

## Appendix C

# Friant Dam Releases for Restoration Flows

**Water Year 2010 Interim Flows Project  
Draft Environmental Assessment/Initial Study**

**SAN JOAQUIN RIVER**  
RESTORATION PROGRAM





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# 1 **List of Abbreviations and Acronyms**

2	°F	degrees Fahrenheit
3	cfs	cubic foot per second
4	cm	centimeter
5	CVP	Central Valley Project
6	DWR	California Department of Water Resources
7	EA/IS	Environmental Assessment/Initial Study
8	PEIS/R	Program Environmental Impact Statement/Report
9	RA	Restoration Administrator
10	Reclamation	U.S. Department of the Interior, Bureau of
11		Reclamation
12	RWA	Recovered Water Account
13	Settlement	Stipulation of Settlement
14	SJRRP	San Joaquin River Restoration Program
15	State	State of California
16	SWP	State Water Project
17	TAF	thousand acre-feet

# 1.0 Introduction

This Friant Dam Releases for Restoration Flows Appendix to the Draft Environmental Assessment/Initial Study (EA/IS) was prepared in support of the San Joaquin River Restoration Program (SJRRP). This appendix provides context for describing the release of Interim and Restoration Flows from Friant Dam, and is intended to supplement the evaluation of program alternatives for the Program EA/IS and Program Environmental Impact Statement/Report (PEIS/R).

## 1.1 Purpose and Scope of This Appendix

This appendix describes guidelines for implementing Restoration Flows under the Stipulation of Settlement in the court case *NRDC, et al., vs. Kirk Rodgers, et al.* (Settlement), focusing on the following topics associated with Restoration Flows:

- Restoration Year-Type classification and application (Paragraph 13(j)(i))
- Determination of total annual Restoration Allocation (Paragraphs 13(a), 13(b) and Exhibit B)
- Setting Initial Restoration Flows (Paragraphs 13(j)(iii), 13(j)(v), and 13(j)(vi))
- Framework for modifying actual releases from Friant Dam necessitated by hydrologic uncertainties and other real-time operation considerations (Paragraphs 13(j)(v) and 18)
- Framework for modifying actual releases from Friant Dam to enhance the success of the Restoration Goal (Exhibit B)
- Procedures for debiting releases for Restoration Flows against an annual allocation, including the extent to which flood releases meet Restoration Flow hydrograph requirements (Paragraphs 13(d) and 13(j)(vi))

Actions to reoperate Friant Dam discussed in this document comprise a methodology for determining an annual allocation for restoration, and a process for transforming the initial Restoration Flow Schedule. Actions to reoperate Friant Dam were developed and reviewed with technical analysis, and against other materials used in expert testimony. The contents of this document were periodically reviewed by the Settling Parties so that they could come to mutual agreement by December 2008, as required in the Settlement.

Impacts of the Settlement on the Friant Division long-term contractors were evaluated using a simulation over the historical hydrologic record from 1922 through 2004. The same period was used to review the impact of actions to reoperate Friant Dam on Restoration allocation and long-term contract delivery volumes.

The ecological functionality intended for the actions to reoperate Friant Dam was provided through a review of the Expert Testimony submitted to the court during litigation.

1 This appendix is organized as follows:

2 **Section 1** introduces the appendix and presents its purpose and scope, and additional  
3 operations considerations.

4 **Section 2** presents a digest of relevant Settlement language on Restoration Flows.

5 **Section 3** presents a digest of relevant expert testimony on ecological intentions, and  
6 objectives.

7 **Section 4** presents basic interpretations of Settlement language needed for framing  
8 actions to reoperate Friant Dam.

9 **Section 5** presents the approach developed to set annual allocation volumes for  
10 Restoration Flows.

11 **Section 6** presents the approach developed to transform annual allocations into initial  
12 Restoration Flow Schedules.

13 **Section 7** lists the remaining concepts and procedures needed for full implementation of  
14 the actions to reoperate Friant Dam for Interim and Restoration flow periods.

15 **Section 8** contains the sources used to compile this document.

## 16 **1.2 Additional Operational Considerations**

17 The following topics, included in Paragraph 13, Paragraph 16, and Exhibit B of the  
18 Settlement, will not be addressed in this attachment:

- 19 • Procedures and protocols for implementing recommendations from the  
20 Restoration Administrator (RA) and/or other advisory parties (Exhibit B). These  
21 are addressed in the *Restoration Flow Guidelines*, which will be an attachment to  
22 the *Operational Guidelines for Water Service – Friant Division Central Valley*  
23 *Project* (Reclamation 2005).
- 24 • Development of methodology and procedures for seepage evaluation (Paragraph  
25 13(j)(iv)) and other measurement procedures and monitoring requirements  
26 (Paragraph 13(j)(ii)). These are addressed in the *Physical Parameters Monitoring*  
27 *Plan* and in three monitoring and management plan documents for conveyance,  
28 seepage, and invasive vegetation.

- 1       • Framework for developing a plan to achieve the Water Management Goal and  
2 details of plan components, including management of the Recovered Water  
3 Account (RWA) (Paragraph 16). These topics are addressed at a programmatic  
4 level within the PEIS/R and in the *Restoration Flow Guidelines*, and will be  
5 further refined in an SJRRP Water Recapture Plan.

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## 2.0 Related Settlement Language

Paragraph 13 of the Settlement describes implementing Restoration Flows. Some subsections are especially relevant to this attachment, and are included in the following:

### **Line 24, Page 10**

*13. In addition to the channel and structural improvements identified in Paragraph 11, releases of water from Friant Dam to the confluence of the Merced River shall be made to achieve the Restoration Goal as follows:*

*(a) All such additional releases from Friant Dam shall be in accordance with the hydrographs attached hereto collectively as Exhibit B (the “Base Flow”), plus releases of up to an additional ten percent (10 percent) of the applicable hydrograph flows (the “Buffer Flows”) may be made by the Secretary (of the Interior) based upon the recommendation of the Restoration Administrator to the Secretary, as provided in Paragraph 18 and Exhibit B. The Base Flows, the Buffer Flows and any additional water acquired by the Secretary from willing sellers to meet the Restoration Goal are collectively referred to as the “Restoration Flow.” Additional water acquired by the Secretary may be carried over or stored provided that doing so shall not increase the water delivery reductions to any Friant Division long-term contractor beyond that caused by releases made in accordance with the hydrographs (Exhibit B) and the Buffer Flows.*

*(b) The Restoration Flows identified in Exhibit B include releases from Friant Dam for downstream riparian interests between Friant Dam and Gravelly Ford and assume the current level of downstream diversions and seepage losses downstream of Gravelly Ford.*

### **Line 19, Page 13**

*(d) Notwithstanding Paragraphs 13(a), (b), and (c), the Parties acknowledge that flood control is a primary authorized purpose of Friant Dam, that flood flows may accomplish some or all of the Restoration Flow purposes to the extent consistent with the hydrographs in Exhibit B and the guidelines developed pursuant to Paragraph 13(j), and further acknowledge that there may be times when the flows called for in the hydrographs in Exhibit B may be exceeded as a result of operation of Friant Dam for flood control purposes. Nothing in this Settlement shall be construed to limit, affect, or interfere with the Secretary’s ability to carry out such flood control operations.*

1           (e) Notwithstanding Paragraphs 13(a), (b), and (c), the Secretary may  
2 temporarily increase, reduce, or discontinue the release of water  
3 called for in the hydrographs shown in Exhibit B for the purpose of  
4 investigating, inspecting, maintaining, repairing, or replacing any of  
5 the facilities, or parts of facilities, of the Friant Division of the Central  
6 Valley Project (the "CVP"), necessary for the release of such  
7 Restoration Flows; however, except in cases of emergency, prior to  
8 taking any such action, the Secretary shall consult with the  
9 Restoration Administrator regarding the timing and implementation of  
10 any such action to avoid adverse effects on fish to the extent possible.  
11 The Secretary shall use reasonable efforts to avoid any such increase,  
12 reduction, or discontinuance of release. Upon resumption of service  
13 after any such reduction or discontinuance, the Secretary, in  
14 consultation with the Restoration Administrator, shall release, to the  
15 extent reasonably practicable, the quantity of water which would have  
16 been released in the absence of such discontinuance or reduction when  
17 doing so will not increase the water delivery reductions to any Friant  
18 Division long-term contractors beyond what would have been caused  
19 by releases made in accordance with the hydrographs (Exhibit B) and  
20 Buffer Flows.

21 **Line 25, Page 16**

22           (j) Prior to the commencement of the Restoration Flows as provided in  
23 this Paragraph 13, the Secretary, in consultation with the Plaintiffs  
24 and Friant Parties, shall develop guidelines, which shall include, but  
25 not be limited to: (i) procedures for determining water-Year-types and  
26 the timing of the Restoration Flows consistent with the hydrograph  
27 releases (Exhibit B); (ii) procedures for the measurement, monitoring  
28 and reporting of the daily releases of the Restoration Flows and the  
29 rate of flow at the locations listed in Paragraph 13(g) to assess  
30 compliance with the hydrographs (Exhibit B) and any other applicable  
31 releases (e.g., Buffer Flows); (iii) procedures for determining and  
32 accounting for reductions in water deliveries to Friant Division long-  
33 term contractors caused by the Interim Flows and Restoration Flows;  
34 (iv) developing a methodology to determine whether seepage losses  
35 and/or downstream surface or underground diversions increase  
36 beyond current levels assumed in Exhibit B; (v) procedures for making  
37 real-time changes to the actual releases from Friant Dam necessitated  
38 by unforeseen or extraordinary circumstances; and (vi) procedures for  
39 determining the extent to which flood releases meet the Restoration  
40 Flow schedule releases made in accordance with Exhibit B. Such  
41 guidelines shall also establish the procedures to be followed to make  
42 amendments or changes to the guidelines.

43

1 **Line 5, Page 23**

2 *18. The selection and duties of the Restoration Administrator and the*  
 3 *Technical Advisory Committee are set forth in this Settlement and*  
 4 *Exhibit D. Consistent with Exhibit B, the Restoration Administrator*  
 5 *shall make recommendations to the Secretary concerning the manner*  
 6 *in which the hydrographs shall be implemented and when the Buffer*  
 7 *Flows are needed to help in meeting the Restoration Goal. In making*  
 8 *such recommendations, the Restoration Administrator shall consult*  
 9 *with the Technical Advisory Committee, provided that members of the*  
 10 *Technical Advisory Committee are timely available for such*  
 11 *consultation. The Secretary shall consider and implement these*  
 12 *recommendations to the extent consistent with applicable law,*  
 13 *operational criteria (including flood control, safety of dams, and*  
 14 *operations and maintenance), and the terms of this Settlement. Except*  
 15 *as specifically provided in Exhibit B, the Restoration Administrator*  
 16 *shall not recommend changes in specific release schedules within an*  
 17 *applicable hydrograph that change the total amount of water*  
 18 *otherwise required to be released pursuant to the applicable*  
 19 *hydrograph (Exhibit B) or which increase the water delivery*  
 20 *reductions to any Friant Division long-term contractors.*

21 Exhibit B presents hydrographs that constitute the Base Flows referenced in Paragraph 13  
 22 of the Settlement. In addition, the exhibit contains specifics of the following subjects:

- 23 • Buffer Flows
- 24 • Restoration Year-Types for applying the six hydrographs
- 25 • Intent to transform the annual allocation methodology from the Exhibit B stair-  
 26 step approach to a more continuous approach
- 27 • Flexibility in timing of releases in selected periods
- 28 • Flushing flows (a block of water averaging 4,000 (cubic feet per second (cfs))  
 29 from April 16 through 30 in Normal-Wet and Wet years
- 30 • Riparian recruitment flows (a block of water averaging 2,000 cfs) from May 1  
 31 through June 30 in Wet years

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## 3.0 Ecological Goals and Objectives for Restoration

The ecological goals and objectives of the Exhibit B flow schedules, and the sources of information used to develop them, are described below.

### 3.1 Expert Testimony

The expert testimony of Drs. Peter B. Moyle, Michael L. Deas, and G. Mathias Kondolf further define and explain the ecological intent of the Exhibit B flow schedules. Except during Critical years, the flow regime should have the following characteristics:

(1) continuous flow from Friant Dam to the Merced River at all times of year to maintain habitat for fish in all reaches of the river, (2) flows from November through December to provide conditions suitable for migration and spawning of fall-run Chinook salmon, (3) flows in January and February to provide conditions suitable for incubation and rearing for fall-run Chinook salmon, (4) flows in March through April to provide conditions suitable for emigration of juvenile salmon of both runs, immigration of adult spring-run Chinook salmon, and spawning of native resident fishes, (5) flows through the summer to maintain holding and rearing habitat for spring-run Chinook, to maintain a diverse community of native fishes, and to support fisheries for warm-water game fishes (Moyle testimony, pages 30–31; Kondolf testimony, pages 19–22). The goal is to establish the annual runs of salmon and Pacific lamprey that existed just before the completion of Friant Dam, as well as to create permanent habitat for 10–14 species of native fishes in the reaches below the dam (Moyle testimony, page 23). While the Restoration Goal encompasses many fish species, salmon are the focus of restoring fish in good condition (Moyle testimony page 25).

The ecological intent of the flow schedules also includes maintenance of spawning gravels and other channel conditions (Kondolf testimony pages 15–16) and riparian vegetation recruitment and maintenance (Kondolf testimony pages 17–19).

### 3.2 Overview of Ecological Intent of the Flow Schedules

Based on information from the expert testimony described above, the overall ecological intent of the flow schedules can be summarized as follows:

- Provide for salmon life history needs (spring-run Chinook, fall-run Chinook), including the following:
  - Adult migration
  - Adult holding (spring-run only)
  - Spawning and incubation
  - Juvenile rearing
  - Juvenile outmigration

- 1       • Support other native fish and warm-water game fish
- 2       • Maintain geomorphic processes (especially gravel mobility)
- 3       • Support recruitment and maintenance of riparian vegetation

4 Each of these four key ecological components and associated flow requirements  
5 described in the expert testimony are discussed below.

### 6 **3.2.1 Chinook Salmon Life History Needs**

7 The Restoration Flow Schedules are intended to provide suitable conditions for these  
8 distinct phases of salmon life history: adult migration for spring-run and fall-run Chinook  
9 salmon; adult holding for spring-run; and spawning, incubation, juvenile rearing, and  
10 outmigration of juveniles of both runs. Adult migration requires continuous flow to the  
11 Merced River confluence and suitable water temperatures. Holding for spring-run adults  
12 requires suitable water temperatures in Reach 1A. Spawning and incubation requires  
13 suitable water temperatures and adequate depths and velocities over spawning gravels in  
14 Reach 1. Juvenile rearing requires suitable water temperatures and adequate habitat. Out-  
15 migration of juveniles requires continuous flow to the Merced River confluence and  
16 suitable water temperatures during the spring and early summer periods (Moyle  
17 testimony pages 27–43; Kondolf testimony pages 14–15). Flow schedules were designed  
18 to take into account the interactions of temperature and flow (as modeled by Dr. Deas) so  
19 that flows for salmonids and other fishes are provided only if they create suitable  
20 temperature conditions for the life history stages present (Moyle testimony page 47, Deas  
21 testimony page 27). Water temperature is a key limiting factor for Chinook salmon, and  
22 appropriate temperatures must be present at all stages of their life cycle (Moyle testimony  
23 page 34).

### 24 **3.2.2 Other Native and Nonnative Fish**

25 The primary focus in Reach 1 is Chinook salmon but the conditions would also foster a  
26 diverse assemblage of native fishes. Reach 1A is expected to provide habitat for spring-  
27 run Chinook salmon because of cold-water dam releases, the presence of deep pools for  
28 adult holding habitat, and extensive riffles and runs for spawning and rearing juvenile  
29 fish. In Reach 2 flows are intended to provide connectivity to downstream and upstream  
30 reaches (for fish movement), to maintain native fishes, and to establish complex habitats  
31 generated by riparian vegetation and other factors (Moyle testimony page 46). Presumed  
32 members of the native fish assemblage would be Kern brook lamprey, Sacramento hitch,  
33 Sacramento blackfish, California roach, hardhead, Sacramento pikeminnow, Sacramento  
34 sucker, rainbow trout, tule perch, threespine stickleback, prickly sculpin and riffle  
35 sculpin. Reaches 3 through 5 would be dominated by nonnative fishes, such as various  
36 basses, sunfishes, and catfishes (Moyle testimony, pages 24, 46).

### 37 **3.2.3 Geomorphic Processes**

38 The flow schedules are intended to achieve mobilization of spawning gravels to maintain  
39 gravel quality. Gravel should be movable by female salmon, have a loose texture, and be  
40 free of sediment so that eggs receive adequate intragravel flow and dissolved oxygen  
41 (Kondolf testimony, page 15). Gravel mobilization requires pulses of high discharge to  
42 transport bed material and entrained sediment. Such “flushing flows” are commonly

1 considered to be needed approximately every 2 years on average (Kondolf and Wilcock  
2 1996, Kondolf 1998; both cited in Kondolf testimony page 16).

### 3 **3.2.4 Riparian Vegetation Recruitment and Maintenance**

4 The flow schedules were designed to establish and maintain native riparian tree species  
5 along all reaches (Kondolf testimony page 17). Riparian vegetation, particularly large  
6 woody species such as Fremont cottonwood and Goodding's black willow, that grows  
7 along the riverbanks provides essential functions for numerous aquatic species, including  
8 native and nonnative fish. Riparian vegetation, particularly trees, shades the channel  
9 (maintaining cooler water temperatures during the spring and summer months); creates  
10 and maintains channel complexity, cycles nutrients; and provides food and cover for a  
11 host of aquatic species. As large trees fall into the channel, they create hydraulic  
12 conditions that scour the bed, cause deposition of gravel deposits, and create sheltered  
13 backwater areas important for juvenile salmonid rearing. Wood-sheltered marginal areas  
14 may retain cooler groundwater and thereby serve as cold-water refugia for adult and  
15 juvenile salmon (Keller and Swanson 1979, cited in Kondolf testimony page 17).

16 Recruitment and maintenance of cottonwood require spring flows for seedbed preparation  
17 and seedling establishment, and summer flows for vegetation maintenance. Seedbed  
18 preparation requires pulses of high discharge for scouring bed and gravel bar surfaces,  
19 and for deposition of sands and silts on bars and floodplains, to produce patches of  
20 mineral soil suitable for seedling establishment (Kondolf testimony page 22). Seedling  
21 establishment requires relatively high flows during the spring germination period so that  
22 seedlings establish on surfaces high enough relative to the channel to prevent seedlings  
23 from being scoured or killed by prolonged inundation, and for gradual recession of the  
24 spring hydrograph during and after the seed germination period so that roots of newly  
25 established seedlings can keep pace with the declining water table well into the summer  
26 months (Kondolf testimony pages 17, 18). The recession limb associated with  
27 cottonwood establishment should create conditions suitable for other tree species such as  
28 black willow and narrow-leaf willow (Kondolf testimony page 18). A flow suitable for  
29 riparian recruitment every 5 to 10 years (Wet years only) should be sufficient to ensure  
30 regeneration of a riparian forest (Kondolf testimony page 17). Spring pulse flows on the  
31 order of 1,500 to 4,000 cfs are needed in Dry, Normal-Dry, and Normal-Wet years to  
32 scour encroaching seedlings or impede seedling establishment in the low-flow channel to  
33 maintain channel conditions (Kondolf testimony page 24). Mature trees require sufficient  
34 summer base flows to provide adequate soil moisture (Kondolf testimony page 18). In  
35 Critical years, one or more pulses of water should be released to flood-irrigate the  
36 riparian plants, increasing their survival rate during the period of desiccation (Kondolf  
37 testimony page 25).

38

**3.3 Ecological Objectives Relating to Flow Schedules**

Ecological objectives associated with each flow schedule component are described below. Aquatic connectivity is considered an objective common to all flow schedules, and is therefore described separately.

**3.3.1 Aquatic Connectivity**

Except during Critical years (5 percent of years), the flow schedules were designed to provide continuous flow from Friant Dam to the Merced River at all times of year for maintaining native fish communities and the aquatic ecosystem, and for suitable establishment of riparian vegetation and, at certain times of year, for adult and juvenile salmon migration (Moyle testimony page 45, Kondolf testimony page 15).

**3.3.2 Spring Rise and Pulse Flow**

Winter Base Flows ramp up to achieve the Spring Rise and Pulse Flows from March through April (Table 3-1). The spring rise is accompanied by short duration, high discharge pulses of flow to facilitate salmon migration, vegetation recruitment and maintenance, gravel mobility, and other channel conditions. This time period (March 1 – April 30) is included in the spring flexible flow period.

**Table 3-1.  
Spring Rise and Pulse Flow Dates and Discharge**

Period	Settlement Release (cubic feet per second)					
	Critical-Low	Critical-High	Dry	Normal-Dry	Normal-Wet	Wet
3/1–3/15	130	500	500	500	500	500
3/15–3/31	130	1500	1500	1500	1500	1500
4/1–4/15	150	200	350	2500	2500	2500
4/16–4/30	150	200	350	350	4000	4000

**Ecological Objectives**

The following list summarizes the ecological objectives identified in the next subsections:

- Provide suitable conditions for juvenile salmon outmigration of both runs.
- Provide suitable conditions for adult spring-run Chinook salmon upstream migration.
- Provide suitable conditions for spawning of resident native fishes.
- Provide floodplain inundation for salmon rearing and other species (e.g., splittail spawning) in wetter years.
- Provide flows sufficient to initiate fluvial geomorphic processes (i.e., bed scour) in wetter years.
- Provide flows sufficient for riparian seedbed preparation and seedling establishment, and to prevent vegetation encroachment in wetter years.
- Provide base flows to maintain established vegetation.

1 **Fish Goals**

2 Flow schedules were designed to reach water temperatures of 55–68 degrees Fahrenheit  
 3 (°F) for juvenile salmon rearing and migration, and 51–68°F for adult spring-run  
 4 migration (McCullough 1999, McCullough et al. 2001, Moyle 2002, Marine and Cech  
 5 2004, Yurok Tribal Fisheries Program 2004; all cited in Moyle testimony pages 35–36,  
 6 38, 58; Deas testimony page 27). The timing of spring pulse flows should be coordinated  
 7 with the abundance of adults below the mouth of the river to maximize the number of fish  
 8 moving upstream to spawn (Moyle testimony page 48). In Normal-Dry, Normal-Wet, and  
 9 Wet years, flows should provide supplemental edge and side channel habitats and  
 10 floodplain inundation for 2 to 3 weeks to allow spawning of native fishes and rearing of  
 11 juvenile salmon and other native fishes under highly productive conditions (Moyle  
 12 testimony page 49).

13 **Geomorphic Goals**

14 Gravels in most riffles of Reach 1A can be mobilized at flows of 8,000 cfs or lower (Cain  
 15 1997, McBain and Trush 2002, Stillwater Sciences 2003, all cited in Kondolf testimony  
 16 page 16). The actual hydrograph should include a peak flow release of 8,000 cfs for about  
 17 2 hours, thence receding over the course of a few days or more to 4,000 cfs. This release  
 18 is recommended in Normal-Wet and Wet years (50 percent of years) to mobilize  
 19 spawning gravels, to maintain their looseness and flush fine sediments, thus improving  
 20 habitat for fish (Kondolf testimony page 21, Moyle testimony pages 49-50).

21 **Riparian Vegetation Goals**

22 In wetter years, the geomorphic pulse flow (8,000 cfs) is intended to prepare the seedbed  
 23 for cottonwoods (Kondolf testimony page 22, Jones and Stokes 1998, cited in Kondolf  
 24 testimony page 23). Vegetation recruitment flows of approximately 4,000 cfs (3,000 to  
 25 6,000 cfs) combined with the high spring pulse recommended for wetter years, are  
 26 intended to disperse seeds and facilitate seed germination in the target zone of 60–200  
 27 centimeters (cm) (2–6.5 feet) above the Summer Base Flow water level and to reduce  
 28 vegetation encroachment in the low flow channel (Kondolf and Wilcock 1996, Mahoney  
 29 and Rood 1998, Cain 1997, Tsujimoto 1999, Stillwater Sciences 2003, Jones and Stokes  
 30 2001, Cain et al. 2003, all cited in Kondolf testimony pages 18–19, 23–24). Successful  
 31 seedling establishment requires gradual recession of spring flows averaging  
 32 approximately 3 to 4 percent over 60–90 days, corresponding to a general 2.5cm/day rate  
 33 or slower of water table decline in wetter years (Mahoney and Rood 1998, Jones and  
 34 Stokes 1998, Stillwater Sciences 2003, Cain et al. 2003, all cited in Kondolf testimony,  
 35 page 24–25). In Normal-Dry and Dry years, spring pulse flows of 1,500 to 2,500 cfs  
 36 would scour or otherwise impede seedling establishment in the low-flow channel  
 37 (Kondolf testimony page 24).

38 **3.3.3 Summer Base Flow**

39 Spring Rise and Pulse Flows are ramped down in Normal-Wet and Wet years to achieve  
 40 summer base flows (Table 3-2). Summer base flows in all years except Critical years are  
 41 350 cfs. The 2,000 cfs block of water in May–June of Wet years is for shaping a riparian  
 42 recruitment recession flow. In Critical years, flows ramp up through August to achieve  
 43 reduced summer base flows ranging from 190 to 255 cfs. May 1–May 28 is included in  
 44 the flexible flow period.

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**Table 3-2.  
Summer Base Flow Dates and Discharge**

Period	Restoration Year-Types and Settlement Release (cfs)					
	Critical-Low	Critical-High	Dry	Normal-Dry	Normal-Wet	Wet
5/1–6/30	190	215	350	350	350	2000
7/1–8/31	230	255	350	350	350	350

Key:  
cfs = cubic feet per second

3 **Ecological Objectives**

4 The following list summarizes ecological objectives identified in the next sections:

- 5 • Provide flows to maintain holding and rearing habitat for spring-run Chinook
- 6 salmon in Reach 1.
- 7 • Provide flows to maintain a diverse community of native fishes in Reaches 1
- 8 and 2.
- 9 • Provide flows to promote riparian seedling establishment in wetter years.
- 10 • Provide base flows to maintain established riparian vegetation.

11 **Fish Goals**

12 Summer Base Flows were designed to achieve water temperatures of 50–61°F for adult  
 13 spring-run Chinook holding, and less than or equal to 68°F for fry/juvenile rearing  
 14 spring-run Chinook in Reach 1 (Moyle et al. 1995, McCullough 1999, Moyle 2002, Ward  
 15 et al. 2002, 2003, Marine and Cech 2004, all cited in Moyle testimony pages 36–39, 58;  
 16 Deas testimony page 27). Summer Base Flows of 350 cfs are also intended to provide  
 17 general habitat for resident native fishes and a wetted channel down to the mouth of the  
 18 Merced River to maintain populations of native, game, and other fishes, based on  
 19 temperature models (Moyle testimony page 47). In Critical-Low years, only flows to  
 20 satisfy riparian diversions would be released. These releases maintain continuous flow  
 21 approximately to Gravelly Ford, thus maintaining holding and rearing habitat for salmon  
 22 below Friant Dam and other native fish habitat through Reach 1. Under these conditions,  
 23 the objective of maintaining continuous flow down to the Merced River confluence  
 24 would be abandoned (Moyle testimony page 50, Kondolf testimony page 25).

25 **Riparian Vegetation Goals**

26 In wetter years, spring recruitment flows are followed by a gradual stage recession (less  
 27 than 2.5 cm/day rate of water table decline) to promote seedling establishment (Mahoney  
 28 and Rood 1998, Jones and Stokes 1998, Stillwater Sciences 2003, Cain et al. 2003, all  
 29 cited in Kondolf testimony, pages 24–25). Summer Base Flows of 350 cfs are required to  
 30 maintain established vegetation (Kondolf testimony pages 18, 22). In Critical-High years,  
 31 one or more pulses of water should be released to flood-irrigate the riparian plants,  
 32 increasing their survival rate during the period of desiccation (Kondolf testimony page  
 33 25). In Critical-Low years, only riparian diversion flows would be released and riparian  
 34 vegetation would be affected. Some trees (especially young, recently established plants  
 35 without extensive and deep roots) may die during the period of desiccation while better  
 36 established trees may be able to survive (Kondolf testimony page 25).

1 **3.3.4 Spring-Run Spawning Flow**

2 The spring-run spawning flows maintain 350 cfs except in Critical years (Table 3-3).

3 **Table 3-3.**  
4 **Spring-Run Spawning Flow Dates and Discharge**

Period	Restoration Year-Type and Settlement Release (cfs)					
	Critical-Low	Critical-High	Dry	Normal-Dry	Normal-Wet	Wet
9/1–9/30	210	260	350	350	350	350

Key:  
cfs = cubic feet per second

5 **Ecological Objectives**

6 The following list summarizes ecological objectives identified in the next section:

- 7 • Provide conditions suitable for spring-run Chinook spawning in Reach 1.
- 8 • Provide flows to maintain a diverse community of native fishes in Reaches 1
- 9 and 2.

10 **Fish Goals**

11 Spring-Run Spawning Flows were designed to achieve water temperatures of 48–55°F  
12 for spring-run Chinook salmon spawning in Reach 1 (McCullough 1999, Stillwater  
13 Sciences 2003, both cited in Moyle testimony pages 37–38, 58; Deas testimony page 27).  
14 In Dry, Normal-Dry, Normal-Wet, and Wet years, flows in September are set at 350 cfs  
15 to provide for continuous flow all the way to the Merced River for adult salmon  
16 migration and general habitat for resident native fishes (Moyle testimony page 47,  
17 Kondolf testimony page 20). Reduced flows in Critical years are intended to maintain  
18 minimum populations of Chinook salmon and other fishes so that these populations can  
19 expand again when water returns (Moyle testimony page 50).

20 **3.3.5 Fall Base and Spring-Run Incubation Flows**

21 The Fall Base and Spring-Run Incubation Flows maintain 350 cfs except in Critical  
22 years, in which flows decrease from the Spring-Run Spawning Flows (Table3-4).

23 **Table 3-4.**  
24 **Fall Base and Spring-Run Incubation Flow Dates and Discharge**

Period	Restoration Year-Type and Settlement Release (cfs)					
	Critical-Low	Critical-High	Dry	Normal-Dry	Normal-Wet	Wet
10/1–10/31	160	160	350	350	350	350

Key:  
cfs = cubic feet per second

25

1 **Ecological Objectives**

2 The following list summarizes ecological objectives identified in the next section:

- 3 • Provide conditions suitable for spring-run Chinook salmon incubation in Reach 1.
- 4 • Provide flows to maintain a diverse community of native fishes in Reaches 1
- 5 and 2.

6 **Fish Goals**

7 Fall Base and Spring-Run Incubation Flows were designed to achieve water temperatures  
 8 of 48–55°F for spring-run Chinook salmon incubation and rearing in Reach 1  
 9 (McCullough 1999, Moyle 2002, Stillwater Sciences 2003, Marine and Cech 2004, all  
 10 cited in Moyle testimony pages 37–38, 58; Deas testimony page 27). Fall Base Flows  
 11 also provide general habitat for resident native fishes in Reaches 1 and 2 (Moyle  
 12 testimony page 47). In all but Critical years, Fall and Winter Base Flows are set at the  
 13 level prevailing during spring-run spawning in September, to prevent dewatering of  
 14 spring-run redds (Kondolf testimony page 20).

15 **3.3.6 Fall-Run Attraction Flow**

16 The Fall-Run Attraction Flow is an increase in flow from the Fall Base and Spring-Run  
 17 Incubation Flow in all years except Critical-Low years, in which flows decrease  
 18 (Table 3-5). The duration of the fall-run attraction flow is 7 days in Critical-Low and  
 19 Critical-High years and 10 days in wetter years.

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**Table 3-5.  
Fall-Run Attraction Flow Dates and Discharge**

Period	Restoration Year-Type and Settlement Release (cfs)					
	Critical-Low	Critical-High	Dry	Normal-Dry	Normal-Wet	Wet
11/1–11/6	130	400	700	700	700	700
11/7–11/10	n/a	n/a	700	700	700	700

Key:  
 cfs = cubic feet per second  
 n/a = not applicable

22 **Ecological Objectives**

23 The following list summarizes ecological objectives identified in the next subsection:

- 24 • Provide conditions suitable for adult fall-run Chinook salmon migration.
- 25 • Provide conditions suitable to stimulate emigration of juvenile spring-run
- 26 Chinook salmon.

27 **Fish Goals**

28 A 400–500 cfs pulse flow at the mouth of the Merced River, for 10 days, including 2  
 29 days for ramping up and down at each end, is designed to bring adult fall-run Chinook  
 30 salmon upstream to spawn (USFWS 1994, cited in Kondolf testimony pages 15, 19–20;  
 31 Moyle testimony page 47). The exact time of the pulse would be based on monitoring for  
 32 the presence of fall-run Chinook at the Merced River. The duration of the release is based

1 in part on estimated travel times of adult fall-run Chinook salmon to the potential  
 2 spawning areas in Reach 1 (3–7 days). This pulse should also enable some spring-run  
 3 Chinook salmon fry to emigrate (as they do in Butte Creek) (Moyle testimony page 47).

4 **3.3.7 Fall-Run Spawning and Incubation Flow**

5 Fall-run spawning and incubation flow begins on November 7 in Critical-Low and  
 6 Critical-High years, and on November 11 in wetter years. The Fall-Run Spawning and  
 7 Incubation Flow ramps down from the Fall-Run Attraction Flow to maintain the Fall  
 8 Base Flow of 350 cfs, except in Critical years, in which flows further decrease  
 9 (Table 3-6).

10 **Table 3-6.**  
 11 **Fall-Run Spawning and Incubation Flow Dates and Discharge**

Period	Restoration Year-Type and Settlement Release (cfs)					
	Critical-Low	Critical-High	Dry	Normal-Dry	Normal-Wet	Wet
11/7–11/10	120	120	n/a	n/a	n/a	n/a
11/11–12/31	120	120	350	350	350	350

Key:  
 cfs = cubic feet per second  
 n/a = not applicable

12 **Ecological Objectives**

13 The following list summarizes ecological objectives identified in the next section:

- 14 • Provide conditions suitable for fall-run Chinook salmon spawning and incubation  
 15 in Reach 1.
- 16 • Provide conditions suitable to stimulate emigration of juvenile spring-run  
 17 Chinook salmon.

18 **Fish Goals**

19 The Fall-Run Spawning And Incubation Flows were designed to achieve water  
 20 temperatures of 48–55°F for fall-run Chinook salmon spawning and egg incubation in  
 21 Reach 1 (McCullough 1999, Stillwater Sciences 2003, both cited in Moyle testimony  
 22 pages 37–38, 58; Deas testimony page 27). Releases of 350 cfs from Friant Dam, which  
 23 should assure a flow of 150 cfs to the confluence with the Merced River, would allow for  
 24 continued upstream adult fall-run Chinook salmon migration (Fry and Hughes 1958,  
 25 USFWS 1994, McBain and Trush 2002, Cain et al. 2003, Kondolf testimony page 20). A  
 26 Base Flow of 350 cfs is also needed to maintain wetted spawning habitat in Reach 1 (i.e.,  
 27 flow over redds) (Moyle testimony page 48).

28 **3.3.8 Winter Base Flow**

29 Winter Base Flows maintain the Fall-Run Spawning And Incubation Flow of 350 cfs  
 30 except in Critical years, in which flows further decrease (Table 3-7).

31

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**Table 3-7.  
Winter Base Flow Dates and Discharge**

Period	Restoration Year-Type and Settlement Release (cfs)					
	Critical-Low	Critical-High	Dry	Normal-Dry	Normal-Wet	Wet
1/1–2/28	100	110	350	350	350	350

Key:  
cfs = cubic feet per second

3 **Ecological Objectives**

4 The following list summarizes ecological objectives identified in the next section.

- 5 • Provide conditions suitable for egg incubation and rearing of fall-run Chinook
- 6 salmon in Reach 1.
- 7 • Provide conditions suitable for rearing of spring-run Chinook salmon in Reach 1.
- 8 • Provide flows to maintain a diverse community of native fishes in Reaches 1
- 9 and 2.

10 **Fish Goals**

11 Winter Base Flows were designed to achieve water temperatures of 48–55°F for fall-run  
 12 Chinook salmon egg incubation and less than or equal to 68°F for fry/juvenile rearing of  
 13 both runs of Chinook salmon in Reach 1 (Moyle et al. 1995, McCullough 1999, Moyle  
 14 2002, Ward et al. 2002, 2003, Stillwater Sciences 2003, Marine and Cech 2004, all cited  
 15 in Moyle testimony pages 36–39, 58; Deas testimony page 27). A base flow of 350 cfs is  
 16 also needed to maintain wetted spawning habitat in Reach 1 (i.e., flow over redds)  
 17 throughout the incubation period (Moyle testimony page 48; McBain and Trush 2002,  
 18 Cain et al. 2003, both cited in Kondolf testimony pages 20-21), as well as to provide  
 19 general habitat for resident native fishes in Reaches 1 and 2 (Moyle testimony page 47).

# 4.0 Restoration Year-Types: Classification and Application

This section provides the specifications for Restoration Year-Type classifications, and discusses practical decisions made for managing an account of total annual Restoration Flow volumes.

## 4.1 Settlement Specification and Required Refinements

Exhibit B of the Settlement identifies a set of six hydrographs (see Figure 4-1) that vary in shape and volume according to the total unimpaired runoff of the San Joaquin River below Friant Dam for a water year (October 1 through September 30). The six year-types (referred to as Restoration Year-Types in this appendix) are “Critical-Low,” “Critical-High,” “Dry,” “Normal-Dry,” “Normal-Wet,” and “Wet.”

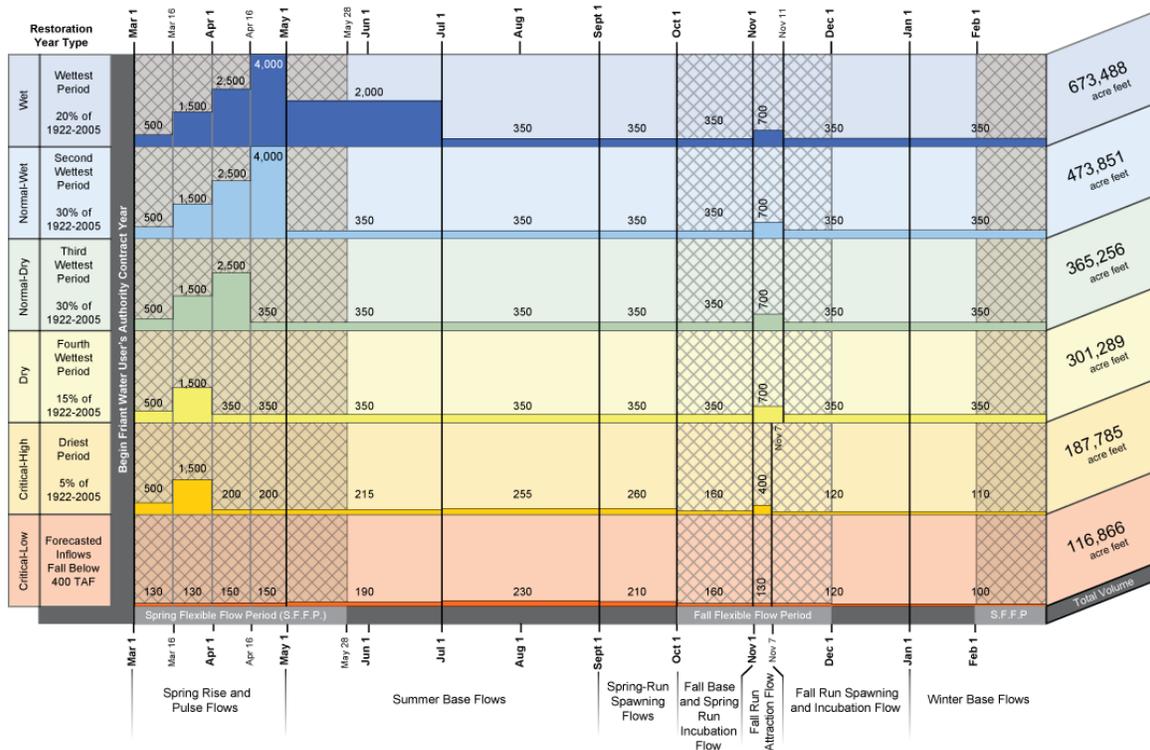


Figure 4-1.  
Restoration Flow Schedules, by Restoration Year-Type,  
Exhibit B Stair-Step Allocation Method

1 Based on the historical record of unimpaired flow for water years 1922 through 2004,  
2 Exhibit B includes a Restoration Year-Type classification system based on percentage of  
3 occurrence in this 83-year period. The wettest 20 percent of these years are classified as  
4 “Wet.” In order of descending wetness, the next 30 percent of the years are classified as  
5 “Normal-Wet,” the next 30 percent of the years are classified as “Normal-Dry,” and the  
6 next 15 percent of the years are classified as “Dry.” The remaining 5 percent of the years  
7 are classified as “Critical.” A subset of the Critical years, with less than 400,000 acre-feet  
8 of unimpaired runoff (i.e., water years 1924 and 1977), are classified as “Critical-Low”;  
9 the remaining critical years are classified as “Critical-High.”

10 The Settlement defines year-types based on their occurrence in an 83-year period, from  
11 1922 through 2004, without using a conventional threshold approach. While the  
12 associated year-type for each year within the 83-year period is clear, the extrapolation of  
13 such a Restoration Year-Type definition for years outside this period is not. Refinements  
14 of Restoration Year-Type classification for the SJRRP are discussed in two parts in the  
15 following section:

- 16 • Classification thresholds
- 17 • Beginning date for year-type application and corresponding Restoration Flows  
18 schedule

## 19 **4.2 Classification Thresholds**

20 The Settlement defines Restoration Year-Types using annual unimpaired inflow below  
21 Friant Dam for water years 1922 through 2004. Table 4-1 compares the Restoration Year-  
22 Type classification with the San Joaquin Valley Water Year-Types (SWRCB 2000),  
23 which are referenced in other management activities throughout the San Joaquin River  
24 basin. Table 4-2 shows the Restoration Year-Type classification of the referenced period,  
25 sorted by annual unimpaired inflow below Friant Dam.

26 As previously mentioned, the Restoration Year-Type classification was not based on a set  
27 of statistical thresholds, but instead on using the percentage of occurrences for annual  
28 inflows over the 83-year period of record; this is equivalent to the *n*-plotting position  
29 method without any hypothesis for the underlying statistical distribution. For Restoration  
30 Year-Type classification purposes, it is necessary to determine the point within the  
31 difference between these two volumes at which the Restoration Year-Type classification  
32 changes.

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**Table 4-1.**  
**Restoration Year-Type Classification**  
**Compared with San Joaquin Valley Water Year-Types**

Water Year	October-through-September San Joaquin River Unimpaired Flow at Friant Dam (TAF)	Restoration Year-Type*	San Joaquin Valley Water Year-Types*
1922	2,355.1	Normal-Wet	Wet
1923	1,654.3	Normal-Wet	Above Normal
1924	444.1	Critical High	Critical
1925	1,438.7	Normal-Dry	Below Normal
1926	1,161.4	Normal-Dry	Dry
1927	2,001.3	Normal-Wet	Above Normal
1928	1,153.7	Normal-Dry	Below Normal
1929	862.4	Dry	Critical
1930	859.1	Dry	Critical
1931	480.2	Critical High	Critical
1932	2,047.4	Normal-Wet	Above Normal
1933	1,111.4	Normal-Dry	Dry
1934	691.5	Dry	Critical
1935	1,923.2	Normal-Wet	Above Normal
1936	1,853.3	Normal-Wet	Above Normal
1937	2,208.0	Normal-Wet	Wet
1938	3,688.4	Wet	Wet
1939	920.8	Dry	Dry
1940	1,880.6	Normal-Wet	Above Normal
1941	2,652.5	Wet	Wet
1942	2,254.0	Normal-Wet	Wet
1943	2,053.7	Normal-Wet	Wet
1944	1,265.4	Normal-Dry	Below Normal
1945	2,138.1	Normal-Wet	Above Normal
1946	1,729.6	Normal-Wet	Above Normal
1947	1,125.5	Normal-Dry	Dry
1948	1,214.8	Normal-Dry	Below Normal
1949	1,164.1	Normal-Dry	Below Normal
1950	1,310.5	Normal-Dry	Below Normal
1951	1,859.0	Normal-Wet	Above Normal
1952	2,840.1	Wet	Wet
1953	1,226.7	Normal-Dry	Below Normal
1954	1,313.8	Normal-Dry	Below Normal
1955	1,161.0	Normal-Dry	Dry
1956	2,960.1	Wet	Wet
1957	1,326.6	Normal-Dry	Below Normal
1958	2,631.0	Wet	Wet
1959	949.3	Normal-Dry	Dry
1960	828.6	Dry	Critical
1961	646.9	Critical High	Critical
1962	1,923.6	Normal-Wet	Below Normal
1963	1,944.9	Normal-Wet	Above Normal
1964	922.2	Dry	Dry
1965	2,272.2	Normal-Wet	Wet
1966	1,298.6	Normal-Dry	Below Normal
1967	3,232.2	Wet	Wet
1968	862.1	Dry	Dry
1969	4,040.3	Wet	Wet
1970	1,445.6	Normal-Dry	Above Normal
1971	1,417.5	Normal-Dry	Below Normal
1972	1,039.0	Normal-Dry	Dry
1973	2,047.0	Normal-Wet	Above Normal
1974	2,190.5	Normal-Wet	Wet
1975	1,795.7	Normal-Wet	Wet
1976	629.2	Critical High	Critical
1977	361.6	Critical Low	Critical
1978	3,401.9	Wet	Wet
1979	1,830.3	Normal-Wet	Above Normal
1980	2,972.7	Wet	Wet
1981	1,068.0	Normal-Dry	Dry
1982	3,316.1	Wet	Wet
1983	4,641.9	Wet	Wet
1984	2,048.9	Normal-Wet	Above Normal
1985	1,129.0	Normal-Dry	Dry
1986	3,031.4	Wet	Wet
1987	757.6	Dry	Critical
1988	862.1	Dry	Critical
1989	939.2	Normal-Dry	Critical
1990	742.5	Dry	Critical
1991	1,034.1	Normal-Dry	Critical
1992	808.5	Dry	Critical
1993	2,672.9	Wet	Wet
1994	826.4	Dry	Critical
1995	3,877.7	Wet	Wet
1996	2,202.8	Normal-Wet	Wet
1997	2,781.5	Wet	Wet
1998	3,159.8	Wet	Wet
1999	1,527.1	Normal-Wet	Above Normal
2000	1,741.9	Normal-Wet	Above Normal
2001	1,065.1	Normal-Dry	Dry
2002	1,170.9	Normal-Dry	Dry
2003	1,449.9	Normal-Wet	Below Normal
2004	1,130.7	Normal-Dry	Dry

\*Based on D-1641

Key: TAF = thousand acre-feet

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San Joaquin River Settlements	San Joaquin Valley Water Year-Types				
	Wet	Above Normal	Below Normal	Dry	Critical
Wet	16				
Normal-Wet	8	15	2		
Normal-Dry		1	11	11	2
Dry				3	9
Critical High					4
Critical Low					1

**San Joaquin River Restoration Year-Types:**

The total annual unimpaired runoff at Friant Dam for the water year (October through September) is the index by which the water year-type is determined.

In order of descending wetness, the wettest 20 percent of the years are classified as Wet, the next 30 percent of the year are classified as Normal-Wet, the next 30 percent of the year are classified as Normal-Dry, the next 15 percent of the years are classified as Dry, and the remaining 5 percent of the year are classified as Critical. A subset of the Critical years, those with less than 400 TAF of unimpaired runoff, are identified as Critical Low.

**San Joaquin Valley Water Year-Types:**

The San Joaquin Valley Water Year-Type is determined through the use of an index. The index is based upon Stanislaus River inflows to New Melones Lake, Tuolumne River inflows to New Don Pedro Reservoir, Merced River inflows to Lake McClure, and San Joaquin River inflows to Millerton Lake, in million acre-feet (MAF).

San Joaquin Valley Water Year Index  
= 0.6 \* Current Apr-Jul Runoff Forecast (MAF)  
+ 0.2 \* Current Oct-Mar Runoff in (MAF)  
+ 0.2 \* Previous Water Year's Index (if the Previous Water Year's Index exceeds 4.5, then 4.5 is used).

Wet Equal to or greater than 3.8 MAF;  
Above-Normal Greater than 3.1, and less than 3.8;  
Below-Normal Greater than 2.5, and equal to or less than 3.1;  
Dry Greater than 2.1, and equal to or less than 2.5;  
Critical Equal to or less than 2.1

This index, originally specified in the 1995 SWRCB Water Quality Control Plan, is used to determine the San Joaquin Valley water year-type as implemented in SWRCB D-1641. Water year-types are set by first of month forecasts beginning in February. Final determination for San Joaquin River flow objectives is based on the May 1st 75% exceedence forecast.

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**Table 4-2.  
Restoration Year-Type Classification,  
Sorted by Annual Unimpaired Inflow Below Friant Dam**

Water Year	October-through-September San Joaquin River Unimpaired Flow at Friant Dam (TAF)	Restoration Year-Type
1983	4,641.9	Wet
1969	4,040.3	Wet
1995	3,877.7	Wet
1938	3,688.4	Wet
1978	3,401.9	Wet
1982	3,316.1	Wet
1967	3,232.2	Wet
1998	3,159.8	Wet
1986	3,031.4	Wet
1980	2,972.7	Wet
1956	2,960.1	Wet
1952	2,840.1	Wet
1997	2,781.5	Wet
1993	2,672.9	Wet
1941	2,652.5	Wet
1958	2,631.0	Wet
1922	2,355.1	Normal-Wet
1965	2,272.2	Normal-Wet
1942	2,254.0	Normal-Wet
1937	2,208.0	Normal-Wet
1996	2,202.8	Normal-Wet
1974	2,190.5	Normal-Wet
1945	2,138.1	Normal-Wet
1943	2,053.7	Normal-Wet
1984	2,048.9	Normal-Wet
1932	2,047.4	Normal-Wet
1973	2,047.0	Normal-Wet
1927	2,001.3	Normal-Wet
1963	1,944.9	Normal-Wet
1962	1,923.6	Normal-Wet
1935	1,923.2	Normal-Wet
1940	1,880.6	Normal-Wet
1951	1,859.0	Normal-Wet
1936	1,853.3	Normal-Wet
1979	1,830.3	Normal-Wet
1975	1,795.7	Normal-Wet
2000	1,741.9	Normal-Wet
1946	1,729.6	Normal-Wet
1923	1,654.3	Normal-Wet
1999	1,527.1	Normal-Wet
2003	1,449.9	Normal-Wet
1970	1,445.6	Normal-Dry
1925	1,438.7	Normal-Dry
1971	1,417.5	Normal-Dry
1957	1,326.6	Normal-Dry
1954	1,313.8	Normal-Dry
1950	1,310.5	Normal-Dry
1966	1,298.6	Normal-Dry
1944	1,265.4	Normal-Dry
1953	1,226.7	Normal-Dry
1948	1,214.8	Normal-Dry
2002	1,170.9	Normal-Dry
1949	1,164.1	Normal-Dry
1926	1,161.4	Normal-Dry
1955	1,161.0	Normal-Dry
1928	1,153.7	Normal-Dry
2004	1,130.7	Normal-Dry
1985	1,129.0	Normal-Dry
1947	1,125.5	Normal-Dry
1933	1,111.4	Normal-Dry
1981	1,068.0	Normal-Dry
2001	1,065.1	Normal-Dry
1972	1,039.0	Normal-Dry
1991	1,034.1	Normal-Dry
1959	949.3	Normal-Dry
1989	939.2	Normal-Dry
1964	922.2	Dry
1939	920.8	Dry
1929	862.4	Dry
1988	862.1	Dry
1968	862.1	Dry
1930	859.1	Dry
1960	828.6	Dry
1994	826.4	Dry
1992	808.5	Dry
1987	757.6	Dry
1990	742.5	Dry
1934	691.5	Dry
1961	646.9	Critical-High
1976	629.2	Critical-High
1931	480.2	Critical-High
1924	444.1	Critical-High
1977	361.6	Critical-Low

Key: TAF = thousand acre-feet

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1 For example, the Restoration Year-Type classification changes from a Normal-Wet year-  
2 type to a Wet year-type between the historical runoff volumes associated with 1922  
3 (2,355,000 acre-feet) and 1958 (2,631,000 acre-feet). Because hydrological conditions in  
4 the years after 2004 are not likely to be the same as those from 1922 through 2004, it is  
5 necessary to define a set of thresholds for Restoration Year-Type classification that is  
6 consistent with the classification in the Settlement.

7 To be consistent with Exhibit B, a threshold was defined using a practical point near the  
8 average of the unimpaired runoff amounts of 2 years that bracket the transition.  
9 Therefore, the following classification of Restoration Year-Types is recommended (based  
10 on annual October-through-September unimpaired flow below Friant Dam):

- 11 • Wet – equal to or greater than 2,500,000 acre-feet
- 12 • Normal-Wet – equal to or greater than 1,450,000 acre-feet
- 13 • Normal-Dry – equal to or greater than 930,000 acre-feet
- 14 • Dry – equal to or greater than 670,000 acre-feet
- 15 • Critical-High – equal to or greater than 400,000 acre-feet
- 16 • Critical-Low – less than 400,000 acre-feet

17 Based on the Settlement, the designation of year-type is for the period of October through  
18 September that is consistent with the water year definition. For water years 2005, 2006,  
19 and 2007, annual unimpaired flows of the San Joaquin River below Friant Dam are 2,830  
20 and 3,181, and 684 thousand acre-feet (TAF), respectively (DWR 1999-2007). Therefore,  
21 based on this set of thresholds for Restoration Year-Type classification, water years 2005,  
22 2006, and 2007 would be classified as Wet, Wet, and Dry years, respectively.

### 23 **4.3 Review of Hydrologic Forecasts**

24 The California Department of Water Resources (DWR) uses a composite approach to  
25 produce 10-, 50- and 90-percent forecasts. The 50-percent forecast is produced from  
26 snow survey data, using correlations between historical flows and snow survey data.  
27 However, the 90- and 10-percent forecasts are produced by imposing a range of likely  
28 inflows around the 50-percent forecast.

29 The envelope is defined with data from the previous 50 years, and reflects 10- and  
30 90-percent deviations from the 50-percent forecast that have occurred during the  
31 remaining portions of the year. The timing and volumes of the 90<sup>th</sup> and 10<sup>th</sup> percentile  
32 forecasts are distributed across the forecast period based on historical patterns and  
33 professional judgment. Thus, 50-percent forecasts are based directly on snow survey data  
34 (i.e., antecedent conditions), whereas the 10- and 90-percent exceedences are based on  
35 the distribution of the previous 50 years of inflow in relation to the 50-percent forecast,  
36 and professional judgment (Rizzardo 2007).

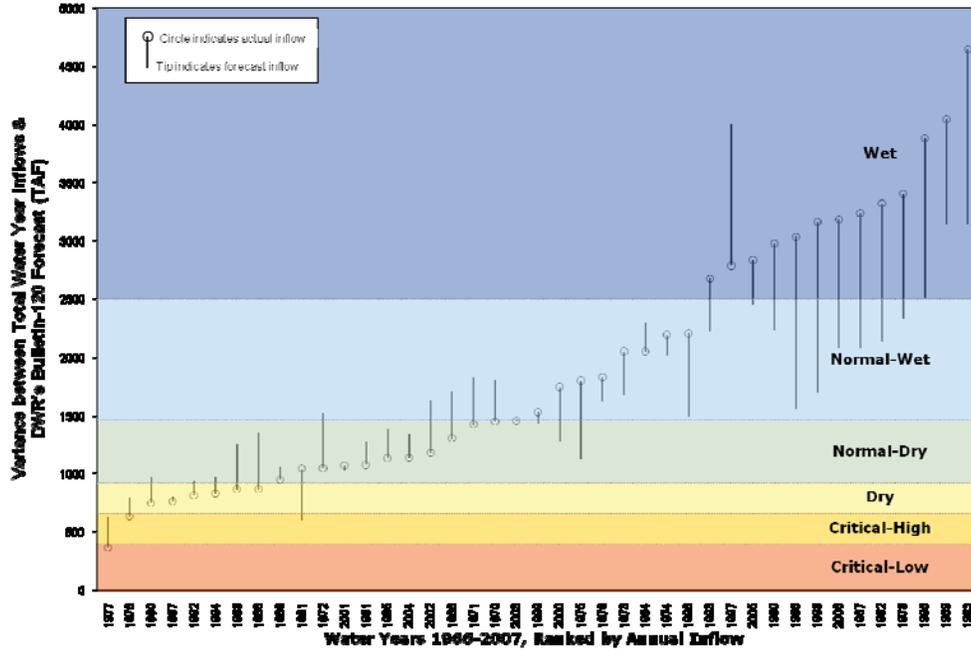
1 The details of DWR *Bulletin 120* forecast methodology are beyond the scope of this  
2 document. Though those details are relevant, the more important consideration herein is  
3 the adequate application of such forecast data.

4 Figures 4-2 through 4-5 compare the historical annual unimpaired flow of 1966 through  
5 2007, the common period for available 50-percent and 90-percent forecast data by DWR,  
6 with corresponding February, March, April, and May forecasts. Each page presents a  
7 comparison of a single month's 50-percent and 90-percent forecasts for the 1966 through  
8 2007 time frame. Years are ordered across the x-axis by ascending wetness. Actual total  
9 water year inflows are represented with an open dot. The annual forecast for the given  
10 month is located at the end of the whisker extending from the open dot. Colored bands  
11 across the background represent the classification thresholds for the six Restoration Year-  
12 Types. Implications for determining the Restoration Year-Type with a given forecast can  
13 be drawn by comparing the colored band behind the end of the whisker (forecast) with  
14 the colored band behind the dot (hindsight determination).

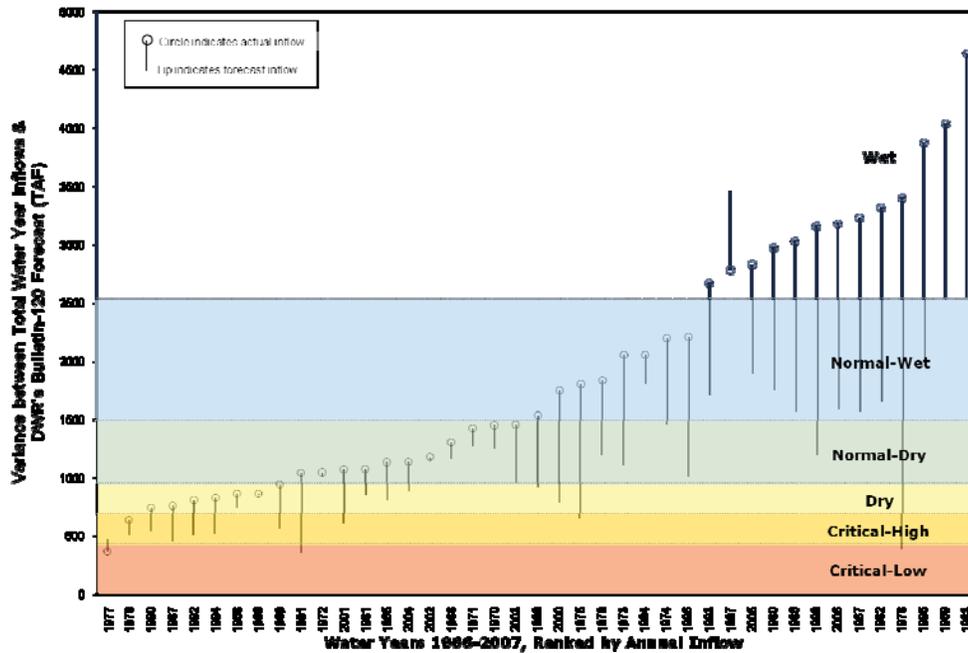
15 Several observations on forecast quality are summarized as follows:

- 16 • In general, forecast qualities are not ideal, with significant variations in error.
- 17 • The quality of the February forecast is low for both 50-percent and 90-percent  
18 exceedence forecasts; more forecast errors in quantity occur in wetter years.
- 19 • The quality of the forecast improves significantly for May; however, the forecast  
20 for wetter years has greater error.
- 21 • By definition, the 90-percent exceedence forecast would be more likely to  
22 underestimate the annual unimpaired flow than the 50-percent exceedence  
23 forecast; however, the actual quantity difference between these two forecasts  
24 gradually diminishes in later months.

4.0 Restoration Year-Types: Classification and Application



(a) 50-Percent Exceedence Forecast

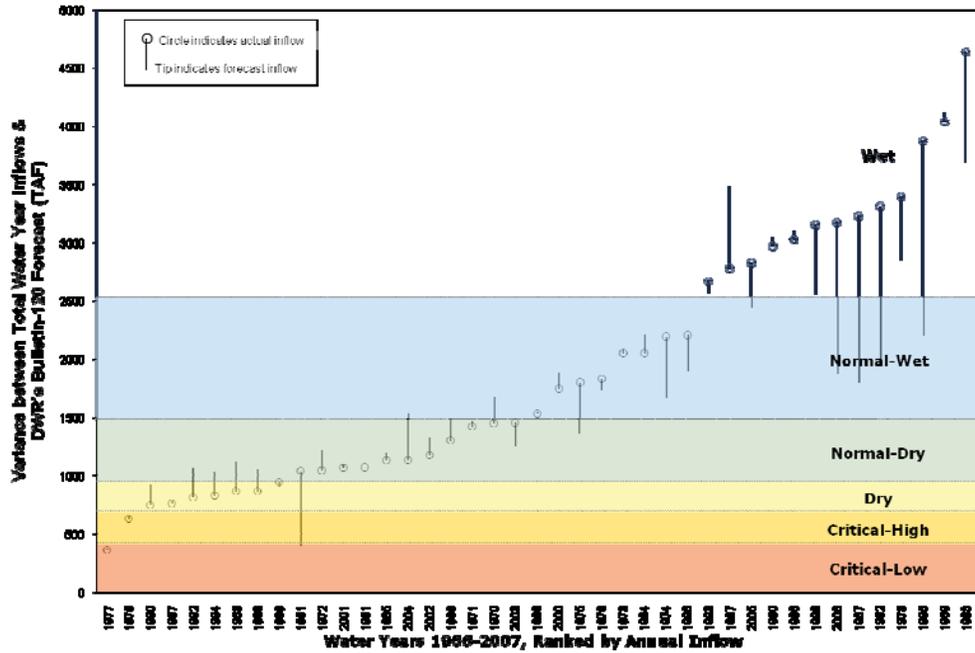


(b) 90-Percent Exceedence Forecast

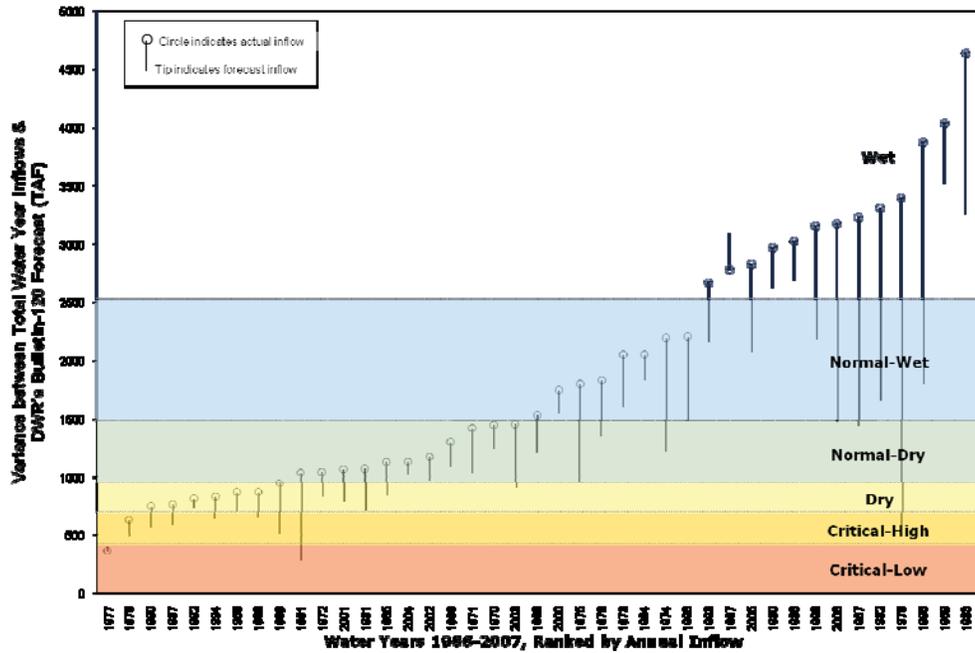
Figure 4-2.  
Comparison of Actual Annual Unimpaired Flow and February Forecast from DWR  
Bulletin 120, for Water Years 1966-2007

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(a) 50-Percent Exceedence Forecast



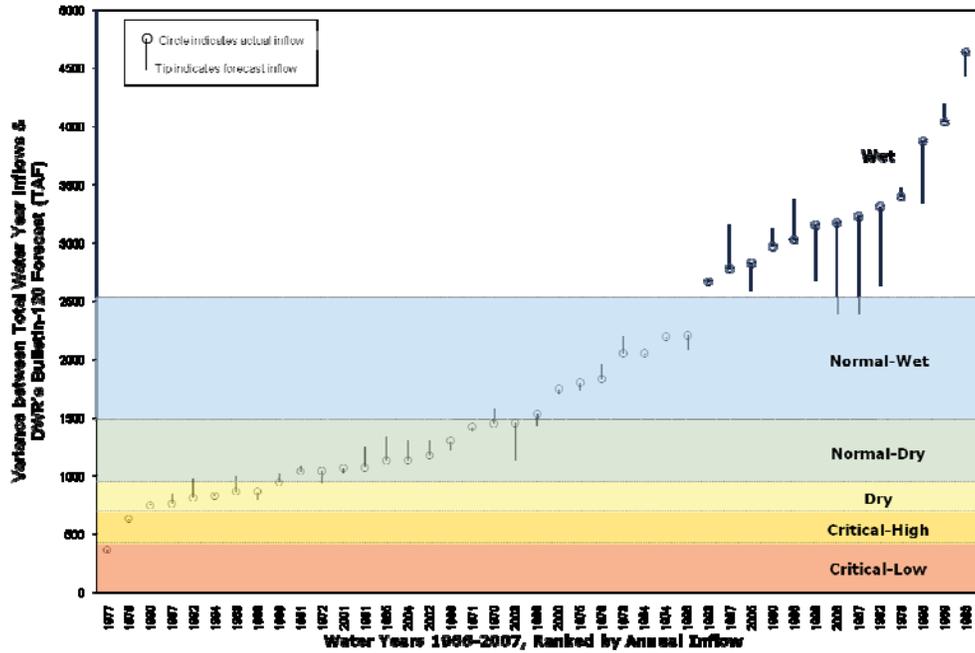
(a) 90-Percent Exceedence Forecast

Figure 4-3.  
Comparison of Actual Annual Unimpaired Flow and March Forecast from DWR  
Bulletin 120, for Water Years 1966-2007

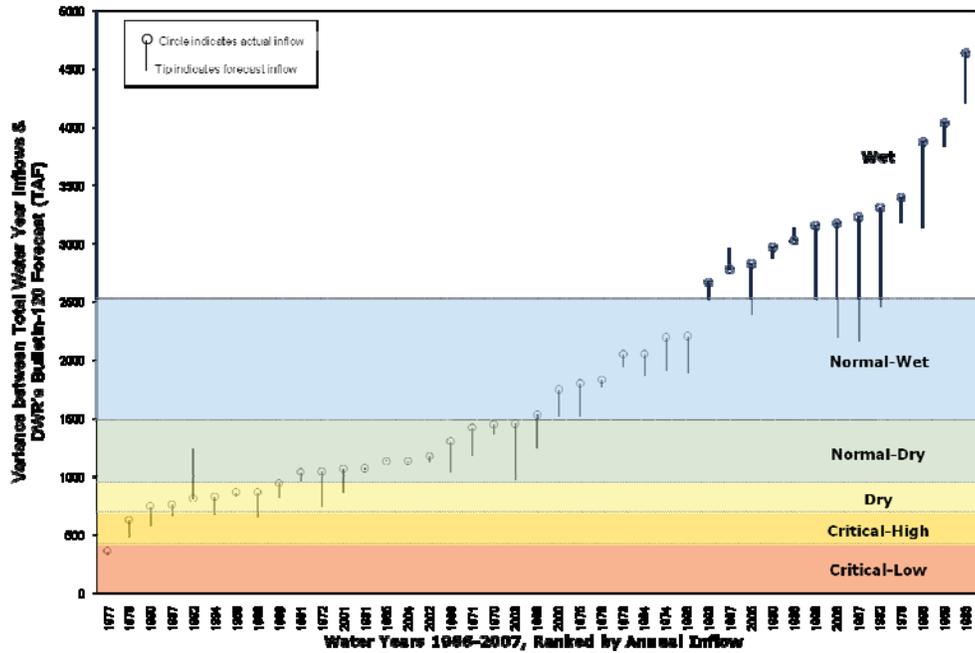
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4.0 Restoration Year-Types: Classification and Application



(a) 50-Percent Exceedence Forecast

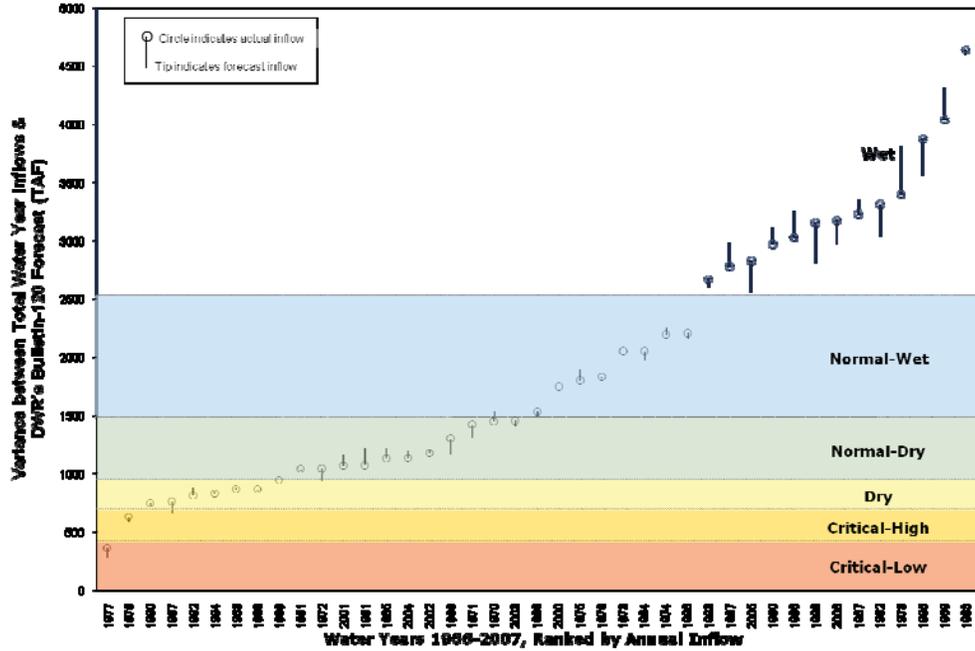


(b) 90-Percent Exceedence Forecast

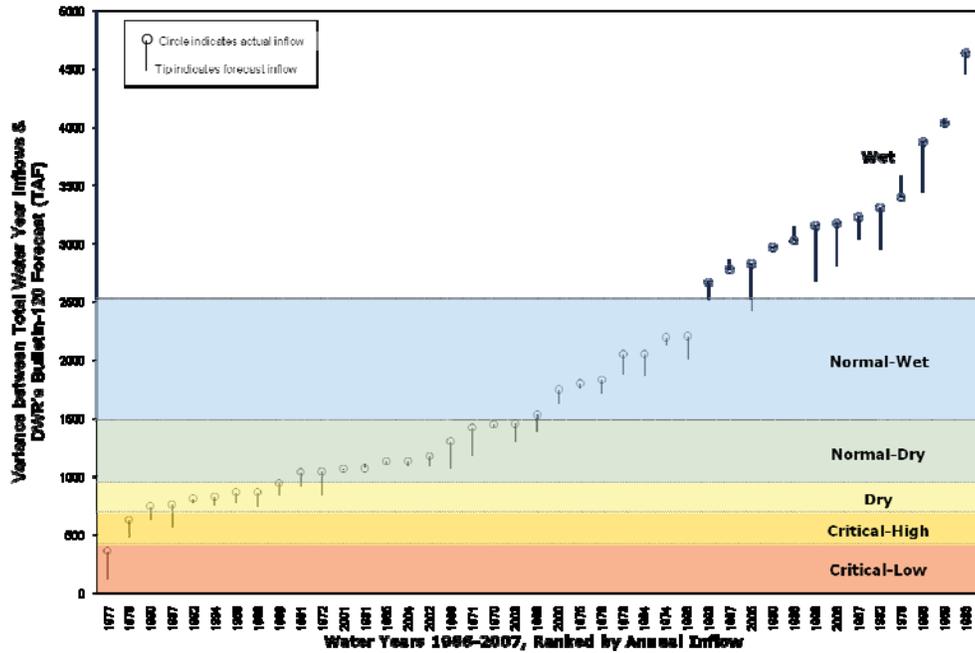
Figure 4-4.  
Comparison of Actual Annual Unimpaired Flow and April Forecast from DWR  
Bulletin 120, for Water Years 1966-2007

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(a) 50-Percent Exceedence Forecast



(b) 90-Percent Exceedence Forecast

Figure 4-5.  
Comparison of Actual Annual Unimpaired Flow and May Forecast from DWR  
Bulletin 120, for Water Years 1966-2007

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1 Table 4-3 shows another DWR *Bulletin 120* forecast summary for assessing associated  
 2 forecast quality. Because the unimpaired flow largely originates from snowmelt, the  
 3 period forecast (i.e., April through July) may be more reliable than forecasts for  
 4 individual months. However, 2006 is a good example of a forecast that cannot capture the  
 5 associated year-type until much later in spring because of storms that occurred late that  
 6 year. The volatility associated with a hydrologic forecast is a great challenge for real-time  
 7 operations, and a water year definition and associated operations hinge on the total annual  
 8 unimpaired flow amount, as required in the Settlement.

9 **Table 4-3.**  
 10 **Summary of DWR Bulletin 120 Forecasts for San Joaquin River Unimpaired Inflow**  
 11 **Below Friant Dam from 2001 Through 2006 (TAF)**

Year	Forecast Month	Forecast Period															
		Apr-Jul	% Error	Feb	% Error	Mar	% Error	Apr	% Error	May	% Error	Jun	% Error	Jul	% Error	Aug-Sept	% Error
2001	Feb	730	-8%	55	56%	105	-17%	130	1%	300	-33%	180	57%	60	28%	40	74%
	Mar	830	4%			110	-13%	200	6%	350	-21%	220	91%	60	28%	40	74%
	Apr	740	-7%					310	-30%	180	57%	60	28%	35	52%		
	May	970	9%					370	-17%	230	100%	80	70%	45	96%		
	Actual	795		42		126		188		445		115		47		23	
2002	Feb	1,190	41%	100	75%	140	49%	240	-3%	450	39%	380	70%	120	126%	45	114%
	Mar	960	13%			105	12%	230	-15%	300	10%	200	20%	100	65%	45	114%
	Apr	950	12%					210	-15%	380	18%	270	21%	90	70%	45	114%
	May	860	2%						355	10%	200	-10%	60	13%	35	57%	
	Actual	846		57		94		247		323		223		53		21	
2003	Feb	1,030	-3%	70	17%	130	19%	250	58%	400	-8%	290	-23%	90	1%	35	-24%
	Mar	880	-17%			110	1%	240	52%	340	-22%	240	-36%	60	-33%	25	-46%
	Apr	760	-20%					240	52%	290	-35%	100	-52%	50	-44%	25	-46%
	May	1,020	-4%						420	-4%	330	-12%	110	24%	35	-24%	
	Actual	1,058		60		109		158		436		375		89		46	
2004	Feb	1,060	43%	45	-35%	85	-56%	200	-10%	420	48%	310	79%	120	118%	45	125%
	Mar	1,170	59%			130	32%	240	8%	480	69%	350	102%	100	82%	50	150%
	Apr	880	20%					210	-6%	350	23%	240	39%	80	45%	50	150%
	May	780	6%						295	4%	200	16%	60	9%	40	100%	
	Actual	735		69		192		223		284		173		55		20	
2005	Feb	1,730	-17%	150	13%	180	-20%	325	26%	590	-26%	565	-15%	250	-27%	90	0%
	Mar	1,720	-17%			200	-12%	310	21%	610	-25%	565	-15%	205	-31%	90	0%
	Apr	1,840	-12%					370	44%	650	-21%	585	-12%	235	-31%	90	0%
	May	1,810	-13%						685	-16%	620	-6%	250	-27%	90	0%	
	Actual	2,080		133		226		257		818		662		343		90	
2006	Feb	1,460	-41%	95	-16%	140	-29%	270	-46%	525	-41%	470	-38%	195	-40%	60	-31%
	Mar	1,270	49%			115	42%	230	54%	460	48%	410	46%	170	48%	60	31%
	Apr	1,700	-31%					300	-40%	550	-38%	580	-24%	270	-17%	60	-31%
	May	2,180	-12%						680	-23%	660	-13%	345	6%	170	95%	
	Actual	2,471		113		198		498		884		763		326		87	

12 Source: DWR, Bulletin 120  
 13 Key: TAF = thousand acre-feet  
 14

## 15 4.4 Considerations for Restoration Flow Application

16 While the Restoration Year-Type classification is determined by inflows on the San  
 17 Joaquin River for a water year (October 1 through September 30), October 1 was  
 18 determined to be a poor beginning date for applying a corresponding hydrograph because  
 19 of the following hydrologic and ecological considerations, and existing contract  
 20 allocation practices.

### 21 4.4.1 Existing Allocation Practice for Friant Division Contractors

22 The Friant Division uses a contract year of March through February to be consistent with  
 23 practical allocation practices. Contractors receive initial allocations in mid-February,  
 24 after the first forecast of unimpaired inflow to Millerton Lake becomes available (i.e., in  
 25 February).

26 Existing contract allocation practices for the Friant Division allow the U.S. Department  
 27 of the Interior, Bureau of Reclamation (Reclamation) to exercise its discretion in using a  
 28 forecast within the range of 50 to 90 percent of exceedence (Reclamation 2005). Contract

1 allocations are based on the review of several forecasts, which combine estimates of  
2 snow accumulation, antecedent conditions, and a statistical range of precipitation  
3 predictions. Using discretion, Reclamation tends to establish initial allocations in  
4 February by using higher probability forecasts (i.e., an expectancy that forecasted runoff  
5 would have a 90-percent exceedence) early in the year, and when dry conditions have  
6 prevailed. In years with wet conditions, with surplus water or possible flood control  
7 releases, an initial forecast might favor a lower percent of exceedence because the  
8 negative consequences of overestimating runoff and allocations are potentially great.

9 Declarations of allocation to long-term contractors and temporary contractors are  
10 periodically revised as changing water supply conditions evolve; typically, revisions  
11 continue through June. As additional forecast information becomes available in  
12 subsequent months, water contract allocations are amended to reflect the increasing  
13 confidence in hydrologic forecasts. Allocations may also increase during this period if  
14 inflows are projected to be greater than previously forecasted.

15 The majority of snow in the Sierra typically melts by the end of June, causing the forecast  
16 of unimpaired runoff for the remainder of the year to become more certain. After June,  
17 inflow to Millerton Lake depends greatly on releases from upstream storage. At this  
18 point, allocations are set mostly by the projected operation of upstream projects and  
19 end-of-year carryover targets. Allocations are generally held constant from July through  
20 the following February (i.e., the end of the contract year).

#### 21 **4.4.2 Availability of Hydrologic Forecasts**

22 Forecasts of annual unimpaired flow below Friant Dam, while imperfect, will be a  
23 necessary tool for Restoration Year-Type designations. Making the current year's  
24 Restoration Flow schedule representative of the current year's runoff requires a forecast  
25 of a portion of the entire year's runoff. These forecasts combine estimates of snow  
26 accumulation, antecedent precipitation, and a statistical range of precipitation predictions.  
27 More than one forecast of runoff is made for the San Joaquin River basin, including  
28 forecasts from Southern California Edison Company, Reclamation, and DWR.

29 For establishing Restoration Year-Types, it is recommended that the California  
30 Cooperative Snow Survey forecast, prepared by DWR (provided periodically in *Bulletin*  
31 *120 – Water Conditions in California*) be used to forecast unimpaired flow of the San  
32 Joaquin River below Friant. Reclamation currently operates Friant Dam using *Bulletin*  
33 *120* forecast information. In addition, Reclamation and DWR rely on the *Bulletin 120*  
34 forecasts to make water allocations for the Central Valley Project (CVP) and State Water  
35 Project (SWP). Therefore, using *Bulletin 120* forecast information for the SJRRP would  
36 be consistent with statewide water management practices.

37 DWR publishes *Bulletin 120* four times a year, generally during the second week of  
38 February, March, April, and May. *Bulletin 120* contains forecasts of the volume of  
39 seasonal runoff from the State of California's (State) major watersheds (including  
40 unimpaired flow of the San Joaquin River below Friant Dam), with values for different  
41 forecast confidence intervals. The earliest available forecast information is in February.

42

1 Additional information contained in *Bulletin 120* includes summaries of precipitation,  
 2 snowpack, reservoir storage, and runoff in various regions of the State (see  
 3 <http://cdec.water.ca.gov/snow/bulletin120/>). Supplementing the published report are  
 4 periodic updates to the forecasts during the primary runoff season.

#### 5 **4.4.3 Considerations When Using Forecasts for Setting Restoration Flows**

6 Concern over hydrologic forecast uncertainties in Settlement implementation is due to the  
 7 resulting Restoration Year-Type classification, and potential undefined risks associated  
 8 with overestimated or underestimated Restoration Flow requirements. The actual impacts  
 9 of misclassification of year-type and associated flow requirements are significantly  
 10 reduced when hydrographs are transformed into a continuous format to alleviate abrupt  
 11 changes in flow requirements.

12 Within a restoration year, Restoration Flow releases would be accounted for and  
 13 compared with the total allocated volume. Because of a changing annual allocation of  
 14 flow due to revised forecasts (through June) of unimpaired runoff, diligent management  
 15 and planning of the release of Restoration Flows is necessary.

16 As with all forecasts, projection accuracy increases as the year progresses, with more of  
 17 the predictive element of the forecast being eliminated with the passage of time. As a  
 18 result, allocations to Restoration Flow schedules will need to consider the potential  
 19 inaccuracy of runoff forecasts to prevent overcommitting water supplies to restoration  
 20 and long-term contractors before their availability, or undercommitting water and thus  
 21 frustrating either goal in the Settlement.

22 In principle, when an allocation is revised as a result of a changed forecast, the total  
 23 volume of Restoration Flows for the entire Restoration Flow year (March through  
 24 February) would be reevaluated and the remaining portion of the Restoration Flow  
 25 schedules would be modified. When the revised forecast of unimpaired inflow below  
 26 Millerton Lake becomes available each month, a balance of flow to date would be  
 27 calculated as the difference between annual Restoration Flow allocations under the  
 28 previous current determinations. The balance would then add to or subtract from the  
 29 remaining year releases in a manner proportional to the Restoration Flow schedules.

30 Note that many options of this adjustment protocol are based on fishery management  
 31 preferences and risk management, the use of other provisions in the Settlement on Buffer  
 32 Flows and Flexible Flows described in Exhibit B, and the management structure that  
 33 would be established for SJRRP implementation. Therefore, further coordination and  
 34 development will be necessary when drafting the *Restoration Flow Guidelines*.

#### 35 **4.4.4 Consideration of Chinook Salmon**

36 Concern over how the application of Restoration Flows could impact Chinook stems  
 37 from a concern that the date selected as the “beginning-of-year” for accounting purposes  
 38 could interfere with flexibility for Restoration Flows or exacerbate situations where  
 39 Restoration allocations are retracted because of forecast uncertainty. Concerns for  
 40 Chinook were checked against the timing of life-stage needs for salmon within the  
 41 Restoration Area.

1 The SJRRP is addressing requirements for both spring-run and fall-run Chinook salmon;  
2 other fishery species may also be considered. The flow schedule has been developed with  
3 priority on the biological needs of Chinook salmon, and it is believed that other fish will  
4 also benefit. The discussion on Chinook salmon herein is a surrogate for biological  
5 considerations being used to determine the start date for Restoration Flow schedule  
6 application.

### 7 ***Spring-Run Life Cycle Timing***

8 In the Sacramento River watershed (the closest population of spring-run Chinook salmon  
9 to the San Joaquin River), adult spring-run Chinook salmon have historically returned to  
10 freshwater between late March and early July (DFG 1998). After they arrive in their natal  
11 streams in the spring, they hold in deep pools through the summer, conserving energy  
12 until the fall when their gonads ripen and they spawn, between August and October (DFG  
13 1998, McReynolds et al. 2005). In the Sacramento River, the egg incubation period for  
14 spring-run Chinook salmon extends from August to March (Fisher 1994, Ward and  
15 McReynolds 2001).

16 After hatching, fry may move downstream to the estuary and rear, or may take up  
17 residence in the stream for a period of time from weeks to a year (Healey 1991). The  
18 Butte Creek fry primarily disperse downstream from mid-December through February,  
19 whereas the subyearling smolts primarily migrate between late March and mid-June.  
20 Spring-run yearlings in Butte Creek migrate from September through March (Hill and  
21 Webber 1999, Ward and McReynolds 2001, Ward et al. 2002).

### 22 ***Fall-Run Life Cycle Timing***

23 Adult fall-run Chinook salmon in the San Joaquin River basin typically migrate into the  
24 upper rivers between late September and mid-November (S.P. Cramer and Associates  
25 2004, 2005; Cramer Fish Sciences 2006, 2007). Spawning in the San Joaquin River takes  
26 place between October and December (DFG 1991-2005), and the incubation period  
27 extends from late October through February. Fall-run juveniles will rear and migrate  
28 between January and June (Vick et al. 2000)

### 29 ***Restoration Flow Schedule Concerns Related to Chinook Timing***

30 In noncritical years, Restoration Flow schedules (Figure 4-1) have the same flow rates  
31 between August and February, with volumetrically minor differences in fall-run  
32 attraction flows in the first week of November. The scale of flow change during August  
33 through February across the various Restoration Year-Types is significantly less than that  
34 from March through July. In other words, Restoration Year-Type classification is a more  
35 meaningful consideration for Restoration Flow schedule implementation after March.

36 The period with the most important differences among the Restoration Flow schedules is  
37 during the months of March and April. Restoration Years classified as Wet are  
38 additionally unique in scheduling additional flow for the months of May and June.  
39 However, the Settlement (Exhibit B, Paragraph 4) allows flexibility in the release of  
40 Restoration Flows within some periods, specifically as follows:

1           ... releases allocated during the period from March 1 through May 1  
2           (“Spring Period”) in any year may be shifted up to four weeks earlier  
3           and later than what is depicted in the hydrograph for that year, and  
4           managed flexibly within that range (i.e. February 1 through May 28),  
5           so long as the total volume ... allocated for the Spring Period is not  
6           changed.

7           Accommodating this intended flexibility will require restoration management and  
8           accounting protocols to allow volumes initially scheduled for release in March to be  
9           released in February, regardless of whether the accounting period begins in February.  
10          Restoration Flow flexible operations may begin as early as February in response to  
11          Chinook salmon, or other requirements needed to accomplish the Restoration Goal.

#### 12          **4.4.5 March 1 as Start Date for Restoration Flow Scheduling**

13          March 1 was selected as the start date for Restoration Year-Type classification and, more  
14          importantly, the start date for the resulting annual Restoration Flow scheduling and  
15          accounting processes.

16          The start date of March 1 is not intended to reduce or preclude spring period flexibility  
17          specified in the Settlement, which allows the release of initial March flow schedule  
18          allocations in the preceding February. Accounting procedures for Restoration Flows will  
19          need to retain the flexibility to borrow water from a following year’s allocation for  
20          potential release in February, if it is determined necessary for meeting the Restoration  
21          Goal.

22          This decision was based on the above discussion, summarized below:

- 23           • From a practical viewpoint, the first determination of Restoration Year-Type and  
24           flow schedules could be in mid-February, when DWR *Bulletin 120* forecast  
25           information becomes available. Before the February forecast, information is  
26           insufficient for a determination.
  
- 27           • Based on review of historical forecasts, February forecasts are subject to a much  
28           greater margin of error than preceding months, causing year-type determinations  
29           to have a greater risk of misclassification. From a fisheries management  
30           viewpoint, it is preferable to maintain established winter flows through March to  
31           avoid a risk of dewatering redds. Reviewing the Restoration Flow schedules in  
32           Figure 4-1, March Restoration Flows of all year-types (except Critical-Low years)  
33           are higher than 350 cfs, the maximum of February Restoration Flows for all year-  
34           types. Therefore, the risk of dewatering the redds due to misclassification of year-  
35           type using early forecast information can be avoided completely by delaying the  
36           beginning point of the new year until March.

- 1       • While the flexibility of shifting Restoration Flow schedules to start as early as  
2       February 1 is given in the Settlement, because of the risk of redd dewatering, such  
3       flexibility would be better provided through real-time adjustments based on  
4       monitoring information. Provisions for tracking the release of a following year's  
5       Restoration Allocation in February will be provided in procedures for daily  
6       operations in the *Restoration Flow Guidelines*.

7       The Restoration Year-Type classification will be revised as subsequent *Bulletin 120*  
8       forecasts become available in April and May. In some years, an additional forecast in  
9       June is available (although not necessarily published officially in *Bulletin 120* format); in  
10      these years, additional revisions of Restoration Year-Type classification may be made.  
11      The Restoration Flow schedule for months before the March 1 date would follow the  
12      Restoration Year-Type designation of the prior year. This practice is commonly applied  
13      to river management in California watersheds.

#### 14      **4.4.6 Consideration of Flood Releases**

15      The Settlement allows using flood releases to meet Restoration Flow requirements.  
16      However, reductions to the annual allocation for restoration will be limited to the  
17      scheduled Restoration Flows. While obligations to release water in excess of Restoration  
18      Flow schedules may serve an ancillary benefit to the Restoration Goal, they will not  
19      necessarily be charged against the annual allocation for restoration. The volume of flows  
20      released from Friant Dam for the explicit purposes of meeting Restoration Flow  
21      obligations at the dam or one of the downstream flow targets will be charged against the  
22      restoration allocation. Flows released greater than those specified in the Restoration Flow  
23      schedule, including flows required to ramp down to the specified Restoration Flow  
24      schedule from higher release rates, will be made from Friant Dam at no additional charge  
25      against the annual allocation for Restoration Flows.

## 5.0 Development of a Continuous Annual Allocation Method

This section presents the need and process for revising the Exhibit B stair-step annual allocation method into a continuous (i.e., incremental) method to make a total annual allocation for restoration.

### 5.1 Need for a Continuous Allocation Method

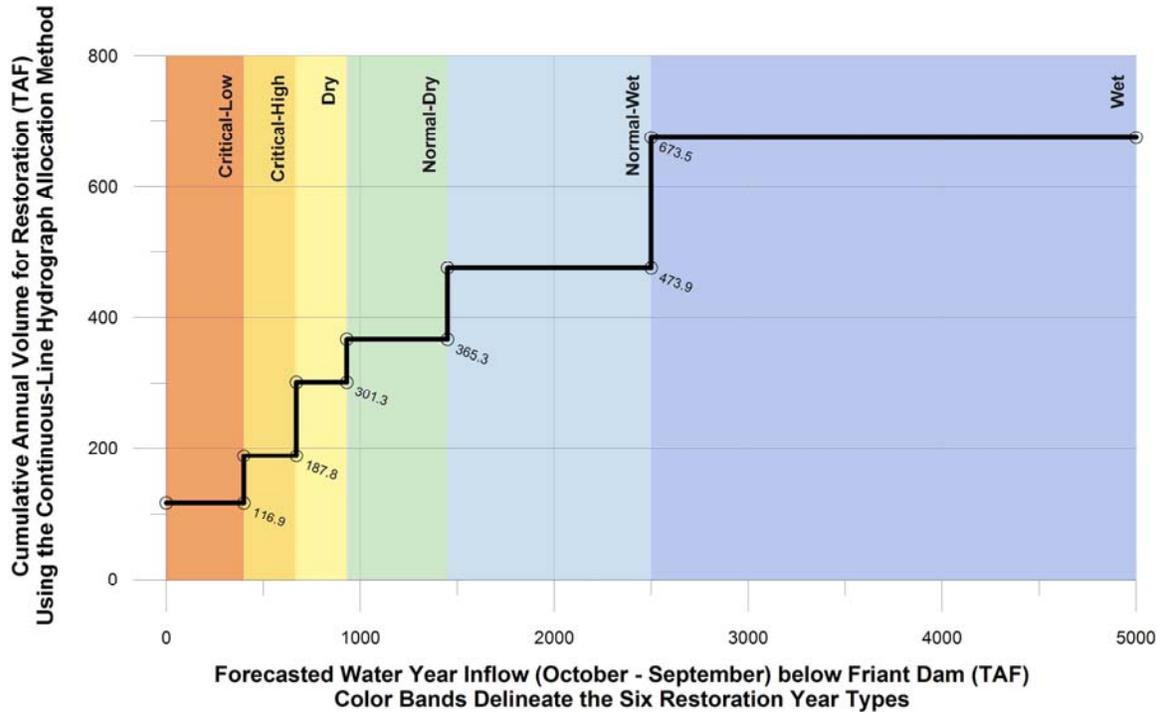
Exhibit B of the Settlement identifies a set of six Restoration Flow schedules. These schedules present a singular prescriptive distribution of volumes for each of the six Restoration Year-Types. These schedules vary in cumulative annual volume and distribution across the year in accordance with the San Joaquin River basin's established wetness. The method producing a single flow schedule for each Restoration Year-Type is referred to as "stair-step hydrographs" method in the Settlement: a change in the established wetness would 'step' the entire schedule (and thereby annual allocation) or down to one of the six provided schedules. The Settlement indicates that transforming the stair-step method into a continuously annual allocation method is desired:

*The Parties agree to transform the stair step hydrographs to more continuous hydrographs prior to December 31, 2008 to ensure completion before the initiation of Restoration Flows, provided that the Parties shall mutually-agree that transforming the hydrographs will not materially impact the Restoration or Water Management Goal.*

The Exhibit B stair-step annual allocation method is relatively easy to apply, and the ranges of wetness indices associated with a year-type provide some level of buffer against hydrologic uncertainties. However, challenges could regularly arise when a year's projected wetness is near a transition point between two Restoration Year-Type classifications, especially when hydrologic forecast uncertainties are considered. The resulting differences in annual allocations between the two borderline year-type classifications could be subject to disagreement; the disagreement could increase as availability and quality of hydrologic forecasts are also considered.

Figure 5-1 shows the classification system developed in Section 2, the associated annual flow volume, as defined in Exhibit B stair-step hydrographs, and corresponding historical records for the 1922 through 2004 period. The potential for disagreement on Restoration Year-Type classification and associated hydrograph volume is evident in borderline years using forecast hydrology. For example, for a year with approximately 1,400,000 acre-feet of unimpaired runoff, an additional 1 acre-foot of runoff would lead to the year-type being changed in the classification from Normal-Dry to Normal-Wet, and require more than 100,000 acre-feet of additional release for Restoration Flows. This could lead to challenges in real-time water and fishery management.

1 Developing a continuous allocation method reduces such potential challenges. The  
 2 continuous function responds to the need for a systematic methodology to distribute the  
 3 resulting restoration hydrograph allocation into a Restoration Flow schedule.



4  
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 6 **Figure 5-1.**  
 7 **Continuous Annual Allocation Method for Restoration Flows**  
**Following the Exhibit B Stair-Step Method**

8 **5.2 Continuous Methods Evaluation**

9 As described in Exhibit B, the six Restoration Flow schedules were developed for fishery  
 10 management and, in Wet years only, with an additional consideration of vegetation  
 11 recruitment. The annual cumulative volumes were estimated to have a certain impact on  
 12 CVP Friant Division long-term contractors' water supply. The Settlement text cited in the  
 13 previous section states that the Settling Parties mutually agree on a transformation  
 14 method. Implicitly, any modifications to the Exhibit B stair-step method should be  
 15 consistent with the understanding of Restoration Flow allocations and water supply  
 16 reductions agreed to in the Settlement.

17 Basic design requirements for a continuous allocation method were as follows:

- 18 • The method would be simple and easy to implement
- 19 • The method would preserve the intended functionality of Restoration Flows
- 20 • The method would not further reduce supplies to Friant Division long-term
- 21 contractors

1 Four general allocation methods were developed and assessed for implementing a  
 2 continuous allocation method. For discussion purposes, the Settlement’s stair-step  
 3 method (i.e., no transformation) was considered Method 1.

4 Method 2 was presented as the first draft and found to have two deficiencies:

- 5 • The ecological benefit of annual allocations less than 187 TAF (the volume  
 6 provided for Critical-High years in the stair-step method) is negligible, and the  
 7 starting point for interpolating annual allocations should be above the Critical-  
 8 High volumes specified in the Settlement.
- 9 • An ecological intention of the Settlement flow schedules was to mobilize gravel  
 10 for 50 percent of the year-types (Wet and Normal-Wet). Annual allocations of  
 11 385 TAF may not be sufficient for mobilizing gravel.

12 Methods 3 and 4 were developed in response to the critical year-type deficiencies in  
 13 Method 2. The conceptual difference between Methods 3 and 4 is the interpretation of  
 14 supply equity. “Supply equity,” as defined here, is the assurance that departures from the  
 15 stair-step allocation method (1) do not decrease the potential volume of water allocated to  
 16 Restoration releases and (2) do not increase the simulated long-term water supply  
 17 reductions to Friant Division long-term contractors. The Method 3 concepts for assuring  
 18 supply equity restricted the definition of equity to each year-type. The Method 4 concept  
 19 attempted to provide for supply equity *across* multiple year-types.

20 Method 3 concepts were determined to be preferable, and the Method 3 formulation was  
 21 further evaluated in an attempt to explore the range of water supply impacts that might be  
 22 experienced within the Method 3 concept. The enumerations on Method 3 were labeled  
 23 3.1, 3.2, and 3.3, and all three reflected adjustments for critical year-type and Normal-  
 24 Wet gravel mobilization concerns.

25 Ultimately, Method 3.3 was mutually agreed on by the Settling Parties for use in the  
 26 SJRRP.

## 27 **5.3 Annual Allocation Methods**

### 28 **5.3.1 Exhibit B Annual Allocation (Method 1)**

29 The Settlement contains a basic method for setting annual allocations with forecasts of  
 30 annual flow. This method (Figure 5-1) is referred to as the “stair-step hydrograph,” and  
 31 allocates a specific volume of water for each of the six Restoration Year-Types.

#### 32 **Advantages**

33 Advantages of Method 1 are as follows:

- 34 • Method 1 was specified in the Settlement and agreed to by the Settling Parties.
- 35 • Intended ecological functions were preserved as negotiated.

- 1 • Associated water supply impacts are known in the Settlement.
- 2 • A fixed volume for each year-type could simplify real-time operation planning.

3 **Disadvantages**

4 Disadvantages of Method 1 are as follows:

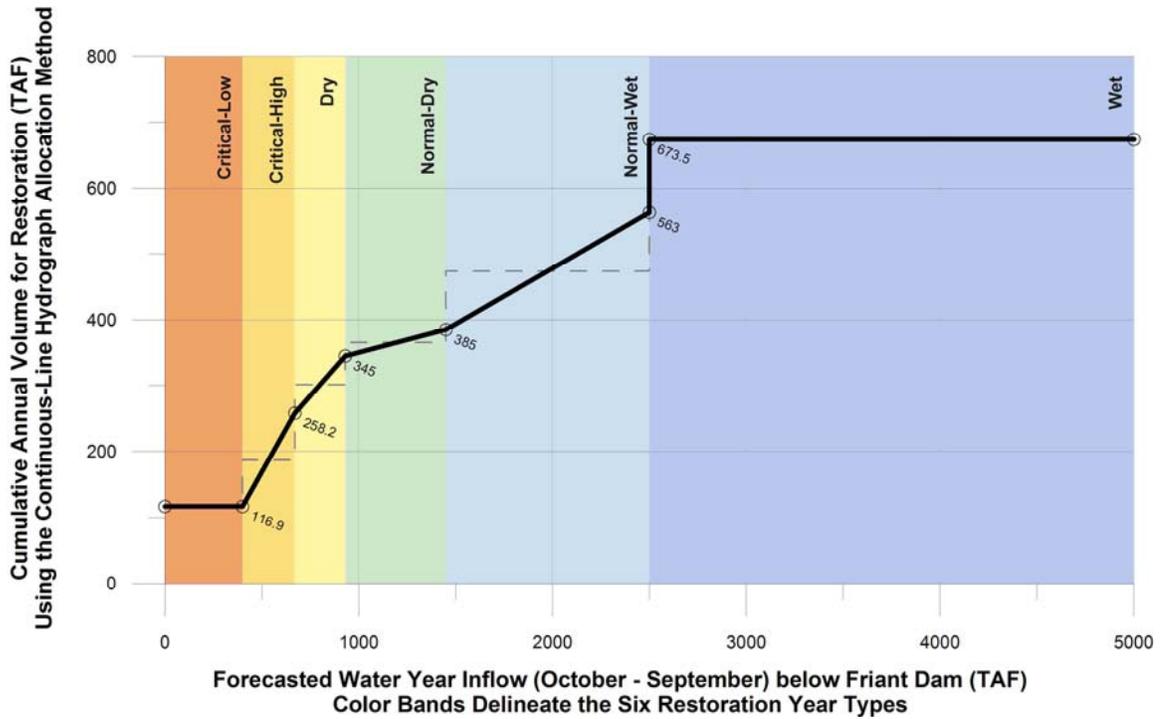
- 5 • Potential significant changes in volume allocation could occur because of
- 6 mid-year changes in hydrologic forecast and thus, year-type classification.
- 7 • Rigid volume allocation for each year-type could result in missed opportunities
- 8 for improving overall accomplishments in both the Restoration and Water
- 9 Management goals from hydrologic variation within a year-type.

10 **5.3.2 Annual Allocation Method 2**

11 The *Draft Operation Guidelines for Implementing Restoration Flow* Technical  
12 Memorandum (TM) (SJRRP 2008) presented the concepts and results for implementing  
13 Method 2. Following are details for development of Method 2:

- 14 • The Restoration Flow volume for Critical-Low years is the existing release from
- 15 Friant Dam for downstream riparian water right diversions, and can be used as the
- 16 starting point for developing the piece-wise linear function for annual volume.
- 17 • The Critical-Low year-type was classified to be any year when unimpaired San
- 18 Joaquin River flow below Friant Dam is less than 400 TAF (see Section 2). A
- 19 Critical-High year-type was classified to be any year when unimpaired San
- 20 Joaquin River flow below Friant Dam is between 400 TAF and 670 TAF, with a
- 21 midpoint unimpaired inflow of 535 TAF. Considering that the midpoint
- 22 unimpaired inflow of 535 TAF is the representative condition for Critical-High
- 23 years, it is assumed that the corresponding volume of Restoration Flows would be
- 24 the volume of 187 TAF, as prescribed by the stair-step hydrograph for the
- 25 Critical-High years.
- 26 • A line can be drawn through the following two points:
  - 27 – The point corresponding to the Critical-High midpoint unimpaired inflow
  - 28 (535 TAF) and Restoration Flow volume of 187 TAF
  - 29 – The boundary condition for Critical-Low years with unimpaired flow of 400
  - 30 TAF and Restoration Flow requirements of 117 TAF
- 31 • The linear function for determining Restoration Flow volume for Critical-High
- 32 year-types can be completed by extending a line from the dry end of the Critical-
- 33 High forecast/allocation (400 TAF/117 TAF), through the identified midpoint's
- 34 forecast/allocation (535 TAF/187 TAF) , to the high-end range of the Critical-
- 35 High years (670 TAF). The resulting Restoration Flow, for the high end of the
- 36 Critical-High year-type range, is 257 TAF.

- 1       • This mathematical procedure continues for the Dry, Normal-Dry, and Normal-  
2       Wet year-type ranges.
  
- 3       • For Wet years, no median reference point exists for the above linear process.  
4       Therefore, it is recommended that the original stair-step hydrograph volume of  
5       673 TAF be used whenever unimpaired inflow is estimated to equal or exceed  
6       2,500 TAF. This would result in an abrupt change in hydrograph volume, at a  
7       much reduced scale, when the annual unimpaired flow forecast suggests a change  
8       from a Normal-Wet to a Wet Restoration Year-Type. However, associated  
9       concerns over the abrupt change in Restoration Flow volume for water supply and  
10      fishery management are less in years of high runoff.
  
- 11      • Figure 5-2 illustrates the piece-wise linear function of Method 2. This function for  
12      annual Restoration Flow volume runs through the midpoint of each Restoration  
13      Year-Type's range of indexed flows, with the continuous flow requirement being  
14      less than the explicit Restoration Flow volume for the lower half of the range, and  
15      higher than the explicit Restoration Flow volume for the higher half of the range.
  
- 16      • Using the midpoint-driven volumes as connecting points between Restoration  
17      Year-Types closely approximates the average Restoration Flow volume and  
18      potential water supply impacts within each classification, thereby maintaining  
19      consistency with the Settlement. The transformation should alleviate concerns  
20      over abrupt changes in the volume requirement for Restoration Flows, and  
21      enhance the correspondence between volumes of Restoration Flows and annual  
22      unimpaired flow.



**Figure 5-2.**  
**Continuous Annual Allocation Method for Restoration Flows**  
**Following Method 2**

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**Advantages**

Advantages of Method 2 are as follows:

- The long-term and year-type average of allocation to Restoration Flow and of associated water supply impacts are preserved compared to those negotiated in the Settlement (Tables 5-1 and 5-2).
- There is a smooth transition in annual allocations for each increment of change in hydrologic forecast.

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**Disadvantages**

Disadvantages of Method 2 are as below:

- Ecological intentions envisioned for the flow schedules were not properly captured:
- The ecological benefit of annual allocations less than 187 TAF (the volume provided for Critical-High years in the stair-step method) is negligible, and the starting point for interpolating annual allocations should be above the Critical-High volumes specified in the Settlement.
- An ecological intention of the Settlement flow schedules was to mobilize gravel for 50 percent of the year-types (Wet and Normal-Wet). Annual allocations of 385 TAF may not be sufficient for mobilizing gravel.

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**Table 5-1.**  
**Simulated Average Restoration Flow Volumes by Restoration Year-Type for**  
**Contract Years 1922 Through 2003**

Restoration Year-Type (Mar – Feb)	Average Annual Release from Friant Dam (TAF)			
	Without Restoration (existing condition)	With Restoration Releases		
		Continuous Method 2	Stair-Step Hydrograph (Method 1)	Difference Between Methods
Wet	117	673	673	0
Normal-Wet	117	471	474	-3
Normal-Dry	117	365	365	0
Dry	117	311	301	10
Critical-High	117	195	187	8
Critical-Low	117	117	117	0
All Years	117	438	437	1

4 Key: TAF = thousand acre-feet

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**Table 5-2.**  
**Simulated Average Canal Delivery Volumes by Restoration Year-Type for**  
**Contract Years 1922 Through 2003**

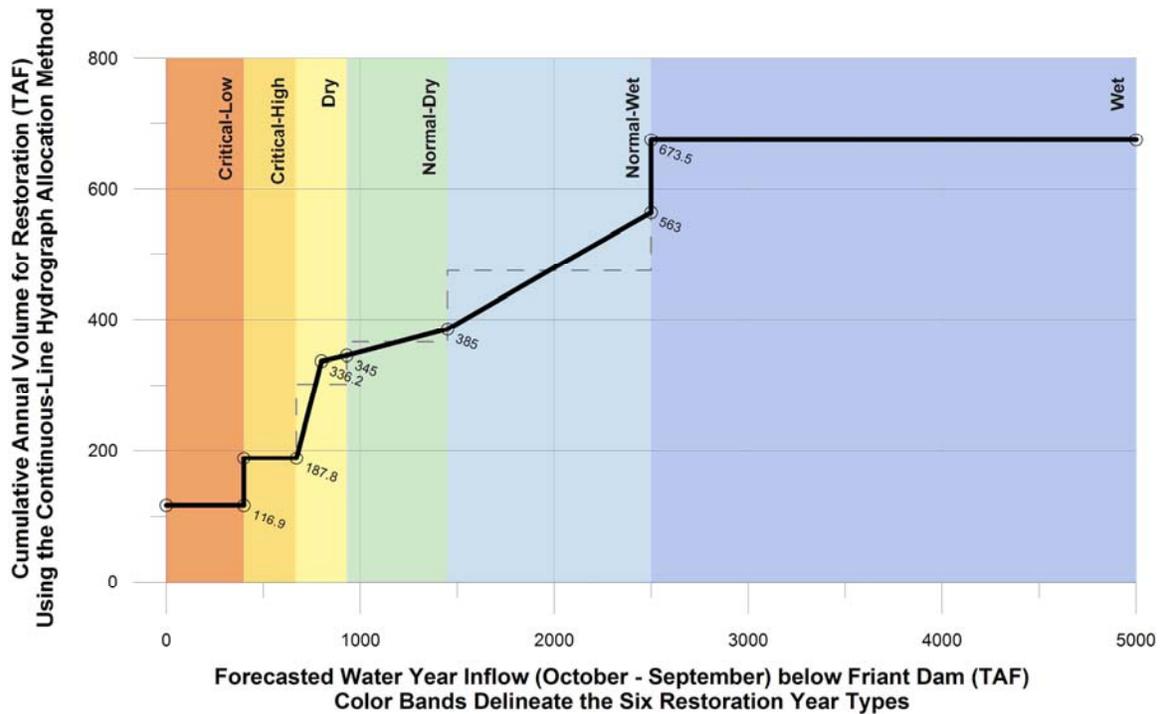
Restoration Year-Type (Mar – Feb)	Average Canal Delivery to Friant Division Long-Term Contractors (TAF)			
	Without Restoration (existing condition)	With Restoration Releases		
		Continuous Method 2	Stair-Step Hydrograph (Method 1)	Difference Between Methods
Wet	1,967	1,802	1,802	0
Normal-Wet	1,627	1,343	1,339	3
Normal-Dry	1,095	892	892	1
Dry	778	615	627	-13
Critical-High	525	401	389	12
Critical-Low	322	289	320	-31
All Years	1,344	1,135	1,136	0

8 Key: TAF = thousand acre-feet

1 **5.3.3 Annual Allocation Method 3**

2 Method 3 (Figure 5-3) mimics most of Method 2, but incorporates changes in the  
 3 Critical-High and Dry year-types in response to deficiencies with respect to the  
 4 Settlement’s Restoration Goal. Method 3 holds to the interpretation of supply equity  
 5 developed for Method 2, meaning that supply *within* each Restoration Year-Type closely  
 6 matches supply results agreed on in the Settlement (Method 1).

7 Method 3 assures equity within Restoration Year-Types and protects ecological  
 8 intentions during Critical-High year-types by maintaining a stair-step allocation for the  
 9 classification. This departs from Method 2, which reduced allocations below the  
 10 Settlement’s Critical-High allocation over the drier half of the range.



11 **Figure 5-3.**  
 12 **Continuous Annual Allocation Method for Restoration Flows**  
 13 **Following Method 3**  
 14

15 **Advantages**

16 Advantages of Method 3 are as follows:

- 17 • Ecological intentions for Critical-High years are preserved by creating a stair-step
- 18 • for both Critical-Low and Critical-High years, and by beginning the interpolation
- 19 • process at the forecast-boundary between Critical-High and Dry years.
- 20 • The long-term and year-type average of allocation to Restoration Flow is
- 21 • preserved compared to those negotiated in the Settlement, (Table 5-3).
- 22 • There is a smooth transition in annual allocations for each increment of change in
- 23 • hydrologic forecast, except between Critical-High and -Low allocations.

1 **Disadvantages**

2 Disadvantages of Method 3 are as follows:

- 3 • An ecological intention of the Settlement flow schedules was to mobilize gravel
- 4 for 50 percent of the year-types (Wet and Normal-Wet). Annual allocations of
- 5 385 TAF may not be sufficient for mobilizing gravel.
  
- 6 • The long-term average reduction in water supply for Dry years was determined to
- 7 be significant (Table 5-4).

8 **Table 5-3.**  
 9 **Simulated Average Restoration Flow Volumes by Restoration Year-Type for**  
 10 **Contract Years 1922 Through 2003**

Restoration Year-Type (Mar – Feb)	Average Annual Release from Friant Dam (TAF)			
	Without Restoration (existing condition)	With Restoration Releases		
		Continuous Method 3	Stair-Step Hydrograph (Method 1)	Difference Between Methods
Wet	117	673	673	0
Normal-Wet	117	471	474	-3
Normal-Dry	117	365	365	0
Dry	117	319	301	18
Critical-High	117	188	187	1
Critical-Low	117	117	117	0
All Years	117	439	437	2

11 Key: TAF = thousand acre-feet

12 **Table 5-4.**  
 13 **Simulated Average Canal Delivery Volumes by Restoration Year-Type for**  
 14 **Contract Years 1922 Through 2003**

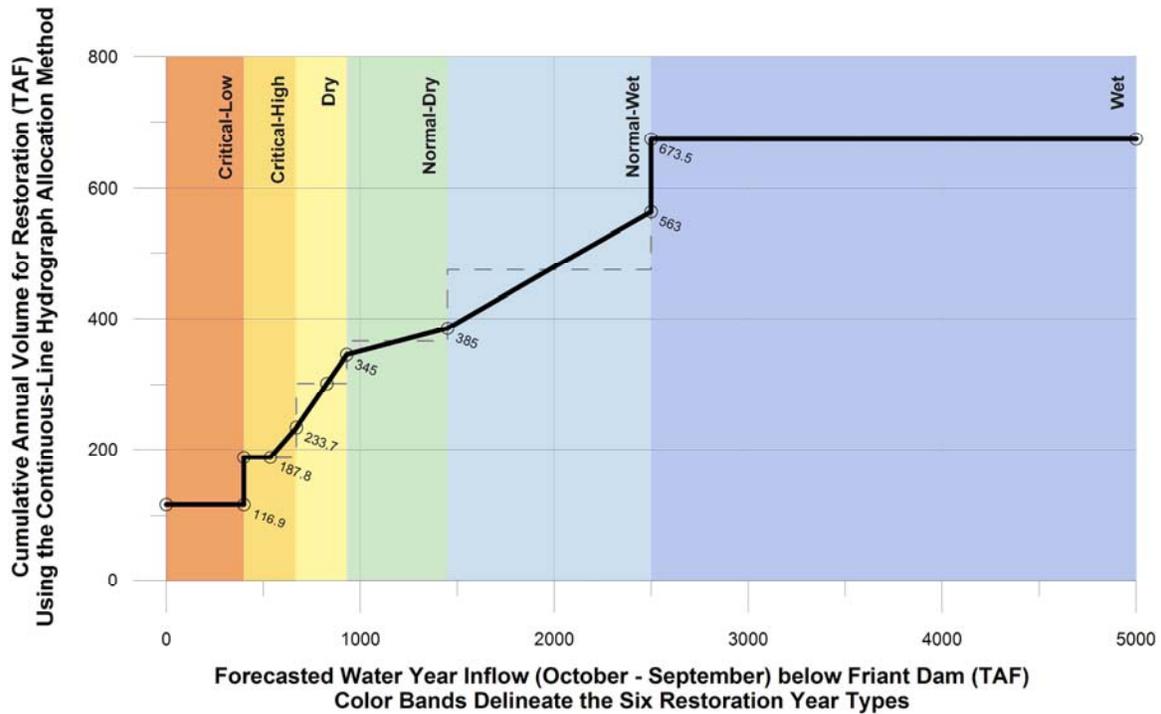
Restoration Year-Type (Mar – Feb)	Average Canal Delivery to Friant Division Long-Term Contractors (TAF)			
	Without Restoration (existing condition)	With Restoration Releases		
		Continuous Method 3	Stair-Step Hydrograph (Method 1)	Difference Between Methods
Wet	1,967	1,802	1,802	0
Normal-Wet	1,627	1,345	1,339	6
Normal-Dry	1,095	892	892	0
Dry	778	604	627	-23
Critical-High	525	393	389	4
Critical-Low	322	319	320	-1
All Years	1,344	1,134	1,136	-2

15 Key: TAF = thousand acre-feet

**5.3.4 Annual Allocation Method 4**

Method 4, presented below as Figure 5-4, adjusts for the concerns raised in consultation with the Settling Parties by preserving the “stair-step” approach through both Critical-Low and Critical-High periods. Method 4 departs from Method 3 by seeking to balance allocations to Restoration and water supply reductions *across* Restoration Year-Types.

The Method 4 interpolation begins midway between Critical-Low and Dry. This effectively increases both (1) Restoration allocation and (2) the water supply reductions for Critical-High year-types. To compensate for this, decreases are made to both (1) average allocation and (2) the water supply reductions for Dry year-types.



**Figure 5-4.**  
**Continuous Annual Allocation Method for Restoration Flows**  
**Following Method 4**

**Advantages**

Advantages of Method 4 are as follows:

- Ecological intentions for Critical-High years are preserved by creating a stair-step for both Critical-Low and Critical-High years, and by beginning the interpolation process at the forecast boundary between Critical-High and Dry years.

1 **Disadvantages**

2 Disadvantages of Method 4 are as follows:

- 3 • Equity for both Restoration and long-term water supplies becomes harder to
- 4 quantify and qualify. Different year-types have differing frequencies of
- 5 occurrence; therefore, resolving average volumes between them is not
- 6 mathematically meaningful. Also, the economic and intrinsic value for water
- 7 varies greatly from year-type to year-type, making it difficult to assure that the
- 8 tenets of the Settlement are being maintained (Tables 5-5 and 5-6).

9 **Table 5-5.**  
 10 **Simulated Average Restoration Flow Volumes by Restoration Year-Type for**  
 11 **Contract Years 1922 Through 2003**

Restoration Year-Type (Mar – Feb)	Average Annual Release from Friant Dam (TAF)			
	Without Restoration (existing condition)	With Restoration Releases		
		Continuous Method 4	Stair-Step Hydrograph (Method 1)	Difference Between Methods
Wet	117	673	673	0
Normal-Wet	117	471	474	-3
Normal-Dry	117	365	365	0
Dry	117	302	301	-1
Critical-High	117	205	187	18
Critical-Low	117	117	117	0
All Years	117	437	437	0

12 Key: TAF = thousand acre-feet

13 **Table 5-6.**  
 14 **Simulated Average Canal Delivery Volumes by Restoration Year-Type for**  
 15 **Contract Years 1922 Through 2003**

Restoration Year-Type (Mar – Feb)	Average Canal Delivery to Friant Division Long-Term Contractors (TAF)			
	Without Restoration (existing condition)	With Restoration Releases		
		Continuous Method 4	Stair-Step Hydrograph (Method 1)	Difference Between Methods
Wet	1,967	1,802	1,802	0
Normal-Wet	1,627	1,343	1,339	4
Normal-Dry	1,095	892	892	0
Dry	778	624	627	-3
Critical-High	525	388	389	-1
Critical-Low	322	297	320	-3
All Years	1,344	1,136	1,136	0

16 Key: TAF = thousand acre-feet

1 **5.4 Process of Refining Method 3**

2 The Settling Parties agreed on the principles of Method 3, but suggested further  
3 refinements to assure gravel mobilization in Normal-Wet year-types, and to explore  
4 further reductions to Dry year-type supply impacts. This section reports refinements to  
5 Method 3.

6 **5.4.1 Adjustment for Normal-Wet Year Gravel Mobilization**

7 The first concern was addressed in the subsequent methods by retaining the first two  
8 “stair-steps” through the Critical-Low and Critical-High periods. The second comment  
9 was addressed with a preliminary SJRRP Fisheries Management Work Group assessment  
10 of instream flow ramping requirements. A determination was made that an annual  
11 allocation of 400,300 acre-feet would provide sufficient volumes for providing a short  
12 duration 8,000 cfs pulse in the second half of April.

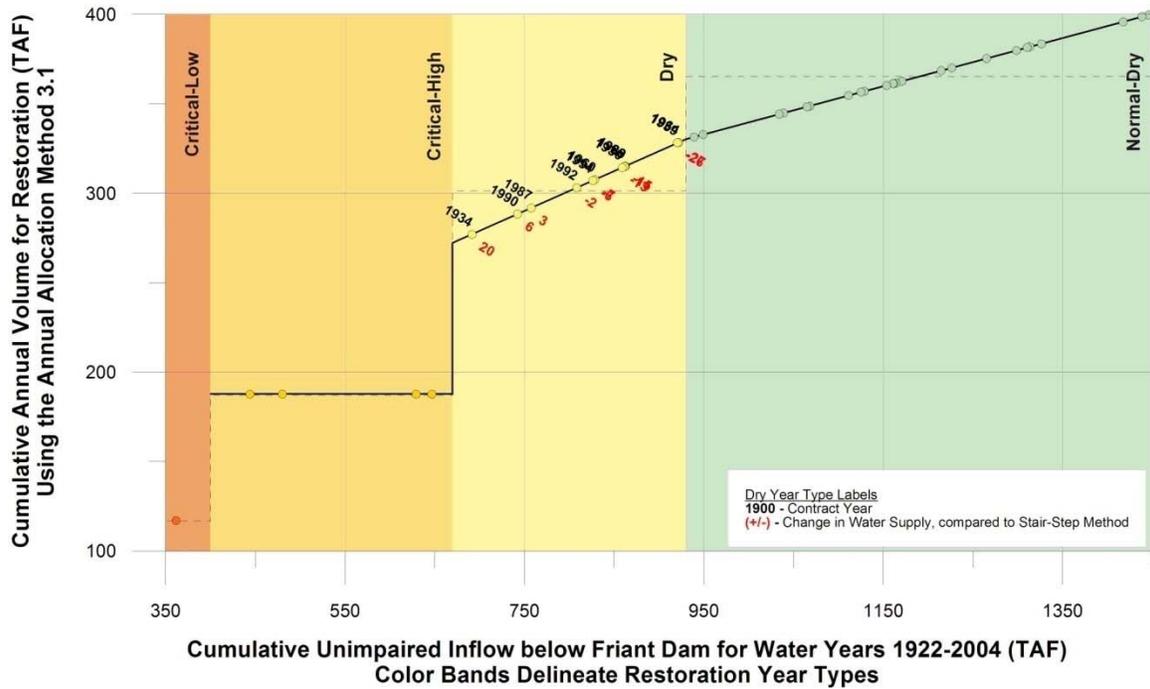
13 **5.4.2 Range of Dry Year-Type Allocation Methods**

14 Three iterations were prepared for the Method 3 continuous annual allocation method,  
15 referred to as Methods 3.1, 3.2, and 3.3. These three methods differ from Method 3 in  
16 that they make an adjustment for gravel mobilization on the boundary between Normal-  
17 Dry and Normal-Wet. This changes (i.e., decreases) the inflection point location for the  
18 boundary between Dry and Normal-Dry from 345,000 to 330,000 acre-feet. This change  
19 reduces the effect of the continuous allocation on water supplies for all methods by  
20 reducing the demand for Restoration Flows on the Wet end of Dry year-types.

21 The following subsections describe the three methods explored. Each of the these  
22 methods made adjustments for the deficiencies identified in Method 2, and held to the  
23 Method 3 supply equity concepts, in contrast to Method 4, which proposed rebalancing  
24 impacts for both Settling Parties between multiple Restoration Year-Types. The  
25 principles demonstrated in Method 4 were not carried forward.

26 ***Method 3.1 – Stair-Step Approach***

27 Method 3.1 (Figure 5-5) was developed to present one of the extreme “boundary”  
28 conditions for implementing Method 3, wherein the “dogleg” inflection point is placed on  
29 the boundary between Critical-High and Dry.



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**Figure 5-5.**  
**Detail of Dry-Year Continuous Annual Allocation Method for Restoration Flows Following Method 3.1**

5 **Advantages**

6 Advantages of Method 3.1 are as follows:

- 7
- Restoration Allocations are consistent with those in the Settlement (Table 5-7).
  - Dry year-type impacts to water users are the least for this method (Table 5-8).
- 8

9 **Disadvantages**

10 Disadvantages of Method 3.1 are as follows:

- 11
- This method maintains a steep stair-step on the boundary of Critical-High and Dry year-types, which could lead to potential conflicts that the continuous approach was intended to reduce or avoid.
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**Table 5-7.**  
**Simulated Average Restoration Flow Volumes by Restoration Year-Type for**  
**Contract Years 1922 Through 2003**

Restoration Year-Type (Mar – Feb)	Average Annual Release from Friant Dam (TAF)			
	Without Restoration (existing condition)	With Restoration Releases		
		Continuous Method 3.1	Stair-Step Hydrograph (Method 1)	Difference Between Methods
Wet	117	673	673	0
Normal-Wet	117	471	474	-3
Normal-Dry	117	365	365	0
Dry	117	308	301	7
Critical-High	117	188	188	0
Critical-Low	117	117	117	0
All Years	117	437	437	0

4 Key: TAF = thousand acre-feet

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**Table 5-8.**  
**Simulated Average Canal Delivery Volumes by Restoration Year-Type for**  
**Contract Years 1922 Through 2003**

Restoration Year-Type (Mar – Feb)	Average Canal Delivery to Friant Division Long-Term Contractors (TAF)			
	Without Restoration (existing condition)	With Restoration Releases		
		Continuous Method 3.1	Stair-Step Hydrograph (Method 1)	Difference Between Methods
Wet	1,967	1,802	1,802	0
Normal-Wet	1,627	1,343	1,340	3
Normal-Dry	1,095	892	892	0
Dry	778	620	627	-7
Critical-High	525	393	389	4
Critical-Low	322	319	319	0
All Years	1,344	1,136	1,136	0

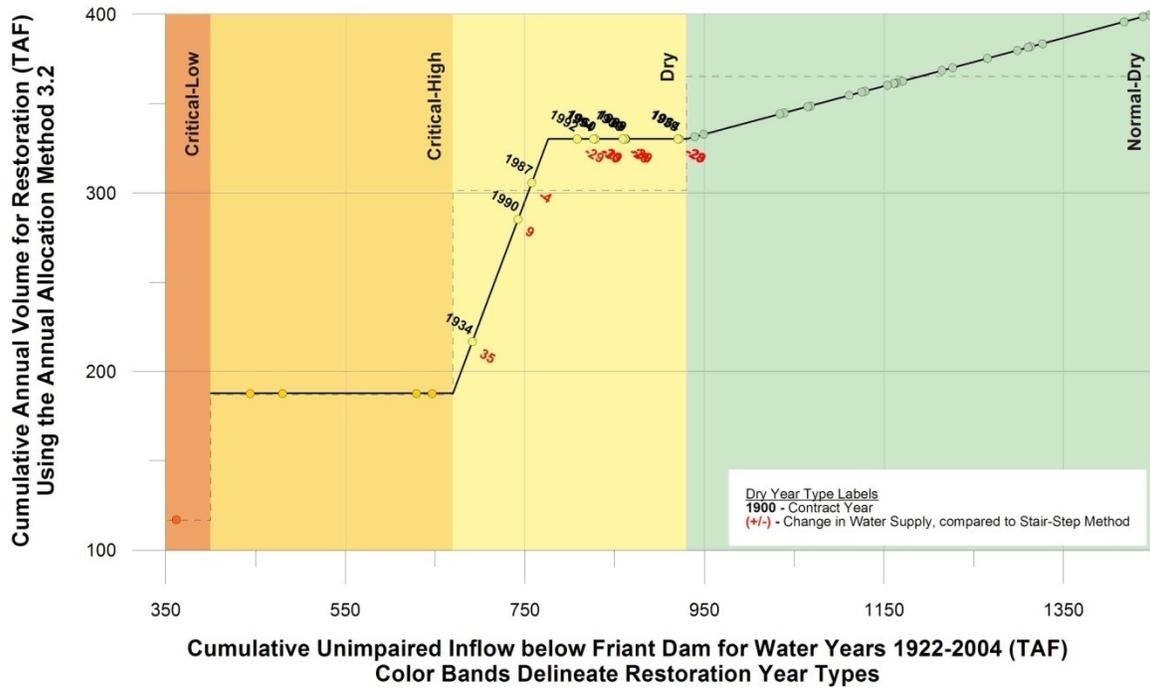
8 Key: TAF = thousand acre-feet

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1 **Method 3.2 – Plateau Approach**

2 Method 3.2 (Figure 5-6) was developed to present the second extreme “boundary”  
 3 condition for implementing Method 3. Placing the dogleg point on the boundary between  
 4 Dry and Normal-Dry was not possible without reducing the average allocation to Dry  
 5 years for restoration, thereby violating supply equity for the Restoration Goal. Therefore,  
 6 the “dogleg” inflection point is set equal to the allocation on the boundary between Dry  
 7 and Normal-Dry (330 TAF), creating an allocation “plateau.”

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**Figure 5-6.**  
**Detail of Dry-Year Continuous Annual Allocation Method for Restoration**  
**Flows Following Method 3.2**

13 **Advantages**

14 Advantages of Method 3.2 are as follows:

- 15 • Restoration Allocations are consistent with those in the Settlement (Table 5-9).
- 16 • This method eliminates a stair-step on the boundary of Critical-High and Dry
- 17 year-types, and represents the most that could be done to reduce boundary
- 18 forecasting issues without rebalancing year-type supplies (as provided for in
- 19 Method 4).

20 **Disadvantages**

21 Disadvantages to Method 3.2 are as follows:

- 22 • Dry year-type impacts to water users are the highest for this method (Table 5-10).

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**Table 5-9.**  
**Simulated Average Restoration Flow Volumes by Restoration Year-Type for**  
**Contract Years 1922 Through 2003**

Restoration Year-Type (Mar – Feb)	Average Annual Release from Friant Dam (TAF)			
	Without Restoration (existing condition)	With Restoration Releases		
		Continuous Method 3.2	Stair-Step Hydrograph (Method 1)	Difference Between Methods
Wet	117	673	673	0
Normal-Wet	117	471	474	-3
Normal-Dry	117	365	365	0
Dry	117	315	301	14
Critical-High	117	188	187	1
Critical-Low	117	117	117	0
All Years	117	439	437	2

4 Key: TAF = thousand acre-feet

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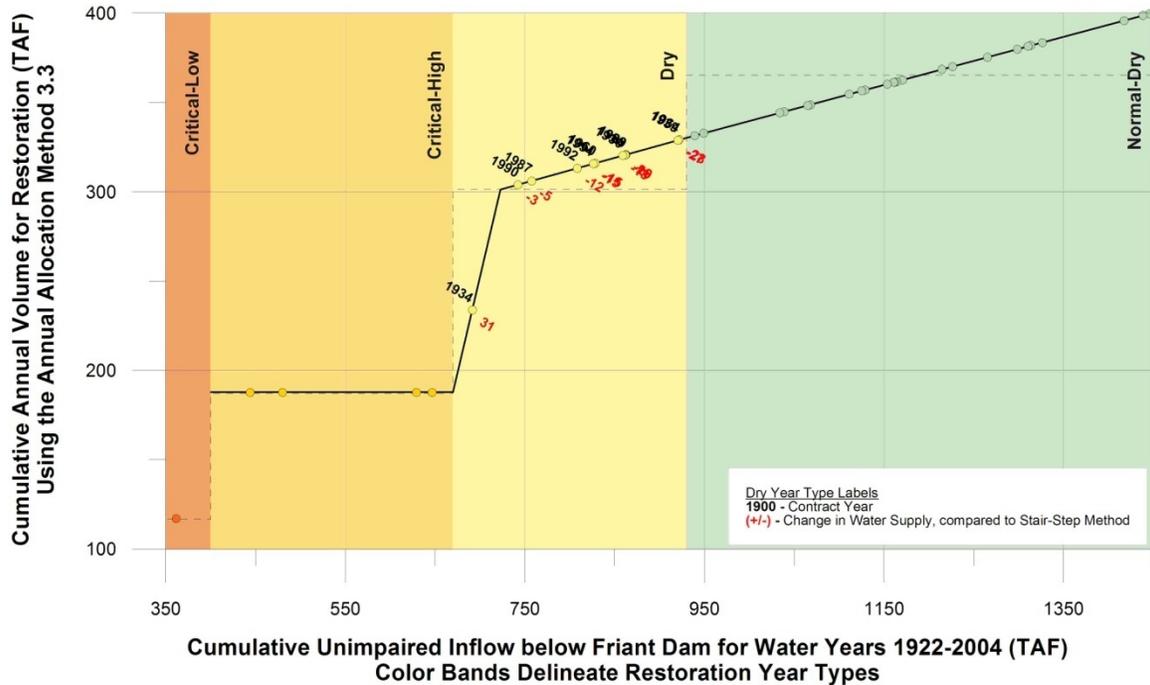
**Table 5-10.**  
**Simulated Average Canal Delivery Volumes by Restoration Year-Type for**  
**Contract Years 1922 Through 2003**

Restoration Year-Type (Mar – Feb)	Average Canal Delivery to Friant Division Long-Term Contractors (TAF)			
	Without Restoration (existing condition)	With Restoration Releases		
		Continuous Method 3.2	Stair-Step Hydrograph (Method 1)	Difference Between Methods
Wet	1,967	1,802	1,802	0
Normal-Wet	1,627	1,344	1,339	5
Normal-Dry	1,095	892	892	0
Dry	778	609	627	-18
Critical-High	525	393	389	4
Critical-Low	322	319	320	-1
All Years	1,344	1,135	1,136	-1

8 Key: TAF = thousand acre-feet

9  
10

1 **Method 3.3 – Compromise Between Stair-Step and Plateau Approaches**  
 2 Method 3.3 (Figure 5-7) was developed to present a compromise condition for  
 3 implementing Method 3, wherein the “dogleg” inflection point is set on the stair-step,  
 4 thus splitting the difference between the two previous methods.



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10 **Advantages**

11 Advantages of Method 3.3 are as follows:

- 12
- 13 • Restoration Allocations are consistent with those in the Settlement (Table 5-11).
  - 14 • Dry year-type impacts for this method are relatively low (in the single digits) (Table 5-12).
  - 15 • This method reduces the stair-step, and could help alleviate forecast-related
  - 16 conflicts.

17 **Disadvantages**

18 Disadvantages to Method 3.3 are as follows:

- 19
- 20 • The historical tendency for year-types classified as Dry occur toward the wetter end, which is also closer to the mean of any assumed bell-curve distribution.
  - 21 • Under this method, every Dry year on record (but one) would carry a larger
  - 22 supply reduction than was agreed to in the Settlement.

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**Table 5-11.**  
**Simulated Average Restoration Flow Volumes by Restoration Year-Type for**  
**Contract Years 1922 Through 2003**

Restoration Year-Type (Mar – Feb)	Average Annual Release from Friant Dam (TAF)			
	Without Restoration (existing condition)	With Restoration Releases		
		Continuous Method 3.3	Stair-Step Hydrograph (Method 1)	Difference Between Methods
Wet	117	673	673	0
Normal-Wet	117	471	474	-3
Normal-Dry	117	365	365	0
Dry	117	309	301	8
Critical-High	117	188	187	1
Critical-Low	117	117	117	0
All Years	117	438	437	1

4 Key: TAF = thousand acre-feet

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**Table 5-12.**  
**Simulated Average Canal Delivery Volumes by Restoration Year-Type for**  
**Contract Years 1922 Through 2003**

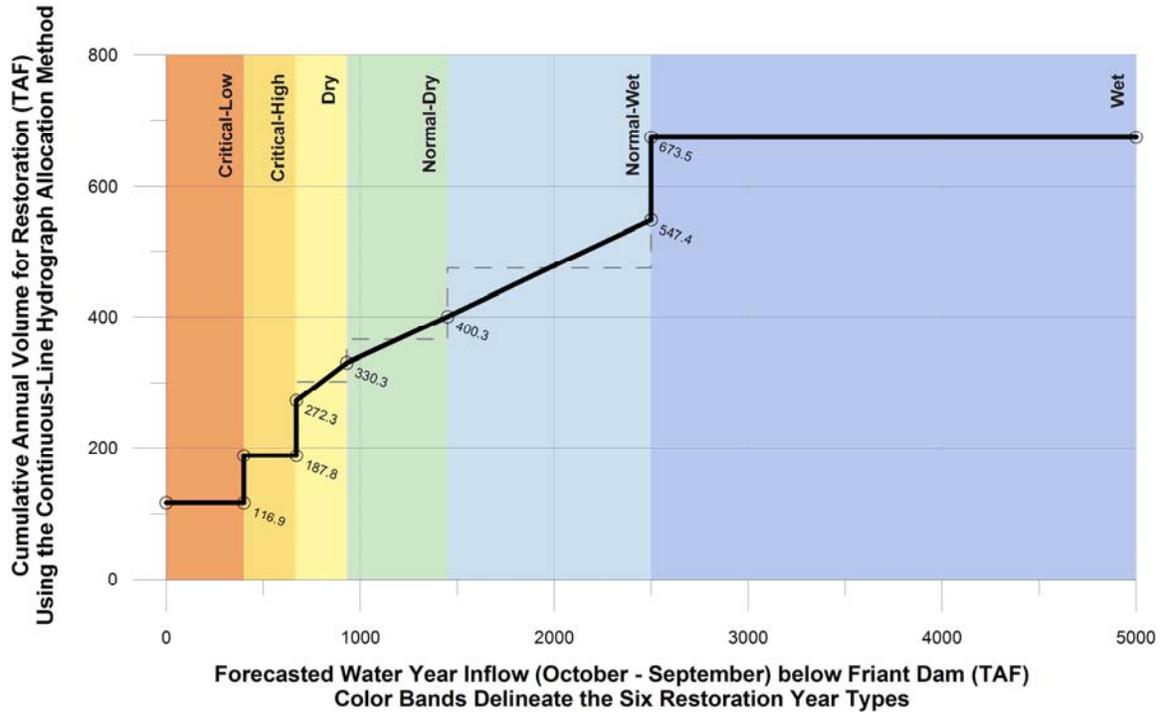
Restoration Year-Type (Mar – Feb)	Average Canal Delivery to Friant Division Long-Term Contractors (TAF)			
	Without Restoration (existing condition)	With Restoration Releases		
		Continuous Method 3.3	Stair-Step Hydrograph (Method 1)	Difference Between Methods
Wet	1,967	1,802	1,802	0
Normal-Wet	1,627	1,343	1,339	4
Normal-Dry	1,095	892	892	0
Dry	778	618	627	-9
Critical-High	525	393	389	4
Critical-Low	322	319	320	-1
All Years	1,344	1,136	1,136	0

8 Key: TAF = thousand acre-feet

9

**5.5 Selected Continuous Allocation Method**

Method 3.1 was found to be acceptable by the Settling Parties. Method 3.1, hereafter called the Continuous Allocation Method, is displayed in Figure 5-8. Inflection points defining the actual allocations are given in Table 5-13.



**Figure 5-8.**  
**Agreed-On Continuous Annual Allocation Method for Restoration Flows**

**Table 5-13.**  
**Inflection Points Defining Annual Allocations Under Method 3.1**

Unimpaired Inflow Below Friant Dam (TAF)	Restoration Releases (TAF)
0	116.9
400	116.9
400	187.8
670	187.8
670	272.3
930	330.3
1450	400.3
2500	547.4
2500	673.5
5000	673.5

13

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# 6.0 Flow Schedule Transformation

Development of a continuous annual allocation method creates a situation in which the total annual allocation is unlikely to equal one of the six identified annual allocations in the Exhibit B flow schedules. This creates a need for methods to distribute annual allocations (i.e., transform the flow schedules) in a manner consistent with, but not explicitly defined in, the Settlement.

This section discusses the inferences about transforming an annual allocation based on observations of the six Exhibit B flow schedules (Figure 6-1); the development of transformation pathways that would yield an initial flow schedule (i.e., the schedule used for accounting purposes, prior to implementing real-time management tools like flexible or buffer flows); and the collection of transformation pathways retained for implementation.

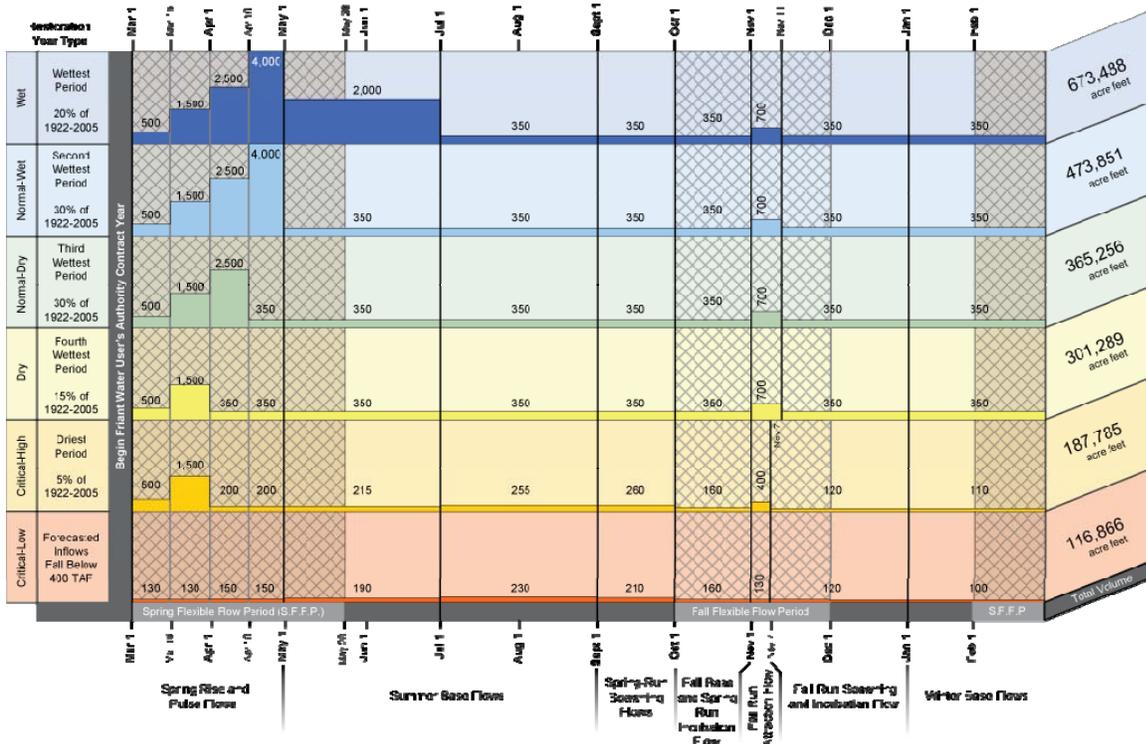


Figure 6-1. Restoration Flow Schedules, by Restoration Year-Type, Using the Exhibit B Stair-Step Allocation Method

## 6.1 Inferences About Transformation from Exhibit B

In comparing the various Exhibit B flow schedules, it is apparent that monthly releases for wetter year-types are always equal to or higher than those of any drier year-type; the increase in release occurs only in selected months in November and in the spring months. To be consistent with the Settlement, the method for distributing the above-determined annual amount should be consistent with the progressive characteristics in the original stair-step hydrographs.

Although they are not discussed in this document, the specifications for daily flow operations (e.g., ramping rate restrictions for ecological purposes and recommendations to the Secretary of the Interior) will further refine the default release patterns presented in this section.

## 6.2 Transformation Pathway Development

The transformation pathways presented here are prioritizations for increasing flow according to forecasted runoff based on biological rationale for transformation of the stair-step hydrographs to more continuous line hydrographs, as stipulated by the Settlement. In the Settlement, hydrograph components are plotted for each year-type, with various types of flow in specified amounts throughout the year, some of which vary in amount and duration depending on year-type classification. Transformation is the incremental increase or decrease between year-types of the seven flow schedule components that make up the annual allocation of water. Development of transformation pathways is a first step for potential interpolations of the annual allocation, and suggests sequences or pathways to be considered during development of the real-time decision matrix. The pathways for transformation use rationale based on the ecological intent of the Settlement flow schedules. The ecological intent of the Settlement flow schedules is based on providing the following flows:

- **Fall Base and Spring-Run Incubation Flow** – To provide conditions (temperature and connectivity between reaches) suitable for spawning and incubation of spring-run Chinook salmon
- **Fall-Run Attraction Flow** – To provide conditions (temperature, connectivity between reaches, and duration) suitable for fall-run Chinook salmon migration and to stimulate emigration of juvenile spring-run Chinook salmon
- **Fall-Run Spawning and Incubation Flow** – To provide conditions (temperature and connectivity between reaches) suitable for fall-run Chinook salmon spawning and incubation
- **Winter Base Flow** – To provide conditions (temperature and connectivity between reaches) suitable for incubation, emergence, and rearing of fall-run Chinook salmon

- 1       • **Spring Rise and Pulse Flow** – To provide conditions (temperature, connectivity  
2       between reaches, duration, and quantity) suitable for juvenile salmon  
3       outmigration, for adult spring-run Chinook salmon upstream migration, spawning  
4       of resident native fishes, initiation of fluvial geomorphic processes, riparian  
5       vegetation recruitment, and floodplain inundation for salmon rearing and other  
6       species (e.g., splittail spawning)
- 7       • **Summer Base Flow** – To provide conditions (temperature and connectivity  
8       between reaches) suitable for holding and rearing of spring-run Chinook, summer  
9       life stages of native fishes and warm-water game fishes, and riparian vegetation  
10      recruitment
- 11      • **Spring-Run Spawning Flow** – To provide conditions (temperature and  
12      connectivity between reaches) suitable for spring-run Chinook salmon spawning

13      Initial pathways for transforming the Exhibit B flow schedules are described below for  
14      each transformation step in the context of moving from a drier year-type to a wetter year-  
15      type (i.e., Critical-Low to Critical-High); moving from a wetter year-type to a drier year-  
16      type (i.e., Critical-High to Critical-Low) would involve directly reversing the steps  
17      described below for transforming up.

#### 18      **6.2.1 Critical-Low to Critical-High**

19      The Critical-Low flow schedule represents riparian diversion releases only, with no  
20      additional Restoration Flows. Restoration Flow allocation begins with the Critical-High  
21      year-type. Because the Critical-High Restoration Allocation is regarded as the minimum  
22      flow allocation to meet ecological objectives, no attempt is made to transform between  
23      Critical-Low and Critical-High flow schedules.

#### 24      **6.2.2 Critical-High to Dry**

25      Four distinct pathways were developed for incrementing between Critical-High and Dry  
26      years based on differing prioritization of fish restoration goals. Primary differences center  
27      on the prioritization given to spring-run Chinook salmon, fall-run Chinook salmon, and  
28      other native fishes.

#### 29      ***Alpha Pathway: Spring-Run Chinook Prioritization***

30      The alpha pathway, shown in Table 6-1 and Figure 6-2, prioritizes spring-run Chinook  
31      salmon. The steps in the alpha pathway are as follows:

32

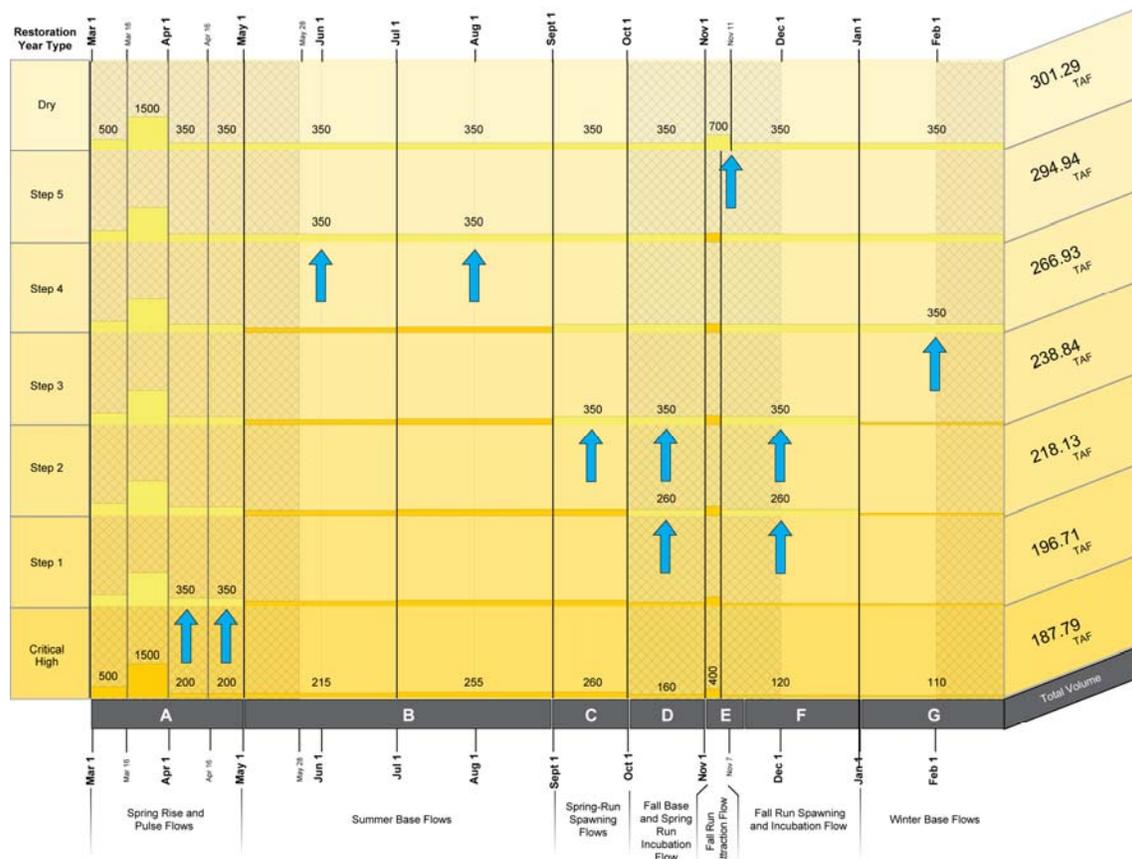
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**Table 6-1.**  
**Alpha Critical-High to Dry Pathway: Prioritizes Spring-Run Chinook Salmon**

Priority	Action* (cubic feet per second)	Rationale
1 Spring rise and pulse flow	A to 350	<ul style="list-style-type: none"> <li>Spring-run Chinook adult upstream migration</li> <li>Juvenile salmon outmigration of both runs</li> </ul>
2 Fall base and spring-run incubation flow Fall-run spawning and incubation flow	D to 260 F to 260	<ul style="list-style-type: none"> <li>Spring-run Chinook incubation</li> </ul>
3 Spring-run spawning flow Fall base and spring-run incubation flow Fall-run spawning and incubation flow	C to 350 D to 350 F to 350	<ul style="list-style-type: none"> <li>Spring-run Chinook spawning and incubation</li> </ul>
4 Winter base flows	G to 350	<ul style="list-style-type: none"> <li>Fall-run Chinook incubation</li> </ul>
5 Summer base flows	B to 350	<ul style="list-style-type: none"> <li>Spring-run Chinook adult holding and juvenile rearing</li> <li>Other native fish habitat and general aquatic habitat</li> <li>Maintenance of established riparian vegetation</li> </ul>
6 Fall-run attraction flow	E to 700	<ul style="list-style-type: none"> <li>Fall-run Chinook upstream migration</li> </ul>

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Note:  
\* Letters A-G refer to the time periods shown in Figure 6-2.



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**Figure 6-2.**  
**Alpha Critical-High to Dry Pathway: Prioritizes Spring-Run Chinook Salmon**

- 1 1. Bring up the Spring Rise and Pulse Flows to 350 cfs to provide conditions  
2 suitable for spring-run Chinook salmon adult upstream migration and juvenile  
3 salmon outmigration of both runs.
- 4 2. Bring up both the fall base and spring-run incubation flow and the fall-run  
5 Spawning and Incubation Flow to 260 cfs to provide conditions suitable for  
6 spring-run Chinook salmon egg incubation. This flow increase is not intended to  
7 help fall-run Chinook egg incubation because fall-run redds could be dewatered  
8 when winter base flows subsequently drop to 110 cfs.
- 9 3. Increase the Spring-Run Spawning Flow, the Fall Base and Spring-Run  
10 Incubation Flow, and the Fall-Run Spawning and Incubation Flow to 350 cfs to  
11 improve conditions for spring-run Chinook salmon spawning and incubation.
- 12 4. Increase Winter Base Flows to 350 cfs to provide suitable conditions for fall-run  
13 Chinook salmon egg incubation.
- 14 5. Increase the Fall-Run Attraction Flow to 700 cfs to stimulate adult fall-run  
15 Chinook salmon upstream migration.

16 ***Beta Pathway: Spring- and Fall-Run Chinook Prioritization***

17 The beta pathway, shown in Table 6-2 and Figure 6-3, prioritizes spring-run and fall-run  
18 Chinook salmon equally. The steps in the beta pathway are as follows:

- 19 1. Bring up the Spring Rise and Pulse Flows to 350 cfs to provide conditions  
20 suitable for spring-run Chinook salmon adult upstream migration and juvenile  
21 salmon outmigration of both runs.
- 22 2. Simultaneously bring up the Fall Base and Spring-Run Incubation Flow, the Fall-  
23 Run Spawning and Incubation Flow, and the Winter Base Flows to 260 cfs to  
24 provide conditions suitable for spring-run Chinook salmon egg incubation and  
25 fall-run Chinook spawning and egg incubation
- 26 3. Increase the Spring-Run Spawning Flow, the Fall Base and Spring-Run  
27 Incubation Flow, the Fall-Run Spawning and Incubation Flow, and the Winter  
28 Base Flows to 350 cfs to improve conditions for spawning and incubation of both  
29 runs of salmon.
- 30 4. Increase summer base flows to 350 cfs to provide spring-run Chinook adult  
31 holding and rearing habitat, other native fish habitat, and irrigation of riparian  
32 plants.
- 33 5. Increase the Fall-Run Attraction Flow to 700 cfs to stimulate adult fall-run  
34 Chinook salmon upstream migration.

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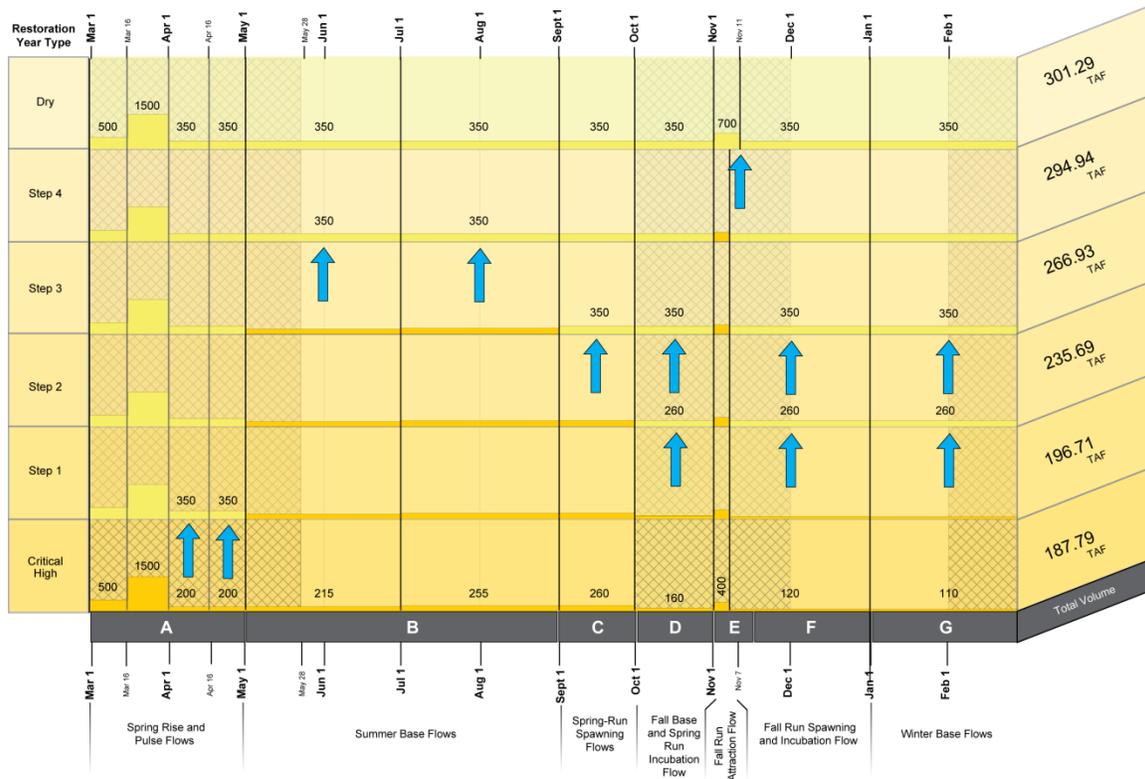
**Table 6-2.**  
**Beta Critical-High to Dry Pathway:**  
**Equally Prioritizes Spring-Run and Fall-Run Chinook Salmon**

Priority	Action* (cubic feet per second)	Rationale
1 Spring rise and pulse flow	A to 350	<ul style="list-style-type: none"> <li>Spring-run Chinook adult upstream migration</li> <li>Juvenile salmon outmigration of both runs</li> </ul>
2 Fall base and spring-run incubation flow Fall-run spawning and incubation flow Winter base flows	D to 260 F to 260 G to 260	<ul style="list-style-type: none"> <li>Spring-run Chinook incubation</li> <li>Fall-run Chinook spawning and incubation</li> </ul>
3 Spring-run spawning flow Fall base and spring-run incubation flow Fall-run spawning and incubation flow Winter base flows	C to 350 D to 350 F to 350 G to 350	<ul style="list-style-type: none"> <li>Spring-run Chinook spawning</li> <li>Spring-run Chinook incubation</li> <li>Fall-run Chinook spawning and incubation</li> </ul>
4 Summer base flows	B to 350	<ul style="list-style-type: none"> <li>Spring-run Chinook adult holding and juvenile rearing</li> <li>Other native fish habitat and general aquatic habitat</li> <li>Maintenance of established riparian vegetation</li> </ul>
5 Fall-run attraction flow	E to 700	<ul style="list-style-type: none"> <li>Fall-run Chinook upstream migration</li> </ul>

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Note:

\* Letters A-G refer to the time periods shown in Figure 6-3.



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**Figure 6-3.**  
**Beta Critical-High to Dry Pathway:**  
**Equally Prioritizes Spring-Run and Fall-Run Chinook Salmon**

1 **Gamma Pathway: Spring-Run, Then Fall-Run Chinook and Native Fish**  
2 **Prioritization**

3 The gamma pathway, shown in Table 6-3 and Figure 6-4, prioritizes spring-run Chinook  
4 salmon first, and fall-run and other native fishes second. The gamma pathway steps are as  
5 follows:

- 6 1. Bring up both the Fall Base and Spring-Run Incubation Flow and the Fall-Run  
7 Spawning and Incubation Flow to 260 cfs to improve conditions for spring-run  
8 Chinook salmon egg incubation. This flow increase is not intended to help fall-  
9 run Chinook egg incubation because fall-run redds could be dewatered when  
10 Winter Base Flows subsequently drop to 110 cfs.
- 11 2. Increase Winter Base Flows to 260 cfs to improve conditions for fall-run Chinook  
12 salmon egg incubation.
- 13 3. Bring up both the spring rise and pulse flows and the summer base flows to 260  
14 cfs to improve conditions for juvenile salmon rearing and other native fish habitat.
- 15 4. Increase the Spring-Run Spawning Flow, the Fall Base and Spring-Run  
16 Incubation Flow, the Fall-Run Spawning and Incubation Flow, and the Winter  
17 Base Flows to 350 cfs to improve conditions for spawning, incubation, and  
18 juvenile rearing for both runs of salmon.
- 19 5. Increase the Spring Rise and Pulse Flows to 350 cfs to provide habitat for other  
20 native fish.
- 21 6. Increase the Fall-Run Attraction Flow to 700 cfs to stimulate adult fall-run  
22 Chinook salmon upstream migration.
- 23 7. Increase the Summer Base Flows to 350 cfs for spring-run Chinook adult holding  
24 and juvenile rearing, other native fish habitat, and maintenance of established  
25 riparian vegetation.
- 26

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**Table 6-3.  
Gamma Critical-High to Dry Pathway: Spring-Run First Priority,  
Then Fall-Run and Other Native Fishes**

<b>Priority</b>	<b>Action* (cubic feet per second)</b>	<b>Rationale</b>
1 Fall base and spring-run incubation flow Fall-run spawning and incubation flow	<i>D</i> to 260 <i>F</i> to 260	<ul style="list-style-type: none"> <li>• Spring-run Chinook incubation</li> </ul>
2 Winter base flows	<i>G</i> to 260	<ul style="list-style-type: none"> <li>• Fall-run Chinook incubation</li> </ul>
3 Spring rise and pulse flows Summer base flows	<i>A</i> to 260 <i>B</i> to 260	<ul style="list-style-type: none"> <li>• Other native fish habitat</li> <li>• Juvenile salmon rearing</li> </ul>
4 Spring-run spawning flow Fall base and spring-run incubation flow Fall-run spawning and incubation flow Winter base flows	<i>C</i> to 350 <i>D</i> to 350 <i>F</i> to 350 <i>G</i> to 350	<ul style="list-style-type: none"> <li>• Spring-run Chinook spawning and incubation</li> <li>• Fall-run Chinook spawning and incubation</li> <li>• Spring-run Chinook juvenile rearing</li> <li>• Fall-run Chinook incubation and rearing</li> </ul>
5 Spring rise and pulse flows	<i>A</i> to 350	<ul style="list-style-type: none"> <li>• Other native fish habitat</li> </ul>
6 Fall-run attraction flow	<i>E</i> to 700	<ul style="list-style-type: none"> <li>• Fall-run Chinook upstream migration</li> </ul>
7 Summer base flows	<i>B</i> to 350	<ul style="list-style-type: none"> <li>• Spring-run Chinook adult holding and juvenile rearing</li> <li>• Other native fish habitat and general aquatic habitat</li> <li>• Maintenance of established riparian vegetation</li> </ul>

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Note:  
\* Letters A-G refer to the time periods shown in Figure 6-4.

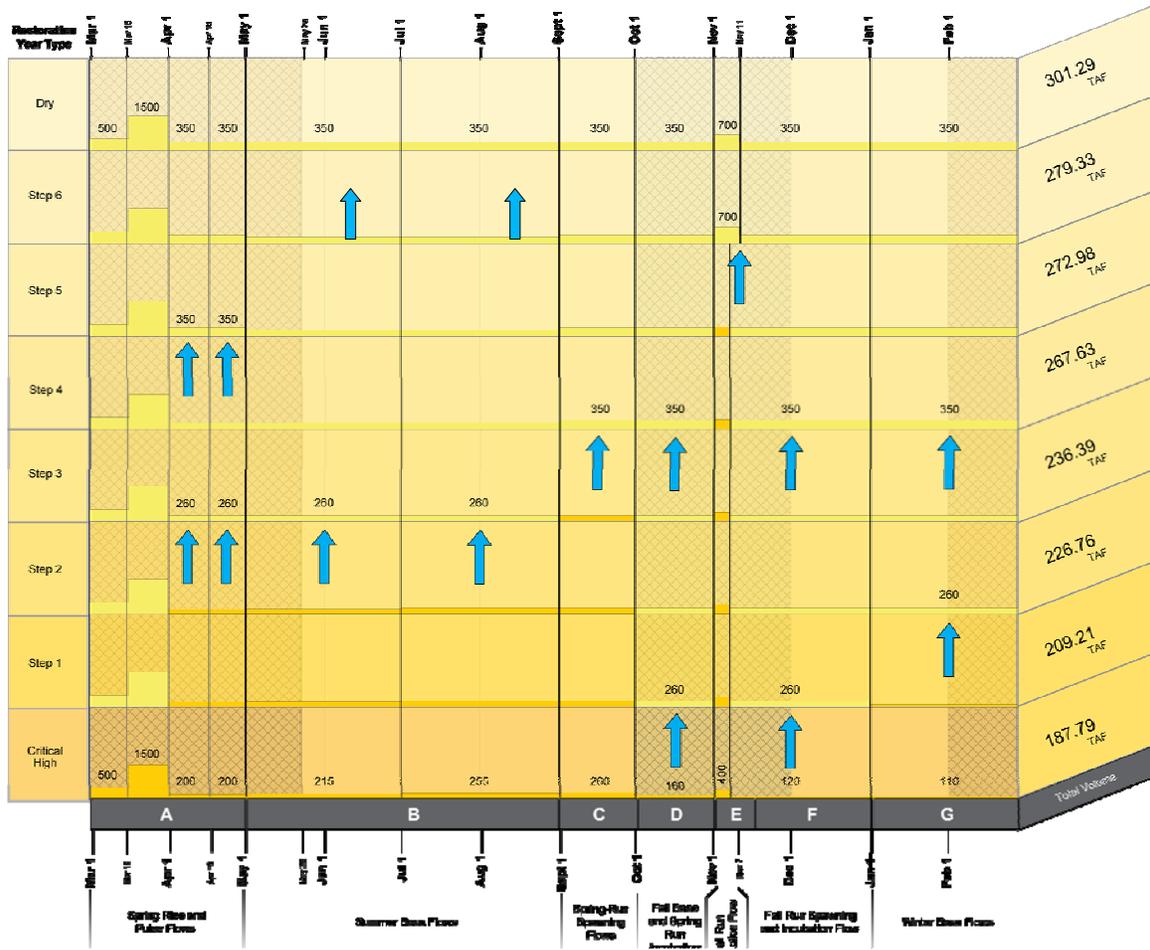


Figure 6-4.  
 Gamma Critical-High to Dry Pathway: Spring-Run First Priority,  
 Then Fall-Run and Other Native Fishes

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**Delta Pathway: Spring-Run, Then Fall-Run Chinook, Then Native Fishes Prioritization**

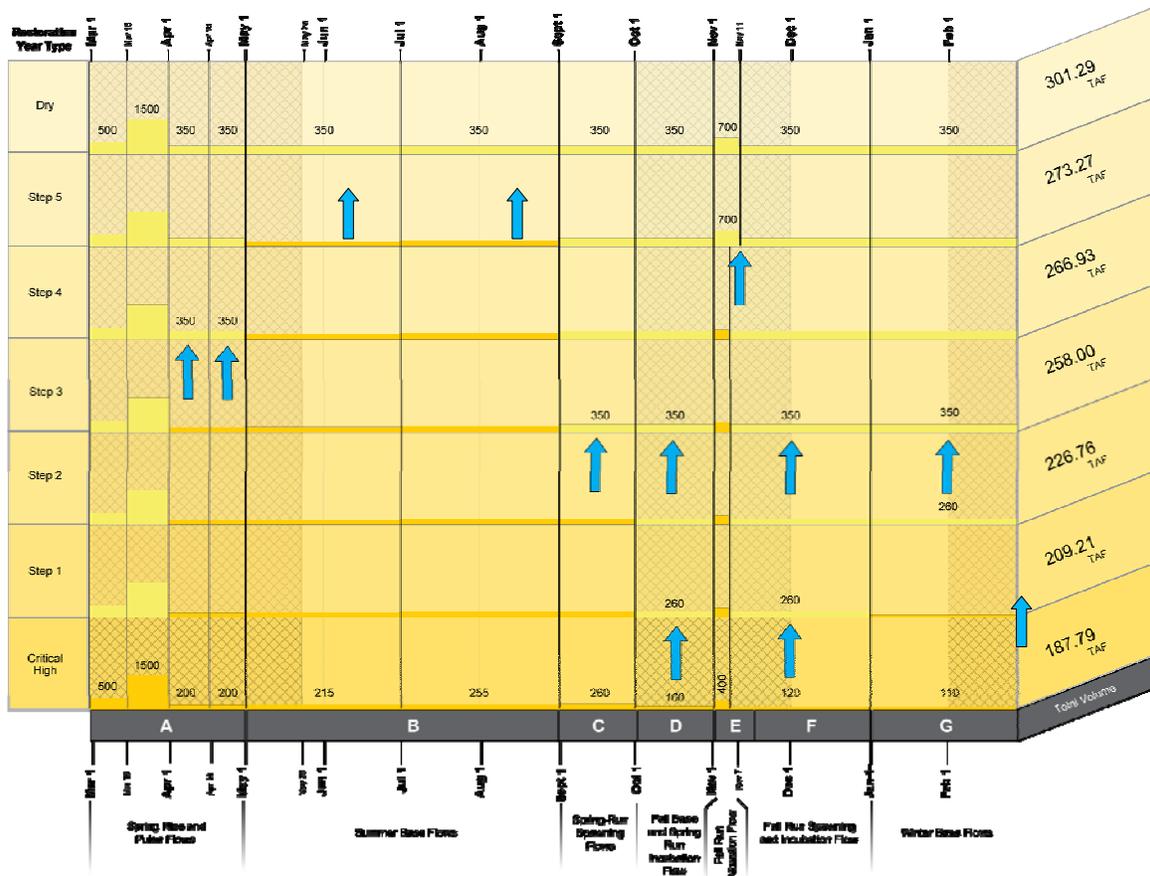
The delta pathway, shown in Table 6-4 and Figure 6-5, prioritizes spring-run Chinook salmon first, then fall-run Chinook salmon second, and other native fishes third.

1. Bring up both the Fall Base and Spring-Run Incubation Flow and the Fall-Run Spawning and Incubation Flow to 260 cfs to improve conditions for spring-run Chinook salmon egg incubation. This flow increase is not intended to help fall-run Chinook egg incubation because fall-run redds could be dewatered when Winter Base Flows subsequently drop to 110 cfs.
2. Increase Winter Base Flows to 260 cfs to improve conditions for fall-run Chinook salmon egg incubation.
3. Increase the Spring-Run Spawning Flow, the Fall Base and Spring-Run Incubation Flow, the Fall-Run Spawning and Incubation Flow, and the Winter Base Flows to 350 cfs to improve conditions for spawning, incubation, and juvenile rearing for both runs of salmon.
4. Increase the Spring Rise and Pulse Flows to 350 cfs to provide habitat for other native fish.
5. Increase the Fall-Run Attraction Flow to 700 cfs to stimulate adult fall-run Chinook salmon upstream migration.
6. Increase the Summer Base Flows to 350 cfs for spring-run Chinook salmon adult holding and juvenile rearing, other native fish habitat and irrigation of riparian plants.

**Table 6-4. Critical-High to Dry Delta Pathway: Prioritizes, in Order, Spring-Run Chinook Salmon, Fall-Run Chinook Salmon, Native Fishes**

Priority	Action* (cfs)	Rationale
1 Fall base and spring-run incubation flow Fall-run spawning and incubation flow	D to 260 F to 260	• Spring-run Chinook incubation
2 Winter base flows	G to 260	• Fall-run Chinook incubation
3 Spring-run spawning flow Fall base and spring-run incubation flow Fall-run spawning and incubation flow Winter base flows	C to 350 D to 350 F to 350 G to 350	• Spring-run Chinook spawning and incubation • Fall-run Chinook spawning and incubation • Spring-run Chinook juvenile rearing • Fall-run Chinook incubation and rearing
4 Spring rise and pulse flow	A to 350	• Other native fish habitat
5 Fall-run attraction flow	E to 700	• Fall-run Chinook upstream migration
6 Summer base flows	B to 350	• Spring-run Chinook adult holding and juvenile rearing • Other native fish habitat and general aquatic habitat • Maintenance of established riparian vegetation

Note:  
\* Letters A-G refer to the time periods shown in Figure 6-5.  
Key: cfs = cubic feet per second



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**Figure 6-5. Critical-High to Dry Delta Pathway: Prioritizes, in Order, Spring-Run Chinook Salmon, Fall-Run, Other Native Fishes**

5 **6.2.3 Dry to Normal-Dry**

6 In transforming from the Dry to Normal-Dry year-types, additional flow would be added  
7 incrementally to the spring rise and pulse flows.

8 **6.2.4 Normal-Dry to Normal-Wet**

9 In transforming from the Normal-Dry to Normal-Wet year-types, additional flow would  
10 be added incrementally to the spring rise and pulse flows. There is an unknown point at  
11 which the allocation made in addition to the Normal-Dry flow schedule would transition  
12 from being used to augment fisheries functions to being shaped effectively to perform  
13 geomorphic goals intended for the Normal-Wet year-type. The precise location of this  
14 transition point would be affected by future channel grading, levee setbacks, and other  
15 projects that are yet to be determined. This point would be identified during real-time  
16 operations.

17 **6.2.5 Normal-Wet to Wet**

18 In transforming from the Normal-Dry to Normal-Wet year-types, additional flow would  
19 be added incrementally to the summer base flows. As in the Normal-Dry to Normal-Wet  
20 transformation, there is an unknown point at which the allocation made in addition to the

1 Normal-Wet flow schedule would transition from being used to provide additional  
 2 fisheries benefits to being shaped to meet geomorphic goals. The additional water also  
 3 can be shaped effectively to meet riparian vegetation goals by providing riparian  
 4 recruitment flows, as described in the Settlement. The precise location of this transition  
 5 point is subject to channel grading, levee setbacks, and other projects that are yet to be  
 6 determined. This point would be identified during real-time operations.

7 **6.3 Retained Flow Schedule Transformation Pathways**

8 The transformation pathways described in Section 5.2 were developed in parallel with the  
 9 continuous line allocation method in Section 5.3. Unlike the annual allocation method,  
 10 the result of the transformation pathway work was not a prescription for a singular  
 11 technique. Instead, a range of possible flow scheduling outcomes was retained to bracket  
 12 the identified range of priorities that were evident in the Settlement’s expert testimony.

13 Table 6-5 presents the collection of transformation pathways leading from Critical-Low  
 14 allocation levels to Wet allocation levels. The only variation between the transformation  
 15 pathways exists for the Critical-High to Dry transformation, wherein there are four  
 16 pathways (alpha, beta, delta, and gamma) based on the ecological rationales presented in  
 17 the above section. Primary differences between the four methods center on the  
 18 prioritization of flows for the needs of spring-run Chinook salmon, fall-run Chinook  
 19 salmon, and other native fishes.

20 **Table 6-5.**  
 21 **Retained Flow Schedule Transformation Pathways**

Flow Schedule Transformation Between Year-Types		Retained Transformation Pathway(s)			
Normal-Wet	Wet	<i>single pathway</i>			
Normal-Dry	Normal-Wet	<i>single pathway</i>			
Dry	Normal-Dry	<i>single pathway</i>			
Critical-High	Dry	<i>alpha</i>	<i>beta</i>	<i>gamma</i>	<i>delta</i>
Critical-Low	Critical-High	<i>stair-step: no transformation</i>			

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 23  
 24 Initial evaluations of all four alternative transformation pathways revealed that water  
 25 supply impacts to Friant Division long-term contractors would not vary regardless of  
 26 which pathway is chosen. In addition, it was concluded that the range of flows released  
 27 from Friant Dam under any pathway would not differ with the application of any  
 28 transformation pathway. Therefore, all four transformation pathways were retained for  
 29 consideration in future implementation processes.

## 7.0 Further Considerations for Real-Time Operations at Friant Dam

Additional real-time operational considerations may be considered as part of Friant Division operations. While some of the considerations are not stipulated in the Settlement, they could still relate to Restoration Flow management as part of overall water management practices of the Friant Division. Following is a list of additional real-time operational considerations that will be considered during SJRRP implementation:

- Formal protocol for real-time adjustments that the Secretary of the Interior may use for equity issues, in consultation with advising parties. The organization of advising parties and associated responsibilities is expected to be formalized through a policy document and through continued discussion with the RA, Settling Parties, and potential advising parties.
- Inclusion of changes in allocation due to changes in forecasted inflow.
- Ramping rates that consider operational constraints at Friant Dam and downstream channels and levees, and constraints in fishery management for the Restoration Goal.
- Implementation of flexible flow periods in spring and fall.
- Regular maintenance of facilities, which may require rescheduling Restoration Flow releases.
- Power operations as part of the release mechanism for Restoration Flows.

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## 8.0 References

- 1  
2 Cain, J. R., Walkling, R.P., Beamish, S., Cheng, E., Cutter, E., Wickland, M.W. 2003 San  
3 Joaquin basin Ecological Flow Analysis. Prepared for the California Bay-Delta  
4 Authority by the Natural Heritage Institute under cooperative agreement  
5 #01FC20001.
- 6 Cain, J.R. 1997. Hydrologic and geomorphic changes to the San Joaquin River between  
7 Friant Dam and Gravelly Ford and implications for restoration of Chinook salmon  
8 (*Oncorhynchus tshawytscha*) Masters thesis, Department of Landscape  
9 Architecture, University of California, Berkeley. 143 pp.
- 10 California Data Exchange Center (CDEC). Full natural flow of the San Joaquin River  
11 below Friant Dam, <http://cdec.water.ca.gov/>. Last access in December 2007.
- 12 California Department of Fish and Game. 1998. Report to the Fish and Game  
13 Commission: A Status Review of the Spring-Run Chinook Salmon  
14 (*Oncorhynchus tshawytscha*) in the Sacramento River Drainage. Candidate  
15 Species Status Report 98-01. Inland Fisheries Division, Sacramento, California.
- 16 California Department of Fish and Game (DFG). 1991–2005. Annual reports, fiscal years  
17 1987-2004, San Joaquin River Chinook Salmon Enhancement Project. Sport Fish  
18 Restoration Act. Region 4, Fresno.
- 19 California Department of Water Resources (DWR). 1999-2007. Bulletin 120 – Water  
20 Conditions in California.
- 21 CDEC. *See* California Data Exchange Center.
- 22 Cramer Fish Sciences. 2006. 2005-06 Stanislaus River Weir Data Report. Final report  
23 prepared for the Anadromous Fish Restoration Program. June.
- 24 ———. 2007. Upstream Fish Passage at a Resistance Board Weir Using Infrared and  
25 Digital Technology in the Lower Stanislaus River, California, 2006–2007 Annual  
26 Data Report. Report prepared by Jesse T. Anderson, Clark B. Watry, and Ayesha  
27 Gray for the Anadromous Fish Restoration Program.
- 28 DFG. *See* California Department of Fish and Game.
- 29 DWR. *See* California Department of Water Resources.
- 30 Expert Report of Michael L. Deas, Ph.D., E. E.D. Cal. No. Civ. 88-1658 LKK. 98 pp.
- 31 Expert Report of Professor Mathias Kondolf, Ph.D. E.D. Cal. No. Civ. 88-1658 LKK.  
32 122 pp.

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- 1 Expert Report of Professor Peter B. Moyle, Ph.D. E.D. Cal. No. Civ. 88-1658 LKK.  
2 77 pp.
- 3 Fisher, F. W. 1994. Past and present status of Central Valley Chinook salmon.  
4 Conservation Biology 8: 870-873.
- 5 Fry, B. H., and E. Hughes. 1958. Potential value of San Joaquin River salmon.
- 6 Hill, K.A., and J. D. Webber. 1999. Butte Creek spring-run Chinook salmon,  
7 Oncorhynchus tshawytscha, juvenile outmigration and life history, 1995-1998.  
8 CDFG Inland Fisheries Admin. Report 99-5: 46 pp.
- 9 Jones and Stokes Associates, Inc. 1998. Analysis of Physical Processes and Riparian  
10 Habitat Potential of the San Joaquin River, Friant Dam to the Merced River.  
11 Prepared for the San Joaquin River Riparian Habitat Restoration Program.
- 12 ———. 2001. Technical Memorandum on the Potential Barriers to Migrating Steelhead  
13 and Chinook Salmon on the San Joaquin River. December 17. (J&S 00343.)  
14 Sacramento. Prepared for Friant Water Users Authority, Lindsay, CA, and Natural  
15 Resources Defense Council, San Francisco, California.
- 16 Keller, E.A., and F.J. Swanson. 1979. Effects of large organic material on channel form  
17 and fluvial processes. Earth Surface Processes and Landforms 4:361-380.
- 18 Kondolf, G.M. 1998. Development of flushing flows for channel restoration on Rush  
19 Creek, California. Rivers. 6(3):183-193.
- 20 ———. 2000. Assessing salmonid spawning gravels. Transactions of the American  
21 Fisheries Society 129:262-281.
- 22 Kondolf, G.M., and R. Wilcock. 1996. The flushing flow problem: defining and  
23 evaluating objectives. Water Resources Research. 32(8):2589-2599.
- 24 Mahoney, J.M., and S.B. Rood. 1998. Streamflow requirements for cottonwood seedling  
25 recruitment – an integrative model. Wetlands 18:634-645.
- 26 Marine, K. R. and J. J. Cech, Jr. 2004 Effects of high water temperatures on growth,  
27 smoltification, and predator avoidance in juvenile Sacramento River Chinook  
28 salmon. *North American Journal of Fisheries Management* 24:198-210.
- 29 McBain and Trush (eds). 2002. San Joaquin River restoration study background report.  
30 Prepared for Friant Water Users Authority, Lindsay, California, and Natural  
31 Resources Defense Council, San Francisco.
- 32 McCullough, D.A. 1999. A review and synthesis of effects of alteration to the water  
33 temperature regime on freshwater life stages of salmonids, with special reference  
34 to Chinook salmon. EPA 910-R-99-010.

- 1 McCullough, D. A., S. Spalding, D. Sturdevant, and M. Hicks. 2001. Summary of  
2 technical literature examining the physiological effects of temperature on  
3 salmonids. Issue Paper 5. USEPA. EPA-910-D-01-005. 106 pp.
- 4 McReynolds, T. R., C. E. Garman, P. D. Ward, and M. C. Schommer. 2005. Butte and  
5 Big Chico creeks spring-run Chinook salmon, *Oncorhynchus tshawytscha* life  
6 history investigation 2003-2004. California Department of Fish and Game,  
7 Sacramento Valley – Central Sierra Region, Inland Fisheries Administrative  
8 Report No. 2005-1.
- 9 Moyle, B. 2002. *Inland Fishes of California*. Revised and Expanded. Berkeley:  
10 University of California Press. 502 pp.
- 11 Moyle, P.B., R.M. Yoshiyama, J.E. Williams, and E.D. Wikramanayake. 1995. Fish  
12 Species of Special Concern in California. Second Edition. Prepared for California  
13 Department of Fish and Game, Rancho Cordova. Contract No. 2128IF.
- 14 Natural Resources Defense Council et al. (NRDC). 2006. Notice of Lodgment of  
15 Stipulation of Settlement. E.D. Cal. No. Civ. S-88-1658 LKK/GGH. *NRDC, et*  
16 *al., v. Rodgers, et al.* September 13.
- 17 NRDC. *See* Natural Resources Defense Council.
- 18 Reclamation. *See* U.S. Department of the Interior, Bureau of Reclamation.
- 19 Rizzardo, D. 2007. Personal communication, California Department of Water Resources.
- 20 San Joaquin River Restoration Program (SJRRP). 2008. *Draft Operation Guidelines for*  
21 *Implementing Restoration Flow* Technical Memorandum. April.
- 22 S.P. Cramer and Associates. 2004. 2002-04 Stanislaus River Weir Data Report. Final  
23 report prepared for the Anadromous Fish Restoration Program. October.
- 24 ———. 2005. 2004-05 Stanislaus River Weir Data Report. Final report prepared for the  
25 Anadromous Fish Restoration Program. June.
- 26 State Water Resources Control Board (SWRCB). 2000. Water Right Decision 1641.
- 27 Stillwater Sciences. 2003. Draft Restoration Strategies for the San Joaquin River.  
28 Prepared for the Natural Resources Defense Council and the Friant Water Users  
29 Authority.
- 30 SWRCB. *See* State Water Resources Control Board.
- 31 Tsujimoto, T. 1999. Sediment transport processes and channel incision: mixed size  
32 sediment transport, degradation, and armouring. Pages 37-66 in S.E. Darby and  
33 A. Simon, eds., *Incised river channels: processes, forms, engineering, and*  
34 *management*. John Wiley & Sons, Chichester.

- 1 U.S. Department of the Interior, Bureau of Reclamation (Reclamation). 2005.  
2 Operational Guidelines for Water Service – Friant Division Central Valley  
3 Project.
- 4 U.S. Fish and Wildlife Service (USFWS). 1994. The relationship between instream flow,  
5 adult immigration, and spawning habitat availability for fall-run Chinook salmon  
6 in the upper San Joaquin River, California. Final report 9/21/94. 42 pp.
- 7 USFWS. *See* U.S. Fish and Wildlife Service.
- 8 Vick, J. C., A. J. Keith, and P.F. Baker. 2000. 1999 Tuolumne River outmigrant trapping  
9 report. Report 99-5 in 1999 Lower Tuolumne River annual report, Volume II.  
10 Prepared by Stillwater Sciences, Berkeley, California with assistance from S. P.  
11 Cramer and Associates, Gresham, Oregon for the Tuolumne River Technical  
12 Advisory Committee.
- 13 Ward, P. D., and T. R. McReynolds. 2001. Butte and Big Chico Creeks spring-run  
14 Chinook salmon, *Oncorhynchus tshawytscha*, life history investigation, 1998-  
15 2000. California Department of Fish and Game, Inland Fisheries Administrative  
16 Report.
- 17 Ward, P.D., T.R. McReynolds, and C.E. Garman. 2002. Butte and Big Chico Creeks  
18 spring-run Chinook salmon, *Oncorhynchus tshawytscha*, life history investigation,  
19 2000-2001. California Department of Fish and Game, Inland Fisheries  
20 Administrative Report No. 2001-2.
- 21 ———. 2003. Butte and Big Chico Creeks spring–run Chinook salmon, *Oncorhynchus*  
22 *tshawytscha*, life history investigation 2001-2002. California Department of Fish  
23 and Game Administrative Report: 1- 53.
- 24 Yurok Tribal Fisheries Program. 2003. The Klamath River fish kill of 2002; analysis of  
25 contributing factors. Unpublished Report.