiles, synthesizes, and integrates information on the life history characteristics and genetics of candidate stocks along with an assessment of the compatibility of each stock with anticipated future environmental conditions on the San Joaquin River to support a recommendation regarding the selection of one or multiple founding stocks for the reintroduction strategy.

Initial Reintroduction Strategies for Spring-run Chinook Salmon

The primary objective of recommending a reintroduction strategy is to establish a self-sustaining and naturally reproducing population in the San Joaquin River between Friant Dam and the mouth of the Merced River by the end of the Reintroduction Period. A secondary but important objective of the re-introduction strategy is to conduct reintroduction experiments that will improve understanding of adult and juvenile habitat utilization prior to and during the Reintroduction Period. The TAC developed the following principles for considering an initial reintroduction strategy on the San Joaquin River: (1) use best available stock(s), not just the most available; (2) use a mixture of reintroduction strategies; (3) use reintroduction strategies at least partly based on maximizing learning potential and informing adaptive management decisions; (4) initially, if necessary, use a combination of hatchery production, human intervention, and trap and haul techniques if doing so supports information gathering or other recommendations in this report; (5) use adaptive management principles to guide the reintroduction strategy; (6) reintroduction success should be considered over a period of years and be flexible; and (7) prioritize spring-run Chinook salmon over fall-run Chinook salmon.

Based on these criteria and review of the available stock reintroduction literature to date, the TAC makes the following initial recommendations on a reintroduction strategy:

Recommendation 19: A phased strategy should be used during the early stages of reintroduction that blends a wide variety of techniques, incorporating additional information developed in the coming years and offering a diversified approach to reintroduction.

Recommendation 20: The structure of the reintroduction strategy and subsequent evaluation of the performance of the management actions and success of reintroduction should be conducted within a formal adaptive management framework.

Recommendation 21: A wide variety of techniques, including intervention techniques, should be used to help establish the initial founding population on the river. As the founding population becomes better established over time and able to respond to conditions through local adaptation, the reliance on intervention techniques should be reduced, with a greater proportion of the production originating from in-river spawning and rearing in order to meet the recommended population goals, targets, and milestones.

Recommendation 22: The information available from monitoring salmonid populations in other Central Valley river systems should be compiled and a critical assessment of monitoring needs and alternative approaches should be conducted prior to reintroduction. The monitoring and evaluation program should be designed to address and evaluate these and other key issues affecting the design, implementation, priorities, and success of the reintroduction program and for informing future decisions regarding refinements or modifications to the reintroduction strategy.

Recommendation 23: Program performance should focus on meeting the population targets over a period of years reflecting multiple cohorts and generations. With the exception of minimum population targets, Program performance should not be based on results from any one year. Caution should be exercised in modifying the fundamental reintroduction strategy until a clear trend is established, which may take a number of years to become evident.

Recommendation 24: The monitoring program and implementation of the reintroduction strategy should give priority status, in the early phase of restoration, to establishing spring-run Chinook salmon as the primary objective of the reintroduction strategy.

Recommendation 25: In developing the phased reintroduction strategy, information should be gathered and compiled to provide technical support for initial decisions regarding the proposed reintroduction strategy.

Finally, because available information on population dynamics, genetics, and reintroduction strategies is limited, and new information will be developed in the years to come, it is anticipated that the initial recommendations above will be refined. Information needs and uncertainties should be addressed prior to and during the Reintroduction Period, which will improve the overall success at achieving the program goal of naturally-reproducing and self-sustaining populations of Chinook salmon as specified by the Settlement.

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1 INTRODUCTION

The San Joaquin River Restoration Program Technical Advisory Committee (TAC) is required under the Stipulation of Settlement in NRDC v. Rodgers (CIV-S- 88-1658-LKK/GGH) (Settlement) to develop recommendations for interim and long-term population targets, goals and milestones for restoration of spring and fall-run Chinook salmon, as well as recommendations on stock selection and strategies for reintroduction. The recommendations of the TAC are provided to the Restoration Administrator (RA) for consideration in preparing recommendations to the Secretary of the Interior for the targets, goals, and milestones as required under the Settlement.

The following recommendations focus primarily on Central Valley spring-run Chinook salmon, herein referred to as spring-run Chinook salmon. Similar recommendations regarding fall-run Chinook salmon will be provided in a separate report. While the Settlement calls for the reintroduction of both fall and spring-run Chinook salmon, a higher importance is placed on restoring spring-run Chinook salmon where competing issues require prioritizing the needs of one run over another.

The TAC, with input from the federal implementing agencies, developed the following recommendations based on the best available information. These recommendations are intended to provide technical guidance as required by the Settlement based on the expertise of TAC members who have all worked on San Joaquin River restoration issues for many years. The TAC anticipates and recommends in several places, the development of new information to further refine some of these recommendations.

2 INTERIM AND LONG-TERM TARGETS, GOALS, AND MILESTONES FOR SPRING-RUN CHINOOK SALMON RESTORATION IN THE SAN JOAQUIN RIVER

The Settlement provides the following language to help guide the TAC in providing recommendations to the RA with respect to the Restoration Goal:

> "The Parties agree that a goal of this Settlement is to restore and maintain fish populations in 'good condition' in the main stem of the San Joaquin River below Friant Dam to the confluence of the Merced River, including naturally-reproducing and self-sustaining populations of salmon and other fish (the 'Restoration Goal')."

In Paragraph 20 (d)(1)(B) of the Settlement, the evaluation of a requested change in the Restoration Flows must be made in light of the following among other criteria:

> "…beginning 7 years after the reintroduction of spring-run Chinook salmon to the San Joaquin River, whether the annual escapement of wild spring-run adult salmon has dropped below 500 in any year."

Exhibit D of the Settlement addresses roles and responsibilities of the TAC and RA, declaring that:

> "In consultation with the TAC, as soon as possible, but not later than one year after the Effective Date of the Settlement, [the RA shall] make recommendations to the Secretary regarding the following:
>
> "…c. appropriate interim targets, goals and milestones for annual escapement of wild adult Chinook salmon, including interim targets designed to achieve continual population growth and the long-term population target for spring and fall-run Chinook salmon by 2025. Interim goals shall include objective criteria to prevent restored populations of wild salmon from dropping below a level of low risk for extirpation;
>
> "d. appropriate long-term targets for annual escapement of wild adult Chinook salmon, which shall reflect the potential of the restored River to support robust populations of wild Chinook salmon."

In response to the directives of the Settlement, this document focuses mainly on recommendations regarding interim and long-term goals, milestones, and targets for annual escapement of wild adult spring-run Chinook salmon. It is expected that there will be incidental benefits for other fish species that will occur as a result of meeting the spring-run Chinook salmon goals, although there may be conflicts in some situations. Where conflicts arise, spring-run Chinook salmon should have the highest priority.

Establishing targets, goals, and milestones for spring-run Chinook salmon in the San Joaquin River is challenging for at least three reasons:

1. There have not been runs of salmon on the upper San Joaquin for almost 60 years, so it is difficult to determine what factors will regulate the abundance of a newly established population. Salmon populations naturally fluctuate by large numbers. In the Central Valley, populations vary due to factors both inside and outside the spawning and rearing streams, including conditions in the Delta, conditions in the ocean, and variations in stream flow, with larger returns generally resulting from wetter years.
2. In-channel habitat conditions on the San Joaquin River have degraded since the last runs occurred in the 1940s, although restoration actions required under the Settlement will greatly improve conditions.

3. Chinook salmon have variability in their life history strategies so juveniles can emigrate as 0+ and 1 yr olds and adults can return as 2, 3, 4, and even 5 yr olds, assuming commercial and recreational harvest is regulated to permit substantial returns of older fish. This variability is a positive attribute that increases the likelihood that re-establishment can occur in conformance with the schedule stated in the Settlement; however, it also increases the difficulty of predicting population level responses.

Establishing population targets, goals, and milestones is essential for planning purposes, as well as to monitor progress towards restoring self-sustaining populations. Thus, in this document, we recommend targets, goals, and milestones for the re-establishment of spring-run Chinook salmon and provide rationales for the recommendations. As populations and better information develop, other factors may also have to be taken into consideration. Additionally, while a primary goal of the Settlement is to establish a self-sustaining population of spring-run Chinook salmon, it is the opinion of the TAC that other related biological benefits will likely accrue as well (Appendix 1).

2.1 Goals and Objectives

The general goal for this effort is to re-establish a self-sustaining population of Central Valley spring-run Chinook salmon in the upper San Joaquin River below Friant Dam to the confluence of the Merced River.

"Self-sustaining" means a population that maintains itself indefinitely by completing its entire life cycle with no artificial propagation. Accomplishing the goal will require: (1) improving habitat for all life stages; (2) improving passageways; (3) maintaining or improving water quality; (4) regulating fisheries; and (5) reducing human-caused sources of mortality. The Settlement anticipates accomplishing these objectives between Friant Dam and the Merced River confluence. While the Settlement only contemplates physical changes in the upper San Joaquin River below Friant Dam to the confluence of the Merced River, our ability to achieve our goals will in part depend on these other life history considerations being met along the entire river.

The TAC believes that the following three objectives must be achieved in order to achieve the general goal.

Objective 1. Establish a natural population of spring-run Chinook salmon that is specifically adapted for conditions in the upper San Joaquin River. In other words, allow natural selection to operate on the population initially established from Sacramento River basin stock in order to produce a strain that has its timing of upstream migration, spawning, and outmigration, as well as its physiological and behavioral characteristics, adapted to conditions in the San Joaquin River, including those conditions created or improved by implementation of the Settlement.

Objective 2. Establish a spring-run Chinook salmon population that is genetically diverse so that it is not subject to the genetic problems of small populations, such as founder's effects and inbreeding. The minimum population threshold established in the Settlement was set with this objective in mind and indicates that genetic as well as population monitoring is required.

Objective 3. Establish a spring-run Chinook salmon population that is demographically diverse in any given year, so returning adults represent more than two age classes. Given the vagaries of ocean conditions, the likelihood of extreme droughts, and other factors that can stochastically affect salmon numbers in any given year, resiliency of the population requires that multiple cohorts be present. Chinook salmon populations in the Central Valley are dominated by three year old fish, plus two year old jacks, partly as the result of the effect of fisheries harvest. Both population resiliency and genetic diversity require that four, five, and even six year old salmon be part of the population each year.

2.2 Milestones

Milestones are the dates by which specific targets should be reached to accomplish the goal and objectives of the restoration program. Two principal milestones provided in the Settlement related to re-establishing Chinook salmon populations are December 31, 2012 (year of reintroduction), and December 31, 2024 (date by which a self-sustaining population is re-established). Thus, based on the average generation time of three years in Chinook salmon and the uncertainties involved in predicting success of the reintroduction strategies, the TAC recommends that the Reintroduction and Interim time periods be from 2012 to December 31, 2019, and 2020-December 31, 2024, respectively. We also recommend that a Growth Population Period of January 1, 2025, through December 31, 2040, be designated. This period will reflect the potential of the restored river (related to actions of the Settlement) to increase its population of wild spring-run Chinook salmon for five generations (assuming three years is the basic generation time). The goal is to achieve an increasing target run size from 2,500 to 30,000 fish, with the five-year running average increasing throughout the 15 year period (see Section 2.3). We recommend that the Long-term Period start after 2040, during which time the population should be maintained with a five-year running average of 30,000 fish. An annual population assessment should occur every year, as is done with downstream tributaries to the San Joaquin River. After 2024, we recommend a strategy reassessment of population status and numeric targets (minimum, running average) at a maximum of every 15 years (once every five generations), unless there are extraordinary and unexpected declines in the spring-run Chinook salmon populations.

The recommended milestones for spring-run Chinook salmon are provided in Table 1. Lambda refers to population growth, where a value <1 indicates a shrinking population and a value >1 indicates a growing population when averaged over a fixed period. The basis for the numbers is discussed in the following sections.

If numeric targets are not reached at a given milestone, then restoration strategies need to be reviewed in order to establish the nature and severity of the reasons for failing to attain numeric targets and to find means, consistent with the Settlement, of reaching the numeric targets in a reasonable length of time. If the analysis of potential reasons cannot identify remedies that appear capable of attaining the target in a reasonable timeframe, a major re-evaluation of restoration strategies will be required.

Milestone Year	Milestone Name	Milestone Period	Lambda	Minimum Threshold	5-year Running Average Target
2019	Reintroduction	1/1/2012-12/31/2019	>1	variable	variable
2024	Interim Population	1/1/2020 - 12/31/2024	>1	500	2,500
2040	Growth Population	1/1/2025-12/31/2040	>1	500	2,500- 30,000+

Table 1. Milestones and targets for re-establishing a self-sustaining population of naturally produced spring-run Chinook salmon in the San Joaquin River. The five year running average for the 2040 milestone is meant to reflect an increasing trend over the growth period, which starts at 2,500 and achieves at least 30,000 by 2040 (as indicated in Figure 1).

2.3 Targets

The targets are numerical expressions of the recovery goals for naturally produced spring-run Chinook salmon, expressed as numbers that reach the spawning areas (escapement). They represent numbers that we believe can be achieved by habitat improvements resulting from the restoration actions required by the Settlement. These targets assume that all of the restoration work contemplated in Phase 1 and Phase 2, as described in the Settlement, is completed on schedule and creates satisfactory habitat conditions for spring-run Chinook salmon. While these targets take into account existing conditions and the likely benefits of restoration actions, they do not account for all the potential and unforeseen factors that are beyond the scope of the Settlement, including factors related to extreme weather and habitat conditions downstream of the project area which have the potential to affect escapement. These targets do not modify or supersede the provisions of the Settlement relating to criteria used to determine success of the Restoration Flows and the other non-flow restoration measures taken pursuant to the Settlement in achieving the Restoration Goal. If the numeric goals are achieved, we assume more qualitative goals (such as habitat restoration) also are being achieved, although additional monitoring will be necessary to assess whether or not the genetic goals are achieved. Target numbers of spawners for each milestone are provided in Table 1, while Figure 1 presents a model for the expected population establishment. The rationale for the numbers is presented in Section 2.4. The targets should reflect both minimum viable population size (demographic minimum) and minimum effective population size (genetic minimum), as well as numbers the habitat (including water temperature) can actually support. The population size that the habitat can support is uncertain at the present time, although estimates based on spawning gravel availability are generally consistent with escapement numbers in the years immediately after dam construction. The actual numbers could increase as habitat is improved, as returning adults add nutrients to the system and as better management practices are implemented in the river, estuary, and ocean.

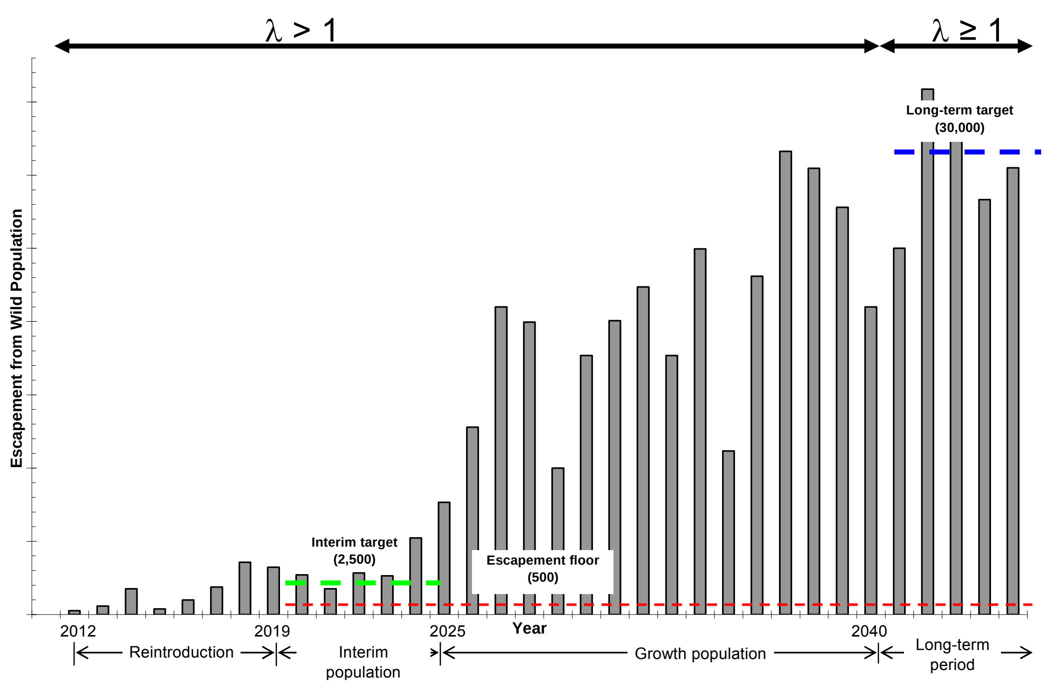

Figure 1. Conceptual model of potential trajectory and population fluctuations of spring-run Chinook salmon in the San Joaquin. This model is meant to show one potential scenario; it does not represent populations that have gone through a long period of drought (for example) The bars are **not** *performance standards for individual years.*

Realistically, it is likely to take a minimum of 10 three-year generations to achieve an annual numeric target of 30,000 fish – the long-term target for escapement. However, the recovery of winter-run Chinook salmon in the Sacramento River following intense management (Figure 2) and the recovery of spring-run Chinook salmon in Butte Creek following removal of barriers suggest that reaching target numbers can occur more rapidly than our model indicates (Figure 3).

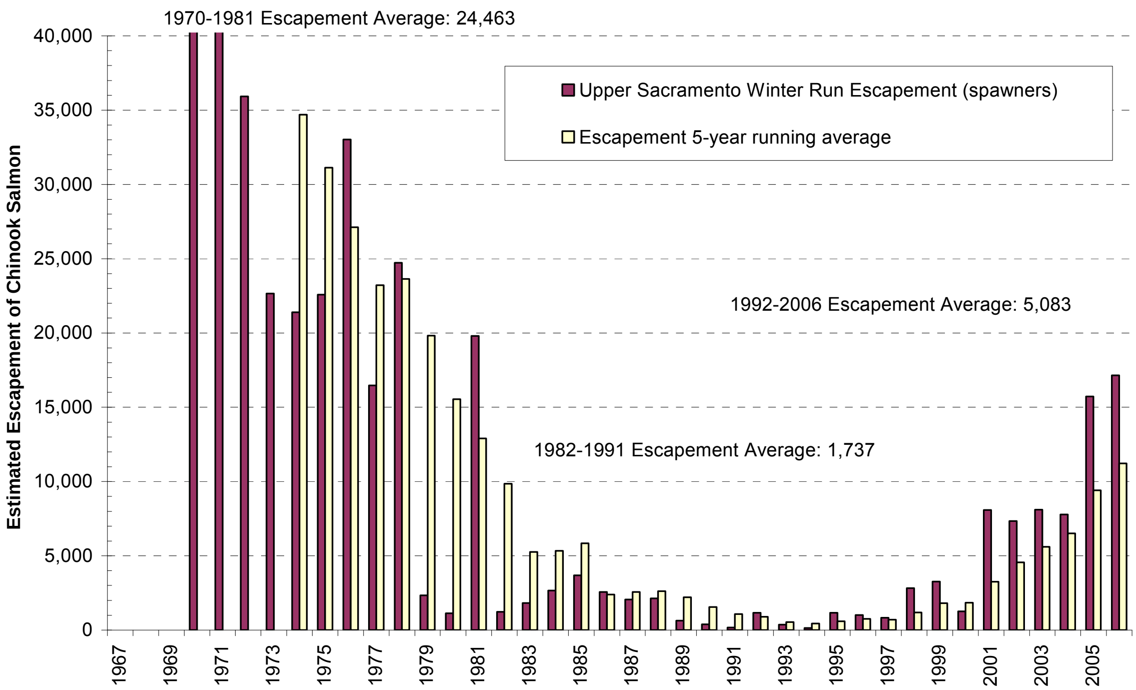

Figure 2. Trends in annual population of winter-run Chinook salmon in the Sacramento River (1970-2006), showing both actual escapement estimates for each year and the five-year running average. Data from USFWS Anadromous Fish Restoration Program (http://www.delta.dfg.ca.gov/afrp).

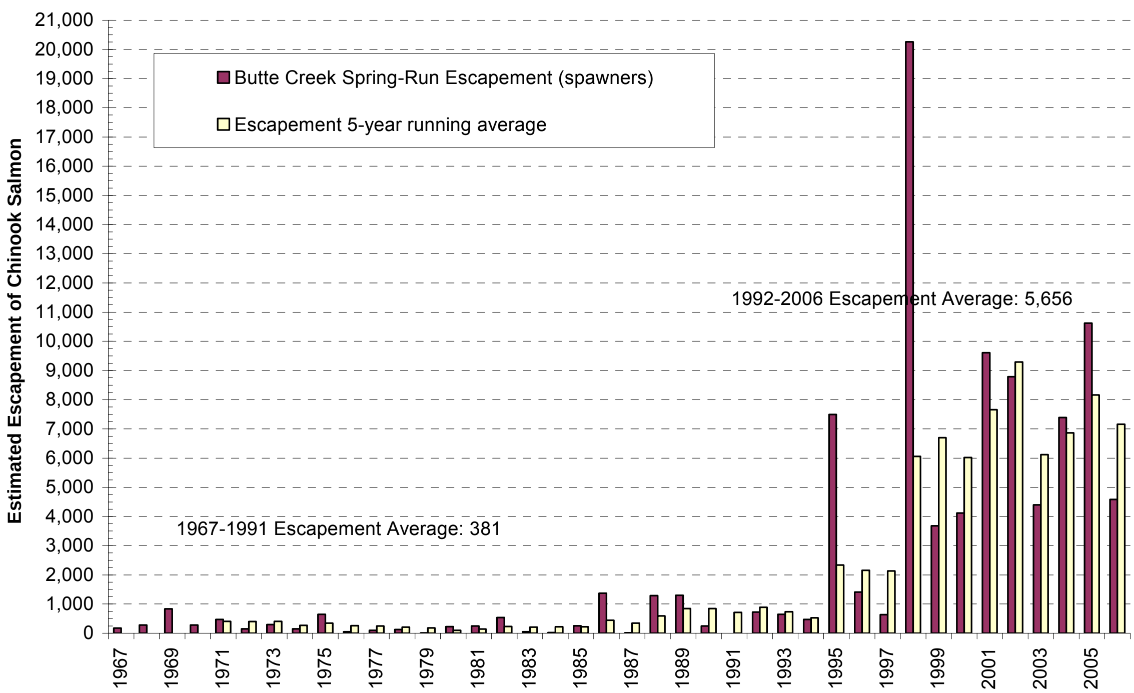

Figure 3. Trends in annual population of spring-run Chinook salmon in Butte Creek (1967-2006), showing both actual escapement estimates for each year and the five-year running average. Data from USFWS Anadromous Fish Restoration Program (http://www.delta.dfg.ca.gov/afrp).

We prefer to retain a conservative view of the speed of recovery of San Joaquin spring-run Chinook salmon because the recovery of the Sacramento River winter-run Chinook salmon and Butte Creek spring-run Chinook salmon took place under more benign conditions than are likely to face spring-run Chinook salmon in the upper San Joaquin River (see Section 2.4.4).

2.4 Rationale for Population Targets

In developing reasonable targets and goals for annual escapement of wild spring-run Chinook salmon, we have taken into account: (1) historic population estimates; (2) sizes of runs immediately after Friant Dam was completed; (3) post-dam runs of fall-run Chinook salmon on the Merced, Tuolumne, and Stanislaus rivers below the lowest major dams; (4) estimates of the number of spawners and juveniles that can be supported by existing and/or improved habitat (habitat carrying capacity); and (5) basic genetic and demographic models for minimum viable population sizes.

2.4.1 Historic Population Estimates

Because Friant Dam now blocks access to over 35% of the historic spawning habitat of spring-run Chinook salmon (Yoshiyama et al. 2001), pre-dam run numbers cannot be used alone as a goal, although they are useful for comparison. The limited information available suggests that a reasonable estimate for the annual average numbers of spring-run Chinook salmon for the entire San Joaquin River basin prior to construction of most of the dams and diversions (e.g., the 1880s) would be around 200,000-300,000 fish, and perhaps more in years of high ocean productivity and less during periods of extreme drought. Anecdotal observations suggest that perhaps half these fish entered the upper San Joaquin River above the Merced confluence. Thus the average number of spring-run Chinook salmon spawning in the upper San Joaquin River was presumably around 100,000 fish per year, with the actual number present each year varying widely depending on the combination of ocean and river conditions in previous years. This estimate is based on (1) the fact that some of the final spring runs from 1943 to 1948 reached 30,000-56,000 fish, (2) the historic availability of cold water flows and adult holding habitat in summer, and (3) extrapolations from 19th century canning operations and fisheries. One source claims that, in 1883 alone, 567,000 spring-run Chinook salmon were taken in the in-river fishery; if only half these fish (280,000) were from the San Joaquin River basin, then a total run (escapement + fish taken in the fishery) of at least 300,000 fish was likely (Yoshiyama et al. 1998). Given that hydraulic mining and small dams were already seriously reducing the spawning habitat available in the Stanislaus, Tuolumne, and Merced rivers, it is likely that a high percentage of these fish were spawning in the upper San Joaquin River; the river was being dammed and diverted seasonally at Mendota and Arroyo Canal, but not at times of the year that affected spring-run Chinook salmon migration. Overall, if we assume that 65% of the historic spring-run Chinook salmon spawning habitat (from Friant Dam down to Lanes Bridge) correspondingly supported approximately 65% of the historic spring-run Chinook salmon spawners in the San Joaquin River above the Merced River confluence, then 50,000-100,000 Chinook salmon would be very roughly the minimum pre-dam numbers once supported by the reach downstream of Friant Dam.

From these numbers it is difficult to estimate how many salmon the river can actually support, but if the runs in 1945 and 1946 were derived from spawning in 1941 and 1943, it would suggest that the river had the capacity even then to sustain runs of around 30,000 fish, discounting large losses of spawners to in-river fisheries. Presumably, the river still retained many favorable conditions for the fish, including residual nutrients from past spawning and abundant gravel for spawning, although conditions were already highly disturbed (less water, smaller channel, reduced gravel recruitment, less riparian vegetation).

2.4.2 Run Sizes after Friant Dam

Until Friant Dam began full storage and diversion operations in the late 1940s, water from the reservoir was released down the river and the San Joaquin River continued to support a spring-run Chinook salmon population. Population estimates of returning spring-run Chinook salmon for the years immediately preceding and after the closure of Friant Dam are: 35,000 in 1943, 5,000 in 1944, 56,000 in 1945, 30,000 in 1946, 6,000 in 1947, and 2,000 in 1948 (Yoshiyama et al. 1998). After 1949, there were occasional records of salmon during the 1950s and 1960s, during wet years. The counts are minimum estimates of adult salmon returns not only because of difficulties in counting the fish but because the fish had become exceptionally vulnerable to fishing, both legal and illegal, in the reduced river, and many were captured before they could make it back to their spawning grounds. The counts are also a minimum estimate of “escapement” from the ocean fishery, which captured a substantial percentage of the run before it even entered the San Joaquin River. CDFG biologist Eldon Vestal (1957) made rough calculations that indicated that about 75% of the San Joaquin salmon were lost to all the fisheries in 1946, indicating a total production (catch + escapement) of about 120,000 salmon.

Upstream access was blocked to spawners in 1941, so fish returning post-1943 (including jacks) represent fish from a post-dam river. Progeny from spawners in fall 1941 (both spring and fall-run Chinook salmon) would begin to return in 1943 (2-yr olds), with the majority of the run returning in 1944. Therefore, spring-run Chinook salmon escapement for 1944, 1945, 1946, 1947, and 1948 would be fish wholly derived from spawning under post-dam, pre-diversion conditions. However, flows in the river in 1944 were greatly reduced to fill the dam, which likely affected returns both in 1944 and three years later in 1947. Hydrographs over the other years indicate that flows below Friant Dam were similar, although flows on the lower river were decreasing over that period (Figure 4). Upstream migration access and vulnerability to in-river fisheries would have been an increasing problem.

2.4.3 Numbers in San Joaquin Tributaries

Early dams on the Stanislaus, Tuolumne, and Merced rivers probably eliminated spring-run Chinook salmon from these rivers in the 19th century, but fall-run Chinook salmon populations persisted below the lowest dams. On the Merced River, the run is sustained at least partially by a hatchery. The sizes of the runs show considerable fluctuation and the fluctuations are usually, but not always, synchronous. In recent years, numbers have generally been low (Figure 5) and reasons for this are not clear. Estimated escapement into the rivers ranges from a few hundred fish in some years to over 40,000 fish over a 15 year period. Recent models suggest that adult run sizes are determined mainly by smolt survival, and this is highest in years when outflows of all three rivers are high and synchronous. It appears that much of the smolt (and fry) mortality takes place after they leave the tributary rivers, presumably in the Delta or the ocean where there are a number of adverse conditions. Thus, understanding what factors influence sizes of the fall-runs in the three San Joaquin River tributaries should help to understand future population dynamics of San Joaquin spring-run Chinook salmon and help to find ways to reduce mortality once the juvenile salmon leave the river.

In summary, recent fall-run Chinook salmon escapement averages from 1992-2006 were 3,700 for the Stanislaus River, 4,600 for the Tuolumne River, and 3,800 for the Merced River. When considering applicability of these fall-run Chinook salmon escapement numbers to potential spring-run Chinook salmon escapement targets *during the Interim Period,* the San Joaquin River escapement targets should be of similar scale because:

- Spring-run Chinook salmon yearlings should have better outmigration success than fall-run Chinook salmon smolts, such that returning escapement success per juvenile would be equal or greater for spring-run Chinook salmon juveniles on the San Joaquin River.

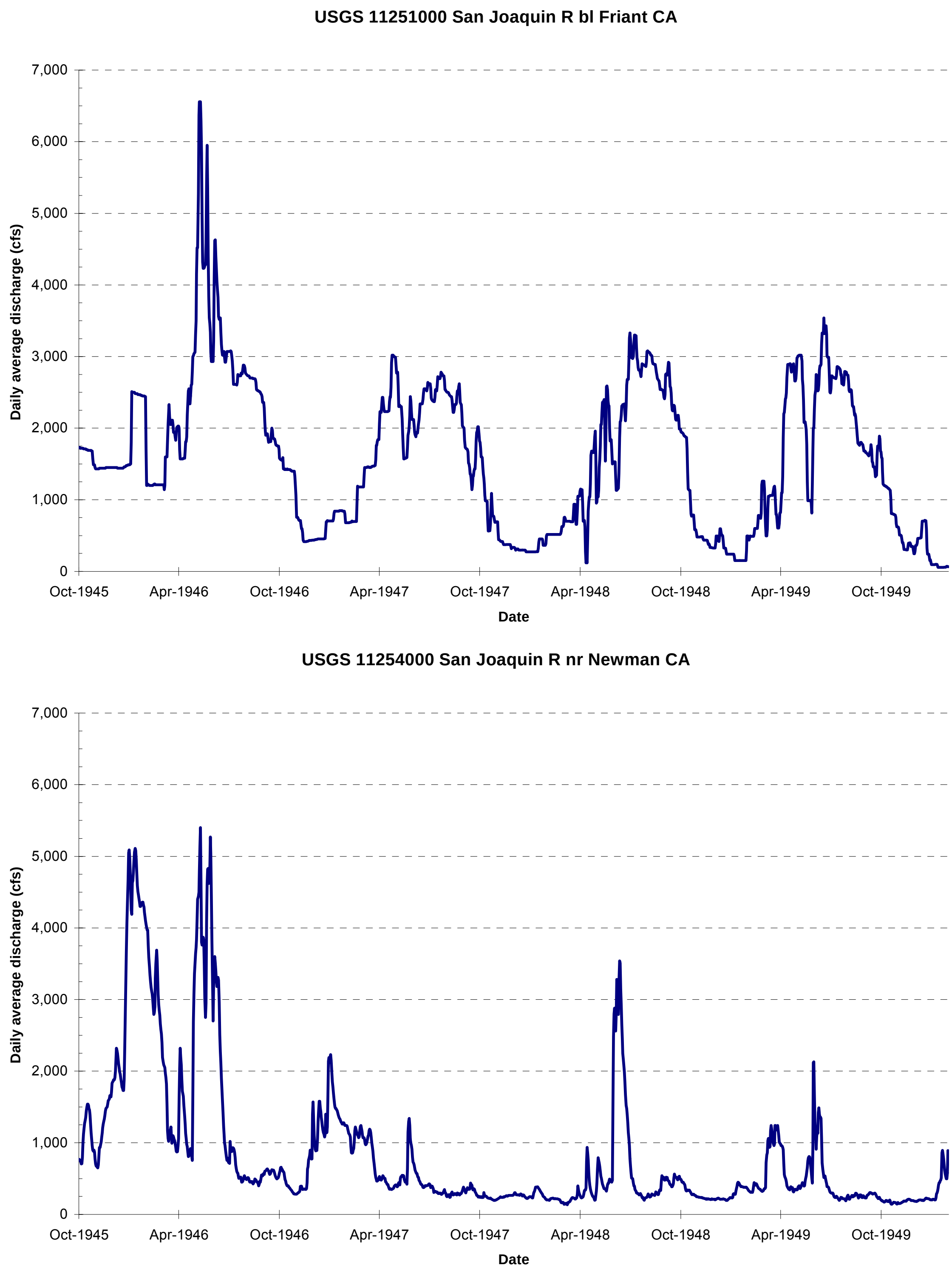

Figure 4. San Joaquin River streamflows A) immediately downstream of Friant Dam, and B) immediately above the mouth of the Merced River near Newman to illustrate fish migration conditions between water years 1946 and 1950.

- Those spring-run Chinook salmon juveniles that do not outmigrate as yearlings will likely be bigger than fall-run Chinook salmon juveniles because of earlier spawning timing, and larger outmigrating juveniles tend to have a higher likelihood of returning as adults.
- The present-day flow releases in the San Joaquin River tributaries are of the same scale as the future flow regime on the San Joaquin River as specified in the Settlement; therefore, salmon escapement should be of similar scale as well.

Overall, we expect adult spring-run Chinook salmon escapement over the Interim Period to be of similar scale to recent adult fall-run Chinook salmon escapement from the San Joaquin River tributaries.

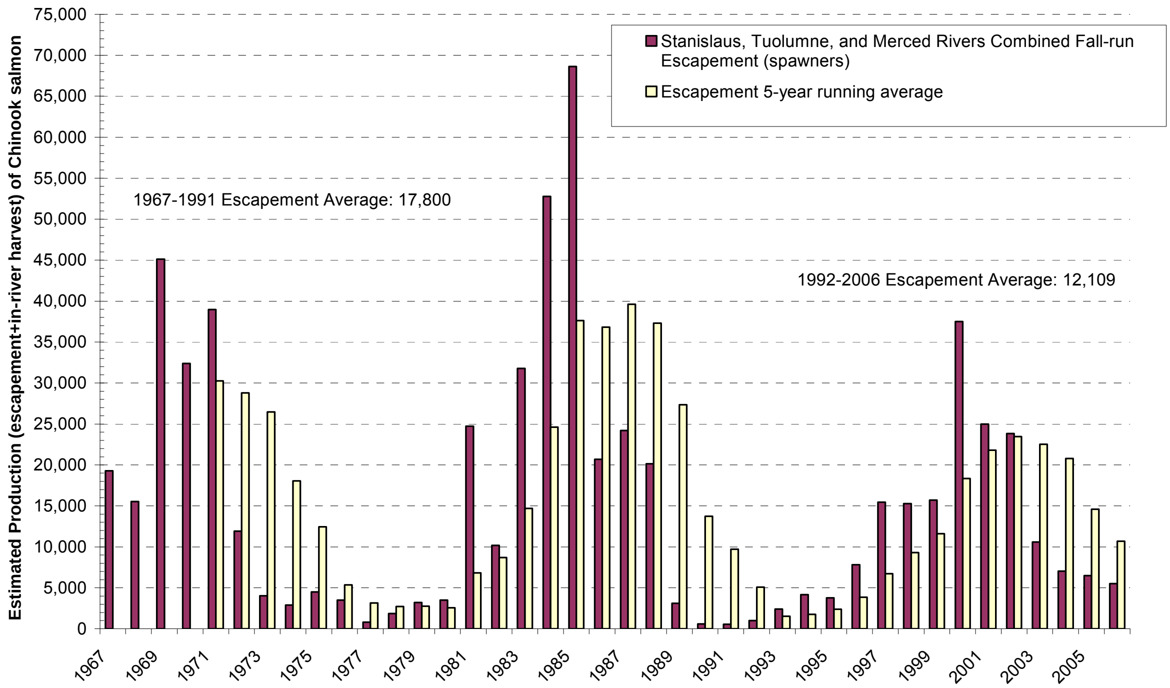

Figure 5. Estimated escapement of fall-run Chinook salmon from the Stanislaus, Tuolumne, and Merced rivers combined. Source: http://www.delta.dfg.ca.gov/afrp.

2.4.4 Recovering Populations

One reason to be optimistic about recovery of San Joaquin spring-run Chinook salmon is that there are two populations of Chinook salmon in the Sacramento River watershed that have recovered dramatically as the result of improved management: Sacramento River winter-run Chinook salmon and Butte Creek spring-run Chinook salmon. Winter-run Chinook salmon populations plunged to near-extinction (Figure 2) but then rebounded following diverse efforts to improve their survival, including: (1) opening the gates at Red Bluff Diversion Dam so as to not to impede migration; (2) lowering summer temperatures in the Sacramento River below Shasta Dam; (3) improving spawning habitat by gravel addition; and (4) reducing take of juveniles at the South Delta pumps. The spring-run Chinook salmon population in Butte Creek rose quickly to higher levels (Figure 3) mainly after barriers to adult migration were removed in the lower creek. Both populations rose to average population sizes of 5,000-6,000 fish in less than 10 years. In the case of Butte Creek, the present run may be close to the number the habitat can actually sustain, although the numbers of winter-run Chinook salmon are still far below historic numbers. The numbers suggest, however, that a sustainable population size (2,500+ fish) can be reached in a shorter period of time than our targets indicate. We project a slower recovery time because:

- The recovery of the two Sacramento River basin populations took place during a relatively benign climatic period (i.e., no severe droughts), which is not likely to be duplicated in the projected recovery period for San Joaquin spring-run Chinook salmon.
- The channel of the Sacramento River through which both runs migrate is fully watered year-round and does not need the large-scale restoration efforts the upper San Joaquin River requires.
- There are no gravel pits potentially impeding outmigration of juveniles in the Sacramento River.
- Water quality of the Sacramento River is generally high at all times, especially following increased cold-water releases from Shasta Dam.
- Pathways through the Delta were different on the Sacramento River side than on the San Joaquin River side, with the main flows of the Sacramento River flowing along the north side of the Delta. While some juveniles enter the Central and South Delta, where they face problems of poor water quality and other health and mortality factors, this is less of a problem than on the San Joaquin side, where all outmigrating salmon are exposed to these problems.

Despite these differences, the potential for rapid recovery of San Joaquin spring-run Chinook salmon exists under favorable conditions of climate and implementation of restoration actions.

2.4.5 Habitat Carrying Capacity

Every cold-water river system has a limited carrying capacity for salmon, wherein one or more habitat elements limit the system's ability to support larger populations of fish than exist there. Presently, it is unclear what will be limiting factors for the spring-run Chinook salmon population in the upper San Joaquin River. Important habitat for non-migrating (adult holding/spawning and juvenile rearing) fish are (1) deep pools for holding over-summering spring-run Chinook salmon adults, (2) gravel riffles for spawning and incubation of embryos, and (3) instream habitat for juvenile rearing. Even today, the reach between Friant Dam and Lanes Bridge still possesses habitat that is suitable for different life stages of spring-run Chinook salmon, given adequate flows. Additional habitat can be restored to suitability using known restoration techniques.

2.4.5.1 Deep pools for holding

Deep pools for holding are needed by spring-run Chinook salmon because they migrate to the spawning reaches in the spring as immature fish and then hold through the summer. After the construction of Friant Dam, at least 5,000 adult spring-run Chinook salmon were observed holding in summer in two pools immediately below the dam (Clark 1942). The largest of the existing pools has a maximum depth of 8 m (26 ft), an average depth of 3 m (10 ft), and covers an area of 8,600 m^2 (93,000 ft^2). Stillwater Sciences (2003) estimated that this pool alone could hold 4,300-12,900 spring-run Chinook salmon through the summer (assuming migration and other habitat conditions were adequate and predation/poaching were not a problem. The numbers of fish that have held through the summer in the area (e.g., 56,000 in 1945) prior to large-scale gravel mining operations, construction of the flood bypass system, and other sources of habitat/migration degradation suggests that large numbers of fish were at one time capable of holding in these areas as long as temperatures were suitably cold. The San Joaquin River channel has changed considerably since the 1940s from a combination of dam-related changes (e.g., loss of coarse sediment supply) and land use changes (e.g., gravel mining); however, the holding pools immediately downstream of Friant Dam have likely not appreciably changed since the mid

1940s. Thus, the extent to which adult holding habitat in the river may limit adult carrying capacity is not known, but it is not likely to be a major factor given the number of fish that held through the summer in the 1940s.

2.4.5.2 Spawning riffles

Spawning riffles with walnut to apple-sized gravels suitable for spawning and incubation still exist in the reach from the dam to Gravelly Ford. The amount and quality of gravel in many of the areas still needs careful evaluation to determine its suitability for spawning and incubation (along the lines of Sommer et al. 2000b), but there is clearly adequate gravel today to support a limited population of spring-run Chinook salmon in the reach below Friant Dam (Table 2). Additional surveys of spawning gravel quantity and quality are reported by Stillwater Sciences (2003). In many areas the existing gravels are intermixed with a relatively high percentage of sand, which affects the ability of salmon fry to successfully emerge. Cain (1997) estimated there was adequate gravel to support spawning by about 5,000 pairs of salmon below Friant Dam. This estimate was 80-90% lower than DFG estimates from the 1950s and reflects the results of vegetation encroachment, instream gravel mining, channel incision, siltation, and reduction in flows due to operation of Friant Dam, Friant/Kern Canal, and Madera Canal. Future spring-run Chinook salmon spawning will likely be focused on the reach between Friant Dam and the Highway 99 Bridge. Spawning habitat estimates from Table 2 (assuming a conservatively high redd size of 216 ft^2 (20 m^2)) suggest that current conditions could support spawning for at least 3,000 adults, and considerably more if smaller redd sizes are assumed.

Fortunately, a variety of actions can help to improve gravel conditions for spawning once flows have been restored to the river. For example, spawning gravels have been successfully added to improve Chinook salmon spawning in many Central Valley streams (Mesick 2001, Wheaton et al. 2004). Gravel for such additions is available in the river terraces along the San Joaquin River. Therefore, physical restoration via gravel augmentation will need to increase, as necessary, the spawning habitat to support the recommended long term targets. In addition, once adult salmon are re-established, the frequent digging and movement of gravel by spawning salmon can improve spawning gravel quality through the mobilization of fine sediment. As part of establishing a restoration strategy for the river, the availability of suitable gravels for Chinook spawning and the carrying capacity under existing and enhanced habitat conditions will be important factors to consider.

2.4.5.3 Juvenile rearing habitat

Juvenile rearing habitat requirements are complex and are closely tied to temperatures and flows. Once the alevins emerge from the gravel, salmon fry require shallow (< 1 m) edge habitat, where they can find small prey and hold at relatively low velocities. Such habitat is presently available and could be expanded with increased flows. As the fry grow larger and more active, they move out into deeper, higher velocity water where larger prey is more available and predators are fewer. Young-of-year (age 0) Chinook often start to move gradually downstream at this stage, the speed of movement and number moving depending, in part, on flows. At this stage, overhead and complex cover are often needed for protection from predators, especially when fish are holding during the day (most migration is at night). Studies by Sommer et al. (2001 a, b) in the Yolo Bypass and the Cosumnes River indicate that if provided the opportunity, these juveniles will move on to floodplains where they grow faster and larger than fry that stay in the river. As the floodplains drain, the juvenile salmon move off with the receding floodwaters.

Many spring-run Chinook salmon juveniles rear in their natal streams for about a year. They basically require cool water through the summer. They typically hold and feed in riffles with complex substrates (boulders, logs, etc.) and at the tails of pools during the day, where they feed on drifting invertebrates. This type of habitat is already present in the reach downstream of Friant

Dam, with adequate summer temperatures, and could easily be improved through addition of structure (logs, boulders) and riparian vegetation. These fish migrate downstream as either large (80-100 mm fork length) juveniles or as smolts.

Source	Extent of Survey	Habitat Area	Potential Adult Population Carrying Capacity		Discussion
			Lower limit based on redd size of 216 ft² (Burner 1951)	Upper limit based on redd size of 55 ft² (EA Engineering 1992)	
Spawning habitat (Clark 1942)	Lanes Bridge to Kirkhoff Powerhouse RM 255.2 – RM 281.5	266,800 ft²	2,470 adults	9,702 adults	Existing habitat is likely less than 1942 habitat, but could create much more spawning habitat for future conditions
Spawning habitat (Fry and Hughes 1958)	Gravelly Ford to Friant Dam RM 229 – RM 267.5	1,000,000 ft²	9,259 adults	36,364 adults	Includes estimates downstream to Gravelly Ford, which probably would not be used for spawning by spring-run Chinook salmon
Spawning habitat (Cain 1997)	Gravelly Ford to Friant Dam RM 229 – RM 267.5	303,000 ft²	2,806 adults	11,018 adults	Numbers based on existing habitat. Could create much more habitat for future conditions
Spawning habitat (R. Ehlers, pers. comm.., in Cain 1997)	Gravelly Ford to Friant Dam RM 229 – RM 267.5	1,820,000 ft²	16,852 adults	66,182 adults	Includes estimates downstream to Gravelly Ford, which probably would not be used for spawning by spring-run Chinook salmon
Spawning habitat (Jones and Stokes Assoc 2001)	Friant Dam to Skaggs Bridge RM 267.5 – RM 234.1	408,000 ft²	3,785 adults	14,836 adults	Based on existing habitat, similar to Cain and Stillwater Sciences. Could create much more habitat for future conditions
Spawning habitat (Stillwater Sciences 2002)	Friant Dam to Highway 99 Bridge RM 267.5 – RM 243.2	357,000 ft²	3,306 adults	12,982 adults	Based on existing habitat, similar to Cain and Jones and Stokes. Could create much more habitat for future conditions

Table 2. Summary of potential spawning habitat capacity information that may inform recommended targets of a self-sustaining population of naturally produced spring-run Chinook salmon in the San Joaquin River.

2.4.6 Genetic and Demographic Models

The standard model based on both genetic and random population (stochastic) factors suggests a minimum viable (= indefinitely self-sustaining) salmonid population is around 500 spawners (Allendorf et al. 1997, Lindley et al. 2007). Cass and Riddell (1999), for example, suggest that 100 female spawners are needed to maintain a population, which translates into 300-500 fish when males and unsuccessful spawners are taken into account. The minimum number suggested by Hedrick et al. (1995) for Sacramento winter-run Chinook salmon, counting fish both spawned in the wild and in restoration hatcheries, is 500+ annual spawners.

In order to achieve the long-term target of >500 spawning fish, 500 fish is recommended to be used as the interim minimum target after six years (starting in 2020). This would show the results of three years of returns from restoration efforts and would indicate the success of the reintroduction strategy. If returns fail to meet the 500 escapement goal in this period, monitoring data should be reviewed, and restoration strategies and efforts should be assessed by the TAC in consultation with implementing agencies to recommend refinements in management actions to improve returns.

It is worth noting that for long-term maintenance of genetic diversity within a population, an *effective population size* of 500 is recommended (Allendorf et al. 1997). This is essentially the minimum number of fish in each year that actually have offspring that survive to contribute to the next generation. Lindley et al. (2007) suggest that for Central Valley Chinook salmon, the proportion of fish that make up the effective population is 20%, so the actual minimum escapement needed is estimated to be approximately 2,500 fish.

2.5 Synthesis

Historic information and present habitat conditions provide reasonable justification for our targets of 500 fish as a minimum population size, 2,500 fish as an interim running average, and 30,000 fish as an approximate long-term target for the average annual population size. Historic numbers and post-dam escapements provide a good indication that the reach between Friant Dam and Lanes Bridge should ultimately support an average of 30,000 spawners, especially if habitat improvements were made. Existing spawning habitat, adult holding habitat, and juvenile rearing habitat, either combined or independently, would most likely be limiting for spring-run Chinook salmon at the present time, at somewhere between 2,200 and 6,500 spawning pairs (ca. 5,000-15,000 fish, including jacks). If we assume that potential spawning areas are the most limiting factor, then an estimate of 2,500 pairs supportable by existing conditions is a reasonable interim target. This number should be increased with channel restoration efforts, probably in association with the reduction of gravel pits as a predation 'sink' for juvenile outmigrants and as traps for spawning gravels. Nutrients provided by the dead adult salmon and other improvements will also enhance ecosystem productivity, improving conditions for rearing of juvenile salmon.

The recent population fluctuations of fall-run Chinook salmon in the three major tributaries to the lower San Joaquin River indicate that outside factors may make it difficult to achieve the stated targets, although the history of recovery of winter-run Chinook salmon and Butte Creek spring-run Chinook salmon in the Sacramento River Basin indicates that recovery could be even more rapid than expected. It is likely that juvenile spring-run Chinook salmon from the San Joaquin will have higher survival rates than juvenile fall-run Chinook salmon from the tributaries, which may mitigate in part for the problems noted for tributary populations. On the other hand, it is obvious that re-establishment of a population of 30,000 spawners will require both successful restoration actions on the San Joaquin River itself (as ordered by the Settlement) and changes in conditions for salmon once they leave the San Joaquin River. However, actions to improve post-river survival are hard to predict at this point.

Thus, our numbers assume restoration will provide adequate spawning and rearing habitat and that there is sufficient cold water and other habitat components to support the salmon. While target escapements will depend on the success of the instream restoration actions called for under the Settlement, there are also a number of potentially harmful conditions that fish could encounter that are completely outside of the control of the Settling Parties. If these conditions persist, they could affect the ability to meet the stated targets.

2.6 Other Considerations

Once the initial efforts to establish a population have started, additional types of information will be useful to establish the carrying capacity of the upper San Joaquin River for spring-run Chinook salmon and to engage in adaptive management of the river and its fish, consistent with the framework of the Settlement.

2.6.1.1 Habitat improvements

As habitat improvements such as gravel addition and cleaning, and growth of riparian vegetation progress, the ability of the environment to support salmon should increase, but other factors (e.g., predation, Delta and ocean conditions) may become increasingly unpredictable and, potentially, limiting. Understanding the tradeoffs among different factors will be crucial for understanding patterns of escapement.

2.6.1.2 Population models

It would be useful to develop a population model that indicates how much fluctuation would be expected and acceptable, based on: (1) studies of fall-run Chinook salmon in the Tuolumne, Merced, and Stanislaus rivers; (2) models for winter-run Chinook salmon in the Sacramento River (Botsford and Brittnacher 1996, Beckman et al. 2007); (3) a model being developed for spring-run Chinook salmon in Butte Creek at UC Davis (L.A. Thompson, pers. comm. 2007); and (4) other models.

2.6.1.3 Straying

The degree to which San Joaquin spring run Chinook salmon 'stray' into other areas will have to be monitored closely to determine the success of imprinting of the fry and smolts produced in the upper San Joaquin River. Concern falls mainly into two areas: (1) straying into the Stanislaus, Tuolumne, and Merced rivers where survival of juveniles is likely to be low and/or hybridization with fall-run Chinook salmon is likely; and (2) straying into spring-run Chinook salmon streams in the Sacramento River system. The latter could actually be regarded as desirable if the number of strays is small (natural genetic exchange) and the San Joaquin fish are not hybridized with fall-run Chinook salmon. At this time, we do not anticipate that either factor is likely to be a major problem, but they may have to be taken into consideration in future management decisions.

2.7 Recommendations

From our review of the information above, and in our best professional judgment, we offer eleven recommendations for Interim and Long-term Targets and Milestones for naturally-produced escapement of spring-run Chinook salmon.

2.7.1 2019 Reintroduction Period

The Settlement requires the following to be considered as one of the criteria in an evaluation of a requested change in the Restoration Flows:

> ". . . beginning 7 years after the reintroduction of spring-run Chinook salmon to the San Joaquin River, whether the annual escapement of wild spring-run adult salmon has dropped below 500 in any year,"

Recommendation 1: The Reintroduction Period should be defined as January 1, 2012, through December 31, 2019.

Recommendation 2: 500 spawners should be the minimum target for fish returning to spawning areas at the end of six years (2019). If returns fail to meet the annual 500 fish target by December 31, 2019, monitoring data should be reviewed, and restoration strategies and efforts should be assessed by the TAC in consultation with implementing agencies to recommend refinements in management actions to improve returns.

2.7.2 2020-2024 Interim Period

Recommendation 3: The Interim Period should be defined as January 1, 2020, through December 31, 2024.

Recommendation 4: The five-year running average target for escapement should be at least 2,500 fish, with allowable population fluctuation between 500 and 5,000 spawners (upper limit to guide maximum capacity of spawning habitat).

Recommendation 5: 500 spawners should be the minimum target for fish returning to spawning areas for any given year after 2019. If the number drops below 500 fish in any given year, or if the targets outlined in Recommendation 4 are not achieved, monitoring data should be reviewed, and restoration strategies and efforts should be assessed by the TAC in consultation with implementing agencies to recommend refinements in management actions to improve returns.

Recommendation 6: Assessment of success of achieving interim targets should take into account fluctuations of other salmon populations in the Central Valley, to serve as indicators of unfavorable conditions for survival of juvenile salmon outside the San Joaquin River system.

2.7.3 2025-2040 Growth Population Period

Recommendation 7: Between 2025 and 2040, the target for the 5-year running average of spawners should increase from 2,500 to 30,000 spawners, and the rate of increase of the number of spawners (cohort replacement rate) should be greater than 1.00.

Recommendation 8: During the Phase 1 and Phase 2 of the Restoration Actions, create in-river holding, spawning, and rearing habitat necessary to support the upper range of returns (45,000 spawners) for the Long-term Period.

2.7.4 2041+ Long-term Period

Recommendation 9: The Long-term Period should be defined as beyond January 1, 2041.

Recommendation 10: By 2040, the long-term target for annual escapement of spring-run Chinook salmon should be a 5-year running average of 30,000 spawners, providing for 50% range of fluctuation (15,000-45,000 spawners).

Recommendation 11: A major re-evaluation of population status should occur at a maximum every 15 years (in addition to routine annual population status assessment).

3 RECOMMENDED STOCK SELECTION AND INITIAL STRATEGIES FOR REINTRODUCING SPRING-RUN CHINOOK SALMON INTO THE SAN JOAQUIN RIVER

The purpose of this section is to describe the TAC recommendations to the RA with regard to (1) objectives, criteria, and procedures for use in selecting the appropriate stock(s) for reintroduction; (2) objectives and principles used to develop a reintroduction strategy; (3) initial recommendations on stock selection and reintroduction strategies; and (4) the need for a robust adaptive management strategy to serve as an appropriate framework for the restoration program. These recommendations of the TAC focus on spring-run Chinook salmon, but we recognize that the principles and procedures set forth could also apply to stock selection and reintroduction strategies of other runs (e.g., fall-run/late fall-run Chinook salmon) which will be addressed in the near future in a follow-up report.

3.1 Stock Selection Objectives, Criteria, and Procedures

3.1.1 Goals and Objectives

The primary goal is to establish a naturally reproducing and self-sustaining population of Central Valley spring-run Chinook salmon because the spring-run was historically the most abundant run in the upper San Joaquin River.

The primary objective is to identify the stock(s) of spring-run Chinook salmon with the greatest likelihood of establishing a self-sustaining population in the upper San Joaquin River. The ‘best’ stock should have life history traits (e.g., adult and juvenile migration timing, habitat requirements, and environmental tolerance) that are compatible with anticipated future habitat conditions (e.g., seasonal hydrology, water temperatures, and physical habitat) within the upper San Joaquin River.

3.1.2 Recommended Stock Selection Criteria and Procedures

The general process recommended for evaluating and selecting a preferred spring-run Chinook salmon stock as a founding population for the San Joaquin River reintroduction strategy is shown in Figure 6. The individual criteria recommended for stock selection are briefly outlined below. For each criterion, we provide reasons for its consideration (importance) as part of stock selection. We also provide a professional judgment of the level of certainty regarding the confidence in the recommendation. The certainty measure is a reflection of the importance of the criterion: high certainty indicates that is should be part of the stock selection process, while lower certainty categories indicate that research is needed to improve the certainty that the principle is important to stock selection decisions. For this report, only criteria with a high measure of certainty or, in one case, a moderate measure of certainty, are recommended. Potential criteria thought to have lower measures of certainty are not discussed. Recommended criteria to be used in evaluation and selection of a preferred founding stock to be considered are described in the following sections.

3.1.2.1 Stock should be of local or regional origin (Central Valley)

Spring-run Chinook salmon inhabiting the San Joaquin River will be exposed to a variety of potentially stressful environmental conditions, including exposure to seasonally elevated water temperatures. We hypothesize that spring-run Chinook salmon stocks that have adapted to local or regional environmental conditions within the Central Valley will be most successful in adapting to the future environmental conditions on the San Joaquin River. Stocks currently inhabiting other Central Valley rivers and tributaries are expected to exhibit local adaptation (e.g., populations inhabiting the southern boundary of the species geographic distribution may have higher thermal tolerances, compatible migration times and residence patterns, etc.). Local stocks are also expected to create fewer problems associated with potential straying and interbreeding with existing stocks. Based on the best available information, our confidence in recommending that the stock be selected from currently existing stocks inhabiting the Central Valley is high.

3.1.2.2 Stock should be genetically diverse

Given the inherent variation in potential future environmental conditions affecting spring-run Chinook salmon on the San Joaquin River, and the desire to provide opportunities for local selection pressures (e.g., seasonal run timing of adults and/or juveniles to coincide with the seasonal restoration hydrograph, tolerance to seasonally elevated water temperatures, etc.), we recommend that the founding stock have adequate genetic material (i.e., population abundance and genotypic/phenotypic diversity) to allow San Joaquin River specific pressures to eventually produce a locally adapted stock. To achieve this objective in stock selection, we recommend that a genetic management plan be developed, in consultation with a qualified fish geneticist, to help guide selection and implementation of the founding stock selection. Several topics to be determined in the genetic management plan include: (1) how adult brood stock should be selected from a population to enhance genetic diversity; (2) what the appropriate number of brood adults should be; (3) what types of genetic testing should be done to characterize the existing population, and other factors. Based on the best available information, our confidence is high in recommending that the founding stock be genetically diverse to ensure the greatest potential for local adaptation to San Joaquin River conditions.

3.1.2.3 Stock use should take into account the status of the source population

Spring-run Chinook salmon inhabiting the Central Valley have been listed as a threatened species under both the California and federal Endangered Species Acts. Spring-run Chinook salmon appear, based on analyses to date, to be the most compatible species, given their life history characteristics, for selection as a primary element of the San Joaquin River Restoration Program. The selection of Central Valley spring-run Chinook salmon as a founding stock for the San Joaquin River has both potential beneficial and adverse effects on existing population dynamics. The collection of a large number of adults from an existing population of spring-run Chinook salmon could potentially result in adverse impacts to the existing stock (e.g., loss of reproduction within a given tributary and independent population) if not carefully managed as part of the stock selection process. In contrast, establishing another independent spring-run Chinook salmon population in the San Joaquin River that is geographically remote from the current populations inhabiting the Sacramento River tributaries (expansion of the current species range) could increase the diversity and stability of the Central Valley population and directly contribute to overall recovery of the species. As part of stock selection, we recommend that consideration be given to factors reflecting the status of the source population, such as the current trends in abundance and whether existing habitat within the source watershed is fully used (i.e. “surplus” fish are available for relocation with minimal or potentially beneficial effects). Our confidence that stock can be selected from an existing population with minimal or no adverse impact to the founding stock, while satisfying the first two criteria (Section 3.1.2.1 and 3.1.2.2), is moderate. We recognize that it is possible that removal of some fish from Sacramento River populations for the San Joaquin River reintroduction program may have a negative impact on existing Sacramento River stocks if the stocks have low numbers. However, this will have to be balanced against the long-term potential for the San Joaquin River introduction to contribute to overall Central Valley spring-run Chinook salmon stock recovery.

Identify Potential Candidate Founding Stocks

↓

Characterize Each Stock

- -Genetic Characteristics
- -Life History
- -Physiological and behavioral characteristics
- -Population status (abundance, hatchery influence)
- -Availability for transport

↓

Evaluate Stock Characteristics with Respect to Compatibility with San Joaquin River Conditions

- -Adult run timing
- -Holding habitat requirements
- -Spawning requirements and timing
- -Juvenile rearing
- -Juvenile migration
- -Tolerances

↓

Prioritize Stocks for Reintroduction

- -Identify life stages and numbers required
- -Impacts to source population
- -Compatibility and adaptability

↓

Recommend Founding Stock(s)

Figure 6. Overview of recommended stock selection process.

3.1.2.4 Stocks used should not jeopardize existing Chinook salmon stocks in the San Joaquin basin

The San Joaquin River tributaries currently provide habitat, and support populations of fall-run Chinook salmon but do not support populations of spring-run Chinook salmon. The selection of a Central Valley salmonid stock(s) for reintroduction into the upper San Joaquin River will probably result in a few adults straying into downstream tributaries. Adult straying, although a natural phenomenon among salmon, has the potential to (1) introduce new diseases into an existing salmon population, or (2) hybridize with local fall-run Chinook salmon populations. Neither of these problems is likely to be a major concern with spring-run Chinook salmon because the stocks proposed to be used are of regional origin and should have the same disease exposures. The proposed stocks are likely to have minimal overlap in spawning time and space with San Joaquin River fall-run Chinook salmon stocks. In addition, because Central Valley spring-run Chinook salmon populations currently exhibit a relatively low degree of inter-basin movement based on their genetic distinctiveness, straying is not expected to be a major problem in any case. However, some future straying of San Joaquin River spring-run Chinook salmon is expected and will need to be monitored for potential adverse effects. We recommend that measures to assure fidelity to the San Joaquin River spawning areas, such as juvenile imprinting and marking programs, be used to help reduce inter-basin movement of spring-run Chinook salmon from the upper San Joaquin River to downstream tributaries while establishing the initial population on the upper San Joaquin River. Based on the best available information, our confidence is high that stocks used for introduction can be selected and managed to minimize straying and inter-basin movement within the San Joaquin River and tributaries.

3.1.2.5 Stock should have life history characteristics that maximize the probability of successful reintroduction into the upper San Joaquin River

We acknowledge that the Settlement hydrographs will be limited in both magnitude and duration. Based on the best available information, we expect that (1) seasonal exposure to elevated water temperatures during migration will occur, (2) competition and predation will affect spring-run Chinook salmon abundance, and (3) other environmental and biological factors will affect survival and abundance of spring-run Chinook salmon inhabiting the upper San Joaquin River. To increase the likelihood of success of the selected stock in adapting to local environmental conditions in the San Joaquin River, we recommend that a founding stock be selected that has behavioral and life history characteristics most compatible with the anticipated conditions on the San Joaquin River. Existing populations currently inhabiting the Central Valley exhibit a range of life history characteristics (e.g., variation in seasonal migration timing for adults and juvenile, etc.). A closer match between the behavioral characteristics and habitat requirements of the founding stock and the anticipated habitat constraints on the San Joaquin River is more likely to result in successful establishment of the run. In selecting a founding stock, careful consideration should be given to selecting the stock that has a life history most compatible with projected San Joaquin River conditions and therefore would maximize the likelihood of a successful reintroduction. Results of a preliminary assessment of potential founding stocks indicate that the Butte Creek spring-run Chinook salmon has life history characteristics that may be most compatible with the anticipated future environmental conditions on the upper San Joaquin River. The TAC recommends that a more detailed analysis be conducted to further evaluate the potential use of the Butte Creek and other potential founding stocks as part of refining the San Joaquin River reintroduction strategy. Based on the best available information, our confidence is high in recommending that the stock should be selected based, in part, on the compatibility of current life history characteristics with anticipated habitat conditions and potentially limiting factors on the San Joaquin River.

3.1.2.6 Stock should have behavioral and physiological characteristics that fit conditions expected to occur on the San Joaquin River

As discussed in response to the criterion in the previous section, existing spring-run Chinook salmon stocks inhabiting Central Valley rivers and tributaries each have somewhat distinct behavioral and physiological characteristics that reflect local adaptations to environmental conditions occurring within a specific watershed. Similarly, the San Joaquin River is anticipated to have distinctive environmental conditions that will affect the seasonal timing of migration, reproduction, growth, and survival of the population. Although a population would be expected to adapt to these conditions over a period of generations in response to natural selection pressures, the most rapid adaptation would occur if the founding stock had behavioral and physiological characteristics that were most compatible with the future environmental conditions of the San Joaquin River. We recommend that information on behavioral characteristics such as seasonal run timing, adult holding, spawning period, habitat requirements, and response to seasonally elevated water temperatures should be compiled for potential candidate founding stocks and evaluated in comparison to the anticipated conditions in the San Joaquin River. Even small or subtle variation in these characteristics among stocks may have an influence on their long-term survival within the San Joaquin River. Based on the best available information, our confidence is high in recommending that the stock should be selected based, in part, on the compatibility of current life history characteristics with anticipated habitat conditions and potentially limiting factors on the San Joaquin River.

3.1.2.7 Hatchery stock should not be used for restoration

Several salmon hatcheries exist within the Central Valley, including hatcheries on the Merced River, Feather River, and upper Sacramento River, that could potentially provide adult salmon, fertilized eggs, or juvenile salmon for use in the San Joaquin River restoration program. There has been considerable concern expressed regarding potential effects of hatchery propagation on the genetic characteristics and diversity of salmonids within the Central Valley. Although efforts are currently underway to develop genetic management programs for these hatcheries, the TAC recommends that hatchery stocks not be used for founding the San Joaquin River salmon restoration program. The TAC recommends that only wild stocks be used. Our confidence in this recommendation is high.

3.1.2.8 Develop a genetic management plan for the reintroduction

One question that should be answered before spring-run Chinook salmon are introduced into the upper San Joaquin River is whether the introduction should be based on one founding stock or multiple founding stocks, assuming life history characteristics of all stocks are similar. Thus, the evaluation of potential founding stocks for use in the reintroduction strategy should require analysis of genetic information on each of the candidate stocks. We recommend that a genetic management plan be developed that compiles, synthesizes, and integrates this genetic information to go along with an assessment of the compatibility of each stock based on the seven evaluation criteria outlined above. This plan should guide the reintroduction process, and results of the analysis should be used to refine (if needed) the recommended founding stock(s) for the reintroduction strategy. The genetic plan should also address the best way to maintain annual populations above the minimum threshold population size of 500 fish, and should include a genetic monitoring program. Our confidence in this recommendation is high.

3.2 Reintroduction Strategy Objectives and Principles

3.2.1 Goals and Objectives

The primary goal is to establish a self-sustaining population of spring-run Chinook salmon following the goals and objectives outlined in Sections 2.1 and 3.1.1.

3.2.2 Reintroduction Principles

The process recommended for reintroducing spring-run Chinook salmon into the upper San Joaquin River is based on a tiered strategy that includes: (1) extensive experimental investigations designed to inform adaptive management decisions, use a variety of techniques and diverse approaches to spring-run Chinook salmon transfer and reintroduction to test and identify the most successful approach, extensive human intervention (e.g., trap and haul, stream-side incubators, etc.), and transfer of the selected stock from out of basin areas into the San Joaquin River during the early phase of reintroduction; and (2) a phased reduction in the level of human intervention as a self-sustaining population of spring-run Chinook salmon becomes established within the river. The factors and considerations used in developing the reintroduction strategy and specific recommendations by the TAC are briefly outlined below.

3.2.2.1 Use best available stock(s)

As discussed above, the greatest likelihood of achieving a successful reintroduction of spring-run Chinook salmon to the San Joaquin River depends, in part, on the compatibility of the life history characteristics of the founding stock with future environmental conditions on the San Joaquin River. Careful stock selection based on the compatibility of the stock and ability to adapt to San Joaquin River conditions will be important determinants in the long-term success of the reintroduction strategy. Stock selection should not necessarily be made solely on those stocks that are most available.

3.2.2.2 Use a mixture of reintroduction strategies

One of the principles used by the TAC in developing the framework for the proposed reintroduction strategy is to identify a wide variety of potential management actions and integrated reintroduction strategy elements in the initial phase of the program. This mixture of strategies can then be refined and modified based on results of a genetic management plan and further analyses used to develop a specific recommended reintroduction strategy and associated performance monitoring and adaptive management plan. Reintroduction of a stock from one watershed into another with highly variable environmental conditions and other constraints is characterized by a high degree of uncertainty. The success of various reintroduction strategies within the San Joaquin River is currently uncertain and will be subject to some degree of experimentation and performance evaluation within the overall framework of adaptive management. A number of alternative strategies exist for reintroduction that could range from complete reliance on in-river natural reproduction to complete human intervention through hatchery propagation (e.g., spawning and rearing wild stocks in a hatchery with planting in the river). The TAC recommends that in the early stages of the reintroduction, a blended strategy be used that relies on a wide variety of techniques offering a diversified approach to reintroduction while avoiding the use of hatchery rearing, if at all possible. The goal of this approach is to diversify the approaches and actions supporting reintroduction to maximize the likelihood of success and to increase genetic diversity within the founding stock. The recommended approach includes a phased reintroduction strategy that includes greater intervention (e.g., trap and haul, use of hatch boxes and stream-side incubators, etc.) in the early years until the stock has been established and local adaptation begins to occur, followed by a phasing out of the level of intervention and a greater reliance on a self-sustaining, in-river, naturally reproducing population.

3.2.2.3 Choose reintroduction strategies at least partly based on the ability to maximize the learning potential and inform potential adaptive management decisions

While we have high certainty that reintroduction can successfully be done, there is a significant amount of information that needs to be developed to improve the success and effectiveness of reintroducing spring-run Chinook salmon to the upper San Joaquin River. Recognizing the value of additional information which will reduce inherent uncertainties, the TAC has recommended that the structure of the reintroduction strategy and subsequent performance evaluation of management actions and success of reintroduction be conducted within a formal adaptive management framework. The reintroduction strategy and performance evaluation would be structured to include hypothesis testing to inform refinements and adjustments in the implementation of future management actions. The reintroduction strategy should include, in part, identifying those restoration and management actions that could be designed to maximize the information and learning during the initial phases of implementing the reintroduction strategy that would have long-term value in refining future decisions. For example, introducing adult spring-run Chinook salmon into the upper San Joaquin River prior to the formal reintroduction period could provide information on the availability and quality of holding and spawning habitat. Releasing juvenile fish at a size that allowed them to be marked or remotely tracked could provide information on rearing habitat, migration corridors, and sources of mortality. The use of artificial spawning and hatch boxes would permit the genetic tracking of progeny of each pair of fish through the use of Single Nucleotide Polymorphism (SNP) markers and/or mitochondrial DNA characterization. Thus, the source (from alternative reintroduction techniques) and numbers (performance evaluation) of fish returning to the upper San Joaquin River could be determined and this information could be used subsequently to modify or refine future elements of the reintroduction strategy. The need for information, especially early in the program, may be one of the primary considerations in selecting methods for reintroduction, even though those methods may not be the most efficient means by which to reintroduce salmon. Based on the best available information, our confidence is high in recommending that the reintroduction strategy be based, in part, on the ability to identify testable hypotheses and conduct performance evaluations that provide information useful in modifying or refining future elements of the reintroduction strategy through a formal adaptive management framework.

3.2.2.4 Application of hatchery production, human intervention, and trap and haul techniques as part of the reintroduction strategy

Although the long-term goal of the San Joaquin River restoration program is to establish a self-sustaining naturally produced spring-run Chinook salmon population and eliminate the need for artificial spawning and rearing programs, the TAC expects that intervention will be required in the early phases of reintroduction, and potentially periodically throughout the program (e.g., in response to extended drought conditions). The TAC recommends that direct human intervention in enhancing salmon numbers should be gradually phased out as part of the ongoing management strategy and subsequently reserved for emergencies (e.g., extreme drought). Intervention can take a variety of forms that include, but are not limited to, trap and haul of adults and/or juveniles, use of stream-side egg incubators and hatch boxes, and so on. As discussed above, the TAC recommends that a wide variety of techniques, including intervention techniques, be used to help establish the initial founding population on the river. As the founding population becomes better established over time and able to respond to conditions through local adaptation, the reliance on intervention techniques can be reduced with a greater proportion of the production originating from in-river spawning and rearing. The San Joaquin River watershed, however, is subject to wide variation in hydrologic conditions, including both floods and droughts that affect habitat conditions, reproduction, and survival of salmonids. For example, under future conditions of an extended drought, conditions on the San Joaquin River for adult and/or juvenile migration may be highly stressed or unacceptable for one or more years. Under these conditions, future limited intervention may periodically be required in order to protect and maintain the founding stock. Additionally, the use of hatcheries and other intervention techniques as part of the reintroduction strategy is discussed in Section 3.3. Based on the best available information, our confidence is high in recommending that the reintroduction strategy be based on a phased program of reducing intervention over time, with a progressively greater reliance on in-river reproduction and rearing as part of the long-term management framework and as necessary to meet the population targets that are based on naturally reproduced adult escapement.

3.2.2.5 A multifaceted monitoring program and adaptive management framework should be integral to the reintroduction strategy

The TAC recommends that the San Joaquin River reintroduction strategy should be developed using the best available information to identify appropriate restoration objectives and corresponding restoration actions. As recommended above, the reintroduction program should include a wide variety of management actions and a corresponding monitoring program to evaluate success and to inform future decisions regarding the prioritization of management actions, refinements or modifications to implementation, or identifying new or alternative management actions as part of the long-term reintroduction strategy. Although the TAC has not identified a specific recommendation for a monitoring program to evaluate performance of individual management actions, several of the key elements recommended to be included in a monitoring program are outlined below.

<u>Population and genetic monitoring programs of both source and San Joaquin stocks are necessary to determine success</u>

Determining the numbers of spawners, numbers of juvenile outmigrants, survival rates, genetic diversity, and other parameters can allow models to predict immediate effects of the reintroduction program as well as long-term stock persistence. This element of the monitoring program should consider both the success of various reintroduction actions in producing spring-run Chinook salmon and the genetic characteristics of the population over time as it adapts and responds to selective pressures within the San Joaquin River. The value of the resulting information in evaluating the long-term performance of the reintroduction strategy and the effectiveness of individual management actions in contributing to the overall restoration goals is high.

<u>Habitat use within various reaches of the San Joaquin River should be monitored</u>

A variety of habitat features have been identified that may affect adult migration, holding, spawning, egg incubation, juvenile rearing, or survival of emigrating juveniles within the San Joaquin River. There is a considerable amount of uncertainty in the biological response of salmonids to these factors. For example, the pathway, environmental cues, and rate of upstream and downstream migration within the river, and the response to factors such as exposure to seasonally elevated water temperatures, alternative migration pathways, physical impediments, and hydrologic conditions will require further investigation. Similarly, there is uncertainty in the importance of features such as captured gravel pits on the migration pathway, rate of migration, exposure to elevated temperatures, and vulnerability to increased predation mortality. The TAC recommends that a focused effort be given to the compilation of information available from monitoring salmonid populations on other Central Valley river systems and a critical assessment of monitoring needs and alternative approaches. The TAC recommends that a robust monitoring and evaluation program be designed and implemented to address and evaluate these and other key issues affecting the design, implementation, priorities, and success of the reintroduction strategy and for informing future decisions regarding refinements or modifications to the reintroduction strategy. The value of the resulting information in evaluating the long-term performance of the reintroduction strategy, and the effectiveness of individual management actions in contributing to the overall reintroduction strategy, is high.

3.2.2.6 Consider a range of environmental factors when assessing the restoration program performance

Salmonid populations are affected by a wide variety of biological and environmental factors beyond those that occur within the upstream spawning and juvenile rearing habitat (e.g., conditions in the Delta and ocean). In addition, factors such as natural variation in hydrologic conditions within a watershed can also have a significant effect on salmonid survival and abundance. In developing the recommended goals for the San Joaquin River restoration program (Section 1), the TAC acknowledged that population abundance on the San Joaquin River is expected to be highly variable among years and that variation should be taken into consideration when evaluating program performance. In this regard, the TAC recommends that evaluation of program performance not be based on results from any one year but rather performance should include consideration of meeting the minimum population target over a period of years reflecting multiple cohorts and generations. Thus the number of fish returning (for example) in a single year may not be indicative of re-establishment success. Results of the monitoring program can be used to help evaluate the contribution, or lack thereof, of various elements of the reintroduction strategy in meeting the long-term goals of the program. The TAC recommends, however, that caution be exercised in modifying the fundamental reintroduction strategy until a clear trend has been established, which may take a number of years to become evident. Rapid modifications to the fundamental reintroduction strategy in response to short-term or individual events is expected to make interpretation of long-term monitoring and performance evaluation results difficult to interpret and use for making meaningful modification within the adaptive management framework.

3.2.2.7 Spring-run Chinook salmon should have higher priority for reintroduction than fall-run Chinook salmon

The Settlement envisions restoration of both spring-run and fall-run Chinook salmon to the upper San Joaquin River. Spring-run Chinook salmon typically spawn during September and October while fall-run Chinook salmon typically spawn during October-December. As a result of the overlapping in seasonal timing and location of spawning within the upper San Joaquin River (Reach 1), there is the potential for (1) hybridization between the two runs that may adversely or beneficially affect population genetics, and (2) fall-run Chinook salmon superimposition of redds that would adversely affect reproductive success of the earlier spawning spring-run Chinook salmon. Hybridization between the two run types, especially early in the reintroduction program, could reduce potential for establishing a spring-run phenotype and increase problems with fish that might stray into spring-run Chinook salmon streams in the Sacramento Valley. Very large fall-runs could overwhelm small populations of spring-run Chinook salmon and eliminate the spring-run phenotype. However, in the Feather River, the two forms apparently hybridize freely and both phenotypes are maintained. The TAC recognizes that the potential for these effects to occur is uncertain, but recommends that the reintroduction strategy make the reintroduction of spring-run Chinook salmon as the primary objective in the early phase of restoration. Various types of management actions could be implemented on an adaptive basis in the event that monitoring results show adverse effects of fall-run Chinook salmon in meeting the primary restoration objective (e.g., segregation weirs, altered hydrology to regulate migration of fall-run Chinook salmon, management of fish passage and ladders, etc.).

3.3 Synthesis

The reintroduction strategy relies on a phased program of intervention. During the early phases of reintroduction, experimental investigations and monitoring will be important in informing adaptive management decisions and refinements to the reintroduction strategy as new information becomes available. During the early phases of reintroduction, a wide variety of techniques and approaches would be applied and tested, and all of the selected spring-run Chinook salmon would originate from out-of-basin stocks with a relatively high degree of human intervention. As a self-sustaining population becomes established on the upper river, the transfer of out-of-basin stocks would decrease and the proportion of in-river spawning to support the population would increase with the ultimate restoration goal of re-establishing a self-sustaining and naturally reproducing spring-run Chinook salmon population (and fall-run Chinook salmon population) on the San Joaquin River. The sections below briefly outline the TAC expectations and vision of the phased approach to the reintroduction strategy.

3.3.1 Phase 1 – Experimental Phase (Prior to 2012)

The early phase of restoration implementation is expected to be experimental and designed to test basic hypotheses and provide information useful in refining the reintroduction strategy under an adaptive management framework. In the beginning of Phase 1, emphasis would focus on identifying uncertainties, hypotheses to be tested, and key management decisions that require additional information or validation. Within the context of the framework provided by the initial reintroduction strategy, specific questions would be identified for preliminary testing using various life history stages of spring-run or fall-run Chinook salmon. During the Interim Period, experiments with different reintroduction methods could be designed and tested. For example, 10 pairs of adult salmon from Butte Creek could be transported to the reach between Friant Dam and Lanes Bridge. Their spawning behavior, choice of adult holding and spawning sites, and survival of embryos in gravel could be monitored. In addition, embryos could be experimentally incubated in hatch boxes in various locations in the below-dam reach to determine optimal sites for such procedures. Salmon fry reared in a hatchery under normal crowded conditions and in a low density enriched environments could be individually marked and released into the river to compare survival. Results of these and other tests could then be used to help refine population models of the number of broodstock, eggs, fry, or smolts that would need to be introduced in a particular year to achieve the target for returning adults. This approach would make use of both conceptual and quantitative life-history models to identify uncertainties and apportion the expected number of returning adults (or available broodstock) to each of these life history stages (or experimental designs) as part of the reintroduction strategy. Information gained from these experimental tests during the early phase of the program implementation would help refine both the predictive models as well as improve water and fish management and habitat conditions as part of the overall reintroduction strategy. This approach adopts a variety of different methods (or mixed strategies) for reintroduction. The range of methods and test conditions would be reduced as specific questions are addressed and as uncertainty in the reintroduction strategy performance is reduced. The experimental phase runs some risk that experimental fish may ‘escape’ from the study area (e.g., with high flows) and then return after the reintroduction has begun.

3.3.2 Phase 2 – Early Introduction Phase (2012-2019)

All introductions would be made of fish with known genetic history, using progeny of a minimum of 50 pairs of spring-run Chinook salmon each year (out of basin). If there is high success using hatch boxes in the experimental phase, then this should be the primary method of introduction. Each box should contain embryos (eggs) of known parentage so the young can be tracked genetically. This will allow close monitoring of effective population sizes, with genetic diversity gradually increasing with each year. If stream incubation boxes prove too limiting in numbers of fish produced, then a stream-side hatchery system should be developed whereby embryos of known parentage are incubated and planted as fry to augment in-river spawning. During Phase 2, experimental testing and monitoring of the performance and contribution of various management actions and approaches would continue to inform adaptive management decisions and identify refinements to the reintroduction strategy. As the population of spring-run Chinook salmon becomes better established and increases in abundance, Phase 2 would serve as a transition from a greater reliance on human intervention as in Phase 1 to a greater reliance in natural, in-river spawning and production to support a self-sustaining population.

3.3.3 Phase 3 – Establishment Phase (2019-2037)

In the first nine years of Phase 3, use stream incubator boxes along with close monitoring of returning adults until it is determined that genetic diversity and population demographics (e.g., trends in abundance relative to the targets outlined in Section 2.3, reproductive success of in-river spawning spring-run Chinook salmon, juvenile survival, age structure, etc.) is adequate for a self-sustaining population. Consideration will also need to be given to identifying environmental conditions where human intervention in the future can be reduced and those circumstances (such as under an extended drought) when management actions, such as limited trap and haul or other actions, may be required to protect the population. If by year 10 (2029), it appears that population sizes are still too small, monitoring data and restoration strategies and efforts should be assessed by the TAC in consultation with the other implementing agencies, and recommendations should be developed to improve returns.

3.4 Information Needed to Refine and Implement Reintroduction Strategy

In developing the initial reintroduction recommendations outlined above, a range of additional information would be useful to refine and implement the reintroduction strategy. These needs include, but are not limited to the following:

- Review additional literature on the design and success of reintroduction strategies for salmonids to help develop restoration guidelines and milestones. Information is available on the life-history requirements, behavior, environmental conditions, and other factors that should be taken into consideration in developing and refining the reintroduction strategy. In addition, information is available from other fishery restoration programs, involving salmonids and other fish species, that would help provide insight into those management techniques and experimental/monitoring programs that have proven to be successful and potentially applicable to the San Joaquin River.
- Develop a genetic management plan. Protecting and promoting genetic diversity within the re-established San Joaquin River spring-run Chinook salmon population is an important consideration in developing and implementing the reintroduction strategy. A qualified geneticist, familiar with salmonid populations, should assist in evaluating the potential beneficial or adverse effects of alternative management actions on population genetics, developing the criteria and monitoring protocols for genetic management, and the overall integration of genetic considerations into the development and implementation of the reintroduction and restoration plan.
- Select stock for reintroduction. As discussed above, a variety of spring-run and fall-run Chinook salmon stocks are potentially available for use as a founding stock for reintroduction. Selection of a founding stock would be based on a variety of considerations including, but not limited to, the geographic location of the stock, seasonal timing of adult and juvenile migration relative to the anticipated environmental conditions on the San Joaquin River, population genetics, compatibility with Central Valley habitat conditions, and other factors. The general considerations and process recommended by the TAC for stock selection are outlined in Section 3.1.
- Evaluate alternative management actions and methods for reintroduction. Actions and methods may include: evaluation of trap and haul (timing and location of trapping and release, transport of immature adults vs. fertilized eggs, etc.); determining locations for trapping adults and juveniles within the San Joaquin River as part of trap and haul operations in dry and critical water years; determining allocations and performance of alternative production techniques, such as stream-side egg incubators with volitional

release, egg incubator boxes and artificial redds; consider using the hatchery to produce various life stages of juvenile spring-run Chinook salmon and alternative planting strategies; evaluate the allocation between in-river production and alternative production techniques, evaluate needs for segregation between spring-run Chinook salmon and other salmonids; determine adult holding, spawning, and juvenile rearing habitat opportunities and constraints; and other elements of the initial reintroduction strategy.

- Develop monitoring plan. Establish monitoring methods and procedure (e.g., SNP markers, weirs, screw traps, thermal or chemical otolith marks, coded wire or PIT tagging) to evaluate performance of each element of the reintroduction strategy in contributing to long-term adult population trends (e.g., adult migrants, spawning, over-summering survival, juvenile growth rates, rearing survival, production, smolt survival during migration, migration timing, migration rates, and population genetics). Monitoring should also include physical habitat conditions, hydrology, and water quality at various locations within the river as well as within Millerton Lake.
- Conceptual and quantitative population models. Develop the necessary data inputs to support conceptual and quantitative models of spring-run Chinook salmon life history and the effects of various alternative management actions and environmental stressors on population dynamics. The model should eventually expand to fall-run Chinook salmon and be linked with fall-run Chinook salmon populations inhabiting downstream tributaries.
- Adaptive management framework. Develop the testable hypotheses and structure for integrating program monitoring and performance evaluations within the framework of adaptive management for refining and modifying the reintroduction strategy.

The TAC recommends that a phased plan of implementation be developed that addresses these and other information needs and initial decisions regarding refinement and evaluation of the reintroduction strategy. The phased plan would be an evolving document designed to provide program guidance as new information is developed and as new challenges in evaluating the performance and contribution of specific management actions to meeting the program goals are identified.

3.5 Recommendations

From our review of the available literature, criteria and procedures described above, and our best professional judgment, we offer fourteen recommendations for Stock Selection and Reintroduction Strategy for re-establishing naturally-produced spring-run Chinook salmon on the upper San Joaquin River.

3.5.1 Stock Selection

Recommendation 12: The founding stock should be selected from currently existing stocks inhabiting the Central Valley to maximize the likely success of local adaptation to the San Joaquin River. Preliminary assessment of potential founding stocks indicate that the Butte Creek spring-run Chinook salmon has life history characteristics that may be most compatible with the anticipated future environmental conditions on the upper San Joaquin River. The TAC recommends that a more detailed analysis be conducted to further evaluate the potential use of the Butte Creek and other potential founding stocks as part of refining the San Joaquin River reintroduction strategy.

Recommendation 13: The founding stock should have adequate genetic material (i.e., population abundance and genotypic/phenotypic diversity) to allow San Joaquin River specific pressures to eventually produce a locally adapted stock.

Recommendation 14: Factors that should be considered when selecting the founding stock(s), include current trends in abundance of source spring-run Chinook salmon populations (e.g., Butte Creek population), whether existing habitat conditions within a source watershed are fully used (e.g., are "surplus" fish available for relocation with minimal or potentially beneficial effects), logistic conditions affecting the ability to successfully collect and transport adults, eggs, or juveniles, and the genetic characteristics of the founding stock. These recommendations are intended to inform the Secretary of Interior, as well as state and federal fishery biologists who are responsible for final identification and selection of the founding stock(s) for reintroduction on the San Joaquin River.

Recommendation 15: Measures to assure fidelity to the San Joaquin River spawning areas, such as juvenile imprinting and marking programs, should be used to help reduce inter-basin movement of spring-run Chinook salmon from the upper San Joaquin River to downstream tributaries while establishing the initial population on the upper San Joaquin River.

Recommendation 16: A founding stock should be selected that has behavioral and life history characteristics most compatible with the anticipated conditions on the San Joaquin River.

Recommendation 17: Wild stocks should be evaluated from various Central Valley rivers as a founding stock with the goal of maximizing, to the extent possible, the genetic diversity of the founding stock to support the greatest degree of local adaptation to the San Joaquin River and to match the compatibility of life history characteristics with anticipated future environmental conditions.

Recommendation 18: A technical report should be developed that compiles, synthesizes, and integrates information on the life history characteristics and genetics of candidate stocks along with an assessment of the compatibility of each stock with anticipated future environmental conditions on the San Joaquin River to support a recommendation regarding the selection of one or multiple founding stocks for the reintroduction strategy.

3.5.2 Reintroduction Strategy

Recommendation 19: A phased strategy should be used during the early stages of reintroduction that blends a wide variety of techniques, incorporating additional information developed in the coming years and offering a diversified approach to reintroduction.

Recommendation 20: The structure of the reintroduction strategy and subsequent evaluation of the performance of the management actions and success of reintroduction should be conducted within a formal adaptive management framework.

Recommendation 21: A wide variety of techniques, including intervention techniques, should be used to help establish the initial founding population on the river. As the founding population becomes better established over time and able to respond to conditions through local adaptation, the reliance on intervention techniques should be reduced, with a greater proportion of the production originating from in-river spawning and rearing in order to meet the recommended population goals, targets, and milestones.

Recommendation 22: The information available from monitoring salmonid populations in other Central Valley river systems should be compiled and a critical assessment of monitoring needs and alternative approaches should be conducted prior to reintroduction. The monitoring and evaluation program should be designed to address and evaluate these and other key issues affecting the design, implementation, priorities, and success of the reintroduction program and for informing future decisions regarding refinements or modifications to the reintroduction strategy.

Recommendation 23: Program performance should focus on meeting the population targets over a period of years reflecting multiple cohorts and generations. With the exception of minimum population targets, Program performance should not be based on results from any one year. Caution should be exercised in modifying the fundamental reintroduction strategy until a clear trend is established, which may take a number of years to become evident.

Recommendation 24: The monitoring program and implementation of the reintroduction strategy should give priority status, in the early phase of restoration, to establishing spring-run Chinook salmon as the primary objective of the reintroduction strategy.

Recommendation 25: In developing the phased reintroduction strategy, information should be gathered and compiled to provide technical support for initial decisions regarding the proposed reintroduction strategy. Tasks and information should include:

- Review available literature on the design and success of reintroduction strategies for salmonids to help develop restoration guidelines and milestones;
- Select stock for reintroduction;
- Evaluate alternative management actions and methods for reintroduction including the application of trap and haul; determine locations for trapping adults and juveniles within the San Joaquin River as part of trap and haul operations in dry and critical water years; determine allocations and performance of alternative production techniques such as stream-side egg incubators with volitional release, egg incubator boxes and artificial redds; use of the hatchery to produce various life stages of juvenile salmonids and alternative planting strategies; the allocation between in-river production and alternative production techniques; needs for segregation between spring-run Chinook salmon and other salmonids; determine adult holding, spawning, and juvenile rearing habitat opportunities and constraints; and other elements of the initial reintroduction strategy;
- Establish monitoring methods and procedures to evaluate performance of each element of the reintroduction strategy in contributing to long-term adult population trends. Monitoring should also include physical habitat conditions, hydrology, and water quality at various locations within the river as well as within Millerton Lake;
- Develop the necessary data inputs to support conceptual and quantitative models of salmonid life history and the effects of various alternative management actions and environmental stressors on population dynamics; and

- Develop testable hypotheses and a structure for integrating program monitoring and performance evaluations within the framework of adaptive management for refining and modifying the reintroduction strategy.

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5 APPENDIX 1. ECOSYSTEM AND SOCIETAL BENEFITS OF RESTORING SPRING-RUN CHINOOK SALMON TO THE SAN JOAQUIN RIVER

While re-establishing spring run Chinook salmon to the San Joaquin River between Friant Dam and the Merced River is the most visible goal of the program to restore the San Joaquin River, the ecological requirements of this run provide an umbrella that covers many other societal and ecosystem benefits. The actions implemented as part of the Settlement are expected to result in restoration of the upper San Joaquin River as an ecosystem in order to sustain Chinook salmon populations. The following is a partial list, focused on fish, of benefits that may accrue from spring-run Chinook salmon restoration.

- *Populations of native resident fishes are expected to increase or be re-established.* This may result from a combination of increased flows, habitat improvements implemented for Chinook salmon, and the re-introduction of marine-derived nutrients into the system from the salmon. The improved flow and habitat conditions may recreate habitat for cool-water native fishes. Some species will likely expand naturally (e.g. Sacramento pikeminnow, Sacramento sucker) from existing refuges.
- *Populations of native migratory fishes may be enhanced or re-established.* The improved flow regime under the Settlement is expected to result in improved access and habitat conditions for species such as Pacific lamprey, white sturgeon, splittail, fall-run Chinook salmon, steelhead and resident trout, and other species.
- *Riparian ecosystems will be enhanced, re-established and/or expanded above the Merced River.* Healthy riparian systems greatly improve conditions for salmon and other fish by providing shade (cooler water), food (terrestrial insects), and cover (fallen and overhanging trees and shrubs). There is a whole complex of native animal and plant species associated with riparian ecosystems that may return as the riparian ecosystem recovers.
- *The recovery (delisting) of Central Valley spring-run Chinook salmon may become more likely.* A restored population of spring-run Chinook salmon on the upper San Joaquin River may significantly reduce the probability of extirpation of spring-run Chinook salmon from the Central Valley and could aid in their delisting under both the California and federal Endangered Species Acts. Even though the San Joaquin River population will be an ‘experimental’ population, if restoration is successful, the San Joaquin population could more than double existing Central Valley spring-run Chinook salmon populations, as well as provide a refuge distant from the other populations, which are clustered together.
- *Ocean and in-river fisheries for salmon may be improved.* Once a large self-sustaining population of salmon is re-established on the upper San Joaquin River the population may support some increase in the number of salmon available to be harvested by commercial and recreational fisheries, especially in the ocean.

The ecosystem restoration actions and benefits identified above should result in benefits for a broad array of aquatic species and terrestrial flora and fauna. These benefits, which should be significant, are beyond the scope of discussion and analysis for this report.