REVISED FINAL

Technical Report: Analysis of Fish Benefits of Reach 2B Alternatives of the San Joaquin River

PREPARED FOR:

U.S. Department of the Interior
Bureau of Reclamation
Mid-Pacific Regional Office
2800 Cottage Way
Sacramento, CA 95825
Contact: Katrina Harrison
916.978.5465

PREPARED BY:

ICF International
630 K Street, Suite 400
Sacramento, CA 95814
Contact: Monique Briard
916.737.3000

March 2014

ICF International. 2014. *Revised Final Technical Report: Analysis of Fish Benefit for Reach 2B Alternatives of the San Joaquin River*. March. (ICF 00787.11.) Sacramento, CA. Prepared for U.S. Department of the Interior, Sacramento, CA.

Contents

Appendices

Tables

Page

Figures

Page

List of Acronyms and Abbreviations

Act	San Joaquin River Restoration Settlement Act
cfs	cubic feet per second
Court	U.S. Eastern District Court of California
CVP	Central Valley Project
EDT	Ecosystem Diagnosis & Treatment
FWA	Friant Water Authority
Neq	Equilibrium abundance
NRDC	Natural Resources Defense Council
Project	Mendota Pool Bypass and Reach 2B Improvements Project
RA	Restoration Administrator
Reclamation	Bureau of Reclamation
RWA	Recovered Water Account
Secretary	Secretary of the Interior
SJRRP	San Joaquin River Restoration Program
State	State of California

Chapter 1
Introduction

The San Joaquin River Restoration Program (SJRRP) is intended to restore a self-reproducing salmon population in the San Joaquin River below Friant Dam. Knowledge of the challenges Chinook would face in the San Joaquin River and the most prudent actions that can be taken to ensure their survival is necessary to guide management actions. The purpose of this analysis was to evaluate the impact of Reach 2B restoration actions on habitat for spring Chinook. This report presents the results of analyses of Reach 2B actions (San Joaquin River Restoration Program 2012) for four life history types of spring Chinook in dry, normal-wet, and wet year types.

1.1 Project Background

Spring-run Chinook salmon have been extirpated from the San Joaquin River since about 1950 largely as a result of declines in water flow and quality as a result of irrigation and agricultural practices. In 1988, a coalition of environmental groups led by the Natural Resources Defense Council (NRDC) filed a lawsuit, known as NRDC, *et al., v. Kirk Rodgers, et al.*, challenging the renewal of long-term water service contracts between the United States and Central Valley Project (CVP) Friant Division contractors. On September 13, 2006, after more than 18 years of litigation, the Settling Parties, including NRDC, Friant Water Authority (FWA), and the U.S. Departments of the Interior and Commerce, agreed on the terms and conditions of a Settlement subsequently approved by the U.S. Eastern District Court of California (Court) on October 23, 2006. The San Joaquin River Restoration Settlement Act (Act), included in Public Law 111-11 and signed into law on March 30, 2009, authorizes and directs the Secretary of the Interior (Secretary) to implement the Settlement. The Settlement establishes two primary goals:

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

To achieve the Restoration Goal, the Settlement calls for releases of water from Friant Dam to the confluence of the Merced River (referred to as Interim and Restoration flows), a combination of channel and structural modifications along the San Joaquin River below Friant Dam, and reintroduction of Chinook salmon. *Restoration Flows* are specific volumes of water to be released from Friant Dam during different year types, according to Exhibit B of the Settlement; *Interim Flows* are experimental flows that began in 2009 and will continue until full Restoration Flows are initiated in 2014, with the purpose of collecting relevant data concerning flows, temperatures, fish needs, seepage losses, recirculation, recapture, and reuse. To achieve the Water Management Goal, the Settlement calls for recirculation, recapture, reuse, exchange, or transfer of the Interim and Restoration flows to reduce or avoid impacts on water deliveries to all of the Friant Division long-term contractors caused by the Interim and Restoration flows. In addition, the Settlement establishes a Recovered Water Account (RWA) and recovered water program to make water available to all of the Friant Division long-term contractors who provide water to meet Interim or Restoration flows, to reduce or avoid the impact of the Interim and Restoration flows on such contractors.

The San Joaquin River Restoration Program (SJRRP) was established in late 2006 to implement the Settlement. The SJRRP comprises several Federal and State of California (State) agencies responsible for implementing the Settlement. Implementing Agencies include the Bureau of Reclamation (Reclamation), U.S. Fish and Wildlife Service (USFWS), National Marine Fisheries Service, California Department of Water Resources; and California Department of Fish and Wildlife (formerly called California Department of Fish and Game). In addition to the Implementing Agencies, the Settlement stipulates that a Technical Advisory Committee be established, comprising six members appointed by NRDC and FWA. The Settlement also calls for a Restoration Administrator (RA) to be appointed by NRDC and FWA, to facilitate the Technical Advisory Committee and provide specific recommendations to the Secretary in coordination with the Technical Advisory Committee. The RA's duties are defined in the Settlement, and include making recommendations to the Secretary on the release of Interim and Restoration flows. The RA is also responsible for consulting with the Secretary on implementing actions under Paragraph 11 of the Settlement, and for identifying and recommending additional actions under Paragraph 12 of the Settlement. In addition, the RA is responsible for consulting with the Secretary on the reintroduction of Chinook salmon under Paragraph 14 of the Settlement. The RA's recommendations are taken into consideration by the Secretary in making decisions or taking specific actions to be implemented under the Settlement.

Settlement Paragraphs 11 through 16 describe the physical and operational actions considered necessary for achieving the Restoration and Water Management Goals. Paragraph 11(a)(1) and 11(a)(2) specify actions that were addressed in this analysis. These paragraphs of the Settlement call for construction of a Mendota Pool Bypass and modification of Reach 2B to convey at least 4,500 cubic feet per second (cfs), as follows:

(1) Creation of a bypass channel around Mendota Pool to ensure conveyance of at least 4,500 cfs from Reach 2B downstream to Reach 3. This improvement requires construction of a structure capable of directing flow down the bypass and allowing the Secretary to make deliveries of San Joaquin River water into Mendota Pool when necessary;

(2) Modifications in channel capacity (incorporating new floodplain and related riparian habitat) to ensure conveyance of at least 4,500 cfs in Reach 2B between the Chowchilla Bifurcation Structure and the new Mendota Pool bypass channel.

Because the functions of the Mendota Pool Bypass and a modified Reach 2B would be interrelated, the design, environmental compliance, and construction of the two are being addressed together as the Mendota Pool Bypass and Reach 2B Improvements Project (Project). The Project includes the construction, operation, and maintenance of the Mendota Pool Bypass and improvements in the San Joaquin River channel in Reach 2B to convey at least 4,500 cfs. The Project would be implemented consistent with the Settlement and the San Joaquin River Restoration Settlement Act, Public Law 111-11, with implementation dates clarified by the Implementation Framework (San Joaquin River Restoration Program 2012).

The Mendota Pool Bypass would convey at least 4,500 cfs around the Mendota Pool from Reach 2B to Reach 3. A fish barrier would be constructed in Reach 3 to direct adult salmon migrating upriver into the Mendota Pool Bypass. The Mendota Pool Bypass could be accomplished by constructing a new channel around Mendota Pool, or by modifying Mendota Pool to impound water only in areas outside of the San Joaquin River mainstem. This action would include the ability to divert 2,500 cfs to the Mendota Pool and may require construction of a bifurcation structure in Reach 2B. The bifurcation structure would include a fish passage facility to enable salmon migrating upstream to pass the structure and a fish screen to direct outmigrating fish into the bypass channel and minimize or avoid fish entrainment to the Mendota Pool.

Improvements to Reach 2B would include modifications to the San Joaquin River channel from the Chowchilla Bypass Bifurcation Structure South[1] to the new Mendota Pool Bypass to provide a capacity of at least 4,500 cfs with integrated floodplain and related riparian habitat. The options under consideration include potential levee setbacks along Reach 2B to increase the channel and floodplain capacity and provide for habitat. Floodplain and riparian habitat is included along the Reach 2B portion of the Project as required by the Settlement; floodplain and riparian habitat is also being considered along the Mendota Pool Bypass channel for its potential to benefit a restored salmon population.

The Reach 2B Project Area extends from approximately 0.3 miles above the Chowchilla Bypass Bifurcation Structure South to approximately 1.0 mile below the Mendota Dam, in Fresno and Madera counties near the town of Mendota, California. The Project Area comprises the area that could be directly affected by the Project and is the focus of this analysis. The Project may also indirectly affect nearby portions of Reach 2A and Reach 3 (Figure 1-1).

[1] Sometimes referred to as the San Joaquin River Bifurcation Structure or as part of the Chowchilla Bypass Bifurcation Structure.

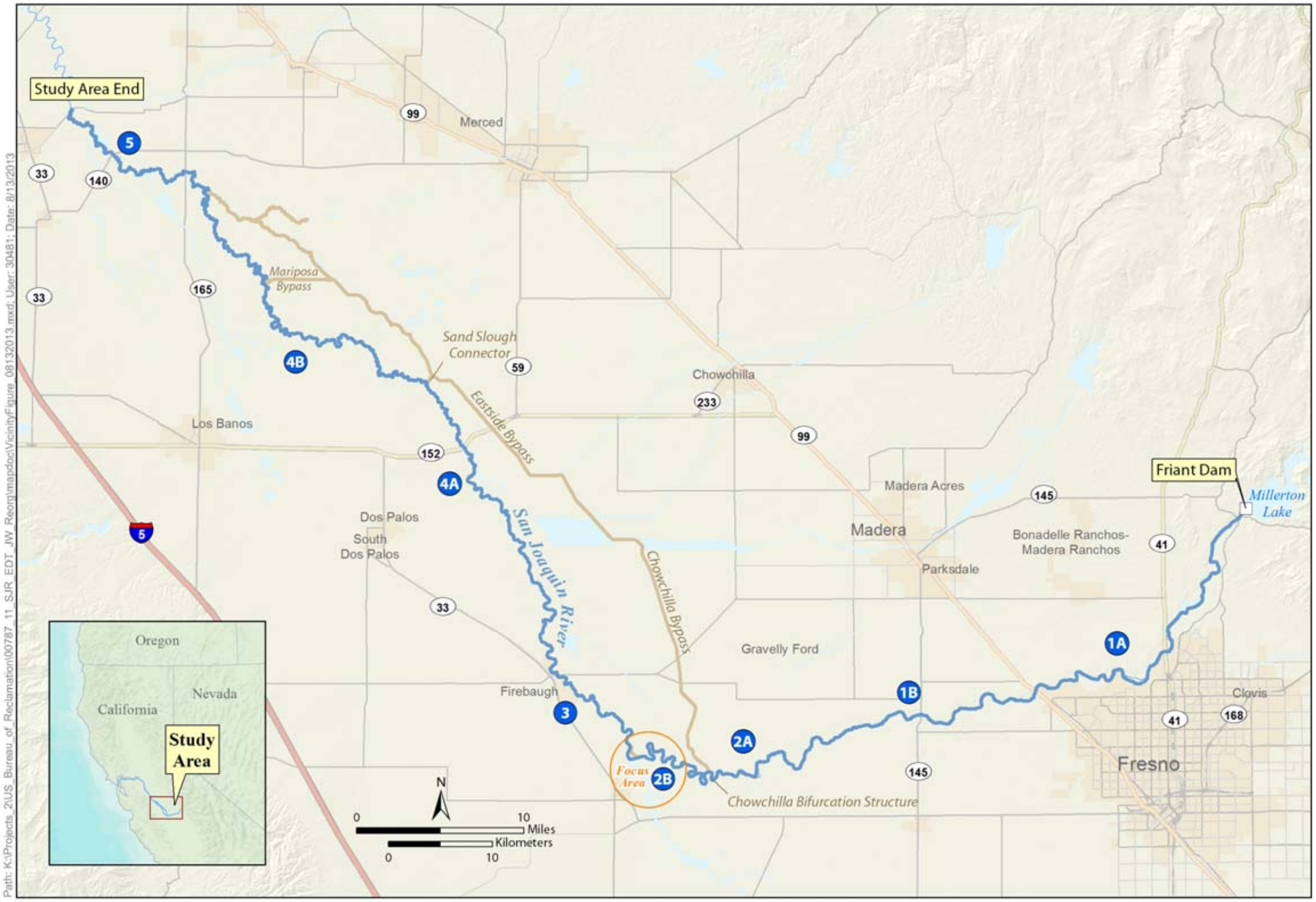

Figure 1-1. San Joaquin River Restoration Project Area

Chapter 2
Methods

The analysis and comparison of potential Reach 2B actions used the Ecosystem Diagnosis & Treatment (EDT) model. The model was parameterized with existing and modeled data that captured conditions expected under alternatives developed by SJRRP resource agency biologists and engineers (Core Team), described and analyzed in Chapter 3. The model evaluated the alternatives in terms of potential performance of spring-run Chinook salmon.

2.1 Ecosystem Diagnosis & Treatment

Ecosystem Diagnosis & Treatment (EDT) is a system to evaluate habitat at a reach scale in terms of potential performance of a fish species (Table 2-1). Carrying capacity and productivity are related to the quantity and quality of habitat respectively; equilibrium abundance is a function of capacity and productivity. Breadth of habitat refers to the "window of opportunity" within the environment where suitable conditions exist for the species. Greater breadth of habitat leads to greater biological diversity and increased resilience to environmental fluctuations. The algorithms and theory of EDT are more fully described in Appendix A, *Ecosystem Diagnosis & Treatment Theory* and in Blair et al. (2009).

EDT approaches river management by diagnosing problem areas in watersheds using fish species as indicators of watershed health. EDT evaluates a stream or river "through the eyes" of an indicator or focal species from the headwaters of a river to the ocean over the course of a defined life cycle (Mobrand et al. 1997). It rates the quantity and quality of habitat in a stream in fish population terms by assuming that the biological capacity and productivity of a fish population are functions of the underlying environment and that conditions are reflected in the shape of the production function (Reisenbichler 1989). Pacific salmon are able to survive in a wide range of habitats across their range. An important component of their survival strategy is diversity of life histories. EDT incorporates life-history variability by evaluating life cycle performance across a suite of life history strategies.

Table 2-1. Habitat Evaluation Parameters in EDT

Habitat Characteristics	Fish Population and Life Stage Response
Quantity (square meters) of habitat	Biological carrying capacity
Quality of habitat by attribute	Productivity (density-independent survival)
Quantity and quality of habitat	Equilibrium abundance (Neq)
Breadth of suitable habitat	Variation across life history trajectories

The environment in EDT is described spatially (by different reaches) and temporally (at a monthly scale). The environment within each spatial-temporal cell is described by environmental attributes (temperature, flow, toxins, etc.), many of which are rated on a 0–4 scale using EDT rating guidelines (Lestelle 2004). The categorical ratings correspond to degrees of reduction of life stage survival benchmarks or survival maxima to capture the effects of reach-level conditions in the stream. In most cases, when an attribute is closer to 0 the condition is closer to “ideal” or benchmark conditions, and when it is closer to 4 it is more severely degraded.

The suitability of an environment for a fish species is evaluated in EDT in terms of the productivity and capacity parameters of the Beverton-Holt production function (Beverton and Holt 1957) (Figure 2-1). This results in an estimate of habitat potential that can be related to measures of desired fish population performance such as those in the Viable Salmonid Population concept (McElhany et al. 2000). The Beverton-Holt function relates the number of spawners to their resulting progeny (recruits) and shows how abundance of the population changes as the number of spawners increases (Figure 2-1). Abundance is constrained by carrying capacity and productivity. *Carrying capacity* is the maximum number of fish that could be supported by the environment and is set by the quantity of suitable habitats such as pools, riffles, or glides. *Productivity* is the density-independent survival rate set by factors such as temperature, food, oxygen, pollutants, and predation. Under steady-state conditions, abundance of a population will stabilize at the equilibrium abundance where density-dependent mortality and survival balance (Figure 2-1). *Equilibrium abundance* (Neq) is therefore a function of both capacity and productivity and provides a useful summary statistic that relates to the quantity and quality of habitat.

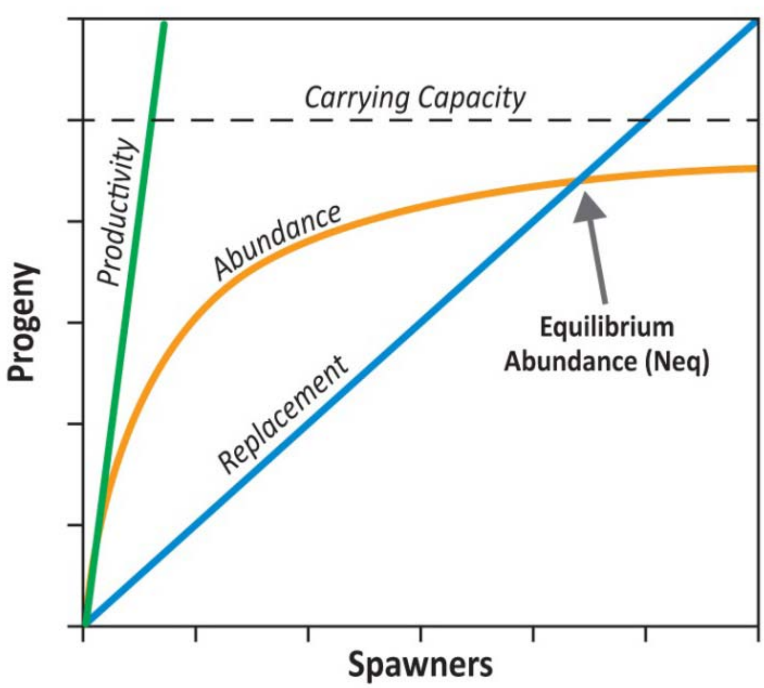

Figure 2-1. Features of a Beverton-Holt Stock-Recruitment Relationship

A unique aspect of EDT is that the model evaluates habitat for a fish species along multiple *life history trajectories*. These evaluate the spatial and temporal variability in habitat and the diversity within the defined life history to evaluate the *breadth* of suitable habitat conditions (Table 2-1). Typically, EDT runs several thousand trajectories across the Project Area to evaluate variation in conditions and life stage exposure to these conditions. Life history trajectories begin and end with spawning at specific locations and times and encompass conditions in time and space defined by the species life history. EDT evaluates habitat along these trajectories based on duration of exposure to condition using rating curves or rules unique for each species and life stage. The species life history defines the order of life stages, the duration of life stages, and the timing for and location of transitions between life stages. Trajectories evaluate habitat within the defined temporal and spatial windows.

Life history parameters, which define duration and exposure to conditions, vary spatially and temporally within defined limits. As a result the model produces a distribution of species performance (the Beverton-Holt features discussed above) that captures the breadth of suitable habitat. "Successful" trajectories are defined as those with habitat resulting in a potential life cycle cumulative productivity greater than 1.0, i.e., above the population replacement line in Figure 2-1. The productivity, capacity, and equilibrium abundance of all successful trajectories are combined to estimate performance at a population scale.

2.2 The San Joaquin Spring Chinook EDT Model

The San Joaquin Spring Chinook EDT model is an application of the EDT model structure to the San Joaquin River between Friant Dam and the confluence with the Merced River, a distance of about 150 miles (Figure 2-2). Within this area the model describes a complex hydrography of riverine reaches, numerous diversion and bypass structures, and irrigation channels. Spatial structure of the model is further described in Section 2.2.1. The focal species used for evaluation for this analysis was spring-run Chinook salmon. Salmon, including spring Chinook salmon, have been extirpated from the SJRRP Project Area. The analysis hypothesized possible life histories of spring Chinook in the Project Area as described in Section 2.2.3.

Spring Chinook spawning reaches, the origin points for all life history trajectories, were defined in the San Joaquin EDT model as SJR-1A1 and SJR-1A2, the approximately 23 miles directly below Friant Dam. For the San Joaquin analysis, EDT evaluated habitat for spring Chinook along several thousand trajectories starting from these two reaches and extending through the SJRRP Project Area, the lower San Joaquin River, the Sacramento–San Joaquin River delta, and the ocean, and back to the starting position. Productivity and capacity for spring Chinook life stages were calculated from habitat conditions in the SJRRP Project Area using the life-stage habitat rating relationships discussed above. Survival through the San Joaquin River below the Merced River and through the Sacramento-San Joaquin River Delta was included as a direct input to the model to create a realistic rate of return of adult fish back to the Merced River confluence and to complete the life cycle survival calculations. The post-Merced survival rates varied between life history strategies as discussed below in Section 2.2.3.

A habitat scenario in EDT consists of a reach-level environmental description shaped across 12 months that is evaluated using the species life-stage rules. All scenarios were developed by the Core Team and provided to ICF for analysis. A scenario is depicted by environmental conditions in each reach in regard to attributes such as channel width, temperature, substrate, habitat type, and access to the floodplain. Scenarios differed based on assumed routing of water into various reaches and conditions along each route. Variation in the parameters was limited to the specific actions relating to conditions in the 12.3 miles between the Chowchilla Bypass and Reach 3B (Table 2-1); all other conditions in the remaining 139 miles of the Project Area were held constant in all scenarios.

Parameterization of the habitat scenarios was based on 1) existing information in studies and reports, 2) derived information from action hypotheses (developed by the Core Team as described below), and 3) HEC-RAS modeling performed by Reclamation. The HEC-RAS modeling provided flow-related attributes such as peak flow, shaping of flow across months, and channel width. The 2B EDT analyses used one of many flow scenarios developed by Reclamation based on the SJRRP Settlement agreement. The flow scenario used was modified by Carl Mesick (USFWS) to address temperature concerns Conditions were modeled for a range of water year conditions that resulted in differences in routing and channel width. Numerous HEC-RAS model runs were required to estimate widths in the various channels and floodplains in the different scenarios.

2.2.1 Geography and Reach Structure

For the SJR analysis, the San Joaquin River Project area was broken down into 32 reaches, starting at Friant Dam and ending at the confluence with the Merced River (Figure 2-2). These reaches include the original river channel of the San Joaquin River and irrigation channels such as the Eastside Bypass. Reaches were based on the SJRRP management reaches but were further subdivided to incorporate additional details of the environment and to address actions in the Core Group scenarios. Descriptions of these reaches, including reach length, are described in Table 2-2.

2.2.2 Project Area

The Project Area is the 150 miles of the San Joaquin River between Friant Dam and the confluence with the Merced River (Figure 1-1). The Reach 2B analysis focused on alternatives for routing and restoration in the river channel from the Chowchilla Bifurcation Structure South to just downstream of the Mendota Dam at Reach 3B (Figure 2-2), a length of 12.3 miles (all shaded reaches in Table 2-2). Conditions in the alternatives only varied in the 12.3 mile section and all other conditions above and below this reach were held constant and set to those in the Minimum Restoration Scenario (base condition) for all scenario comparisons.

Table 2-2. Descriptions and Lengths for EDT Reaches in the San Joaquin River Project Area. Shaded reaches are the focus of this analysis.

	Description	Length (mi)
SJR 1A1	Friant Dam to HWY 41	12.3
SJR 1A2	Hwy 41 to Hwy 99	11.4
SJR 1B1	Hwy 99 to Hwy 145 (Madera Ave.)	9.1
SJR 1B2	Hwy 145 (Madera Ave.) to Gravelly Ford	5.1
SJR 2A	Gravelly Ford to Chowchilla Bifurcation Structure South	12.9
Chowchilla Bypass	Chowchilla Bifurcation Structure South to Ash Slough	22
South Eastside Bypass	Chowchilla Bypass to Central Eastside Bypass	10.5
SJR 2B1A	Below Chowchilla Bifurcation Structure South	1.9
SJR 2B1B	SJR 2B1A to SJR 2B2 or the Mendota Pool Bypass	8.3
SJR 2B2	SJR 2B1B to Mendota Pool	0.65
Mendota Pool	Canals Obstruction Reach to Mendota Dam	0.32
Mendota Pool Bypass	Assumed location for a new bypass, from 2B1B to 3B	1.2
SJR 3A	Mendota Dam to Compact bypass return	0.63
SJR 3B	Mendota Pool Bypass return to Avenue 7.5 (Firebaugh)	8.8
SJR 3C	Avenue 7.5 (Firebaugh) to Sack Dam	12.9
SJR 4A1	Sack Dam to Hwy 152	8.1
SJR 4A2	Hwy 152 to Sand Slough	5.4
Central Eastside Bypass Upper	Sand Slough Connector to Central Eastside Bypass Lower	3.8
Central Eastside Bypass Lower	Central Eastside Bypass Upper to Mariposa Bypass Upper	5.2
SJR 4B1A	SJR 4A2 to SJR 4B1B	5.6
SJR 4B1B	SJR 4B1A to SJR 4B2A	5.6
SJR 4B2A	SJR 4B1B to SJR 4B2B	6.1
SJR 4B2B	SJR 4B2A to SJR 4B3	3.6
Mariposa Bypass Upper	Mariposa Bypass Upper to SJR 4B3	0.98
Mariposa Bypass Lower	Central Eastside Bypass to Mariposa Bypass Lower	3.3
North Eastside Bypass	Mariposa bifurcation to Bear Creek confluence	6.7
Bear Creek_B	Bear Creek	4.8
Bear Creek_A	Bear Creek confluence to SJR 5A	4.2
SJR 4B3	End of Mariposa Bypass to SJR 5A	11.4
SJR 5A	SJR 4B3/ Bear Creek_B to Salt Slough	6.9
SJR 5B	Salt Slough to Mud Slough	5.6
SJR 5C	Mud Slough to Merced River	4.1
Total of all modeled reaches		**209.4**[1]

[1] The total length of the San Joaquin mainstem between Friant Dam and the Merced River confluence is 150 miles. The addition length in this total is due to the addition of bypass reaches

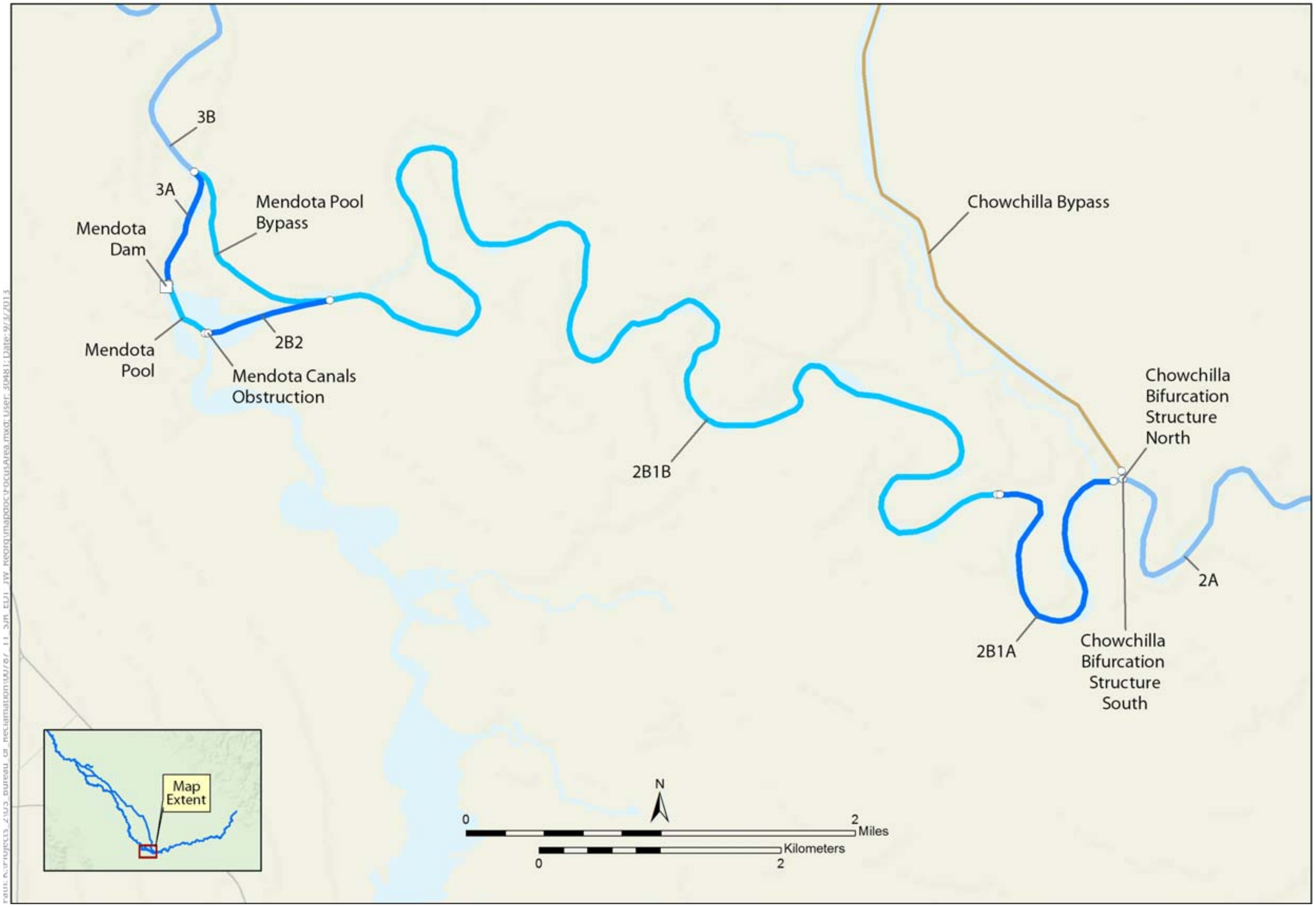

Figure 2-2. Focus Area, Chowchilla Bifurcation Structure South to SJR 3B San Joaquin River

2.2.3 Spring Chinook Life History

Spring-run Chinook salmon have been extirpated from the San Joaquin River since about 1950. As a result, to model restoration scenarios for the San Joaquin it was necessary to create a hypothetical life history pattern against which to evaluate restored conditions. Chinook salmon display great diversity in life history behaviors within and between populations and races (Groot and Margulis 1991). This diversity allows Chinook to adapt to a wide range of environments and cope with extremes of environmental variation. Intra-population life history diversity dampens the effects of fluctuating environmental conditions and longer term climate cycles affecting freshwater, estuarine and marine survival thereby reducing the risk of extinction or reduced production.

San Joaquin spring Chinook are at the extreme southern limit of their range, and may be more susceptible to environmental fluctuations than other populations (MacFarlane and Norton 2002); for this reason a population structure was devised that includes different life history strategies that are hypothesized to be present in a future San Joaquin spring-run Chinook population. Juvenile life histories differ based on timing of downstream migration, distribution within the Project Area, the extent of estuarine rearing, and timing of ocean entrance. The hypothesis is that any or all of these strategies could be expressed in any year, though their success would be expected to vary based on environmental conditions.

Fish life histories in EDT set the location, timing and extent of exposure of life stages to environmental conditions. Life histories are defined by the life stages (Table 2-3) and by a set of specifications (Table 2-4) that describe the location and time period of spawning (the start and end points of trajectories), the timing of transitions between life stages, specific locations of life histories, the duration of life stages, and the speed that fish could move within the Project Area. It is important to stress that, although life history strategies are often described using language that describes movement and behavior of fish life stages, in reality EDT does not move fish in any way. Instead, the life history strategies control the timing and location of the evaluation of habitat and the life stage rules to apply; ultimately performance is based on duration of exposure to conditions at locations and times.

Table 2-3. Chinook Life Stages Used to Construct Life History Trajectories in EDT

Life Stage	Definition
Spawning	Period of active spawning, beginning when fish move on to spawning beds and initiate redd digging and ending when gametes are released. In EDT, the starting point for life history trajectories.
Egg incubation	Egg incubation and alevin development; stage begins at the moment of release of gametes by spawners and ends at fry emergence (losses to egg viability that occur in the instant prior to fertilization are included here).
Fry colonization	Fry emergence and initial dispersal; time period is typically very short, beginning at fry emergence and ending when fry begin active feeding associated with a key habitat.
0-age resident parr rearing	Rearing by age 0 fish (parr) that is largely associated with a small "home range"; these fish are generally territorial
0-age transient parr rearing	Rearing by age 0 fish (parr) accompanied by a seaward directional movement (i.e., these fish do not have home ranges); these fish are non-territorial, though antagonistic behavior may still be exhibited.
0-age migrant	Directional migration by age 0 fish that tends to be rapid and not strongly associated with feeding/rearing.
0-age winter/inactive	Largely inactive or semi-dormant age 0 and 1 fish; this behavior is associated with overwintering, when feeding may be reduced; fish exhibiting this behavior need to be largely sustained by lipid reserves.
1-age resident rearing	Feeding/rearing by age 1 fish that is associated with a home range; these fish are often territorial.
1-age migrant	Directional migration by age 1 fish that tends to be rapid and not strongly associated with feeding/rearing (note: fish displaying strong smolt characteristics typify this life stage).
Delta/Estuary and Ocean rearing juvenile, subadult and adult	Delta/Estuary and ocean phase of life cycle used in San Joaquin EDT model. This was modeled as a survival factor indexed to life history specific assumed survival rates.
Migrant prespawner	Adult fish approaching sexual maturity that are migrating to their natal stream; in the ocean this stage occurs in the final year of marine life, in freshwater feeding has generally ceased.
Holding prespawner	Adult fish approaching sexual maturity that are largely stationary and holding, while en route to their spawning grounds; distance to the spawning grounds from holding sites may be short or long.

Table 2-4. Specifications and Constraints Used to Link Life Stages within EDT to Form Life History Trajectories

Parameter	Definition
Specification: Spawning Reaches	Reaches within the Project Area where spawning may occur—trajectory starting locations are selected from within these reaches
Specification: Spawning Period	Weeks within a year defining the spawning period—trajectory starting times are selected from within this period.
Specification: Life stage transition date	Minimum and maximum date within which a life stage transition must occur—transition dates are selected from within this period
Specification: Life stage location	Minimum and maximum location (kilometers from starting point) where a life stage must occur—transition location
Constraint: Life stage duration	Minimum and maximum number of days that a life stage can occur
Constraint: Life stage speed	Minimum and maximum rate of travel (kilometers/day) of a life stage—affects the duration of a life stage in a reach and the extent of downstream movement that would occur in the life stage.

Life History Strategies

The attributes in Tables 2-3 and 2-4 were used to devise hypothetical life history strategies for San Joaquin spring-run Chinook salmon. These strategies controlled evaluation of habitat within the set of life history trajectories in the model. Based on discussions with the Core Team, four life histories were developed for spring Chinook for use in the San Joaquin EDT model: Winter Fry Migrant, Spring Parr Migrant Above Chowchilla, Spring Parr Migrant Below Chowchilla, and Yearling Spring Migrant (Table 2-5). The fry life stage is the first post-yolk sac life stage that occurs in late winter, which then matures to the parr stage in the first spring; yearling smolts occur in the second spring after hatching. The hypothesis is that within a San Joaquin spring-run Chinook population a first pulse of fry will leave the Project Area very soon after emergence, another pulse will leave as parr and a third pulse will hold over to the second spring and leave as yearling smolts. Two spring parr patterns were developed based on an assumption that portions of the population would either remain in their natal area or a short distance downstream to rear before leaving as a parr later in the spring (Above Chowchilla) or migrate downstream of the Chowchilla Bypass and rear in the mid and lower reaches of the San Joaquin River before continuing their seaward migration as spring parr.

Each of these four life history strategies is characterized by the same spawning through emergence and adult migration and holding definitions; strategies only varied in regard to juvenile behavior within the Project Area and subsequent downstream survival (Figure 2-3). Spawn timing for all life history strategies was assumed to occur from early September to early November in reaches 1A1 and 1A2. Fry emergence was assumed to occur from mid-December to early February. Adult river entry timing into the San Joaquin River was assumed to occur from mid-February to mid-May. Adult fish entering the Project Area within this period were assumed to move quickly into the spawning reaches below Friant Dam where they would hold until spawning in the fall. Water temperatures were too warm in the lower river to realistically assume spring Chinook entry beyond mid-May. Adult migration (Delta/Estuary and in-river) was assumed to average about 8 weeks, with adults entering the upper San Joaquin River adult holding areas from early April to mid-June.

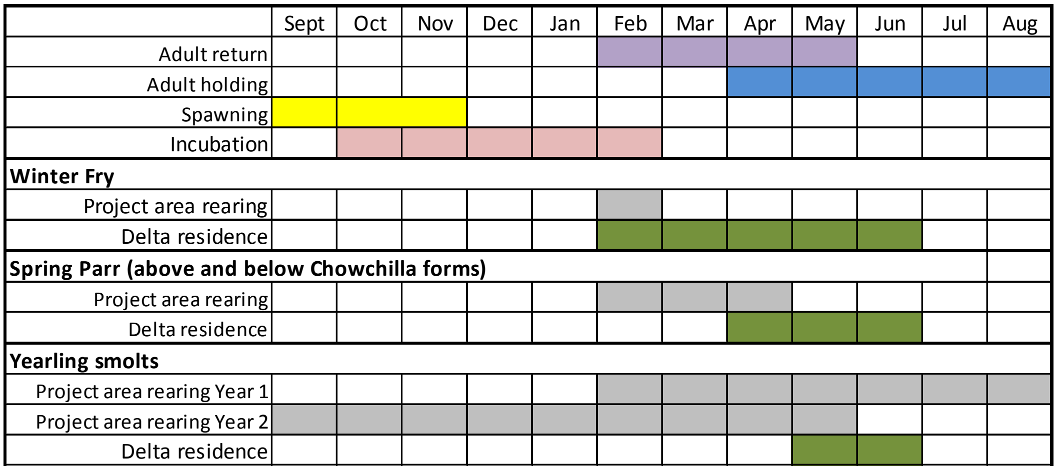

Figure 2-3. Modeled San Joaquin Spring-run Chinook Life History including Three General Patterns of Juvenile Life History

In the *Winter Fry Migrant* strategy, juveniles quickly migrate out of the San Joaquin River as newly emerged fry, reaching the Delta over a 1–2 week period during the winter months. These trajectories have the shortest exposure to conditions in the Project Area but the longest potential duration in the delta, up to 5 months, before continuing their seaward migration (Figure 2-3).

Juveniles in the *Spring Parr Above Chowchilla* strategy either remain near their natal site or move a short distance downstream as newly emerged fry. The rate of speed for fry movement was set low to ensure all trajectories remained in the upper 50 miles of the San Joaquin River upstream of the Chowchilla Bypass structure. Also, migration speed varied across trajectories to distribute rearing across multiple reaches in the upper river (i.e., all reaches upstream of the Chowchilla Bypass). After this short migration, fry would stop and grow as residents, spend 1–2 months in the same general location before continuing their seaward migration through the San Joaquin River in later winter and early spring. Parr migration through the lower San Joaquin River is assumed to be late March through April. Trajectories following this life history pattern are assumed to initiate seaward migration later than trajectories rearing downstream of the Chowchilla Bypass because of cooler water temperatures in the upper river. Because they would have more time to grow in the river system, they spend less time in the estuary overall than the winter fry migrants, up to 2 months (Figure 2-3).

In the *Spring Parr Below Chowchilla* strategy, juveniles rapidly move downstream as newly emerged fry to below the Chowchilla Bypass structure, where they would begin rearing. This pattern is a variant of the winter fry pattern, except that fry stop migrating as they enter the mid and lower San Joaquin River. The rate of speed for fry movement was set high to ensure all trajectories moved downstream of the Chowchilla Bypass, but not so high that trajectories moved into the delta. Migration speed varied across trajectories to distribute rearing across multiple reaches in the mid and lower San Joaquin (i.e., all reaches downstream of the Chowchilla Bypass including, but not limited to the 2B Project Area). After the initial migration, fry would stop and grow as residents, spending 1–2 months in the same general location before continuing their seaward migration through the lower San Joaquin River. Parr migration through the lower San Joaquin River is assumed to be early March to early April. Trajectories following this life history pattern are assumed to initiate seaward migration earlier than trajectories rearing upstream of the Chowchilla Bypass because of warmer winter and spring water temperatures in the lower San Joaquin River. Estuary duration is the same as parr originating upstream of the Chowchilla Bypass (Figure 2-3).

The *Yearling Spring Migrant* strategy has fry staying close to their spawning grounds where they rear through the summer and over-winter in the stream before initiating their seaward migration during their second winter or spring. Thus, for a single trajectory, the spawning, egg incubation, fry colonization, and summer and winter 0-age residence practically overlap spatially. After heading out of the system, the yearling fish arrive in the estuary between January and April, biologically at a larger size than the other life histories, and spend the least time in the estuary on average, with a maximum duration of 1 month (Figure 2-3).

The Core Team did not assume all life history patterns would be used with equal frequency by the spring Chinook population. Evidence from other populations in the Sacramento River and an understanding of likely flow and temperature patterns and their effects on the life history expression helped the Work Group define the frequency of life histories to be modeled for the San Joaquin River (Table 2-5).

Table 2-5. Frequency of Life History Patterns Used to Model San Joaquin Spring Chinook

Life History Pattern	Percentage of Population Trajectories Modeled
Winter Fry Migrant	32%
Spring Parr Above Chowchilla	25%
Spring Parr Below Chowchilla	33%
Yearling Spring Migrant	10%

2.3 Model Input Data

2.3.1 Flow

Flow Hypothesis

Flow is a key environmental attribute that affects many aspects of habitat for salmonid fishes (Hawkins et al. 1993; Poff et al. 1997). In EDT flow is input through flow-specific attributes (Flow High, Flow Low, Inter-annual Variability) but also through hypothesized or modeled effects of flow on other attributes such as channel width. The flow-specific attributes in EDT capture the physiological or behavioral aspects of flow. While important, the larger impact of flow is geomorphological and related to channel dynamics, habitat formation and maintenance and movement of sediment and wood. For this analysis, the primary geomorphic impact of flow was captured as a change in channel width.

Specifically, the effect of flow entered the SJR EDT model through the following attributes:

- Flow—high flows
- Flow—low flows
- Channel width—month maximum width

- Channel width—month minimum width

Specific flow levels by reach by month were developed through HEC-RAS modeling by Reclamation. These flow levels were used to compute the Flow High and Flow Low attributes in EDT using the standard EDT rating guidelines (Lestelle 2004). HEC-RAS was also used to compute channel width as a function of flow. Based on this, width varied monthly in each reach based on the water year and the flow routing appropriate to a scenario.

Flow Modeling

The Settlement stipulated flow for the SJRRP Project Area was assumed for all evaluations. These flows were simulated under dry, normal-wet, and wet year types. Flow, width, and temperature attributes were all dependent on water year type. A temperature-adjusted flow scenario was evaluated, as developed by USFWS within the constraints of the Settlement Exhibit B hydrograph. This flow scenario was then run through the SJRRP Riverware model to incorporate flood flows. The resulting daily flow hydrograph was then used to derive EDT input parameters for flow and channel attributes discussed below. Modeled flow includes a restoration spring pulse with riparian recruitment release hydrographs adjusted for more favorable water temperatures in the river. Routing has all flows reaching the Sand Slough Connector routed into Eastside Bypass except under flood conditions. Figure 2-4 shows daily flows averaged by year types at Friant Dam that were used for model characterization.

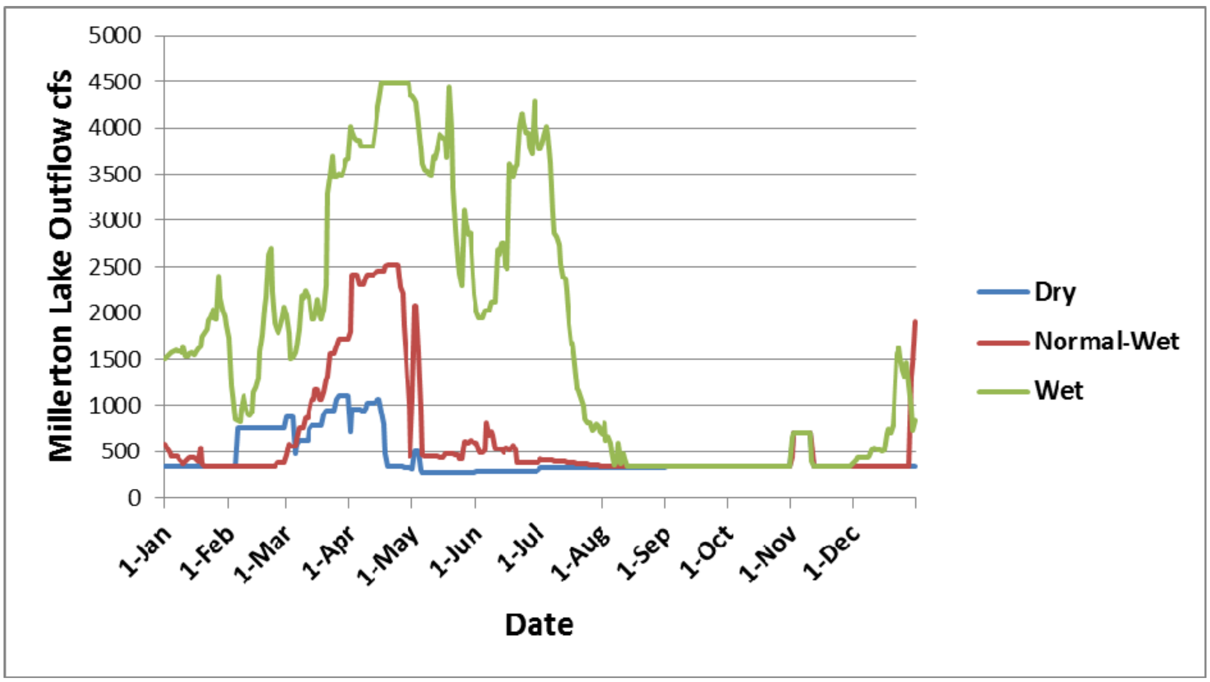

Figure 2-4. Millerton Outflows (Friant Dam): Daily Flows, Averaged by Year Types

Due to flood flow operations during most wet type years, a portion of high flows are routed into the Chowchilla Bypass and do not enter Reach 2B. Thus Reach 2B does not experience flows of greater magnitude in average wet years (Figure 2-5). The differences in flow between wet and normal-wet years are a longer duration in average wet year types than average normal-wet year types, .

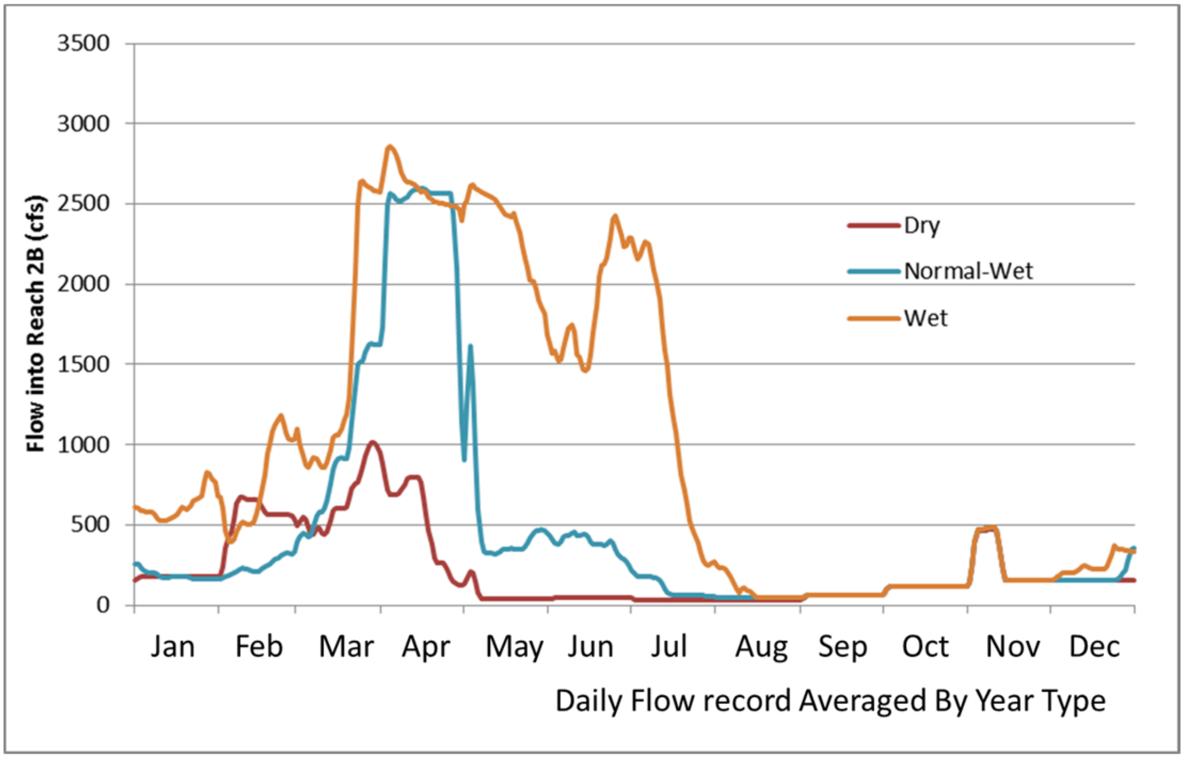

Figure 2-5. Flow into Reach 2B: Daily Flows, Averaged by Year Types

Flow data was provided in the form of a daily flow hydrograph from 1922–2003. Carl Mesick of the Fish and Wildlife Service developed a temperature-adjusted hydrograph by water year type within the rules included in Exhibit B of the Settlement. Reclamation then took this flow schedule and ran it through the Riverware model as the San Joaquin River demand, in order to calculate when flood control releases from the reservoir were necessary. The Riverware model models daily Friant releases, including restoration release flow schedules and flood control releases. The model has the ability to schedule restoration releases in differing patterns, following the constraints defined in the Settlement. The model simulates the operational challenges associated with forecast error and its effects on restoration allocations and scheduling and flood control operations. Model results include Millerton parameters such as storage, releases, and downstream river flows on a daily time step (Vandergrift 2012).

Figure 2-6 shows the flows in Reach 2A (SJR Above Chowchilla Bifurcation), in Reach 2B (SJR Below Chowchilla Bifurcation), in the Chowchilla Bypass (Chowchilla Bypass Inflow from SJR), and in Reach 3 (SJR Below Mendota Pool Restoration Bypass Return) in 1983, the wettest year on record. These Wet year flows are contrasted with flows and routing in 1994, a dry year in Figure 2-7. Note the differences in scale between the two years. The figures show that a substantial proportion of the greater flows in 1983 are routed into the Chowchilla Bypass, lowering the amount of flow entering Reach 2B. In 1994 and other drier years, the entire flow in the San Joaquin River is routed into Reach 2B.

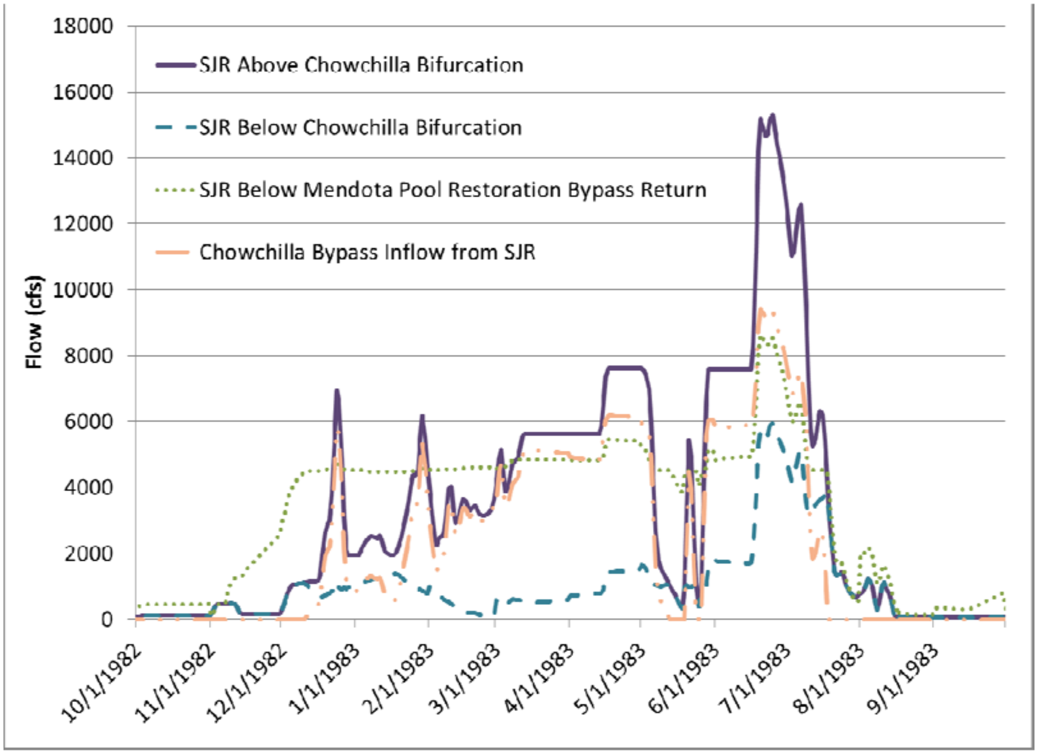

Figure 2-6. Flows into and around Reach 2B in 1983, Wet Year

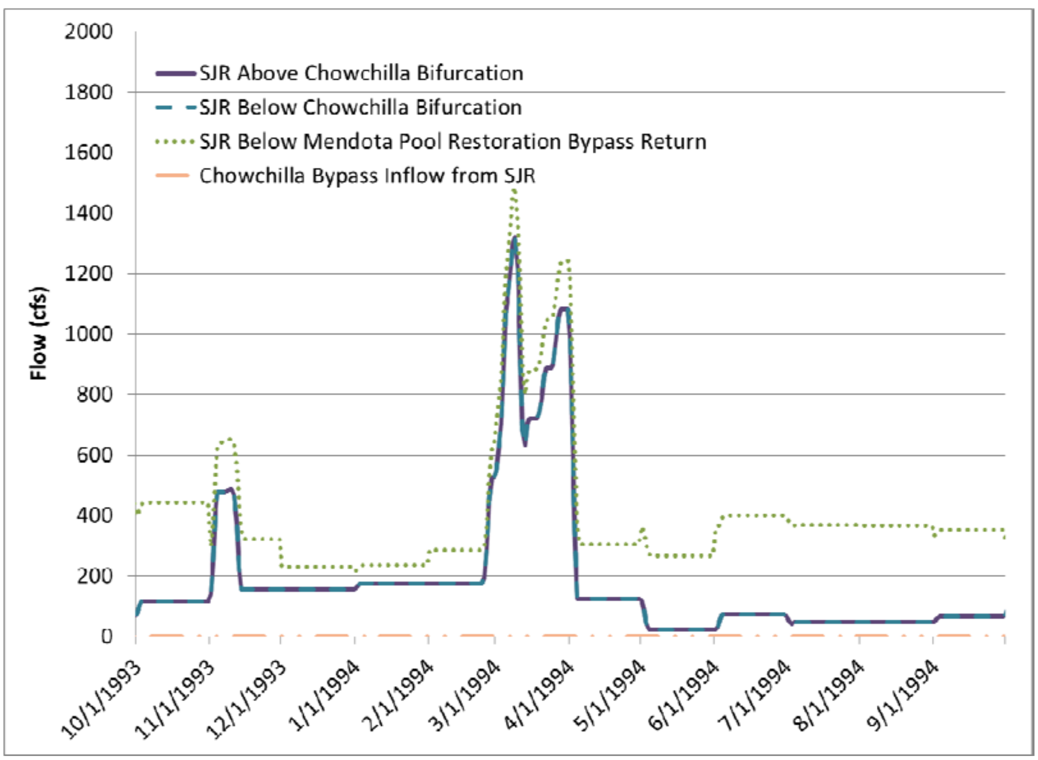

Figure 2-7. Flows into and around Reach 2B in Water Year 1994, a Dry Year

Channel Width

Width data was provided by the Department of Water Resources (DWR) San Joaquin River Restoration Program simplified HEC-RAS model (Tetra Tech 2013). For the baseline condition (Minimum Restoration Scenario), overbank topography in the HEC-RAS model is based on 2008 LiDAR mapping that was developed for the DWR in the North American Vertical Datum of 1988 (NAVD88), and in-channel topography is based on bathymetric data that were collected by DWR in March, August, and September of 2009 and Reclamation in April of 2010. Reclamation developed digital terrain models from this data that provided the basis for the HEC-RAS geometry. The HEC-RAS model was calibrated to flows between 160 and 1,070 cfs. For the Reach 2B Project alternatives, edits to the existing conditions HEC-RAS geometry were made to match structure and floodplain designs.

2.3.2 Routing Scenarios

The alternatives analyzed for the Reach 2B analysis were distinguished based on the routing of water down the various channels of the SJR Project Area. Routing varied by water year condition; as flow increased, the hydraulic capacity of a channel would be reached and water would then move into other channels. Table 2-6 summarizes and Figure 2-8, A–D illustrates the routes used under the different water year types for each alternative.

Routings B and D (Figure 2-8, B and D) involve only flood flows that are above the capacity of Reach 2B to route into the Chowchilla Bypass. At the Sand Slough Bifurcation, all flows are sent to the Eastside Bypass except during flooding, in which case up to 475 cfs are sent into SJR Reach 4B (EDT Reaches 4B1A through 4B2B). At the Mariposa Bypass, the first 8,500 cfs are sent through the Mariposa Bypass with additional flow left in the Eastside Bypass (EDT reaches North Eastside Bypass and Bear Creek). Under this routing schedule, more channels are activated in Wet year types.

Table 2-6. Routing Scenarios by Alternative and Water Year Type

	Water Year Type		
Alternative	Dry	Normal-Wet	Wet
Minimum Restoration (No-Action/No-Project)	A	A	B
Narrow Floodplain	A	A	B
Wide Floodplain	A	A	B
Fresno Slough Dam	A	A	B
Fresno Slough Dam with Short Canal	A	A	B
Mendota Pool Bypass	C	C	D
Chowchilla Bifurcation South Passage	A	A	B

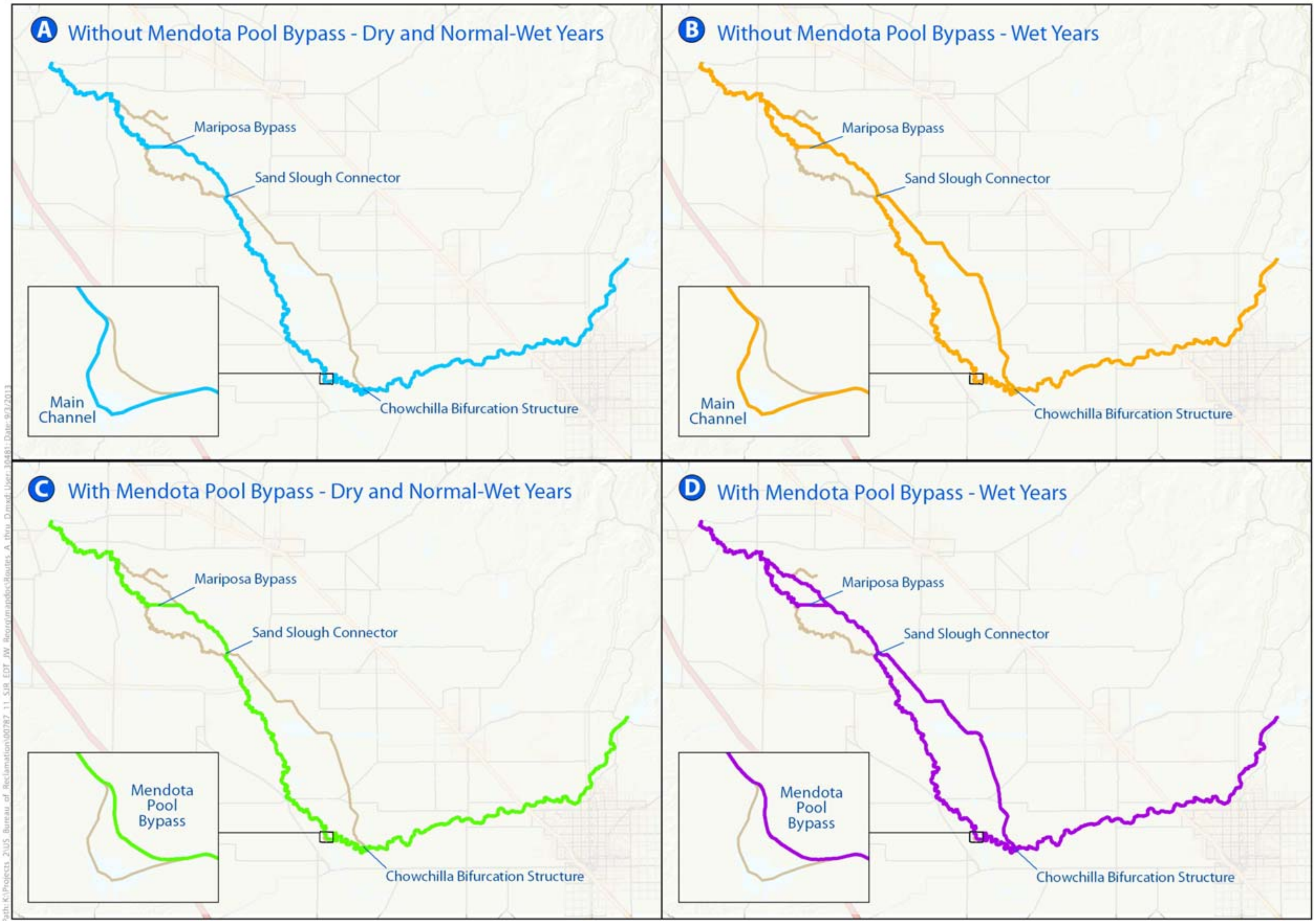

Figure 2-8. Routing Used for Reach 2B Restoration Alternatives

2.3.3 Temperature

Temperature data for the Reach 2B project was provided by Reclamation's HEC-5Q one-dimensional temperature model. Riverware flows, as described in Section 2.3.1, were run through HEC-5Q is based on HEC-5, a predecessor to HEC-RAS, along with evaluation of a heat budget at each river cross-section and comparison to an equilibrium temperature (U.S. Army Corps of Engineers 1986).

Modeled temperatures by water year type are shown in Figure 2-9. Clearly substantial warming of water occurs from below Friant Dam (Reach 1-A1) to the 2B area (Reach 2B). Temperature at Reach 2B equilibrates with air temperature and there is little further warming below that point (see also Temperature Sensitivity Set 2 Results, SJRRP 2008). Temperature is also affected by flow. During wetter water years, cooler temperatures are maintained for a longer period in Reach 2B. Regardless of water year, summer temperatures in Reach 2B were high. Temperature exceeded 20 degrees in April under the Dry condition, May in Normal-Wet condition and June in the Wet condition.

The temperatures calculated from the HEC-5Q model were used to calculated EDT input parameters using the standard EDT rating definitions (Lestelle 2004). EDT temperature inputs rate High Temperature, Low Temperature, and Temperature Refugia for each month and reach in a water year.

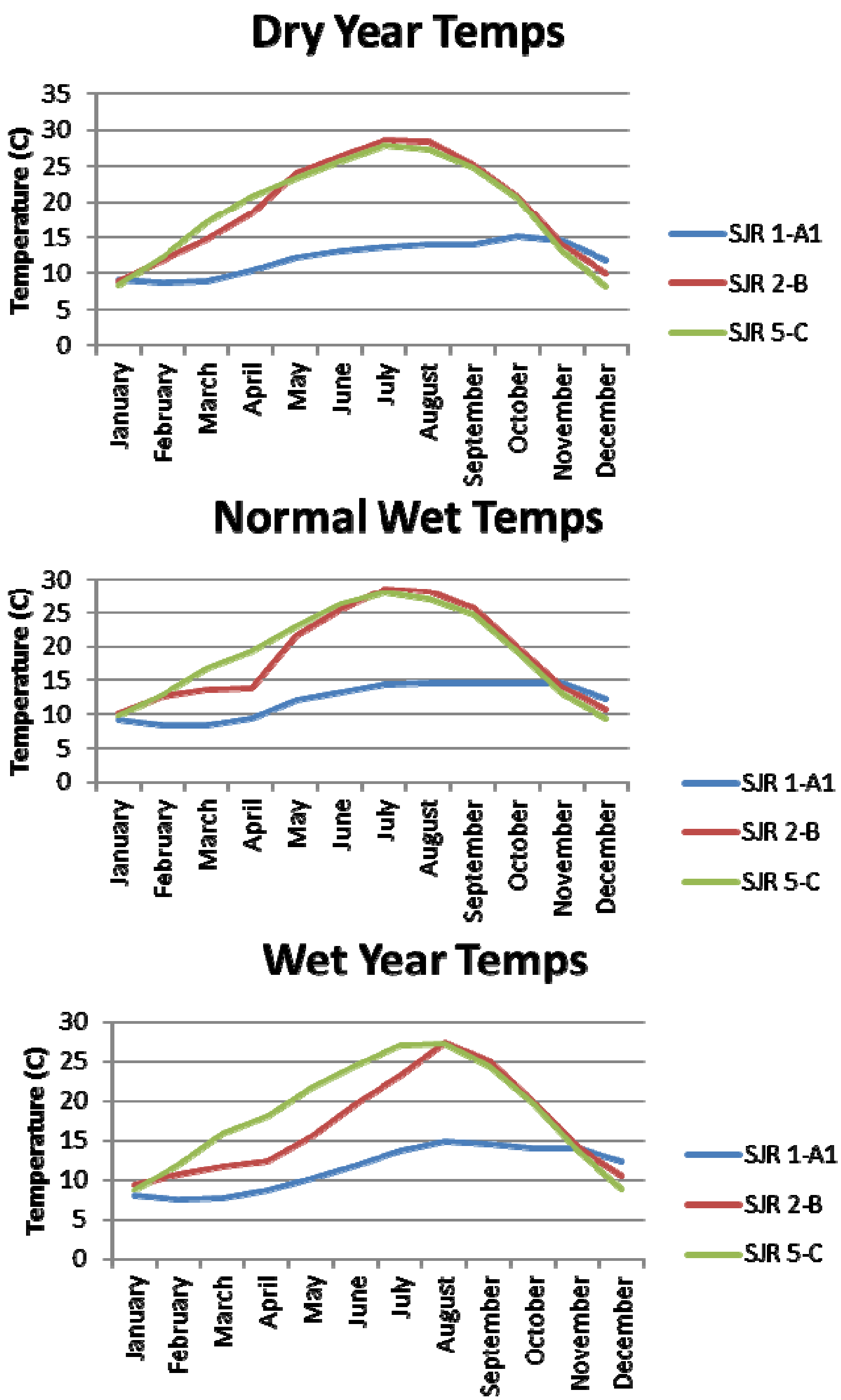

Figure 2-9. Temperatures: In-Stream Temperatures used in EDT for Dry, Normal-Wet, and Wet Years

2.4 Action Hypotheses

Action hypotheses are used to characterize effects of actions in the absence of quantitative models. These action hypotheses can provide transparent, explicit treatment of assumptions; and are designed to separate scientific conclusions (effectiveness of actions to change conditions) from implementation issues (intensity of implementation in time and space).

Effectiveness values are independent of actual project implementation, and are based on scientific conclusions regarding the effectiveness of actions to affect one or more environmental attributes. They begin with conceptual models of the effects of actions on the environment and result in quantitative conclusions regarding the degree of effect of an action on an environmental attribute. Action effectiveness values range from 0, where the action has no effect on the attribute, to 1.0, the case where the action has the theoretical potential to address 100% of the maximum restoration potential for the attribute. Restoration potential is defined as the difference in the attribute rating between the MR scenario and a Template condition. Template conditions capture the intrinsic condition of the San Joaquin River and are used as a reference condition against which to compare the Current or MR scenario. The Template condition for the SJRRP project area is described in Appendix D. For example, the action of restoring large wood to a stream could, theoretically, address 100% of the maximum restoration potential of large wood relative to the template condition regardless of intent or practicality. Generally, the effectiveness value is assigned as the maximum possible effect an action could have on an environmental attribute, because the actual effect will be tempered by action intensity values.

Intensity values are project-specific scalars that adjust the theoretical effectiveness to the reality of a proposed action at a location within the Project Area. The action intensity values describe the actual implementation of the action at specific places within the Project Area. They define the proportion of effectiveness values used in specific river reaches to affect environmental attributes. Some ways to define action intensity values include identifying reaches affected by particular actions, determining to what intensity the action will be implemented (e.g., where and how much wood would actually be placed in the stream), or considering what proportion of a reach would be affected based on length or differences in implementation on left vs. right banks.

Quantitative action hypotheses incorporate both action effectiveness and action intensity values. The result is a proportional change in “restoration potential” for each mapped attribute (for those EDT attributes with 0–4 ratings). The result of an action hypothesis is a percent change in current rating of an attribute relative to the template condition of the attribute in a reach and month.

The Core Team and ICF assigned action effectiveness values to the actions common to all alternatives. These values are displayed in charts accompanying each scenario evaluated. The values indicate a percent improvement in the attribute (towards 0) unless otherwise noted.

For the minimum restoration condition, it was concluded that conveyance of increased flow would increase pool habitat, improve water quality, and result in water temperature changes that would improve the fish community. For these attributes, action intensity was set at 100% for full restoration flows of 4,500 cfs.

Chapter 3
Reach 2B Alternatives

To meet the requirements for Reach 2B restoration as defined in the Settlement, including conveyance of at least 4,500 cubic feet per second (cfs) through the Project area, the Mendota Pool Bypass and Reach 2B Improvement Project Team formulated a number of actions (San Joaquin River Restoration Program 2012). There are three main actions to make for the Project. These include the fish passage action (i.e. Mendota Pool Bypass or Fresno Slough Dam), the floodplain habitat action (narrow or wide), and the water conveyance action (Short Canal, South Canal, North Canal, or the river delivery method). Modeled actions are the following, which are described in San Joaquin River Restoration Program 2012, and outlined in basic terms in Table 3-1.

- No action/no project alternative (minimum restoration).
- Construction of a narrow floodplain using levee setbacks and revegetation in Reach 2B.
- Construction of a wide floodplain using levee setbacks and revegetation in Reach 2B.
- Construction of the Fresno Slough Dam to isolate diversions in Fresno Slough from restoration flows conveyed in Reach 2B and the Mendota Pool area.
- Construction of a bypass channel as an alternate route around Mendota Pool (Mendota Pool Bypass).
- Construction of a Short Canal in conjunction with a Fresno Slough Dam for water deliveries from the San Joaquin River to Mendota Pool.

Routes for the alternative flow pathways throughout the Restoration Area are shown diagrammatically in Figure 2-7. The alternative pathways, which represent different fish migration routes, occur as part of the Mendota Pool Bypass Project and as part of the flood bypass system in reaches 2B and 4B.

The Reach 2B alternatives selected by the Core Team for analysis included fish passage and flow routing infrastructure, floodplain restoration, and additional diversion canals and structures for delivery to Mendota Pool. The alternatives only addressed conditions in Reach 2B, Mendota Pool, and Reach 3A. Conditions above 2B and below 3A were set to those of the Minimum Restoration Scenario.

Combination alternatives, with the narrow floodplain added to both the Mendota Pool Bypass and Fresno Slough Dam scenarios were also examined. The decision to run combination scenarios with narrow as opposed to wide floodplain was an adaptive modeling decision made after evaluating performance of the system among all independent restoration actions.

While the minimum restoration, floodplain, and routing scenarios all assumed optimum required flows and full fish passage at existing barriers, one analysis simulated a *reduced* passage scenario for adult Chinook by assuming that the Chowchilla Bifurcation Structure South would not be modified to enhance adult passage.

Table 3-1. Basic Description of 2B Restoration Alternatives

Alternatives	Descriptions
No-Action/ No-Project	Required under NEPA and CEQA. No 2B restoration Project implemented. Full passage of adult and juvenile salmon, Settlement flow conditions.
Narrow Floodplain	Restoring floodplain habitat an average of approximately 3,000 feet wide in Reach 2B
Wide Floodplain	Restoring floodplain habitat an average of approximately 4,200 feet wide in Reach 2B.
Fresno Slough Dam	Construction of a dam capable of containing Mendota Pool within Fresno Slough and the South Canal to potentially convey up to 2,500 cfs from the Reach 2B channel to Fresno Slough when needed. South Canal diversions would not require raising the water surface at the existing Mendota Dam site.
Mendota Pool Bypass	Construction of new channel and structures capable of conveying up to 4,500 cfs around the Mendota Pool.
Fresno Slough Dam with Short Canal	Construction of Short Canal to potentially convey up to 2,500 cfs from Mendota Pool to Fresno Slough when needed (operation requires raising water surface at the existing Mendota Dam site). This was compared to Fresno Slough Dam with no diversion into Mendota Pool.
Fresno Slough Dam with Narrow Floodplain	Construction of both narrow floodplain restoration and a Fresno Slough Dam
Mendota Pool Bypass with Narrow Floodplain	Construction of both narrow floodplain restoration and a Mendota Pool Bypass at the Mendota Pool reach
Chowchilla Bifurcation South Passage	No modification to improve passage (e.g., no fish ladder or sill modification) at the Chowchilla Bifurcation Structure South
Source: San Joaquin River Restoration Program 2012	

A number of attributes were updated using current monitoring and HEC-RAS data to initiate a current condition for the river system; this formulation is described in Appendix B, *Current Condition Formulation*. A Minimum Restoration scenario (MR scenario) was developed from the current condition scenario indicating how environmental attributes in the river would be shaped by the minimum required Reach 2B restoration actions. The minimum required conditions used for all Reach 2B action alternatives included an altered flow schedule from Friant Dam and conveyance of at least 4,500 cfs through Reach 2B. The minimum restoration conditions are further described below and in Appendix C, *Minimum Restoration Formulation*.

3.1 No Action/No Project (Minimum Restoration)

The No Action/No Project Alternative is a requirement under NEPA and CEQA to analyze effects that would occur if the Project were not implemented (San Joaquin River Restoration Program 2012). For characterization in EDT, this alternative was considered to be the Minimum Restoration condition described in Appendix C, *Minimum Restoration Formulation*. The Minimum Restoration scenario (MR scenario) is the baseline for evaluating the Reach 2B alternatives.

Construction of this alternative begins with a characterization of the current condition in each reach of the Project Area, based largely on Jones & Stokes (Jones & Stokes 2002). Under this condition, no structural changes such as channel construction or levee setbacks are assumed in the system, but changes to some environmental attributes are assumed due to the SJRRP flow schedule affecting flow and temperature (Appendix C). Movement of water through the system was assumed to follow routing A in Dry and Normal-Wet years and routing B in Wet years (Figure 2-5, A and B). The SJRRP Settlement flow condition includes an altered flow schedule from Friant Dam and at control structures to provide conveyance of at least 4,500 cfs through Reach 2B. HEC-RAS analysis by Reclamation provided expected channel widths in the study reaches under the altered flow regime. Finally, full passage of adult and juvenile salmonids was assumed at each of the existing migration barriers, including the diversions in Mendota Pool and the Chowchilla Bifurcation Structure. Action effectiveness values for conveyance of restoration flows in Reach 2B are displayed in Figure 3-1, which shows the expected long-term percent improvement that might be expected under prolonged restoration flows.

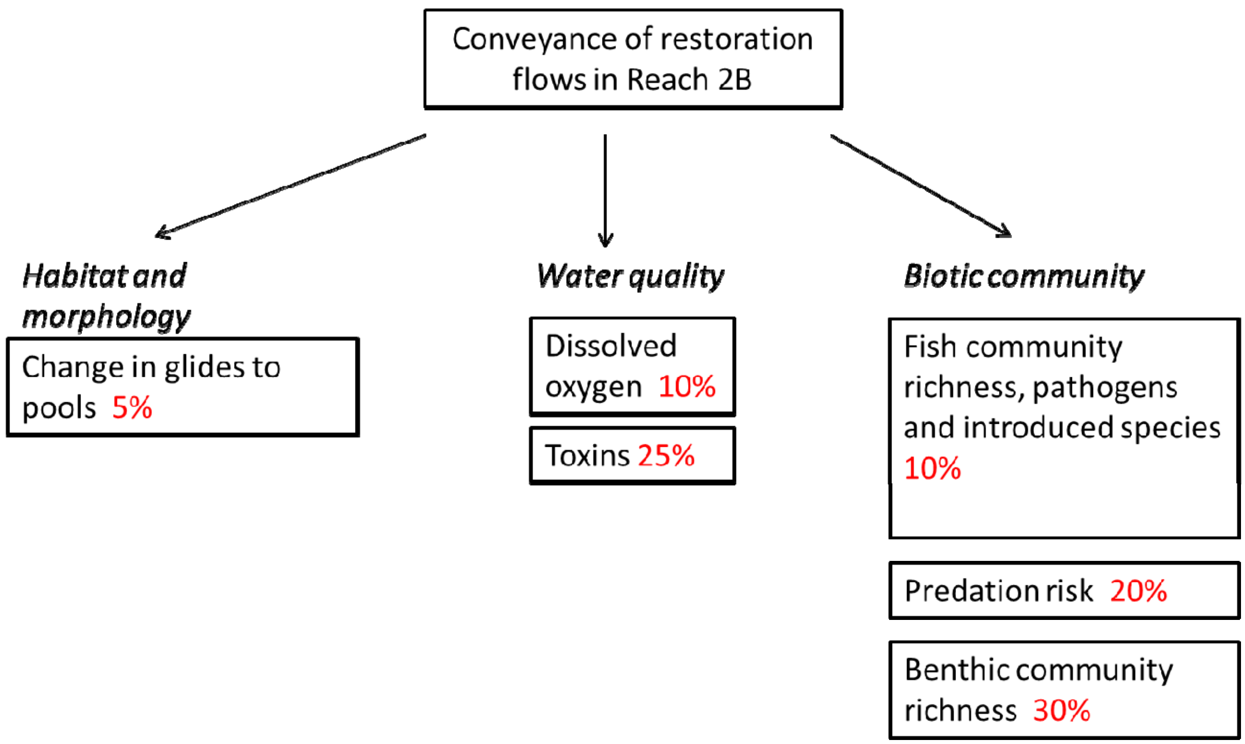

Figure 3-1. Action Effectiveness Values for the Conveyance of Restoration Flows in Reach 2B (The percentages refer to the maximum percent of restoration potential that could be addressed by the action for each attribute; changes were scaled downward to reflect the intensity of application of the action in the Project Area.)

3.2 Floodplain Restoration Alternatives

The SJRRP Settlement calls for restoration of floodplains. Narrow and a Wide floodplain alternatives were analyzed (Figure 3-2), as described in the Project Description Technical Memorandum for the Mendota Pool Bypass and Reach 2B Improvements Project (SJRRP 2012). Conditions above and below Reach 2B were set to the MR scenario.

Floodplain habitat was directly added to the EDT model for these scenarios as acres of inundated area by reach and by month. This acreage was calculated using flow data and HEC-RAS models provided by Reclamation. In-stream attributes were also improved based on hypotheses of floodplain improvements. Conveyance of 4,500 cfs in Reach 2B was assumed to occur and to affect EDT attributes for all Reach 2B actions.

During Dry and Normal-Wet years, flows in both the Narrow Floodplain and Wide Floodplain scenarios route through the main channel at the Chowchilla Bifurcation Structure South. Flow is then routed through the Sand Slough Connector to the Eastside Bypass, and next through the Mariposa Bypass into Reach 4B3 (Figure 2-8, A).

During Wet years, flows in both floodplain scenarios went through both the Chowchilla Bypass and the main river channel at the Chowchilla Bifurcation Structure. Then, all flows passed through the Central Eastside Bypass, with some flows headed through the Mariposa Bypass and others heading on to the Eastside Bypass (Figure 2-8, B).

Action hypotheses related to improvement in attributes in 2B1A and 2B1B due to floodplain restoration are diagrammed in Figure 3-3. Action intensity values were set to 100% for Wide Floodplain and to 80% for Narrow Floodplain; effectiveness values were the same for both. These action effectiveness values further improve habitat from the Minimum Restoration scenario.

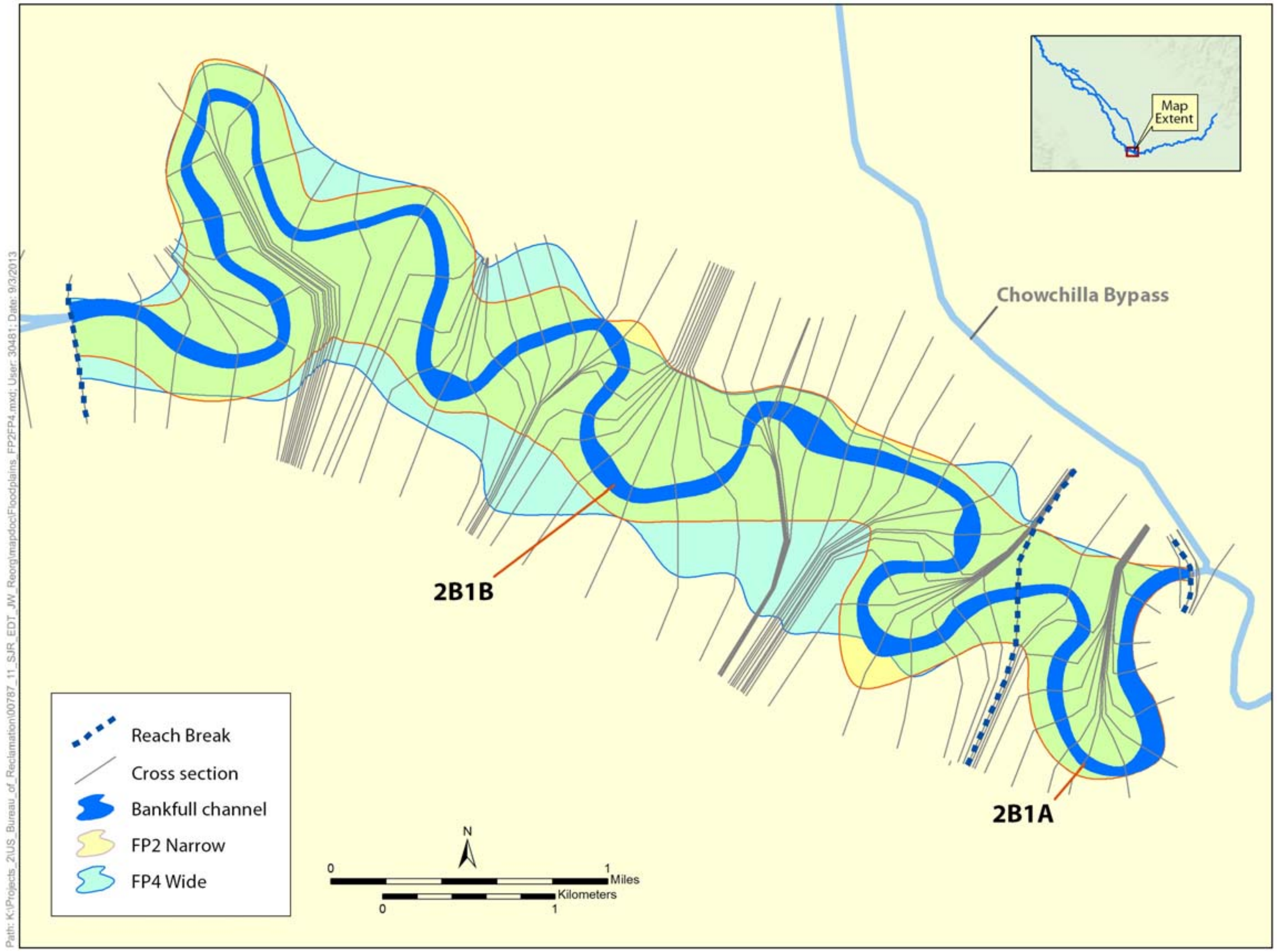

Figure 3-2. Modeled Floodplain in Reach 2B during April

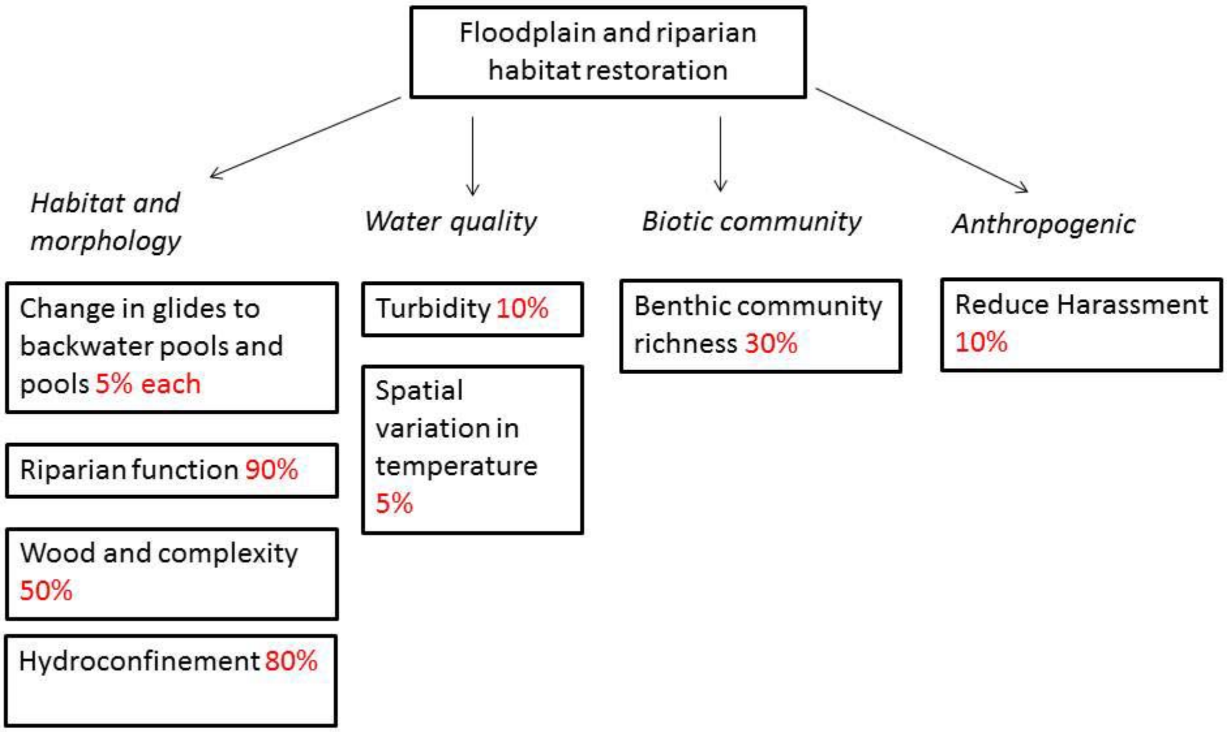

Figure 3-3. Action Effectiveness Value for Floodplain and Riparian Habitat Restoration (The percentages refer to the maximum percent of restoration potential that could be addressed by the action for each attribute; changes were scaled downward to reflect the intensity of application of the action in the Project Area.) Harassment refers to disturbance of fish populations by human activity such as fishing, boating or other activities.

3.2.1 Narrow Floodplain

The narrow floodplain scenario entails restoring floodplain to a mean width of approximately 3,000 feet and planting native riparian habitat in EDT reaches 2B1A and 2B1B for the project length of 10.1 miles. Actions common to floodplain construction—removing existing levees, installing new levees, conducting floodplain grading, and restoring floodplain—were all grouped in the category of "floodplain and riparian habitat restoration." These actions were concluded to affect an array of EDT environmental attributes (Figure 3-3). Action intensity values were set at 80% for reaches 2B1A and 2B1B.

Widths for 2B1A and 2B1B (above the Mendota Pool) were derived from the Fresno Dam Narrow Floodplain alternative HEC-RAS module (although the assumption of Fresno Dam was not evaluated in this action). In-channel widths for other reaches were the same as for the Minimum Restoration scenario. Data to calculate monthly floodplain inundation values based on the flow scenario were also derived from this HEC-RAS module.

To calculate monthly floodplain inundation for the 2B project reaches, channel and floodplain inundation widths based on the relevant flow schedule were measured. A GIS model using the "route events" tool was used to plot data points along cross sections and to connect points to obtain right and left bank channel and flood inundation lines. A Bezier interpolation algorithm was applied to provide the channel and flood inundation lines with a more natural curve. Reach boundary cross sections were used to close off the left and right bank lines and construct polygons. After channel polygons were erased from flood inundation polygons, acres of floodplain inundation were calculated by reach.

Figure 3-2 shows the extent of average inundated floodplain for Narrow and Wide Floodplain scenarios during a Wet year and the maximum inundation in April. Under the Narrow Floodplain scenario, 1,258 acres were inundated in April (maximum inundation).

3.2.2 Wide Floodplain

The Wide Floodplain scenario entails restoring floodplain to a width of approximately 4,200 feet and planting native riparian habitat in EDT reaches 2B1A and 2B1B for the project length of 10.1 miles. Action effectiveness values for effects of floodplain and riparian habitat restoration on EDT attributes were the same as those for Narrow Floodplain (Figure 3-3). Action intensity values were set at 100% for reaches 2B1A and 2B1B for floodplain restoration. Widths and inundation values for 2B1A and 2B1B were derived from the Fresno Dam Wide Floodplain alternative. Under the Wide Floodplain scenario during maximum inundation, floodplain is calculated at 1,576 acres (Figure 3-2), which added 318 acres to the Narrow Floodplain scenario.

3.3 Mendota Pool Alternatives

Three alternatives for directing flow around Mendota Pool were considered. The first alternative, referred to as the Fresno Slough Dam alternative, would involve building a dam on the existing Fresno Slough and relocating all diversions from Mendota Pool to Fresno Slough, which would isolate the diversions from Restoration Flows and the Reach 2B channel. Restoration flows would be routed down the existing Reach 2B, through a channel that would be carved in the current location of Mendota Pool, and over the sill of the existing Mendota Dam. Route A would be utilized in dry and Normal-Wet years and Route B would be utilized in Wet years (Figure 2-8).

The second Mendota Pool alternative is referred to as the Fresno Slough Dam with Short Canal alternative. This added alternative flow diversions to the Fresno Slough Dam alternative. Suboptions evaluated for the Fresno Slough Dam alternative were whether a 2,500 cfs diversion would utilize the Short Canal that would convey water from the existing Mendota Pool location to Fresno Slough; alternatively a South Canal would be used to divert water from the Reach 2B channel upstream of the existing Mendota Pool. The Short Canal option would likely require installing the boards at the existing Mendota Dam, which would cause the flows to pond in the existing Mendota Pool location. The South Canal option would not impound water in Mendota Pool. Both the Short Canal and South Canal options may require flow control structures and training levees. The Short Canal would have a longer juvenile fish salvage return pipe than would the South Canal. Routings A and B would be utilized as described for Fresno Slough Dam.

The Mendota Pool Bypass alternative would avoid sending flows through the main river channel at Mendota Pool. Alternatively, a new channel, the Mendota Pool Bypass, would be constructed to avoid routing restoration flows through the current EDT reaches 2B2, Mendota Pool, and 3A and their many water supply diversions. This alternative would utilize routing C in Dry and Normal-Wet years and routing D in Wet years (Figure 2-8, D).

3.3.1 Fresno Slough Dam

This action evaluated the construction of a dam to hold Mendota Pool water in the Fresno Slough. The construction of the dam was primarily assumed to affect the morphology of the river, represented by changes in minimum and maximum widths and width patterns. Some additional attributes including introduced species, contaminants, habitat, and riparian area were also improved based on team hypotheses concerning effects of increased restoration flows and decreased outflow of Fresno Slough water into the system.

In-channel widths were derived from the Fresno Slough Narrow Floodplain scenario for reaches 2B and Mendota Pool, while other widths were the same as for Minimum Restoration.

During Dry and Normal-Wet years, flows in this scenario headed through the main channel at the Chowchilla Bifurcation Structure South, through the area that is currently Mendota Pool and over the sill of Mendota Dam. They then flowed through the Sand Slough Connector to the Eastside Bypass, and next through the Mariposa Bypass into Reach 4B3 (Figure 2-7, A).

During Wet years, flows in this alternative entered both the Chowchilla Bypass and the main river channel at the Chowchilla Bifurcation Structure South. Then, all flows passed through the Eastside Bypass, with some flows headed through the Mariposa Bypass and others continuing down the Eastside Bypass (Figure 2-8, B).

3.3.2 Fresno Slough Dam with Short Canal

The Short Canal is an option for conveying water from Reach 2B to the pool created behind the Fresno Slough Dam, and assumes construction of the Fresno Slough Dam. It would discharge into Fresno Slough about 0.8 river miles south of Mendota Dam (San Joaquin River Restoration Program 2012). Implementation of the Short Canal would involve flow control structures at the head of the canal and the continued operation of Mendota Dam.

Flow routing scenarios for Dry, Normal-Wet, and Wet years were the same as for Fresno Slough Dam, described above (Figure 2-8, A and B; Table 2-5).

During the rare event when water needs to be diverted to Fresno Slough to supply the San Joaquin River Exchange Contractors, the water level of the area of the current Mendota Pool/EDT Reach 2B2 would have to rise in order to obtain a sufficient water gradient to use the Short Canal. This would be accomplished by replacing the Mendota Dam boards. The fish screen on the Short Canal control structure would use a relatively long return pipe for shunting fish into river below the dam. Backing up the water would "re-create" a "Mendota Pool" when 2,500-cfs diversions occur. However, the "Mendota Pool" would be filled with water released from Friant Dam rather than Delta-Mendota Canal water, and so the potential for introducing exotic species from the Delta (e.g., striped bass) would be reduced.

This scenario was based on the Fresno Slough scenario for a Wet year. Widths were modified for the relevant EDT reaches (the Mendota Pool reach and 2B2) during average flooding months when the Short Canal could be used, to reflect re-formation of Mendota Pool morphometric conditions. Channel widths were the only attribute changed from Fresno Slough Dam conditions. It is hypothesized that predation may increase with installation of the Short Canal due to predators inhabiting the return pipe, reformation of pool conditions, and the greater height as the water and fish spill over Mendota Dam where predators may congregate (pers. comm. Carl Mesick, Fishery Biologist, USFWS). However, these conditions would only be created during a very rare delivery event so these changes were not incorporated into the modeling effort.

3.3.3 Mendota Pool Bypass

This alternative involves constructing a channel between Reach 2B and Reach 3 to convey up to 4,500 cfs of restoration flows around Mendota Pool. The Mendota Pool Bypass channel also includes a series of 10 to 18 grade-control structures to minimize the potential for headcutting and incision in the bypass channel.

Because the Mendota Pool Bypass does not exist, conditions in a bypass had to be hypothesized based on conditions in nearby reaches. Baseline characterization of environmental attributes for the Mendota Pool Bypass took some elements from the parallel Mendota Pool reach (e.g., temperature values, benthic invertebrates) and some elements from other bypass reaches (e.g., habitat type distribution). In-channel widths from the Mendota Pool Bypass Narrow Floodplain HEC-RAS module were used to propagate widths for evaluating the Mendota Pool Bypass as a stand-alone action.

During Dry and Normal-Wet years, flows in the Mendota Pool Bypass alternative headed through the main channel at the Chowchilla Bifurcation Structure South. Flows then are routed from 2B1B into the Mendota Pool Bypass, and then out to 3B. Flows travel through the Sand Slough Connector to the Eastside Bypass, and next through the Mariposa Bypass into Reach 4B3 (Figure 2-8, C and Table 2-5).

During Wet years, flows are split between the Chowchilla Bypass and the main river channel at the Chowchilla Bifurcation Structure South. In the main river channel, flows route from 2B1B into the Mendota Pool Bypass, and then out to 3B. From Reach 3B, all flows passed through the Eastside Bypass, with some flows headed through the Mariposa Bypass and others continuing down the Eastside Bypass (Figure 2-7, D and Table 2-5).

3.4 Reduced Passage at Chowchilla Bifurcation Structure South

While other alternatives assumed 98–100% passage at obstructions for all life stages of Chinook, an action was evaluated to examine the effect of reduced passage at the Chowchilla Bifurcation Structure South that would result without implementation of a fish ladder or other passage enhancement at that location. Adult passage at the Chowchilla Bifurcation Structure South was estimated as a function of the hydraulic conditions at the structure relative to adult passage criteria and expected adult spring Chinook migration timing. Daily flow estimates were generated for years from 1922 to 2003 for the river below the Chowchilla Bifurcation Structure South, using Riverware by the Reclamation Technical Service Center. The adult passage criteria used for the analysis are from the Reach 2B Project Description Technical Memo. The hydraulic conditions at the Chowchilla Bifurcation Structure South relative to flows there were provided by DWR (San Joaquin River Restoration Program 2011).

Flow routing scenarios for Dry, Normal-Wet, and Wet years were the same as for Fresno Slough Dam, described above (Figure 2-8, A and B and Table 2-5).

It was assumed that when water velocities exceeded the optimum passage criteria, the proportion of the adults able to pass would be equal to the ratio of the optimum value divided by the predicted velocity. For example, the highest velocity in the optimum range for cruising speed was 3.4 fps; if maximum Chowchilla Bifurcation Structure South velocities were 5.2 fps, then 65% of the adults were estimated to be able to pass through the structure at that flow. It was also assumed that when the Chowchilla Bifurcation Structure South gates were lowered and any flow was diverted into the bypass, the velocities under the gate would be too high for adult passage.

Adult spring Chinook were assumed to migrate into the Restoration Area from March through June, with the peak period from April 15 to May 15. The mean percentage of adults that could pass on a given day was weighted by a migration timing value. A value of 1.0 was given for passage from April 15 to May 15. A value of 0.75 was given for April 1 to 14 and from May 16 to 31. A value of 0.5 was given from March 15 to 31 and from June 1 to June 15. A value of 0.25 was given from March 1 to 14 and from June 16 to 30. A weighted average of the percent passage was computed for each water year type. Passage was calculated to be 35.9% in dry years, 54.6% in Normal-Wet years, and 59.5% in Wet years for adult Chinook at Chowchilla Bifurcation Structure South (Table 3-2).

Table 3-2, *Chowchilla Passage*, summarizes the routes and characteristics of the passage at the Chowchilla Bifurcation Structure South compared to the Minimum Restoration alternative during various water year types.

Table 3-2. Chowchilla Passage: Review of Routing and Passage Characterization for Passage at Chowchilla Bifurcation Structure South Scenarios

	Dry	Normal-Wet	Wet
Route: Main River Channel?	Yes	Yes	Yes
Route: Chowchilla Bypass?	No	No	Yes
Passage percent at Chowchilla Bifurcation Structure South			
Minimum Restoration	98%	98%	98%
Passage at Chowchilla Bifurcation Structure South	35.9%	54.6%	59.5%

3.5 Combination Scenarios

Combination scenarios were constructed to determine relative benefits of the Mendota Pool Bypass or Fresno Slough Dam construction in conjunction with floodplain construction and planting. In-channel attributes and floodplain acreages for the EDT reaches 2B1A and 2B1B were derived from the Narrow Floodplain scenarios for each respective year type. In-channel attributes for each year type were derived from the Fresno Slough Dam alternative for 2B2, Mendota Pool, and 3A for the Fresno Slough Dam combination scenarios; and from the Mendota Pool Bypass alternative for the Mendota Pool Bypass combination scenarios (Table 3-3).

Table 3-3. Characteristics of Combination Scenarios

	In-channel attributes and floodplain- 2B1A/ 2B1B	In-channel attributes- Fresno area and Mendota Pool Bypass	Maximum floodplain amount (acres)		Route
Fresno Slough Dam with Floodplain	Same as for Narrow Floodplain scenario	Same as for Fresno Slough Dam alternatives	Dry	105.6	A
			Normal Wet	358.7	A
			Wet	1305.1	B
Mendota Pool Bypass with Floodplain	Same as for Narrow Floodplain scenario	Same as for Mendota Pool Bypass alternatives	Dry	121.4	C
			Normal Wet	384.6	C
			Wet	1335.9	D

For these scenarios, floodplain habitat was directly added to the EDT model as acres of inundated area by reach and by month (Figure 3-4). This acreage was calculated based on monthly average streamflow using flow data and HEC-RAS models provided by Reclamation. In-stream attributes were also improved based on hypotheses of floodplain improvements.

Floodplain acreages for the project area (2B2, Mendota Pool, and 3A; or the Mendota Pool Bypass) were calculated using the same methods as for narrow and wide floodplain (see Section 3.2.1, *Narrow Floodplain*). This resulted in overall more floodplain inundation under the Mendota Pool Bypass combination scenarios than the Fresno Slough Bypass combination scenarios (Figure 3-4, Table 3-3).

Flow routing scenarios for Dry, Normal-Wet, and Wet years were the same as for Fresno Slough Dam (Figure 2-8, A and B) and Mendota Pool Bypass alternatives (Figure 2-8, C and D) in their corresponding combination scenarios (Table 3-4).

Table 3-4. Route Options Examined for Each Combination Scenario and Water Year Type

	Water Year Type		
Alternative	Dry	Normal-Wet	Wet
Fresno Slough Dam with Narrow Floodplain	A	A	B
Mendota Pool Bypass with Narrow Floodplain	C	C	D

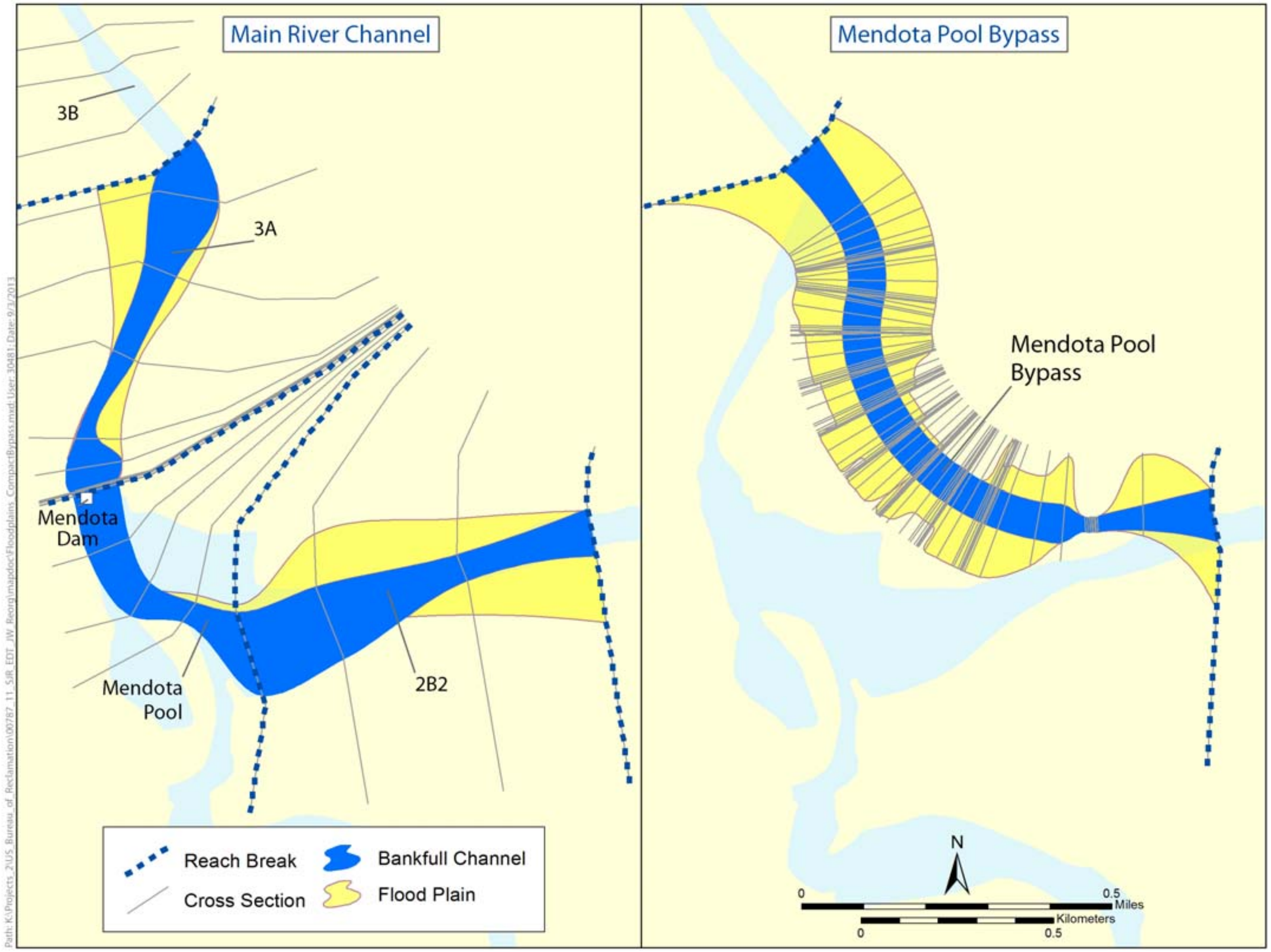

Figure 3-4. Extent of Inundated Floodplain during Wet Year and the Maximum Inundation Month, April, for Narrow and Wide Floodplain Construction in Reaches 2B1A and 2B1B for the Fresno Slough Dam Alignment (left) and the Mendota Pool Bypass Alternative (right)

Chapter 4
Results and Discussion

4.1 No Action/No Project (Minimum Restoration) Alternative

4.1.1 Population Performance

The No Action/No Project alternative (Minimum Restoration Scenario, MR scenario) evaluated conditions under the SJRRP Settlement flow schedule affecting flow and temperature (Appendix C), but with no structural changes to the current configuration except to assume full fish passage at all existing barriers (Section 3.1). The habitat potential of the SJR Project Area under the MR scenario to support spring-run Chinook was low across all water year types in the MR scenario (Table 4-1). Equilibrium abundance ranged from 152 under Dry water conditions to 448 adult returns under Wet water conditions. Compared to the Dry condition, the equilibrium abundance of spring-run Chinook increased by about 50% in the Normal-Wet condition and by almost 200% under the Wet condition. The change in abundance and capacity reflected the change in channel width throughout the entire SJR Project Area that resulted from the increased flow in wetter water years.

Productivity was low and remained relatively constant across water years in the MR scenario (Table 4-1). The major factor limiting productivity in this, and all other alternatives, was water temperature. The relatively modest change in productivity between water years was because the only environmental changes between water years were flow, which mainly affected capacity, and temperature, which affected productivity.

In a somewhat counter-intuitive result, productivity under the MR scenario increased in the Normal-Wet condition relative to the Dry condition but then declined for the Wet year condition (Table 4-1). This pattern is seen throughout the Reach 2B analysis and is the result of how EDT computes population productivity. Recall that EDT computes population performance along multiple life history trajectories, each of which provides an estimate of capacity and productivity that reflects conditions along the time/space route (Section 2.1). We exclude trajectories with a productivity less than 1.0 return per spawner (replacement) and compute the average productivity of the remaining trajectories to compute population productivity reported in Table 4-1. This is seen in Figure 4-1 where very few life history trajectories have productivities greater than 1.0 in the dry year type. In fact, most have productivities close to zero. In a Normal Wet year type (Figure 4-1 B) trajectory performance improves for those life histories originating from the upper reach (SJR-1 – A1) and population productivity is higher. In a Wet year type (Figure 4-1 C) trajectory performance improves sufficiently to introduce trajectories originating from the lower reach (SJR-1 – A2). There is a non-linear relationship between the number of trajectories and the productivity level. In a Wet year type individual trajectory productivities increased relative to the other year types, and more trajectories were successful (i.e., productivity greater than 1.0) – however the total productivity still increased, as there was more increase in productivity than low-level trajectories added. As habitat conditions improve under wetter water year conditions, largely because of improved temperature, trajectories that were excluded under the Dry or Normal-Wet condition moved across the

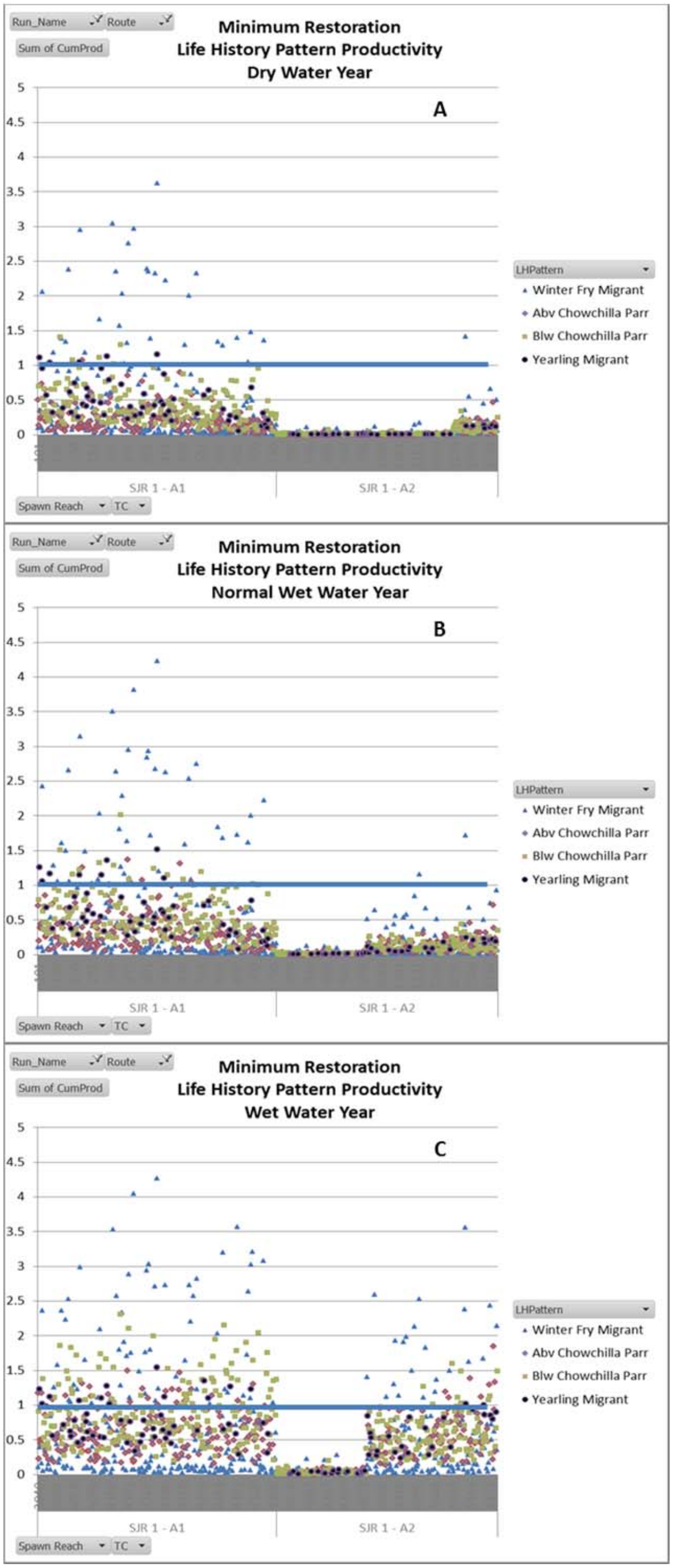

Figure 4-1. Productivity (returns/spawner) of Spring-run Chinook Life Histories for a Dry (A), Normal-Wet (B), and Wet (C) Water Year Types

productivity threshold (1.0) and were added to the average productivity. The addition of many trajectories with a low, but greater than 1.0, productivity lowered the average productivity. The result was a decrease in population productivity relative to the Normal-Wet year type, but an increase in life history diversity (number of sustainable trajectories) reflecting an increase in the breadth of suitable habitat. The equilibrium abundance increased because of the increased capacity.

Table 4-1. Estimated Spring-run Chinook Population Performance of San Joaquin River Project Area under Minimum Restoration Habitat Conditions

	Dry	Normal-wet	Wet
Productivity (returns/spawner)	2.4	2.7	2.4
Capacity (adult returns)	258	356	769
Equilibrium Abundance (adult returns)	152	222	448

4.1.2 Life History Performance

All population level results for EDT represent potential performance of spring-run Chinook salmon averaged across the four life history strategies discussed in Section 2.2.3. In this section, the performance of the individual life histories under the Minimum Restoration condition will be discussed. Relative performance between life history strategies was very similar across all modeled strategies. For this reason, life history performance will only be discussed for the Minimum Restoration condition.

Figure 4-2 compares the productivity (adult returns/spawner) for the four life history strategies for the three water year types. In all conditions the Winter Fry strategy outperformed the other life history strategies; productivity was also relatively constant across water year conditions. The relatively greater productivity of the Winter Fry strategy compared to the other strategies was particularly stark under the Dry condition when only the Winter Fry strategy yielded productivity appreciably greater than 1.0 (productivity less than 1.0 is considered non-viable); performance of the other three life histories improved under Normal Wet and Wet water year conditions.

The relative performance differences between the life history strategies and water year conditions were amplified when considering equilibrium abundance (Figure 4-3). Equilibrium abundance includes the effect of both productivity and capacity. Capacity was particularly responsive to water year conditions (Table 4-1) leading to the strong water year signal seen in Figure 4-3. Note that the equilibrium abundance in Table 4-1 is the average of abundance by strategy in Figure 4-3 weighted by the life history proportions in Table 2-5; hence the sum of abundance across the strategies is much greater than the weighted average in Table 4-1.

The greater performance of the Winter Fry strategy reflects the fact that they are exposed to habitat quantity and quality constraints in the Project Area for a shorter short time than other life history strategies during their migration down river and into the Delta. Figure 4-2 shows example life history trajectories and cumulative capacities (MinRest –Wet year type) for Winter Fry, fry that stopped to rear in the upper reaches (Abv Chow Parr), and fry that moved rapidly to below the Chowchilla Bifurcation Structure to rear (Blw Chow Parr). The parr strategies assumed that fish would spend four to six weeks in the project area before and then move out prior to the summer high water temperature (Figure 2-3). The Blw Chow strategy assumed that fish would spend four to six weeks in the lower San Joaquin Project Area (between the Chowchilla Bifurcation Structure and

Mendota) and then move out. Band capacities shown in Figure 4-2 are an index of habitat quantity and quality for the different life history strategies (Blair et al. 2009). The trajectories shown in Figure 4-2 are just three of several thousand trajectories modeled to simulate spring-run Chinook habitat use in the Project Area. In the examples, capacity, in terms of the number of fish that occupy a standardized area of river, is high right after emergence and declines over time due to competition for space and food, and effects of habitat quality. Severe capacity constraints can occur when fish occupy reaches for extended periods with limited space or poor quality. Winter Fry moved rapidly downstream avoiding some of the constraints in the Project Area. The sharp drop in capacity for the Abv Chow Parr and Blw Chow Parr strategy shown in Figure 4-2 represents a life history strategy that simulates Chinook rearing for an extended period in the upper reaches and the 2B project area, respectively. In both cases habitat constraints have a strong effect on abundance leaving the project area. Generally, trajectories that moved farther downstream to rear experienced greater habitat quantity and had higher capacities leaving the project area.

The rapid migration of Winter Fry is also why productivity of this life history strategy changes very little with water year type compared to the other strategies. While receiving less exposure to conditions in the SJR Project Area, this life history was modeled to have a protracted exposure to conditions in the Delta and did have an appreciably lower post-Merced survival compared to the other strategies. Winter fry migrants in the field appear to make little or no contribution to returns of Chinook salmon in the San Joaquin system (Carl Mesick, USFWS, personal communication). There are no empirical estimates of survival of Chinook fry in the Delta and it is possible that the assumed Delta survival was still too high.

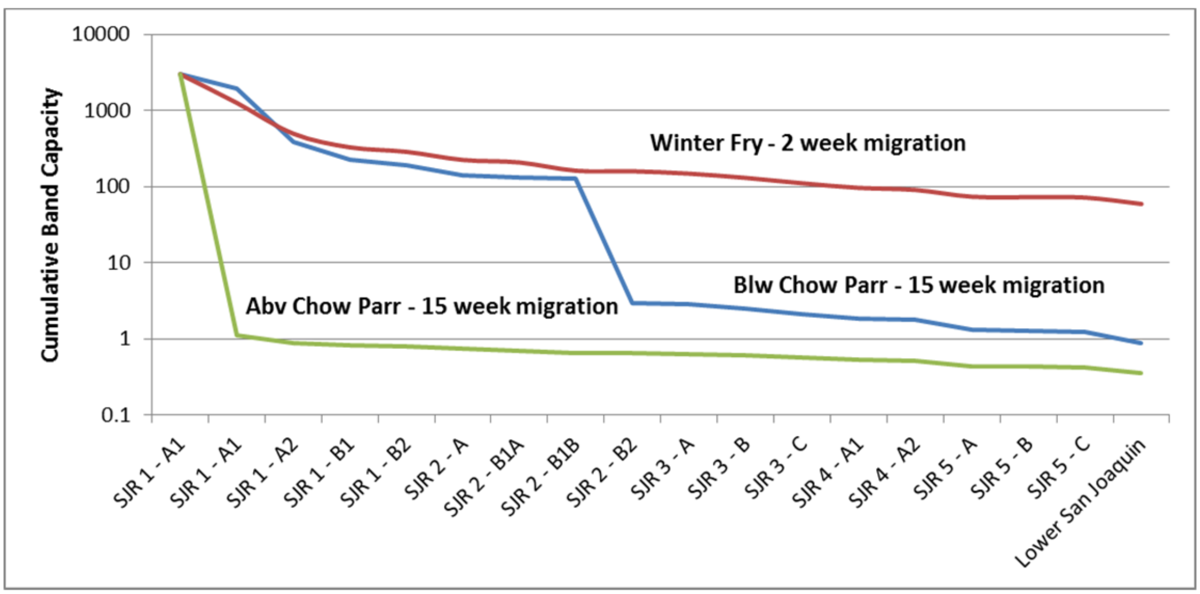

Figure 4-2. Effect of Life History and Habitat Quantity on Cumulative Capacity of Spring-run Chinook Fry and Parr for Wet year type under Minimum Restoration Condition

Among all other modeled life history strategies, the best performing group was the Below Chowchilla (BlwChow) strategy described previously (Figures 4-3 and 4-4). While habitat quality of habitat tended to be similar or slightly better in Reach 1, the quantity of juvenile rearing habitat (pools and glides) tended to be slightly less in Reach 1, constraining the Above Chowchilla (AbvChow) strategy when compared to the Below Chowchilla (BlwChow) strategy. The yearling smolt strategy performed surprisingly well especially considering that the assumption was that this strategy would represent a smaller proportion of the life history distribution in the model—10% versus 25% for the other strategies. In the yearling smolt strategy juveniles stayed up to 1 year in the spawning reaches below Friant Dam and then outmigrated quickly through the river and Delta (Figure 2-3). Temperature conditions below Friant Dam were favorable throughout the year (Figure 2-6) leading to relatively good performance.

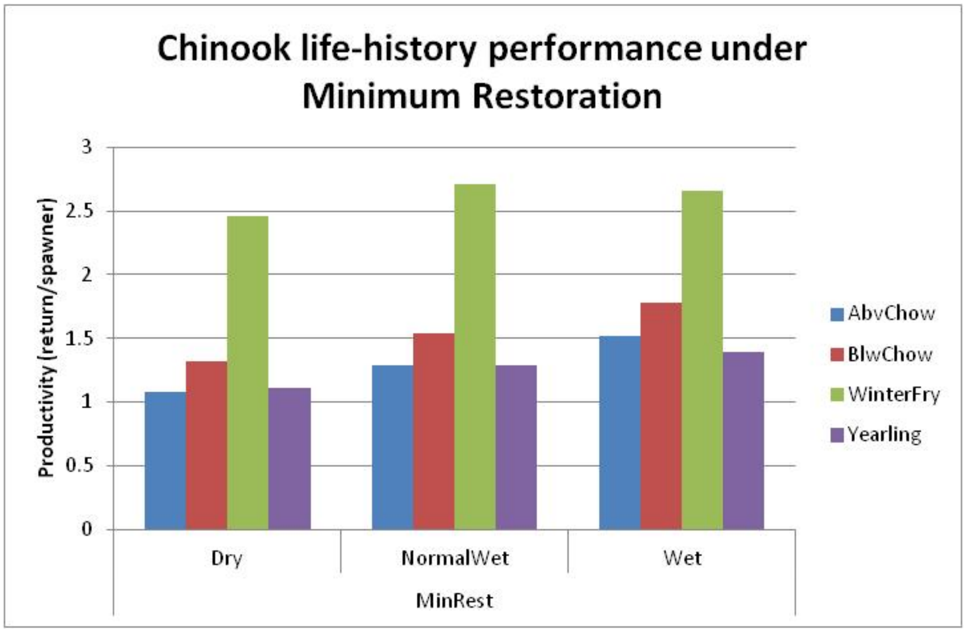

Figure 4-3. Productivity (returns/spawner) of Spring-run Chinook Life Histories by Water Year Type under the Minimum Restoration Condition

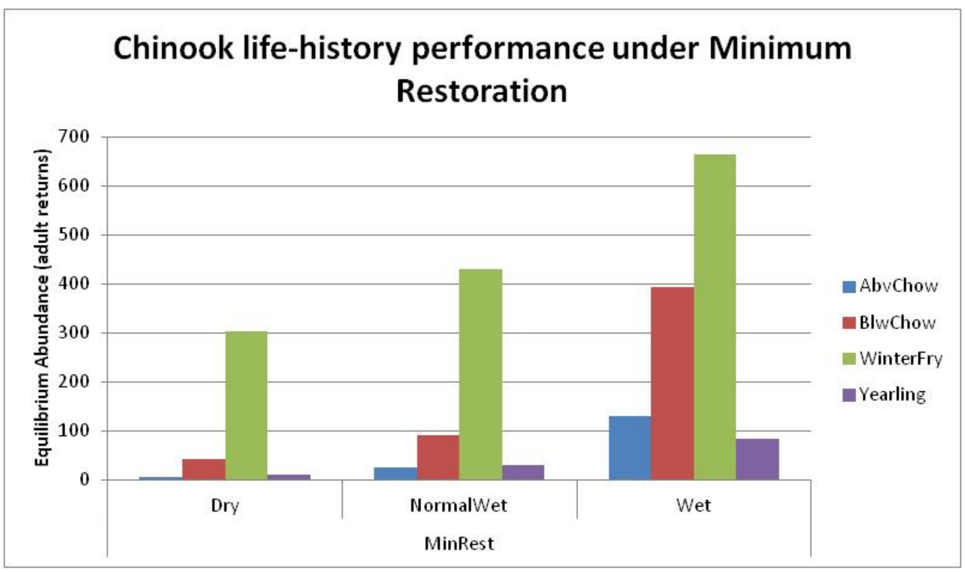

Figure 4-4. Equilibrium Abundance (adult returns) of Spring-run Chinook Life Histories by Water Year Type under the Minimum Restoration Condition

4.2 Floodplain Restoration Alternatives

In evaluating floodplain in the 2B area, two questions were asked:

1. What are the relative benefits of floodplain restoration?
2. Are there different benefits to a narrow vs. a wide floodplain restoration?

Restoring floodplain in 2B1A and 2B1B of the San Joaquin River did improve modeled performance of spring-run Chinook. Relative to the MR scenario population productivity, capacity, and abundance of spring-run Chinook were enhanced by addition of floodplain in Reach 2B (Table 4-2). Abundance improved by 3.3% in dry years, by 5.4% in normal-wet years, and by 1.8% in wet years relative to the MR scenario for each year type. The lesser increase in abundance in the Wet condition reflects the decrease in productivity due to inclusion of additional low-productivity trajectories as discussed above in Section 4.1.1. The difference between the narrow and wide floodplain alternatives was not detectable.

The biological benefits of the Reach 2B floodplain alternatives were limited by three major factors. The first factor limiting the benefits of the modeled floodplain alternatives was scale of physical change. The results in Table 4-2 indicate that the change in spring-run Chinook performance at the population scale due to water year conditions was much greater than the change that resulted from the addition of floodplain in Reach 2B. Abundance increased across the three water year conditions by almost 200%, whereas the addition of floodplain in Reach 2B only increased abundance by, at the most, 5,4%. The explanation for this difference is that the varying flow conditions as a result of water years changed width throughout the entire 150 miles of the San Joaquin Project Area including the spawning area below Friant Dam; the addition of floodplain only added habitat in the 10.1 mile section of Reach 2B above Mendota and only affected juvenile rearing in that section. The Narrow Floodplain alternative added 1,258 acres of connected floodplain, which is a small portion of the entire Project Area. Thus the amount of benefit derived from floodplain restoration was limited not by biological effectiveness but by scale.

Scale of change also explains the lack of discernible difference in performance between the narrow and wide floodplain alternatives (Table 4-2). The Wide Floodplain alternative only added an additional 318 acres to the narrow floodplain alternative (Section 3.2.2). This small change in floodplain area was not enough to change performance for the population at the level of significant figures used for the analysis, especially when weighted by the timing of inundation discussed below.

Table 4-2. Estimated Spring-run Chinook Population Performance under the Reach 2B Floodplain Alternatives Compared to the Minimum Restoration Baseline

	Dry	Normal-wet	Wet
Productivity (returns/spawner)			
Minimum restoration	2.4	2.7	2.4
Narrow floodplain	2.5	2.7	2.4
Wide floodplain	2.5	2.7	2.4
Capacity (adult returns)			
Minimum restoration	258	356	769
Narrow floodplain	265	373	781
Wide floodplain	265	373	781
Equilibrium Abundance (adult returns)			
Minimum restoration	152	222	448
Narrow floodplain	157	234	456
Wide floodplain	157	234	456

The second factor limiting the value of the modeled floodplain is the lack of alignment between the timing of trajectories and the inundation of the floodplain. Figure 4-5 shows that most of the trajectories evaluated conditions in Reach 2B prior to full inundation of the floodplain. As a result, the limited amount of floodplain provided under the alternative was further reduced by the amount inundated during the evaluation period. The modeled flow schedule peaks in April to facilitate adult spring-run passage, whereas juvenile spring-run life histories in Reach 2B are assumed to peak in February and March (Figure 4-5). As a result, most trajectories evaluated conditions for Chinook juveniles in the Reach 2B project area before the time of maximum floodplain inundation. This further reduced size of the added floodplain for the majority of the juvenile migration period. The Winter Fry, the most successful strategy, migrate through Reach 2B before March, when there is very low floodplain inundation. The Below Chowchilla Parr strategy, the next successful strategy, migrates through during March, with moderate floodplain inundation. The Above Chowchilla fry strategy migrate through Reach 2B during April, with maximum floodplain inundation, but when temperatures are getting high.

The third factor limiting the value of the modeled floodplain is the reduction in trajectory capacity before fry get to Reach 2B. The Above Chowchilla example in Figure 4-2 is an example of this effect. Habitat quantity and quality constraints in reaches upstream of the 2B area reduce trajectory cumulative capacity before getting to Reach 2B, thereby limiting the effect of floodplain restoration in 2B to this life history strategy.. Figure 4-6 demonstrates this effect for the same three life history trajectories presented in Figure 4-2. Benefits of floodplain restoration in 2B were greatest for life history trajectories that moved rapidly downstream and then occupied the reach during periods of flow sufficient to inundate the floodplain. The increase in cumulative capacity for the Blw Chow trajectory is approximately 26%.

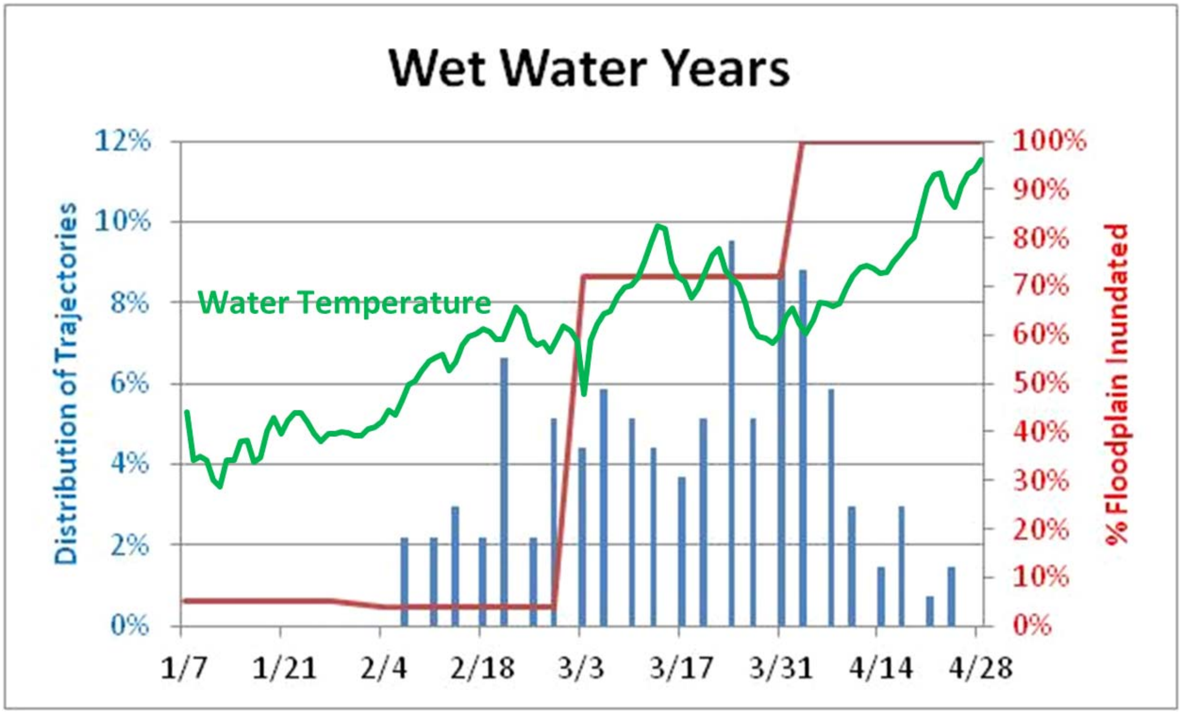

Figure 4-5. Distribution of Trajectories Leaving 2B1A and 2B1B (Blue Bars) and Percent of Inundated Floodplain (Red Line) during Wet Water Years, with Average Daily Wet Water Year Temperature

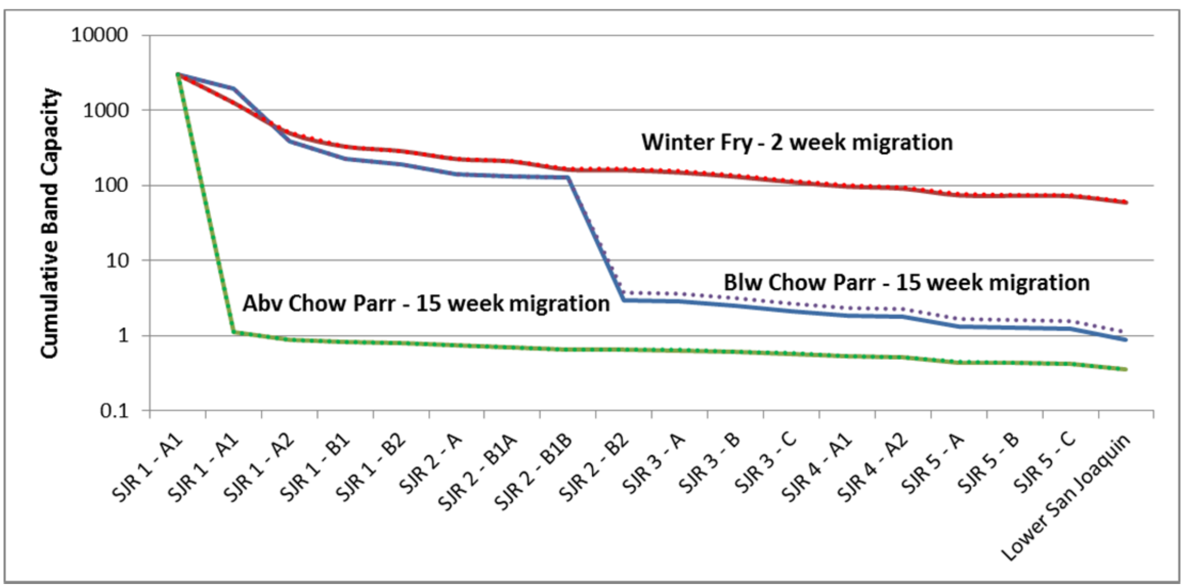

Figure 4-6. Effect Floodplain Restoration (dashed lines) by Life History on Cumulative Capacity of Spring-run Chinook Fry and Parr for Wet Water Years

4.3 Passage Routing Alternatives

4.3.1 Mendota Pool Alternatives

The Mendota Pool alternatives were designed to allow fish to bypass Mendota Pool, an area with high predation, temperatures and other adverse conditions (Jones & Stokes 2002). Three alternative passage routes were evaluated: The Fresno Slough alternatives (Fresno Slough Dam and Fresno Slough Dam with Short Canal) used the existing river channel through Mendota Pool but shunted flow into alternative channels to pass fish. The Mendota Bypass alternative created a new channel that bypassed Mendota Pool entirely. As discussed in Section 3.3, within the model these alternatives differed largely in regard to reach length and width, which mainly affect capacity, with very minor differences in attributes that affect productivity.

Results for the evaluation of the Mendota Pool alternatives are shown in Table 4-3. Because of the very slight differences in attributes affecting survival between the alternatives and water year conditions, there were only very minor differences in productivity and overall productivity values were similar to those seen in MR scenario. Differences between the Mendota alternatives were seen in regard to equilibrium abundance (which takes into account capacity). The Fresno Slough alternatives only slightly improved spring-run Chinook performance relative to the Minimum Restoration baseline (note that the Short Canal option only operated at high flow). For all water year conditions, the Mendota Bypass alternative provided the greatest increase in modeled abundance. That alternative increased abundance by about 5% relative to the MR scenario in the Dry and Normal-Wet year types, and 2.9% in the Wet year type

Table 4-3. Estimated Spring-run Chinook Population Performance of San Joaquin River Project Area under Mendota Bypass Alternatives Compared to Performance under the Minimum Restoration Habitat Conditions[1]

	Dry	Normal-wet	Wet
Productivity (returns/spawner)			
Minimum restoration	2.4	2.7	2.4
Fresno Slough Dam (no Mendota Pool diversion)	2.5	2.7	2.4
Fresno Slough Dam with Short Canal	n/a	n/a	2.4
Mendota Pool Bypass	2.5	2.7	2.4
Capacity (adult returns)			
Minimum restoration	258	356	769
Fresno Slough Dam (no Mendota Pool diversion)	256	356	771
Fresno Slough Dam with Short Canal	n/a	n/a	772
Mendota Pool Bypass	265	368	783
Equilibrium Abundance (adult returns)			
Minimum restoration	152	222	448
Fresno Slough Dam (no Mendota Pool diversion)	151	223	450
Fresno Slough Dam with Short Canal	n/a	n/a	451
Mendota Pool Bypass	160	234	461

[1] See Section 3.3 for an explanation of these alternatives.

Factors Not Addressed in the Analysis

The Fresno Slough with Short Canal scenario (wet year only) performed slightly better than the Fresno Slough Dam wet year scenario, because of a very small increase in capacity. This very small increase in capacity was due to an increase in channel width of the Mendota Pool during April and May, the only environmental attribute modified for this analysis. Predation was not considered. Additional factors that may contribute to the relative success of the Fresno Slough alternatives include the following provided by Carl Mesick (USFWS, personal communication):

- Predators may inhabit the longer return pipe of the Short Canal, and additionally, juveniles may experience higher predation rates in a pool environment when the boards are installed and due to the greater height as the water and fish spill over Mendota Dam into the river below where predators tend to congregate. These conditions would only occur during some wet years and so it is unlikely that predators would quickly move into the pool, below the dam, and into the pipe during diversions. If we assume that approximately 50% of the juvenile salmon would be entrained into the diversion and then salvaged (50% remain in the river) and that the Short Canal would result in a 6% total predator mortality rate for salvaged fish, fish in the pool, and fish spilling over the dam. In contrast, the South Canal, North Canal, or river delivery options would result in a 2% total mortality rate for salvaged fish. Since Reclamation signed the Exchange Contract in 1939, only this year have they had to deliver water to the Exchange Contractors via the San Joaquin River, so the frequency of this event is extremely rare.

In comparison, the South or North Canals are associated with a new flow control structure (similar to the existing Chowchilla Bifurcation Structure) and the return pipe is relatively short. EDT was used to estimate the effects on fish of the increased inundated area in the boards-in Mendota Pool. This can be combined with the above qualitative estimate of mortality to evaluate the effect on fish of the Short Canal option. The greater inundated area and predator issues would only be applied in the extremely rare events that the Mendota Dam boards would be put in and the diversion is made.

4.3.2 Reduced Passage at Chowchilla Bifurcation Structure South

Reducing passage at Chowchilla Bifurcation Structure South, which is a flood control structure on the main river channel, greatly affected population performance of spring Chinook in EDT results. This scenario assumed that no fish ladder or other passage improvements would be made at the Chowchilla Bifurcation Structure South. This would mean that fish could pass at high flows but would be blocked at lower flow. As expected, this action appreciably reduced the projected performance of spring-run Chinook salmon (Table 4-4). In a dry year there was no passage and productivity was 0.0 which resulted in an equilibrium abundance of 0 as well. As passage was allowed under wetter water year conditions productivity and abundance increased. However even under Wet water year conditions equilibrium abundance was about 21% less than under the MR scenario that assumed full passage.

Under the Normal-Wet condition the reduction in fish passage reduced abundance by about 61% relative to the MR scenario. The greater effect is because during Wet water year condition, the impact of the reduced passage was mitigated by activation of the Chowchilla Bypass route. Passage improvement at Chowchilla Bifurcation Structure South will improve fish populations, and would be most evident during dry years.

Table 4-4. Estimated Spring-run Chinook Population Performance under the Chowchilla Bifurcation Structure South Alternative Compared to the Minimum Restoration Baseline

	Dry	Normal-wet	Wet
Productivity (returns/spawner)			
Minimum restoration	2.4	2.7	2.4
No Passage Improvements at Chowchilla Bifurcation Structure South	0	1.8	2.3
Capacity (adult returns)			
Minimum restoration	258	356	769
No Passage Improvements at Chowchilla Bifurcation Structure South	11	199	622
Equilibrium Abundance (adult returns)			
Minimum restoration	152	222	448
No Passage Improvements at Chowchilla Bifurcation Structure South	0	85	356

4.4 Combination Scenarios

Results discussed so far pertain to single actions considered in isolation. However, the San Joaquin River Restoration Program will consist of multiple actions implemented simultaneously or in sequence. Consideration of multiple actions often reveals synergisms that can magnify or even diminish the effects of individual actions. One action can relax one or more limiting factors and thereby increase the benefits derived from individual projects.

The Reach 2B analysis examined two scenarios that combined floodplain restoration with Mendota Pool bypass actions. Specifically, the narrow floodplain restoration was combined with the Fresno Slough and Mendota Bypass actions (Table 4-5). The Fresno Slough/Floodplain combination increased the equilibrium abundance by 2-5% relative to the MR scenario depending on water year. However, this is the same amount of change in abundance that resulted from the narrow floodplain action alone (Table 4-2); by itself the Fresno Slough action resulted in little change in abundance (Table 4-3) and it did not increase the value of floodplain restoration.

Combining the Mendota Bypass action with the narrow floodplain restoration increased equilibrium abundance by 4–10% over the MR scenario depending on water year condition (Table 4-5). This was appreciably more than the benefits of either action considered separately (about 2-5% and 3-5% for the floodplain and bypass separately) so the combined action enhanced the value of both actions. The combined Mendota Bypass/Narrow Floodplain action had the highest benefit of the Reach 2B actions evaluated.

Table 4-5. Estimated Spring-run Chinook Population Performance under the Combination Alternatives Compared to the Minimum Restoration Baseline

	Dry	Normal-wet	Wet
Productivity (returns/spawner)			
Minimum restoration	2.4	2.7	2.4
Fresno Slough Dam with Floodplain	2.5	2.7	2.4
Mendota Pool Bypass with Floodplain	2.5	2.8	2.4
Capacity (adult returns)			
Minimum restoration	258	356	769
Fresno Slough Dam with Floodplain	263	370	780
Mendota Pool Bypass with Floodplain	274	385	794
Equilibrium Abundance (adult returns)			
Minimum restoration	152	222	448
Fresno Slough Dam with Floodplain	156	232	456
Mendota Pool Bypass with Floodplain	166	245	467

Chapter 5
Conclusions

This analysis evaluated a set of proposed actions in Reach 2B of the San Joaquin River in regard to their potential to contribute to the restoration of spring-run Chinook salmon in the San Joaquin River. The actions in Reach 2B will be combined with other actions throughout the Project Area in the actual restoration program. The proposed actions in Reach 2B can improve conditions for spring Chinook and make a successful reintroduction more plausible. All alternatives evaluated (other than the degradation alternative of reduced fish passage at the Chowchilla Bifurcation Structure) improved conditions for spring Chinook compared to the MR scenario (baseline). It is important to stress that the MR scenario baseline is itself a substantial improvement in conditions compared to those that currently exist in the Project Area. The MR scenario assumed the Settlement flow and full passage of adult and juvenile fish throughout the Project Area and minimal entrainment for juvenile salmonids in Mendota Pool and at the Chowchilla Bifurcation Structure. These are significant actions in their own right and therefore, this analysis did not reflect the full benefits of the Reach 2B project relative to current conditions.

The Narrow and Wide floodplain alternatives had no discernible difference in abundance. This was because of:

- Upstream constraints on the capacity
- Mismatch between fish migration and floodplain inundation timing
- Small amount of habitat compared to the entire SJRRP area
- High temperatures during maximum floodplain inundation later in the spring
- Wet year types increase the duration of floodplain inundation but not the quantity

The Mendota Pool Bypass scenario had a greater positive effect on the Spring-run Chinook salmon population than the Fresno Slough Dam.

The Compact Bypass and floodplain alternatives had synergistic effects, increasing abundance more when combined together.

A striking result of the analysis is the remarkable constancy of productivity (returns/spawner) between actions and across water years. This occurred because the actions as parameterized primarily affected the quantity of habitat, which affects capacity. Changes to the quality of habitat, which affects productivity, were relatively small. Habitat quality was enhanced by the cooler water released from Friant Dam under the Normal-Wet and Wet water year conditions. However, the rapid increase in water temperature downstream of Friant dampened the temperature benefits in Reach 2B thereby reducing the effects on modeled productivity. Under the Wet water year condition, the decrease in temperature actually decreased the average productivity. This was because the main effect of the improved conditions was to move low performing life history trajectories across the productivity threshold of 1.0 (replacement) so that they were included in the average productivity for the population. While the average productivity declined slightly under these circumstances, the greater number of viable trajectories in the model did increase the equilibrium abundance, although it resulted in lower percentage increases (i.e. 5.4% increase in abundance under Narrow Floodplain compared to Minimum Restoration in a Normal-Wet year type, only 1.8% increase in abundance for the Narrow Floodplain scenario compared to Minimum Restoration in a Wet year type). The overall performance of the Reach 2B actions was constrained by generally unfavorable water temperatures for much of the Project Area for most of the summer period. Water temperature rises quickly below Reach 1A and fish could benefit from actions in Reach 2B only during the period when water temperatures were favorable.

Scale of the proposed actions is an important consideration for this analysis. The Reach 2B analysis was conducted at the scale of the entire hypothetical San Joaquin spring-run Chinook population in the entire San Joaquin Restoration Program Project Area, whereas the Reach 2B actions changed habitat conditions in only a small portion of the Project Area. As a result the changes in spring-run Chinook performance attributed to the Reach 2B actions were relatively small. In the overall restoration plan these changes would contribute to the overall habitat condition and act synergistically with all restoration actions to promote spring-run Chinook restoration.

Based on the life-history assumptions made here, floodplain restoration benefits are limited due to a mismatch between fish timing and flow timing. If floodplain inundation in Reach 2B, for example, occurred earlier in the year when temperatures were cooler, winter fry or the Below Chowchilla fry strategy could experience some benefit from floodplain restoration. Alternately, if fish adapt to the San Joaquin River temperatures and migrate earlier in the spring, floodplain benefits could be greater.

So what does the analysis say in regard to the potential to restore spring-run Chinook salmon in the San Joaquin River? The analysis indicates that the San Joaquin system as modeled has the potential to support a small but fragile population of spring-run Chinook salmon and that performance would be enhanced by the Reach 2B actions. This conclusion has several important qualifications.

- This analysis only examined the Reach 2B actions. The San Joaquin Restoration Program would include actions throughout the Project Area that would add to the benefits reported here.
- The analysis assumed that spawning of spring-run Chinook would be confined to the two upper-most reaches below Friant Dam (reaches 1A and 1B). In fact, virtually all the successful trajectories in the analysis originated in the 12.3 mile length of Reach 1A. Below this point, fall temperatures were too high to sustain successful spawning in the model. This constraint on potential spawning area will ultimately limit the potential abundance of spring-run Chinook in the Project Area.
- Except for the Chowchilla Bypass alternative, the analysis assumed full passage of adult and juvenile salmon at all existing migration impediments. Even with passage facilities, 100% passage success is unrealistic; in this regard, the analysis is optimistic regarding the actual production parameters (productivity and capacity) of a spring Chinook population in the San Joaquin River.
- This analysis assumed juvenile Spring-run Chinook salmon would outmigrate between February and April except for the yearlings. If these juveniles outmigrate earlier in the year, they could experience cooler temperatures, have greater habitat quality and associated productivity, and potentially be more successful.

- The analysis assumed a flow schedule based on Carl Mesick's temperature adjusted one. This schedule has flows ramping up starting in late February in most years. An earlier flow schedule could result in higher abundance.
- Population productivity may not increase following a series of Wet year types as fish may occupy a greater breath of habitats and life histories resulting in more fish attempting marginally successful strategies.
- Under the habitat assumptions discussed in the preceding sections, the analysis found that habitat in the study would have the potential to support a population with a density independent survival of around 2.5 returns/spawner. This is low for a self-sustaining natural population of Chinook salmon and indicates that the population is likely to be fragile and subject to downturns because of variation in survival conditions in the San Joaquin River, the Delta and the ocean.
- High water temperature was the controlling factor limiting spring-run Chinook production in the Project Area. Modeled water temperature increased quickly below Reach 1A and equilibrated with air temperature around Mendota Pool. Modeling has shown that survival of spring-run Chinook in the San Joaquin depends on overlap between movement timing of adults and juveniles and periods when suitable water temperatures are present. Successful juvenile behavior within the model occurred when fish moved out of the Project Area before water temperatures increased (winter fry or spring parr life histories) or stayed below Friant Dam where cool water was present (yearling smolts). Water temperature can be particularly limiting for spring-run fish that enter the Project Area as adults in the spring but then must hold until they spawn in the fall. To be successful trajectories, in the model adult fish entered the Project Area and had to move rapidly upstream to hold in Reach 1A below Friant Dam.

Finally, restoration of habitat to support spring-run Chinook in the Project Area will be implemented as a set of actions addressing multiple limiting factors and areas. This analysis mainly evaluated the actions independently. Synergisms between actions can have a significant impact on the success of individual actions and the program as a whole. Analysis of groups of actions or scenarios would likely provide important strategic insights into how actions are best implemented spatially and temporally, and assess how the total package of restoration actions relates to the stated management goals for the San Joaquin River Restoration Program.

Chapter 6
References

Beverton, R. J. H., and S. J. Holt. 1957. On the dynamics of exploited fish populations. *U.K. Ministry of Agriculture, Fisheries Investigation Service* 2(19):553.

Blair, G. R., L. C. Lestelle, and L. E. Mobrand. 2009. The Ecosystem Diagnosis and Treatment Model: A tool for assessing salmonid performance potential based on habitat conditions. Pages 289-309. *Pacific Salmon Environment and Life History Models*. Bethesda, MD: American Fisheries Society.

Groot, C., and L. Margulis (eds.). 1991. Pacific Salmon Life Histories. Vancouver, BC: University of British Columbia Press.

Hawkins, C. P., J. L. Kershner, P. A. Bisson, M. D. Bryant, L. M. Decker, S. V. Gregory, D. A. McCullough, C. K. Overton, G. H. Reeves, R. J. Steedman, and M. K. Young. 1993. A hierarchical approach to classifying stream habitat features. *Fisheries* 18(6):3-12.

Jones & Stokes. 2002. San Joaquin River Restoration Plan Background Report (Draft). *Prepared by* Jones & Stokes Associates Sacramento, CA, *for* Friant Water Users Authority and Natural Resources Defence Council

Lestelle, L. C. 2004. Guidelines for Rating Level 2 Environmental Attributes in Ecosystem Diagnosis and Treatment: Mobrand Biometrics, Inc.Vashon, WA.

MacFarlane, B. R., and E. C. Norton. 2002. Physiological ecology of juvenile Chinook salmon (*Oncorhynchus tshawytscha*) at the southern end of their distribution, the San Francisco estuary and the Gulf of the Farallones, California. *Fisheries Bulletin* 100:244-257.

McElhany, P., M. H. Ruckelshaus, M. J. Ford, T. C. Wainwright, and E. P. Bjorkstedt. 2000. Viable salmonid populations and the recovery of evolutionary significant units: U.S. Department of Commerce. Seattle, WA. NOAA Tech. Memo NMFS-NWFSC-42.

Mobrand, L. E., J. A. Lichatowich, L. C. Lestelle, and T. S. Vogel. 1997. An approach to describing ecosystem performance "through the eyes of salmon". *Canadian Journal of Fisheries and Aquatic Sciences* 54:2964-2973.

Poff, N. L., J. D. Allan, M. B. Bain, J. R. Karr, K. L. Pretegaard, B. D. Richter, R. E. sparks, and J. C. Stromberg. 1997. The natural flow regime. *BioScience* 47(1):769-784.

Reisenbichler, R. R. 1989. Utility of spawner-recruit relations for evaluating the effect of degraded environment on the abundance of chinook salmon, *Oncorhynchus tshawytscha*. Pages 21-32 in C. D. Levings, L. B. Holtby and M. A. Henderson (eds.). *Proceedings of the national workshop on effects of habitat alteration on salmonid stocks*: Canadian Special Publication on Fisheries and Aquatic Sciences 105.

San Joaquin River Restoration Program. 2008. Draft Technical Memorandum: Temperature Model Sensitivity Analysis Sets 1 and 2.

San Joaquin River Restoration Program. 2011. Sufficient flow and temporary project necessary for 2012 Chinook salmon reintroduction.: San Joaquin River Restoration Program.

San Joaquin River Restoration Program. 2012. Mendota Pool Bypass and Reach 2B Improvements Project. Second Administrative Draft Project Description and Technical Memorandum: San Joaquin River Restoration Program. Sacramento, CA.

Tetra Tech. 2013. San Joaquin River and Bypass System 1-D Steady State HEC-RAS Model Documentation. *Prepared by* Tetra Tech Fresno, CA, *for* California Department of Water Resources

U.S. Army Corps of Engineers. 1986. HEC-5Q: System Water Quality Modeling: US Army Corps of Engineers Technical Report No. TP-111.

Vandergrift, T. 2012. San Joaquin River Restoration Daily Flow Model (SJRRW): Documentation for the Reach 4B Study: U.S. Bureau of Reclamation Technical Report No. 86-68210-2012-04.

Appendix A

Ecosystem Diagnosis & Treatment Theory

Appendix A
Ecosystem Diagnosis & Treatment Theory

Ecosystem Diagnosis & Treatment (EDT) is a hierarchical, spatially explicit model that analyzes aquatic habitat for multiple salmonid life histories to help managers and scientists investigate the biological and environmental constraints on species performance within a watershed. EDT can be used in the context of a watershed assessment to evaluate the present, past, and future potential of habitat within a watershed or reach and to quantify the impacts and benefits of proposed restoration and protection actions.

This summary presents the major ideas in EDT. Fundamental algorithms and the information structure of EDT are described in Blair et al. (2009) and Lestelle et al. (2004). The theoretical foundations for the model are described in Mobrand et al. (1997), Lichatowich et al. (1995), and Moussalli and Hilborn (1986).

Briefly, EDT is a life-cycle habitat model that characterizes the aquatic environment temporally (monthly) and spatially (by stream reach) "through the eyes of salmon" (Mobrand et al. 1997). Habitat is evaluated along numerous pathways—termed *life history trajectories*—that represent salmonid life histories. Trajectories can be thought of as pathways through time and space that salmonids might use to complete their life histories, which vary in regard to habitat quality and quantity. Fish could spawn early, or later; they could spawn higher or lower in the system; or they could move quickly through some areas and pause in others. These behaviors can be controlled within EDT to present an array of life history trajectories and a different sampling of the environmental conditions of the stream. The quality and quantity of habitat along each trajectory is assessed as the productivity and capacity of salmonids potentially using that pathway (Hayes et al. 1996). The integration of performance across the trajectories estimates the potential productivity and capacity of a fish population in the environment and the variation in performance due to heterogeneity of the habitat and fish behavior. These population-level metrics are then used to compare the alternative scenarios (e.g., land use scenarios, restoration actions, protection scenarios). The population-level estimate of productivity and capacity can be disaggregated to study habitat constraints at sub-basin, stream reach, life stage, and attribute levels.

Conceptual Model for EDT

The concept of EDT is embodied in the widely supported notion that environmental conditions promote and constrain the persistence, abundance, and dispersal of organisms at the species and community levels (Southwood 1977). The environment, filtered through the physiological capabilities of the species, defines the attributes and conditions of habitat for the species and ultimately the population performance (Hall et al. 1997; Mobrand et al. 1997). Habitat quality is affected by both density-dependent and density-independent factors. Density-dependent survival is a function of consumable habitat conditions (e.g., food or space) that leads to the asymptotic approach of abundance to a carrying capacity (Hayes et al. 1996).

EDT uses the relationship between habitat and biological performance to evaluate stream conditions in terms of population success (Figure A-1) monthly and at a reach scale. Species–habitat relationships are used to calculate the productivity and capacity parameters of a Beverton–Holt production function (Beverton and Holt 1957). Life-stage performance is accumulated across the life history to result in an estimate of the potential of the habitat to support the species along the array of life history trajectories; integration of performance across trajectories estimates performance at the population scale.

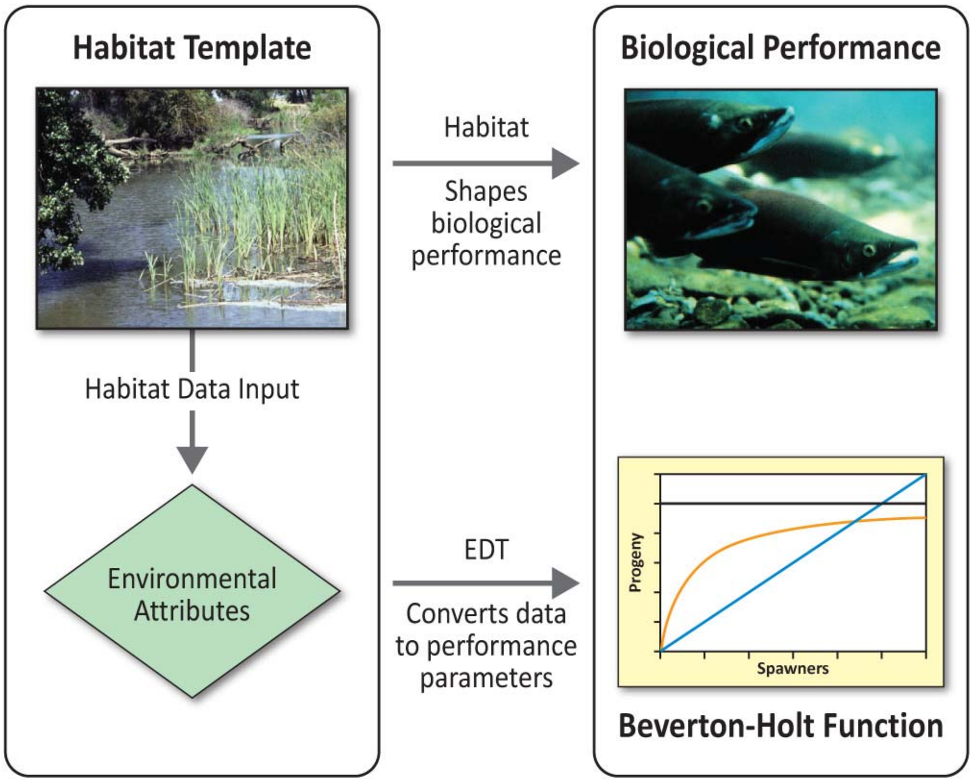

Figure A-1. Conceptual model of EDT. Habitat conditions are linked to biological performance through a stock–recruitment relationship.

Fish performance is life-stage specific through the conditions experienced across space and time. In EDT, fish within a population exhibit multiple life history pathways (Figure A-2) through time and space that reflect genetically based biological diversity and behavioral plasticity (Lichatowich et al. 1995). Population performance is the integration of performance across the diversity of life histories that can be expressed across the environmental mosaic.

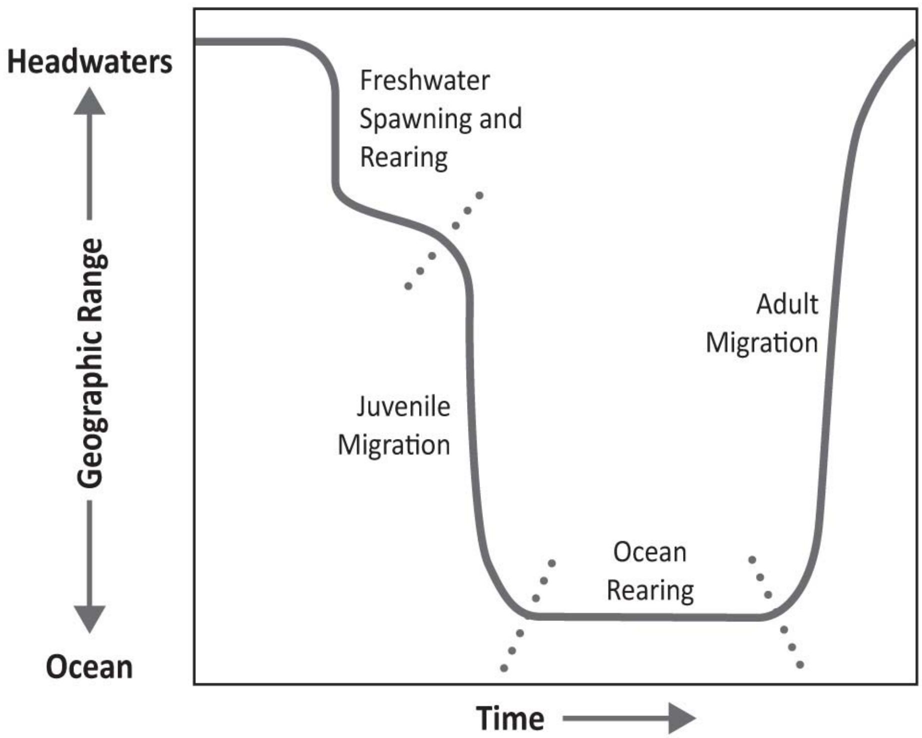

Figure A-2. Example life history pathway in EDT. Life histories contain multiple potential pathways that are sampled across time and space by life stage.

Relating Habitat to Biological Performance in EDT

Habitat is related to population performance in terms of a Beverton–Holt stock–recruitment relationship (Beverton and Holt 1957; Hilborn and Walters 1992) (Figure A-3). The Beverton–Holt function is used to characterize habitat potential because of its tractable mathematical qualities and its fundamental relationship to fisheries population dynamics (Hilborn and Walters 1992). The function has two parameters: density-independent survival (or productivity) and the asymptotic carrying capacity (Figure A-3). These parameters can be related to the quality and quantity of habitat, respectively (Hayes et al. 1996).

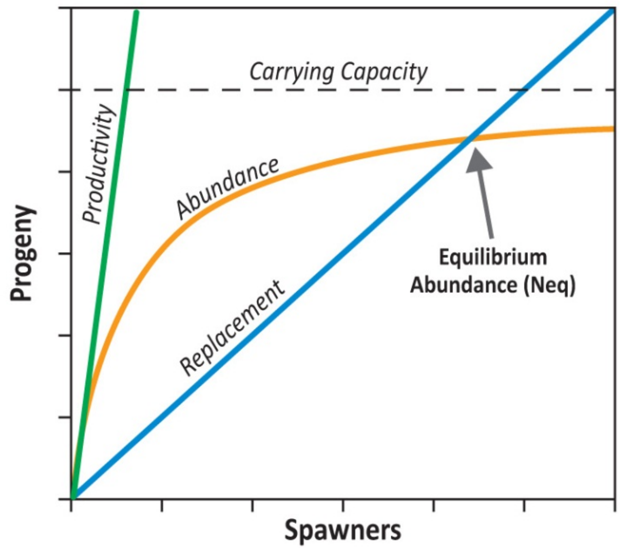

Figure A-3. Features of the Beverton–Holt stock–recruitment relationship.

A particularly useful feature of the Beverton–Holt function is that population performance can be disaggregated into individual life-stage functions (Moussalli and Hilborn 1986). This means that fish survival at one life stage can be related to the survival at a subsequent life stage based on habitat conditions and combined to build a cumulative spawner–recruit Beverton–Holt relationship. This makes it possible to evaluate the performance along a life history trajectory as a series of life-stage functions that can be integrated to estimate an overall Beverton–Holt function for the entire trajectory reflecting environmental conditions along the pathway.

A typical EDT run evaluates habitat along hundreds to thousands of life history trajectories that sample habitat spatially, along and within reaches, and temporally within months across a year. Because the trajectories are built up from life-stage assessments of each reach, biological performance can be examined at a life stage and reach scale leading to a diagnosis of conditions, identification of limiting factors, and prioritization of restoration and protection needs for habitat. Each trajectory is an independent run of EDT using different environmental conditions and life history parameters (within a defined life history). A complete description of the computation of the parameters of an EDT life history trajectory is provided in Blair et al. (2009) and Lestelle et al. (2004). A simplified description of the procedure is included here.

The parameters of the Beverton–Holt function are calculated in EDT using a top-down approach that involves the adjustment of a set of benchmark productivity and capacity (density) values for each life stage to reflect the specific conditions encountered by the life stage in a reach during a time step. The use of benchmark values in EDT is a way to define what is possible for a given fish species and to constrain performance within plausible biological bounds. To estimate productivity of a life stage, p_i, EDT assumes that a productivity benchmark for a species life stage can be adjusted by the product of the effect of multiple survival factors:

$$p_i = B_i \times F_{i1\times} \times F_{i2} \times \ldots F_{ij}$$

where,

$$p_i = productivity\ of\ life\ stage\ i$$

$$B_i = benchmark\ survival\ for\ life\ stage\ i$$

$$F_{ij} = survival\ factors$$

The survival factors decrease the benchmark survival to reflect local conditions along the trajectory in regard to sediment, temperature, channel form, and other conditions (Table A-1). As will be discussed below, survival factors are defined by multivariate relationships among more specific, measurable attributes of the environment. For example, the survival factor of sediment is defined as the effects on survival of fine sediment in riffles, concentration of suspended sediment (turbidity), and streambed embeddedness.

Table A-1. EDT survival factors (F_{ij}) and examples of defining environmental attributes.

Survival Factors ($\boldsymbol{F_{ij}}$)	Examples of Defining Environmental Attributes
Channel condition	Natural and artificial confinement, riparian function, flow
Structural diversity	Large wood, riparian function
Temperature	High temperature, low temperature, temperature diversity
Predation	Predation, introduced species, temperature
Oxygen	Oxygen, high temperature
Flow	High flow, low flow, flashiness
Sediment	Fine sediment in riffles, embeddedness, suspended sediment
Chemicals (toxic substances)	Toxins in sediment or water column
Competition with hatchery fish	Hatchery releases
Competition with other fish	Species richness, introduced species
Food	Alkalinity, benthic richness, riparian function, salmon carcasses
Pathogens	Hatchery releases, high temperature
Harassment	Harassment
Obstructions	Obstructions
Entrainment	Water withdrawals

Productivity along an entire life history trajectory, *P*, is computed as the simple product of productivity at individual life stages:

$$P = \prod p_i$$

The Beverton–Holt capacity parameter in EDT is a measure of the maximum number of fish that can be supported by an environment. It is not just a measure of the quantity of habitat but also a measure of the quantity of suitable habitat. Thus, while the density-independent survival rate (productivity) is independent of capacity, the reverse is not true—capacity in EDT includes a measure of the productivity. For example, 100 m^2 of pool habitat with a temperature of 28°C would have no capacity to support over-summering steelhead; the habitat quantity is suitable, but the high temperature would prevent productivity. A conceptual expression of capacity in EDT is as follows:

$$c = MD \times G \times \mathrm{H}$$

where,

c = capacity (maximum number of fish supportable) of a life stage in a reach

MD = maximum density, a function of fish size and habitat productivity

G = quantity of food available

H = area of key habitat

A more detailed treatment of these parameters can be found in Blair et al. (2009).

Food availability is estimated as a function of alkalinity, benthic richness, riparian function, and availability of salmon carcasses. Alkalinity serves as a watershed-level measure of stream productivity and potential food availability based on the relationship developed by Ptolomy (1993).

Key habitat for a life stage in a reach is calculated as follows:

$$Key\ Habitat = \left(\sum \%\ Habitat\ Type_i \times\ Weight_i\right) \times Area$$

Weight reflects the selection of a particular type of habitat by a life stage. For example, the weight for pool tailouts for the spawning life stage of Chinook salmon is 1.0, whereas the weight of a pool for the same life stage is 0, reflecting the fact that Chinook do not select pools for spawning (Bjornn and Reiser 1991). Percent Key Habitat times the average monthly area of a reach (reach length X average width) provides the weighted area of habitat for a life stage in a reach during a month.

EDT computes the productivity and capacity of an entire population by computing a weighted mean of the cumulative productivity and sum of capacity parameters (productivity and capacity from spawner to adult progeny). The two most common weighting factors for productivity are equilibrium abundance (Neq) and capacity (adult carrying capacity). In Neq weighting, the contribution of a trajectory's productivity to the population mean is weighted by the proportion of total equilibrium abundance contributed by the trajectory. Therefore, under this method, only viable trajectories (those with a productivity >1) are included in the mean that represents the entire population.

EDT computes population-level capacity ("carrying capacity") as the sum of the weighted-mean capacities associated with each spawning reach. Mean spawning-reach capacity may be computed as a simple arithmetic mean or as a mean weighted by the capacity of constituent trajectories.

Habitat Rating Rules in EDT

As discussed above, EDT adjusts a set of benchmark survival values for species life stages to reflect conditions in a reach and watershed with regard to the survival factors in Table 1. Adjustments to the benchmarks are made to reflect conditions in a stream reach based on the survival factors. These survival factors are defined through multivariate relationships among measurable environmental attributes. The conversion of environmental attributes to survival factors occurs through the use of life stage–habitat relationships.

The EDT species–habitat relationship concept is illustrated in Figure A-4, which shows how attribute relationships are combined to estimate the impact of a survival factor on the benchmark survival of a life stage. In this example, the survival factor of sediment (Table 1) is defined to include the impacts of fine sediment in riffles, streambed embeddedness and suspended sediment on life-stage survival. EDT species–habitat relationships define the sensitivity of the model to changes in the attribute values in terms of a reduction to the benchmark survival.

Figure A-4 also illustrates an important feature of data in EDT. EDT categorizes most reach-level data on a scale of 0–4. These categories have precise definitions in EDT (Lestelle 2004). Raw environmental data (e.g., temperature, streambed conditions, and riparian conditions) take a variety of forms, which are processed to develop EDT categorical ratings. Because the ratings represent a reduction of the benchmark values, a categorical rating of 0 in EDT results represents no degradation to the benchmark, while a value of 4 represents an extreme (often fatal) degradation of the benchmark. Further, the curvilinear shape of most rating curves in EDT means that there is small change in the benchmark values for categorical ratings of 0–2 but a steeper decline in survival for conditions resulting in ratings of 2–4.

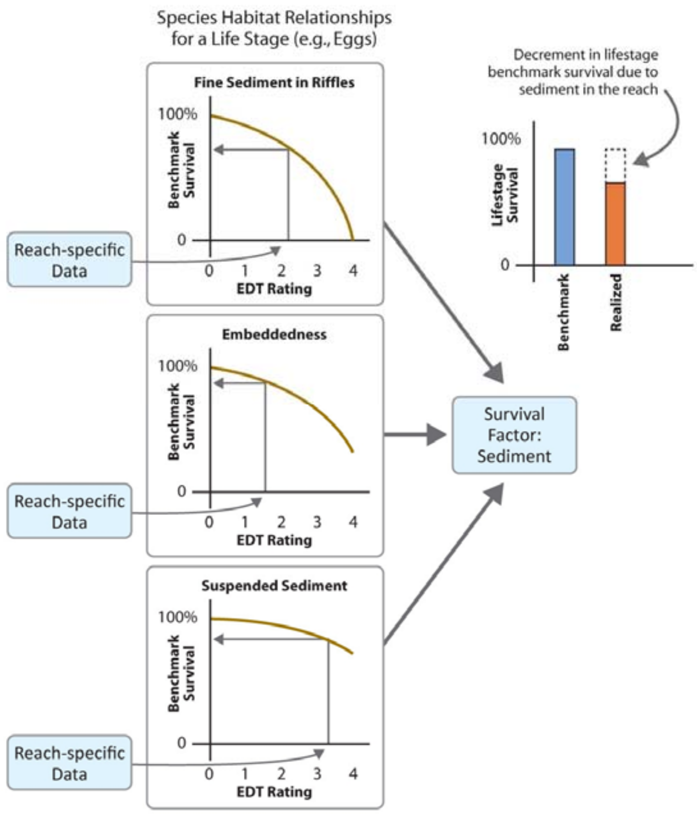

Figure A-4. Example of EDT species–habitat relationship. In this case, three measurable environmental attributes are combined to compute the reduction in benchmark survival for the life stage due to the survival factor of sediment. Rating curves and data are illustrative only.

Benchmark Ratings in EDT

The benchmark ratings in EDT constitute the upper limit to biological performance of the species under ideal habitat conditions. The species–habitat relationships adjust the benchmark values to reflect local habitat conditions as shown in Figure A-4. The benchmarks and the species–habitat relationships constitute an EDT *rule-set* for a species. Rule-sets have been developed for all anadromous salmonids except sockeye and masu salmon, and for several resident salmonids. The benchmarks operate in conjunction with the species–habitat relationships to determine the sensitivity of the model to environmental conditions. The species rule-sets, including the benchmarks and species–habitat relationships, capture the state of knowledge regarding habitat needs of the species. They are intended to reflect genetically based behavioral and physiological needs and are applied across watersheds to broad species or species grouping such as races (e.g., spring Chinook salmon) or Evolutionarily Significant Units (ESUs).

References Cited

Beverton, R. J. H., and S. J. Holt. 1957. *On the Dynamics of Exploited Fish Populations*. U.K. Ministry of Agriculture, Fisheries Investigation Service 2(19):553.

Bjornn, T. C., and D. W. Reiser. 1991. Habitat Requirements of Salmonids in Streams. Pages 83–138 in W. R. Meehan (ed.). *Influences of Forest and Rangeland Management on Salmonid Fishes and Their Habitats*. Bethesda, MD: American Fisheries Society.

Blair, G. R., L. C. Lestelle, and L. E. Mobrand. 2009. The Ecosystem Diagnosis and Treatment Model: A Tool for Assessing Salmonid Performance Potential Based on Habitat Conditions. Pages 289–309. *Pacific Salmon Environment and Life History Models*. Bethesda, MD: American Fisheries Society.

Hall, L. S., P. R. Krausman, and M. L. Morrison. 1997. The Habitat Concept and a Plea for Standard Terminology. *Wildlife Society Bulletin* 25(1):173–182.

Hayes, D. B., C. P. Ferreri, and W. W. Taylor. 1996. Linking Fish Habitat to Their Population Dynamics. *Canadian Journal of Fisheries and Aquatic Sciences* 53(S1):383–390.

Hilborn, R., and C. J. Walters. 1992. *Quantitative Fish Stock Assessment*. London: Chapman and Hall.

Lestelle, L. C. 2004. *Guidelines for Rating Level 2 Environmental Attributes in Ecosystem Diagnosis and Treatment*. Mobrand Biometrics, Inc. Vashon, WA.

Lestelle, L., L. Mobrand, and W. McConnaha. 2004. *Information Structure of Ecosystem Diagnosis and Treatment (EDT) and Habitat Rating Rules for Chinook Salmon, Coho Salmon and Steelhead Trout*. Mobrand Biometrics, Inc. Vashon, WA. Available: <http:// www.Mobrand.com>.

Lichatowich, J. A., L. E. Mobrand, L. Lestelle, and T. Vogel. 1995. An Approach to the Diagnosis and Treatment of Depleted Pacific Salmon Populations in Freshwater Ecosystems. *Fisheries* 20(1):10–18.

Mobrand, L. E., J. A. Lichatowich, L. C. Lestelle, and T. S. Vogel. 1997. An Approach to Describing Ecosystem Performance "Through the Eyes of Salmon." *Canadian Journal of Fisheries and Aquatic Sciences* 54:2964–2973.

Moussalli, E., and R. Hilborn. 1986. Optimal Stock Size and Harvest Rate in Multistage Life History Models. *Canadian Journal of Fisheries and Aquatic Sciences* 43(1):135–141.

Ptolemy, R. A. 1993. Maximum Salmonid Densities in Fluvial Habitats in British Columbia. Pages 223–250 in *Proceedings of the 1992 Coho Workshop, May 26–28, 1992*. Association of Professional Biologists of British Columbia and North Pacific International Chapter of the American Fisheries Society. Nanaimo, B.C.

Rawding, D. 2004. *Comparison of Spawner-Recruit Data with Estimates of Ecosystem Diagnosis and Treatment (EDT) Spawner-Recruit Performance*. Washington Department of Fish and Wildlife. Vancouver, WA.

Southwood, T. R. E. 1977. Habitat, the Template for Ecological Strategies? *Journal of Animal Ecology* 46:337–365.

Appendix B

Current Condition Formulation

Appendix B
Current Condition Formulation

Many Level 2 environmental attributes for the current condition of the San Joaquin River (SJR) were updated or added to the San Joaquin Ecosystem Diagnosis & Treatment (EDT) model to improve the resolution and reliability of model results. The current condition attributes that were updated were dependent upon 1) which data were available, and 2) those attributes declared important by the San Joaquin River Restoration Fisheries Management Workgroup (Fisheries Management Workgroup).

Attributes that were updated or added are listed below.

- Benthos diversity and production.
- Channel width (month maximum width and month minimum width).
- Confinement (hydromodifications).
- Dissolved oxygen.
- Embeddedness.
- Fine sediment (intra-gravel).
- Fish community richness.
- Fish species introductions and predation risk.
- Gradient.
- Habitat types.
- Interannual variability in high and low flows.
- Metals in the water column and metals/pollutants in sediments/soils.
- Miscellaneous toxic pollutants in the water column.
- Riparian function.
- Temperature (daily maximum, daily minimum, and spatial variation).
- Turbidity.
- Water withdrawals.
- Woody debris.

Guidelines for characterizing Level 2 EDT attributes (Lestelle and Mobrand 2005) were followed using available data sources as described below. In general, data from multiple sampling sites within a reach were averaged, and if no raw data were available for an EDT reach, averages of the ratings for the upstream and downstream reaches were used. If no data upstream or downstream were available, data from a parallel reach were generally used. Information concerning data sources and procedures for updated or added attributes is below.

Benthos Diversity and Production

Benthos diversity and production is a measure of benthic production that enters the model primarily as a contributor to food and ultimately stream capacity. Macroinvertebrates are a significant food source for juvenile salmonids and can affect salmonid survival and maximum possible density.

Benthos diversity and production was characterized based on the 2010 San Joaquin River Restoration Program (SJRRP) Surface Water Ambient Monitoring Program (SWAMP) benthic macroinvertebrates per unit of bottom area (BMI/BA) taxonomic data. Invertebrates were collected from late May through the end of September, and samples were processed at the California Department of Fish and Wildlife's (CDFW's) Aquatic Bioassessment Laboratory (ABL) in Rancho Cordova, California (San Joaquin River Restoration Program 2012). The Central Valley Benthic Index of Biotic Integrity (B-IBI) rating system was used to rate the benthos diversity and production attribute.

Channel Width—Month Maximum Width and Month Minimum Width

Average widths of the wetted channel during high and low flow months define the quantity of wetted area available as habitat and are a primary determinant of stream capacity for the focal species. Widths were calculated based on the existing Hydrologic Engineering Centers River Analysis System (HEC-RAS) existing flow scenario and HEC-RAS modeling results (Mussetter Engineering, Inc. 2008).

Confinement—Hydromodifications

Hydroconfinement refers to artificial confinement of the river channel by levees, roads, or other structures. This attribute was characterized using geographic information system (GIS) maps of levees and local knowledge of levee locations and conditions.

Dissolved Oxygen

Dissolved oxygen (DO) refers to the average quantity of dissolved oxygen within the water column for a specified time interval. Dissolved oxygen was characterized using the California Data Exchange Center's (CDEC's) interim flows data for all sites and dates where DO data were available (California Data Exchange Center 2010).

Embeddedness

Embeddedness refers to the extent to which interstitial space in cobble or gravel substrate is filled with fine sand and silt. The attribute primarily refers to substrate condition in pools and other areas not used for spawning. Embeddedness was calculated using the SJRRP bioassessment physical habitat (PHAB) data from 2010 and 2011 (general procedures described in San Joaquin River Restoration Program 2012).

Fine Sediment—Intra-Gravel

Fine sediment characterizes the percentage of fine sediment within salmonid spawning substrates such as riffles and pool tailouts. (Note that it is embeddedness—described above—that refers to fine sediment in the substrate of non-spawning areas such as pools). Fine sediment was calculated using the SJRRP bioassessment PHAB data from 2010 and 2011 (general procedures described in San Joaquin River Restoration Program 2012).

Fish Community Richness, Predation Risk, and Fish Species Introductions

Fish community richness can influence the magnitude of competitive and predatory interspecific interactions. *Predation risk* is based on unnatural concentrations of fish-eating species in the system. *Fish species introductions* refers to the extent of exotic fish in the river; these introduced species can compete with native species and alter food web structure. Information on current fish species in the SJR was taken from Chapter 5, "Biological Resources—Fisheries," of the *San Joaquin River Restoration Program Draft Environmental Impact Statement/Report* (San Joaquin River Restoration Program 2011). Information on feeding preferences was derived from *Inland Fishes of California* (Moyle 2002).

Gradient

The average gradient of the main channel over its length was calculated from the U.S. Geological Survey (USGS) NHDPlus (an integrated suite of geospatial datasets) dataset for the San Joaquin.

Habitat Types

Habitat types are characterized as the percentage distribution of physical habitat types by wetted area of a reach. Quantification of habitat type was based on mesohabitat information (methods described in Guzman 2009), information from beaver dam surveys (from the Fisheries Management Workgroup), and the 2010 and 2011 SJRRP bioassessment PHAB data (San Joaquin River Restoration Program 2012). Habitat types defined in EDT include backwater pools, beaver ponds, large cobble or boulder riffles, pool tailouts, glides, primary pools, and small cobble or gravel riffles.

Flow Changes in Inter-Annual Variability in High Flows and Low Flows

Flow is directly input to EDT as the change in scenario flow relative to a reference condition of an undisturbed watershed of comparable size, geology, orientation, topography, and geography. The attribute captures the extent to which the timing and magnitude of average high and average low flows have changed from a natural condition; such changes can be the result of regulation or other actions. High and low flows were calculated from the existing flow scenario HEC-RAS output (Musseter Engineering, Inc. 2008). The full natural flow at Friant Dam (Millerton) (California Data Exchange Center 2012) station was used as comparison for unimpaired flow. Note that the effect of flow on habitat is entered into the model through other flow-related attributes such as channel width.

Metals in the Water Column, Metals/Pollutants in Sediments/Soils, and Miscellaneous Toxic Pollutants in the Water Column

Attributes related to metals and pollutants were characterized using data from the *Mendota Pool Sediment Quality Investigation* (Department of the Interior 2012). Based on that report, it was assumed that toxicity gradually decreases downstream with virtually no toxicity upstream of Mendota Pool.

Riparian Function

Riparian function captures the extent and character of riparian vegetation. The SJRPP bioassessment PHAB data concerning riparian vegetation structure for 2010 and 2011 was used to characterize riparian condition in the study area (methods described in San Joaquin River Restoration Program 2012). This worksheet contains ratings of average riparian cover per reach (includes herbaceous riparian). In the SJRPP rating system, a 0 indicated no cover or connection while 4 indicates heavy cover or connection to the riparian system. Numerically, this system is opposite of that used in EDT; as such, the SJRPP rating value was subtracted from 4 to convert to an EDT rating. Values were averaged for multiple SJRPP reaches in the same EDT reach and averaged across years. It was assumed that parallel canals would have less connection to the riparian zone, so the value of 1 was added to parallel natural canal EDT ratings.

Temperature—Daily Maximum

EDT water temperature ratings are based on potential exposure time of fish to various temperature criteria. Temperature data is processed in the EDT temperature tool to derive EDT temperature ratings. HEC-5Q (water quality monitoring software from the U.S. Army Corps of Engineers) model results for existing conditions were used as the raw data source to characterize the typical maximum temperature in each month (Musseter Engineering, Inc. 2008). The data were mapped to reaches, and multiple sample sites within a reach were averaged. If no raw data were available for an EDT reach, averages of the ratings for the upstream and downstream reaches were used. Monthly patterns were created for the data.

Temperature—Daily Minimum

HEC-5Q model results for existing conditions were used as the raw data source to characterize the typical minimum temperature in each month (Musseter Engineering, Inc. 2008). The data were processed to determine the average coldest month in the SJR. Multiple sample sites within a reach were averaged, and if no raw data were available for an EDT reach, averages of the ratings for the upstream and downstream reaches were used.

Temperature—Spatial Variation

Spatial variation in temperature refers to the potential for temperature refugia or other features that might intermittently moderate water temperature conditions. Spatial variation in temperature was characterized using input from the Fisheries Management Workgroup concerning temperature variation in the SJR and the presence of springs or groundwater inputs.

Turbidity

Turbidity refers to the amount of suspended sediment carried in the water column and affecting transparency of the water. In EDT, turbidity is based on the scale of severity concept of Newcombe and Jensen (1996), which rates the duration of exposure to suspended sediment. Turbidity was characterized using California Data Exchange Center (CDEC) data from all available sites and years (California Data Exchange Center 2010). Data available from CDEC were in nephelometric turbidity units (NTUs) and were converted to units of suspended solids (SS) using developed relationships (Lloyd 1987; Packman et al. 2000; Environmental Science Associates 2003).

Water Withdrawals

Water withdrawals in EDT refers to the potential for entrainment or impingement of fish on water withdrawal structures; the effect of withdrawals on flow is captured in the flow-related attributes. Locations of withdrawal structures in the study area were characterized using information from a California Department of Water Resources GIS layer.

Wood

PHAB data from 2010 and 2011 were used to characterize wood in the stream (methods described in San Joaquin River Restoration Program 2012). Specifically, counts of small and large woody debris from the instream habitat diversity worksheet were used to create the PHAB wood index that ranges from 0 (less woody debris) to 4 (more woody debris). Numerically, this index is opposite of that used in EDT; as such, the PHAB index value was subtracted from 4 to develop the EDT index, averaged across transects within the same reach, and averaged across wood sizes and years.

References

California Data Exchange Center. 2010. Department of Water Resources. Available: <http://cdec.water.ca.gov/>. Accessed: June 1, 2012.

Department of the Interior. 2012. *Mendota Pool Sediment Quality Investigation—Analytical Results, Data Assessment, and Quality Assurance Summary*. San Joaquin River Restoration Program. Sacramento, CA. 222 pages.

Environmental Science Associates. 2003. *Coast Dairies Long-Term Resource Protection and Use Plan: Existing Conditions Report*. Prepared for The Trust for Public Land. Available: <http://www.mbosc.org/advocacy/coast_dairies/ca_coast_dairies_plan_6_03.pdf>. Accessed: November 19, 2012.

Guzman, E. 2009. *Summary of Pilot Study for Reach 1-A Meso-Habitat Monitoring during the Fall 2009 Interim Flow Period*. San Joaquin River Restoration Fisheries Management Workgroup. 8 pages.

Lestelle, L. C., and Mobrand, L. E. 2005. *Guidelines for Rating Level 2 Environmental Attributes in Ecosystem Diagnosis and Treatment (EDT)*. Jones & Stokes Associates, Inc. 143 pages.

Lloyd, D. S. 1987. Turbidity as a Water Quality Standard for Salmonid Habitats in Alaska. *North American Journal of Fisheries Management* 7(1):34–45.

Moyle, P. B. 2002. *Inland Fishes of California*. Berkeley, CA: University of California Press.

Musseter Engineering, Inc. 2008. *San Joaquin HEC-RAS Model Documentation*. Draft. Seattle, WA. 39 pages.

Newcombe, C. P., and J. O. Jensen. 1996. Channel Suspended Sediment and Fisheries: A Synthesis for Quantitative Assessment of Risk and Impact. *North American Journal of Fisheries Management* 16(4):693–727.

Packman, J. J., K. J. Comings, and D. B. Booth. 2000. *Using Turbidity to Determine Total Suspended Solids in Urbanizing Streams in the Puget Lowlands*. In: Confronting Uncertainty: Managing Change in Water Resources and the Environment, Canadian Water Resources Association Annual Meeting. Vancouver, B.C. October 27–29, 1999.

San Joaquin River Restoration Program. 2011. Chapter 5—Biological Resources—Fisheries. In: *Draft Program Environmental Impact Statement/Environmental Impact Report*. Sacramento, CA. 110 pages.

San Joaquin River Restoration Program. 2012. *Benthic Macroinvertebrate Bioassessment Study: 2012 Mid-Year Technical Report*. Sacramento, CA.

Appendix C

Minimum Restoration Formulation

Appendix C
Minimum Restoration Scenario Formulation

Background

The Minimum Restoration Scenario captures conditions that result from the minimum restoration actions described in the San Joaquin River Restoration Settlement (Settlement). The scenario was developed by the San Joaquin River Restoration Program Core Team (Core Team). The Core Team developed action hypotheses concerning effects of actions described in the Settlement on Level 2 Ecosystem Diagnosis & Treatment (EDT) attributes among all reaches of the study area. The primary restoration action was assumed to be increased conveyance of flow from Friant Dam (to a minimum of 4,500 cfs through Reach 4B) and the addition of spawning gravel to Reach 1-A1 in the form of 10 new gravel beds. Table C-1 shows the attributes that were assumed to improve or degrade due to minimum restoration actions. While most environmental attributes affected by the minimum restoration actions were improved, a few were degraded (e.g., increased transport of metals in the water column).

Scenarios in EDT including the Minimum Restoration Scenario are based on the concept of patient-template analysis (PTA) (Lichatowich et al. 1995). The approach describes scenarios in terms of changes in environmental conditions within a restoration potential for the study area. In this study restoration potential was bounded by the Current Condition (i.e., the *patient*) and the best-case scenario (for 0–4 attributes in EDT, a 0).[1] Generally, restoration actions will not improve attribute values beyond those described in the Reference Condition (although this is possible).[2] The Reference Condition captures the intrinsic condition of the San Joaquin River including development actions that are considered to be inherent changes to the system (see Appendix D for a description of the Reference Condition). The Minimum Restoration Scenario is defined in the model as the percentage movement in the condition of attributes (e.g., large wood, flow, or channel width) in the Current Condition toward the best-case scenario. The EDT model then translates these environmental changes into a projected change in fish abundance and other ecological metrics.

Characterization Methods

Flow, Temperature, and Widths

EDT attributes related to hydrologic flow, temperature, and width were characterized from Hydrologic Engineering Centers River Analysis System (HEC-RAS) and RiverWare output data (described in Musseter 2008). Specifically, a restoration flow scenario with a spring pulse and riparian recruitment release hydrographs were adjusted for more favorable water temperatures in the river. The EDT attributes for high flow and low flow were characterized from the flow output data. Flow is directly input to EDT as the change in scenario flow relative to a reference condition of

[1] Degradation of an attribute relative to the current condition is also allowed.

[2] For some EDT models, the lower bound of restoration potential is defined by the template condition as opposed to the best-case scenario.

an undisturbed watershed of comparable size, geology, orientation, topography, and geography, for which the full natural flow at Friant Dam at Millerton was used. The attribute captures the extent to which the timing and magnitude of the average high flow and average low flow have changed over time; such changes can be the result of regulation or other actions.

Modeled water temperature data associated with this flow scenario were used to characterize EDT daily maximum and minimum temperature attributes. EDT temperature ratings are based on potential exposure time of fish to various temperature criteria. Temperature data are processed in the EDT temperature tool to derive EDT temperature ratings.

Channel widths were also calculated based on this minimum restoration flow scenario and relationships between flow levels and inundated widths among EDT reaches, with current levee positions.

Other Attributes

Besides flow, temperature, and channel width attributes, changes in EDT attributes due to minimum restoration actions were formulated based on action hypotheses. As the first step in developing the Minimum Restoration Scenario action hypotheses, the Core Team identified environmental attributes that would likely change due to implementation of each of the minimum restoration actions (Table C-1). For example, the augmentation of gravel in Reach 1-A1 would be expected to change the percentage of spawning area within the reach and affect other attributes as well. The Core Team's modeling group then hypothesized the amount of change that might occur in these linked attributes as a result of the minimum restoration actions. Attributes are generally rated on a 0–4 scale in EDT, a categorical rating of 0 in EDT results represents no degradation to the benchmark, while a value of 4 represents an extreme (often fatal) degradation of the benchmark. (0 generally indicates ideal conditions and 4 represents less-than-ideal conditions). Attributes that were hypothesized to improve due to minimum restoration actions—such as the amount of large wood or fine sediment—were assumed to improve 25% towards ideal conditions. Attributes that were assumed to degrade were moved 25% further from the Current Condition. Action hypotheses were not formulated for Reaches SJR4-B1A, SJR4-B1B, SJR4-B2A, and SJR4-B2B, which were assumed to be dry, or for the reaches addressed in the 2B project description alternatives.

Table C-1. Attributes Hypothesized to Change due to Minimum Restoration Actions for San Joaquin River Reaches[a]

Reach	Benth	DO	Emb	FSed	FishR	FishInt	MetWat	Tox	Pred	Ripar	Wood	%BPond	%Pool	%SmCob	%Gld
SJR1-A1	+	+	+	+	0	0	0	+	+	+	0	0	0	+	0
SJR1-A2	+	+	0	0	0	0	0	+	+	+	0	0	0	0	0
SJR1-B1	+	+	0	0	+	+	0	+	+	+	+	+	+	0	-
SJR1-B2	+	+	0	0	+	+	0	+	+	+	+	+	+	0	-
SJR2-A	+	+	0	0	+	+	0	+	+	+	+	+	+	0	-
Chowchilla Bypass	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
South Eastside Bypass	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SJR3-A	+	+	0	0	+	+	0	+	+	0	0	+	+	0	-
SJR3-B	+	+	0	0	+	+	0	+	+	0	0	+	+	0	-
SJR3-C	+	+	0	0	+	+	0	+	+	0	0	+	+	0	-
SJR4-A1	+	+	0	0	+	+	0	+	0	0	0	+	0	0	-
SJR4-A2	+	+	0	0	+	+	0	+	0	0	0	+	0	0	-
Sand Slough Connector	+	+	0	0	+	+	0	+	+	0	0	+	+	0	-
Central Eastside Bypass—Upstream	+	+	0	0	+	+	0	+	+	0	0	+	+	0	-
Central Eastside Bypass—Downstream	+	+	0	0	+	+	0	+	+	0	0	+	+	0	-
North Eastside Bypass	+	+	0	0	+	+	0	+	+	0	0	+	+	0	-
Bear Creek_B	+	+	0	0	+	+	0	+	+	0	0	+	+	0	-
Bear Creek_A	+	+	0	0	+	+	0	+	+	0	0	+	+	0	-
Mariposa Bypass Upper	+	+	0	0	+	+	0	+	+	0	0	+	+	0	-
Mariposa Bypass Lower	+	+	0	0	+	+	0	+	+	0	0	+	+	0	-
SJR4-B3	+	+	0	0	+	+	0	+	+	+	0	+	+	0	-
SJR5-A	+	+	0	0	+	+	-	+	+	+	+	+	+	0	-
SJR5-B	+	+	0	0	+	+	-	+	+	+	+	+	+	0	-
SJR5-C	+	+	0	0	+	+	-	+	+	+	+	+	+	0	-

Key: Benth = benthic richness, DO = dissolved oxygen, Emb = embeddedness, FSed = fine sediment, FishR = fish richness, Path = fish pathogens, FishInt = fish species introductions, MetWat = metals in the water column, Tox = miscellaneous toxins, Pred = predation risk, Ripar = riparian function, Wood = woody debris, %BPond = percent habitat beaver ponds, %Pool = percent habitat primary pools, %SmCob = percent habitat small cobble, %Gld = percent habitat glides.

[a] A plus sign (+) indicates improvement and a minus sign (-) indicates degradation, except under those attributes preceded by a percent sign (%), in which case plus signs and minus signs indicate an increase or decrease in percentage, respectively. A zero (0) indicates no change.

References

Lichatowich, J. A., L. E. Mobrand, L. Lestelle, and T. Vogel. 1995. An Approach to the Diagnosis and Treatment of Depleted Pacific Salmon Populations in Freshwater Ecosystems. *Fisheries* 20(1):10–18.

Musseter Engineering, Inc. 2008. *San Joaquin HEC-RAS Model Documentation*. Draft. Seattle, WA. 39 pages.

Appendix D

Template Condition Formulation

Appendix D
Template Condition Formulation

Ecosystem Diagnosis & Treatment (EDT) is frequently used to diagnose habitat problems and prioritize their remedies or treatments. Described by Lichatowich et al. (1995), *patient-template analysis* (PTA) is a process of diagnosis and treatment for stream conditions. PTA is based on comparison of a current condition—i.e., the *patient*—to a reference condition termed the *template*. The template condition is most often the pre-development condition for the stream such that the PTA diagnosis highlights the impacts of all aspects of development. However, the template can also incorporate actions and features (e.g., dams) within the landscape, which enables the PTA diagnosis to highlight changes that have occurred on top of those included features. The comparison between population performance under the patient condition and template condition is the basis for identifying limitations to the stream condition that incorporate the inherent strengths and limitations of the stream. PTA provides considerable insights into spatial and temporal stream functions, particularly in the context of life history expression as captured in EDT. In the modeling process, results from the template condition are "spliced" into the patient condition at an attribute and reach scale, resulting in a change in population performance between reaches and between attributes that can be compared and ranked, providing planners with a road map for restoration.

For the San Joaquin River Restoration Program analysis, the template condition was the pre-development condition for all attributes using the present geometry of the system including bypasses; other than the present channel geometry, no further human impacts on the system were assumed. In other words, flow, temperature, sediment, habitat types, and other attributes in the template are patterned on an assumed pre-development condition within the framework of the present stream geometry. For reaches that did not exist historically (i.e., bypasses), attribute conditions were assumed to be similar to those of either parallel reaches or reaches immediately upstream and downstream. This template definition results in a diagnosis in EDT that focuses on changes in the project area other than those that may have resulted from the construction of the extensive bypass and channel geometry that exists today.

Much of the basis for the ratings in the template condition was taken from the *San Joaquin River Restoration Study Background Report* (McBain and Thrush 2002), including information on temperature and channel morphometry. Other information was derived from Chapter 5, "Biological Resources—Fisheries," of the *San Joaquin River Restoration Program Draft Environmental Impact Statement/Report* (San Joaquin River Restoration Program 2011), which describes historic riparian conditions along the San Joaquin River (SJR).

A decrease in river gradient was assumed for the template condition, because the straightening and shortening of channels have led to an increase in gradient in the current condition. Many attributes were assumed to be in a pristine or undisturbed condition, such as dissolved oxygen (DO) and the presence of toxins. Fine sediment was historically prevalent in the system because the SJR has always had significantly sandy substrate. Water withdrawals were eliminated in the template condition, as was artificial channel confinement (termed *hydroconfinement* in EDT). Riparian function and woody debris were assumed to increase in the template condition due to increased connection to the floodplain and riparian zone relative to the patient condition. Turbidity was greatly improved in the template condition because levels were likely low due to the granitic geology of the system and land uses in the patient condition that increase sediment in the system (San Joaquin River Restoration Program 2011).

Fish richness and predation attributes were calculated using historic condition data from *Inland Fishes of California* (Moyle 2002). The percentage of habitat composed of beaver dams was assumed to be higher in the template, and pool-riffle or pool-glide habitat was expected to increase. Cobble and gravel were also assumed to be higher under an undisturbed condition. Spatial variation in temperature was assumed to be higher with increased floodplain connectivity and habitat complexity.

Historic Floodplain Derivation

The number of floodplain habitat acres per EDT reach was also input into the model's template condition. It was assumed that the historic extent of potential riparian vegetation would be a good indicator of potential floodplain habitat (Figure D-1). To determine the total potential historic extent of riparian vegetation in the vicinity of the reaches of the SJR, soil survey data were downloaded in ESRI shapefile format from the Natural Resources Conservation Service for the five survey areas within the San Joaquin watershed.

- Eastern Fresno Area, California.
- Fresno County, California—Western Part.
- Madera Area, California.
- Merced Area, California.
- Merced County, California—Western Part.

The datasets were loaded into ArcInfo 10, where a definition query was established for each of the soil surveys to isolate soil types determined likely to support riparian vegetation based on geographic position and aerial photo interpretation. This methodology and the soil types queried were based on those used for the riparian soils analysis reported in the *Historical Riparian Habitat Conditions of the San Joaquin* River (Jones & Stokes 1998).

The five queried soil series datasets were merged into a single dataset that included only riparian soils. To determine the acreage of potential historic riparian vegetation within a given reach of the river, a shapefile of polylines representing the flowline of the channel in each reach was buffered by 200 feet. The buffered polygons extended to the left and right of the channel flowline but did not include end cap buffers.

The riparian soils dataset was intersected with the buffered reach polygons, and the riparian soils data was clipped at reach breaks and coded by reach. The data was dissolved by reach name, melding the various soil polygons into a single polygon or set of polygons for each reach. The area for these was then calculated in acreage, resulting in a feature set showing the geometry of the respective soils, and storing data of the reach name and total acreage of suitable soils within each reach (Figure D-1).

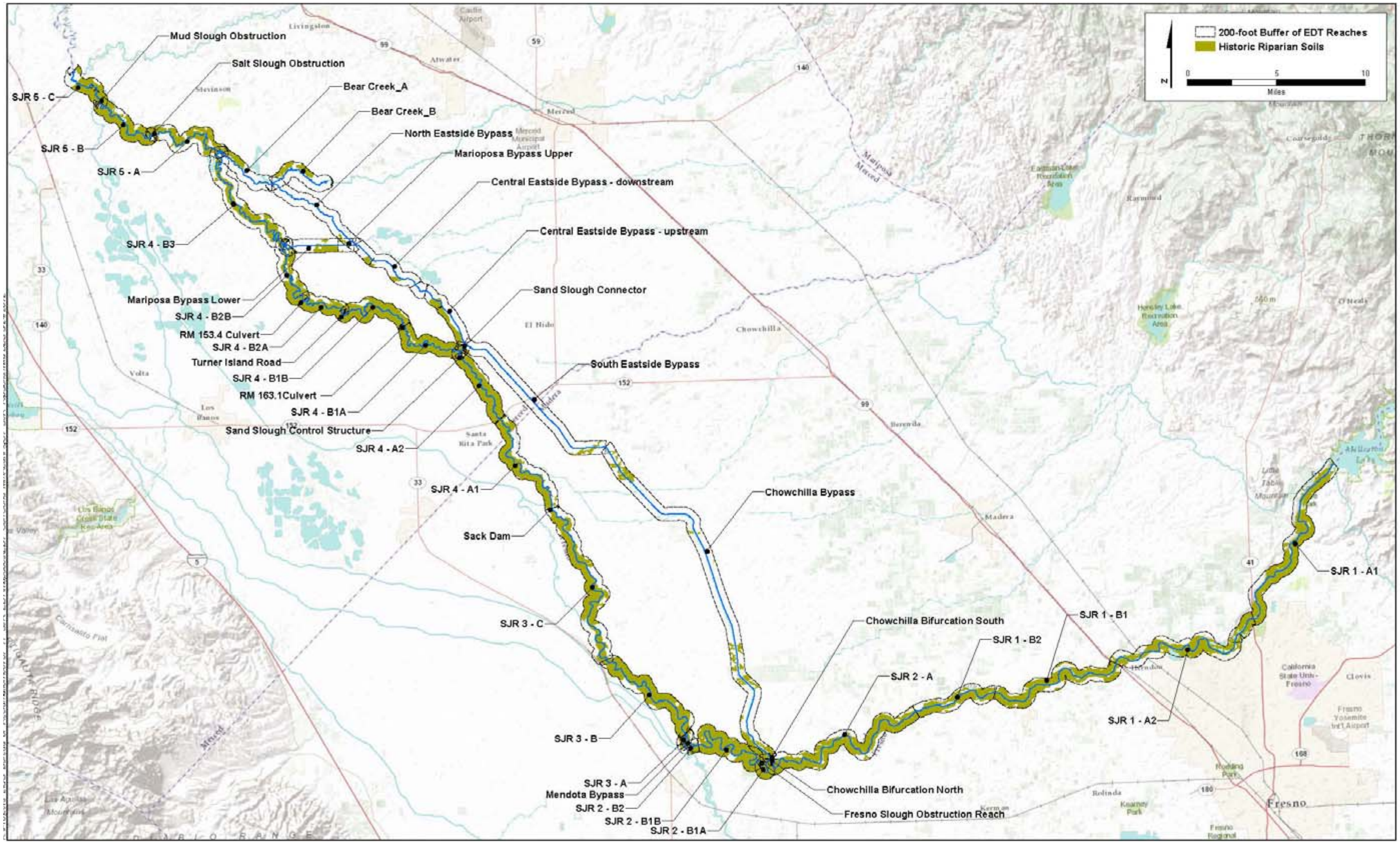

Figure D-1. Extent of Historic Riparian Soils within 200 Feet of the EDT Reaches for the San Joaquin River

References

Jones & Stokes Associates, Inc. 1998. *Historical Riparian Habitat Conditions of the San Joaquin River: Friant Dam to the Merced River*. Prepared for the San Joaquin River Riparian Habitat Restoration Program.

Lichatowich, J. A., L. E. Mobrand, L. Lestelle, and T. Vogel. 1995. An Approach to the Diagnosis and Treatment of Depleted Pacific Salmon Populations in Freshwater Ecosystems. *Fisheries* 20(1):10–18.

McBain and Thrush, Inc. (eds.) 2002. *San Joaquin River Restoration Study Background Report*. Prepared for the Friant Water Users Authority, Lindsay, California and the National Resources Defense Council, San Francisco, California.

Moyle, P. B. 2002. *Inland Fishes of California*. Revised Edition. Berkeley, CA: University of California Press.

San Joaquin River Restoration Program. 2011. Chapter 5—Biological Resources—Fisheries. In: *Draft Program Environmental Impact Statement/Environmental Impact Report*. Sacramento, CA. 110 pages.