Attachment

Restoration Area Channel Capacity Evaluations

Draft
Plan Formulation Appendix

SAN JOAQUIN RIVER RESTORATION PROGRAM

Draft
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List of Abbreviations and Acronyms

cfs	cubic feet per second
DWR	California Department of Water Resources
MEI	Mussetter Engineering, Inc.
RM	River Mile
SJRRP	San Joaquin River Restoration Project

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1.0 Introduction

This Attachment summarizes the results of a sensitivity analysis of proposed floodplains and levee setback alignments in Reaches 2B and 4B to assist the Alternatives Formulation Group for the San Joaquin River Restoration Project (SJRRP). Mussetter Engineering, Inc. (MEI) recently completed an initial sensitivity analysis for these reaches to quantify hydraulic conditions for maximum and minimum floodplain widths under various vegetation scenarios (MEI 2008b). Further analysis was required to define reasonable target floodplain widths with a refined set of parameters. Since acceptable floodplain depths have not been defined by the program, this analysis targets an 18-inch average floodplain depth at discharges of 2,000, 3,000 and 4,000 cubic feet per second (cfs) to allow definition of variable floodplain widths under various vegetation characteristics. It is understood that the 18-inch criteria is only a placeholder and further analysis of suitable floodplain depths will be required. The analysis was performed using the baseline conditions HEC-RAS model, modified to include levees along the main channel. Levee setback widths were designed to provide an average floodplain depth of 18 inches for six simulated vegetation scenarios at three different flow rates.

Reach 2B extends from the Chowchilla Bypass Bifurcation Structure (River Mile (RM) 216.1) to Mendota Dam (RM 204.6). A bypass channel is proposed to carry flows around Mendota Dam. The inlet to the bypass channel would be located at about RM 207.6; thus, only the portion of Reach 2B upstream from the inlet was considered in the analysis. Reach 4B extends from the Sand Slough Control Structure (RM 168.5) to the confluence with Bear Creek (RM 135.8). This analysis considered only the portion of the reach between RM 151.1 to RM 168.5 where setback levees have been proposed.

This analysis was performed by MEI under Contract No. 4600007793, Task Order 19, with the California Department of Water Resources (DWR).

1.1 Limitations

The results presented in this Attachment are based on conceptual work only and provide a general idea of floodplain widths, depths and land impacts in Reaches 2B and 4B. The following assumptions and limitations should be noted in considering the results of this analysis:

1. Setback levee alignments are conceptual and should not be considered as alternatives for specific projects. The evaluations did not consider adjacent land uses and ownership, construction costs or mitigation requirements.

2. Because of the conceptual nature of the analysis, only reach-averaged results are presented. As a result, these results do not reflect the local variability that occurs from cross-section to cross section.

3. Channel and floodplain roughness coefficients (Manning's *n*-values) applied in these evaluations represent average future vegetation effects for an entire reach, and do not reflect the local variability that is expected under project conditions.

4. The evaluations do not consider the suitability of existing levees and foundations to meet Corps levee design and performance standards. Where necessary, the levee heights were extended under the assumption that the levees will be modified as necessary to provide the required level of freeboard. Geologic data to be obtained as part of the overall SJRRP will be used to assess the condition of existing levees to identify needed modifications.

5. Flow scenarios do not account for accretions or losses along the reaches.

6. Future modifications to San Mateo Road culverts, Washington Road Bridge, Turner Island Road Bridge, and the culverts at RM 163 and RM 153.5 will need to be evaluated to determine their potential impact on flood elevation and floodplains.

7. This rigid-boundary analysis did not consider the existing or future geomorphic conditions of the project reach. As a result, the impacts of the levee setbacks on erosional or depositional characteristics of the river were not addressed.

8. Modifications to the floodplain topography were made to the models that were used for the initial appraisal level designs to reflect grading and filling in the floodplain (MEI 2007 and 2008a). These modifications were used in the models for this analysis; no additional modifications to the setback levee model geometries were made. Grading requirements for floodplain areas to meet fish habitat and passage needs will be considered in future study phases.

2.0 Future Floodplain Vegetation Scenarios

Three future floodplain vegetation scenarios were identified for the analysis (Table 2-1):

- **Scenario A** has relatively low roughness associated with a grassy surface and minimal woody vegetation, intended to represent a floodplain that is maintained to provide maximum flood conveyance.
- **Scenario B** uses intermediate roughness values to represent a relatively narrow riparian corridor along the channel, but little or no woody vegetation in the overbank areas beyond the riparian strip.
- **Scenario C** has high roughness values associated with the riparian forest that is expected to develop with minimal maintenance for flood conveyance purposes.

Table 2-1.
Summary of Revised Restoration Alternatives, Future Floodplain Conditions

Scenario A	Scenario B	Scenario C
Grassy floodplain with no woody vegetation and maintenance similar to that applied in the existing flood- control system. This would be reflected by the lowest reasonable *n*-value in system-wide hydraulic simulations. Little or no grading or other physical modification would be done.	Riparian ribbon adjacent to the channel with maintenance in overbank areas to prevent establishment of woody vegetation. This would be reflected in moderate *n*-values for system wide simulations. Moderate grading or other physical modifications would be performed to encourage riparian establishment in limited areas.	Riparian forest along channel and on floodplain with no maintenance in overbank areas to woody vegetation. This would be reflected in high *n*-values for system-wide simulations. Extensive grading or other physical modification would be performed to encourage riparian establishment to the greatest extent possible.

2.1 Overbank Manning's n-value

For this study six Manning's *n* roughness values were used in the model to estimate surface irregularities, presence of obstructions and characteristics of the floodplain vegetation. Two roughness values were estimated for each vegetation scenario to represent the most likely range that would occur, based on the judgment and experience of the project team. The resulting overbank Manning's *n*-values used for each model run are summarized in Table 2-2.

Table 2-2.
Overbank Manning's *n*-Values

Scenario	Low	High
Grassy Floodplain	0.04	0.055
Riparian Ribbon	0.06	0.085
Riparian Forest	0.095	0.16

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3.0 Model Development

As noted above, the hydraulic modeling was performed using a modified version of the existing conditions HEC-RAS model of the restoration reach that was developed by MEI (2008a).

3.1 Reach 2B

For purposes of this analysis, the main-channel Manning's *n* roughness values were averaged from the 4,500-cfs results of the existing conditions model that uses composite values that vary with depth. Based on the averaging, a constant value of 0.04 was used downstream from RM 209.7 and upstream from RM 212.2, and a constant value of 0.05 was used between RM 209.7 and RM 212.2. The downstream water-surface elevation of 153.1 feet used as the boundary condition for this analysis was obtained from the model results for the proposed Mendota Bypass Channel described in MEI (2002).

For the maximum setback levee alignment, the south levee follows the alignment that was used to develop the appraisal-level design (MEI 2007), and the north levee runs along the south side of the Columbia Canal (Figure 3-1). The minimum setback levee alignment was based on the existing internal levees along Reach 2B and corresponds to the minimum setback alignment from the previous analysis (MEI 2008b).

3.2 Reach 4B

The horizontal and vertical variations in Manning's *n* used for the main channel in previous analyses were removed and replaced with a constant Manning's *n*-value of 0.05 in the downstream portion of the reach (RM 157.1 to RM 160.5) and 0.04 in the upstream portion of the reach (RM 160.5 to RM 168.5) based on the average values from the appraisal level design model at 4500 cfs (MEI 2008a). The downstream limit of the HEC-RAS model is at the San Joaquin River near Newman gage (USGS Gage No. 11274000); thus, the starting water-surface elevations were taken from the gage-rating curve.

The proposed minimum setback levee alignment for Reach 4B was developed during the appraisal-level design process (MEI 2008a) and the model includes the proposed Phase I in-channel modifications and removal of the existing local levees proposed for Phase II (Figure 3-2). The maximum setback levee alignment for Reach 4B was developed and presented in MEI (2008b).

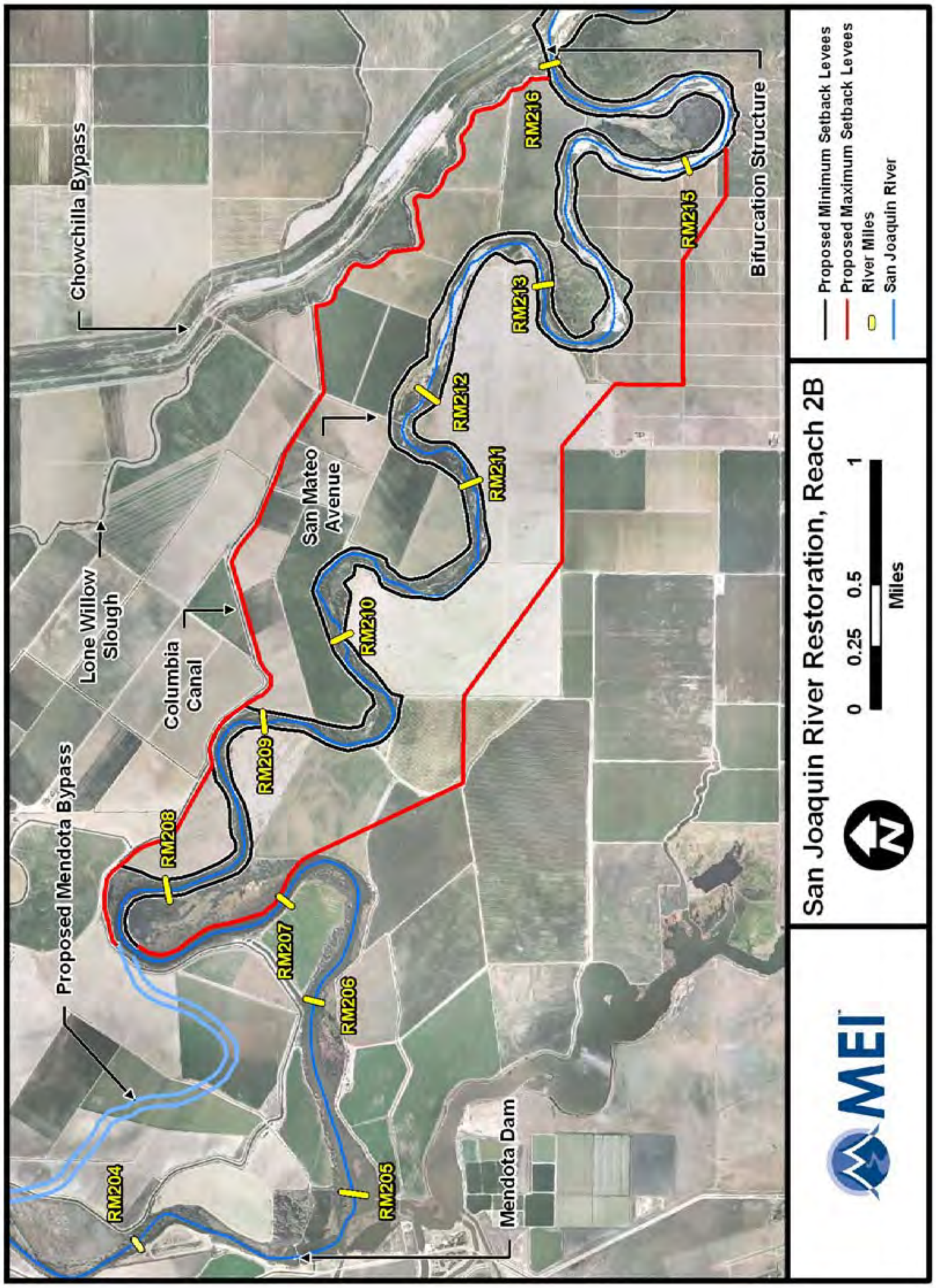

Figure 3-1.
Plan View of Reach 2B Showing the Conceptual Levee Alignments for the Minimum and Maximum Floodplain Width Alternatives

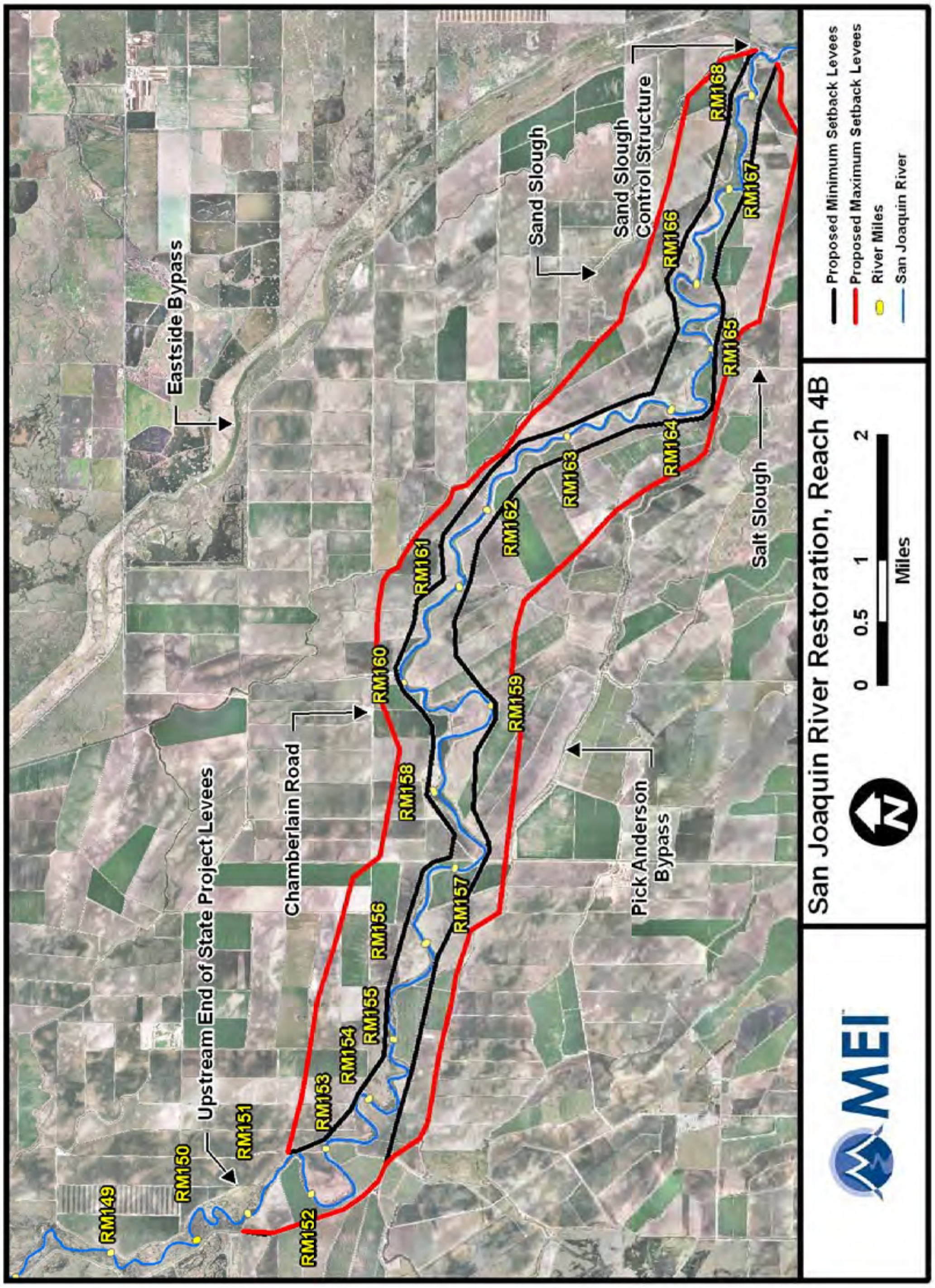

Figure 3-2.
Plan View of Reach 4B Showing the Conceptual Levee Alignments for the Minimum and Maximum Floodplain Width Alternatives

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4.0 Modeling Procedure

The maximum and minimum levee setback alignments were used to determine maximum and minimum floodplain depths for all six simulated vegetation scenarios using steady-state discharges of 2,000, 3,000 and 4,000 cfs. For scenarios where the average floodplain depth at the maximum levee alignment was less than 18 inches and greater than 18 inches at the minimum levee alignment, the levees were set back an equal distance on each side by subtracting (left side of channel) or adding (right side of channel) a constant value to the minimum setback levee station at each cross-section. The distance was iteratively adjusted until the 18-inch average depth was achieved.

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5.0 Model Results

5.1 Reach 2B

The reach-averaged results for the six vegetation scenarios at three different flow rates are presented in Table 5-1. As previously stated these results do not reflect the local variability that exists within the reach but provide a comparison of the relative differences and sensitivity to width and roughness of the floodplain in the overall reach. As shown in Table 5-1, the target average overbank depth was not achievable for all of the scenarios. At 2,000 cfs, the flow is contained primarily in the main channel for all vegetation scenarios. For example, for the maximum roughness condition (i.e., $n = 0.16$) and the minimum levee setback alignment, the reach-averaged overbank depth was only 1.1 feet at 2,000 cfs. At 3,000 cfs, the vegetation scenarios with overbank *n*-values of 0.04, 0.055, and 0.06 also have average overbank depths lower than the target depth of 18 inches. When an average overbank depth of 18 inches was not achievable even at the minimum levee setback alignment, the reported floodplain width in Table 5-1 reflects the wetted width of the water surface as it approaches the levees at the minimum setback alignment.

For Reach 2B, the computed water-surface profiles for levee setback alignments yielding average overbank depths of 18 inches are shown in Figure 5-1. The downstream ends of all the water-surface profiles converge to the same elevation because they are determined by the boundary condition. The profiles plot closely together along the entire reach illustrating similar water-surface elevations at average overbank flow depths of 18 inches. Small divergences in the profiles are evident and correspond to meanders in the river and levee system near RM 213.5, RM 210.5, and RM 208.5.

Table 5-1.
Reach-Averaged Results for Reach 2B

Scenario		*n*	Flow	WSEL	Floodplain Width*	Floodplain Depth	Channel Velocity	Floodplain Velocity
			(cfs)	(ft)	(ft)	(ft)	(ft/s)	(ft/s)
1	Grassy Floodplain	0.04	2,000	159.9	300	0.5[+]	1.72	0.27
			3,000	161.0	340	1.1[+]	2.03	0.56
			4,000	161.6	630	1.5	2.21	0.86
2	Grassy Floodplain	0.055	2,000	160.1	310	0.6[+]	1.66	0.23
			3,000	161.3	350	1.3[+]	1.95	0.46
			4,000	161.7	880	1.5	2.10	0.62
3	Riparian Ribbon	0.06	2,000	160.1	310	0.6[+]	1.64	0.22
			3,000	161.4	350	1.3[+]	1.93	0.43
			4,000	161.8	990	1.5	2.06	0.57
4	Riparian Ribbon	0.085	2,000	160.4	320	0.8[+]	1.56	0.18
			3,000	161.5	610	1.5	1.80	0.39
			4,000	161.8	1,660	1.5	1.91	0.40
5	Riparian Forest	0.095	2,000	160.5	320	0.8[+]	1.53	0.17
			3,000	161.6	680	1.5	1.76	0.35
			4,000	161.8	1,950	1.5	1.86	0.36
6	Riparian Forest	0.16	2,000	161.1	340	1.1[+]	1.39	0.13
			3,000	161.8	1,530	1.5	1.57	0.21
			4,000	161.7	3,770	1.5	1.67	0.23

Notes:
* Including the main channel width.
** 1.5-foot overbank depth was not possible for all scenarios within the proposed minimum and maximum levee alignments.

Key:
cfs = cubic feet per second
ft = feet
ft/s = feet per second

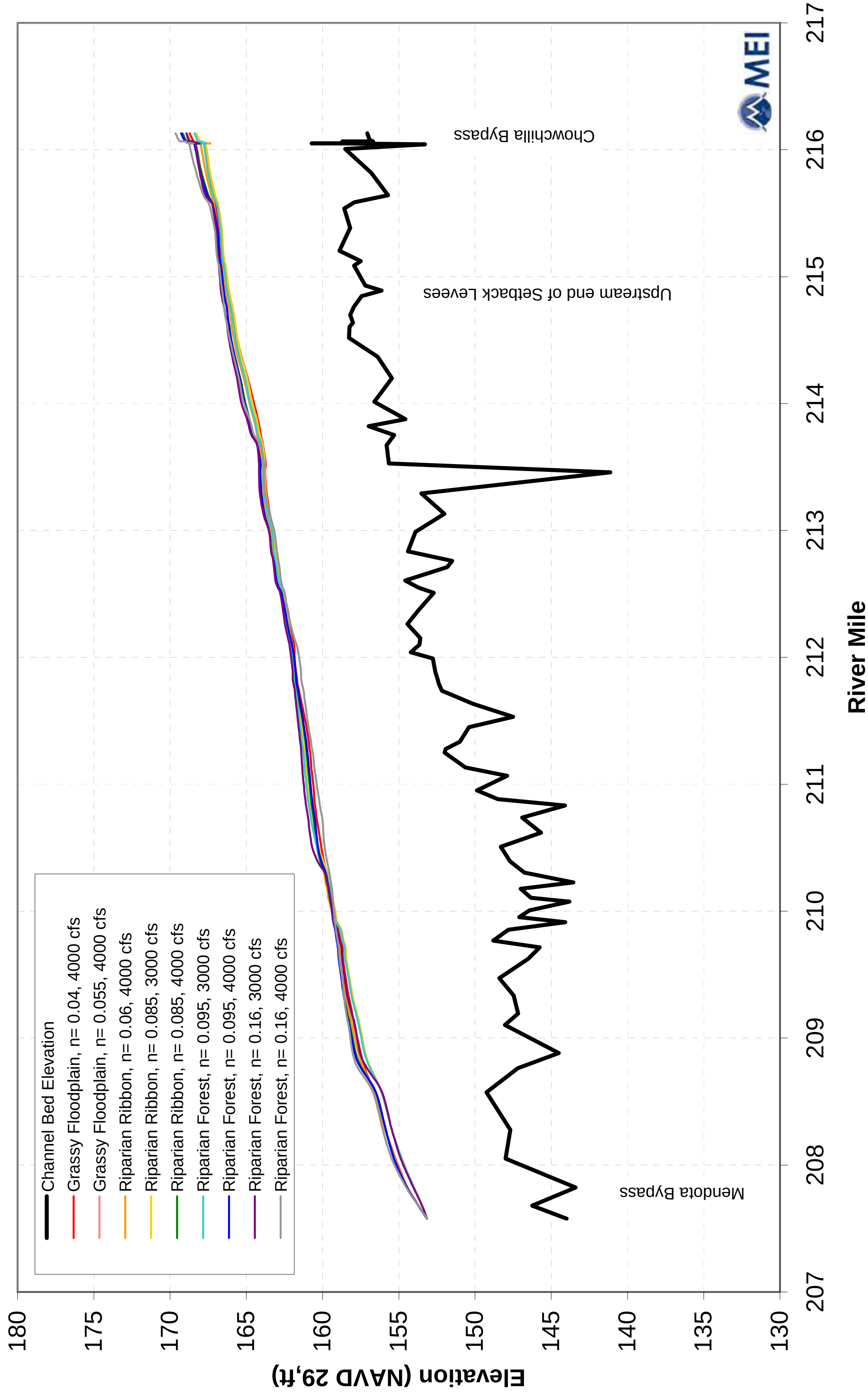

Figure 5-1.
Water-Surface Profiles for the Range of Flows, Vegetation Conditions, and Associated Levee Alignments in Reach 2B

Figures 5-2 through 5-4 show typical cross sections in Reach 2B with the average floodplain widths, water-surface elevations, and levee locations for the three vegetation scenarios. For the grassy floodplain, a flow rate of 4,000 cfs was necessary to produce 18-inch average overbank flow depths for both roughness values, with average widths of 630 and 880 feet. For the riparian ribbon scenario, the 18-inch average overbank depths can be met at a floodplain width of 609 feet with the high roughness value at 3,000 cfs, and at widths ranging from 992 feet (high roughness conditions) to 1,664.3 feet (low roughness conditions) at 4,000 cfs. For the riparian forest scenario, floodplain widths of 682 to 1,531 feet are required to meet the criteria at 3,000 cfs. At a higher discharge of 4,000 cfs, the required reach-averaged floodplain widths for each scenario range from 1,947 to 3,771 feet.

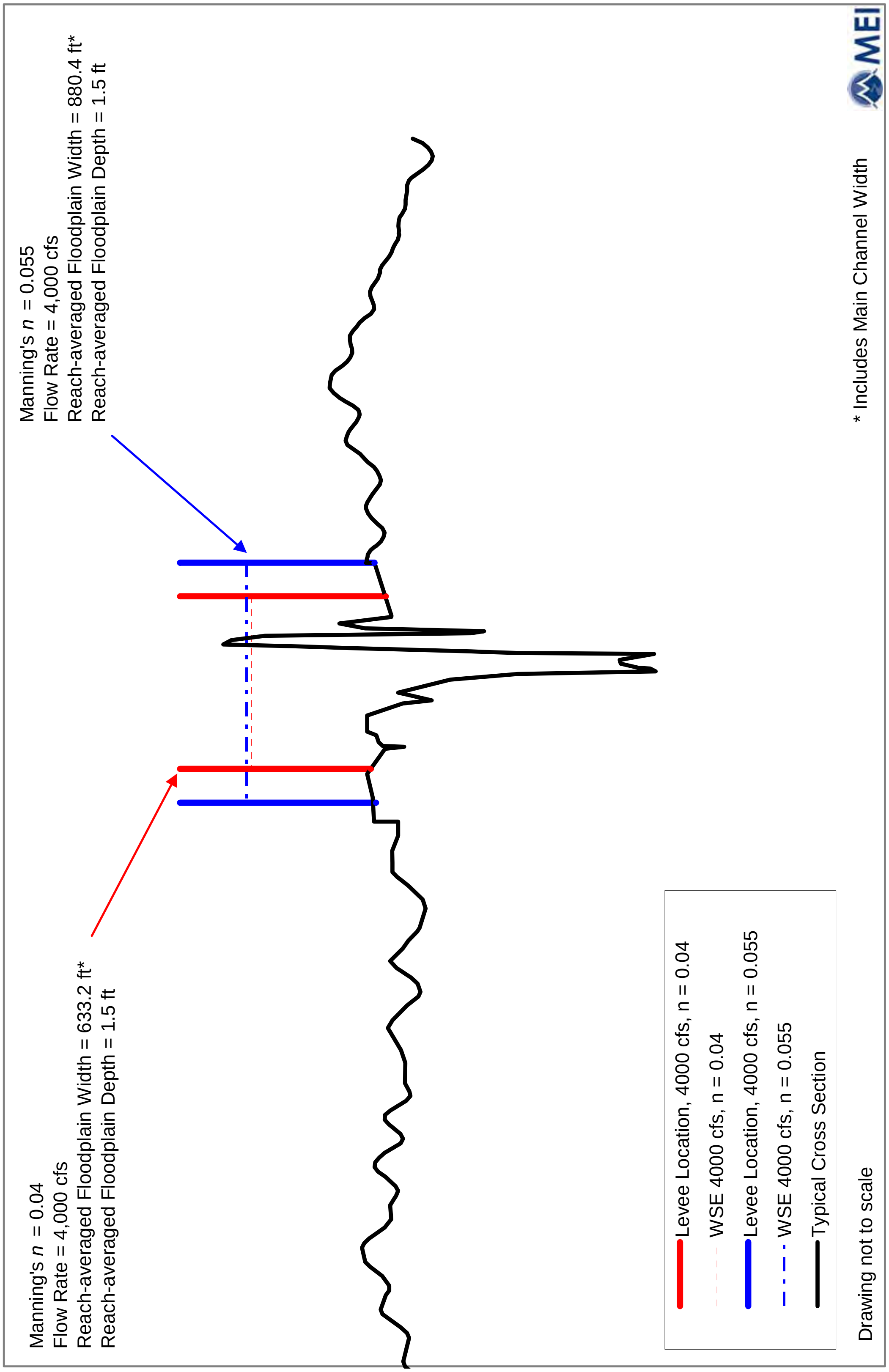

Figure 5-2.
Reach 2B Typical Cross Section (RM 213.82), Levee Locations, and Flows to Achieve an Average 1.5-foot Overbank Depth for a Grassy Floodplain (*n* = 0.04 and 0.055)

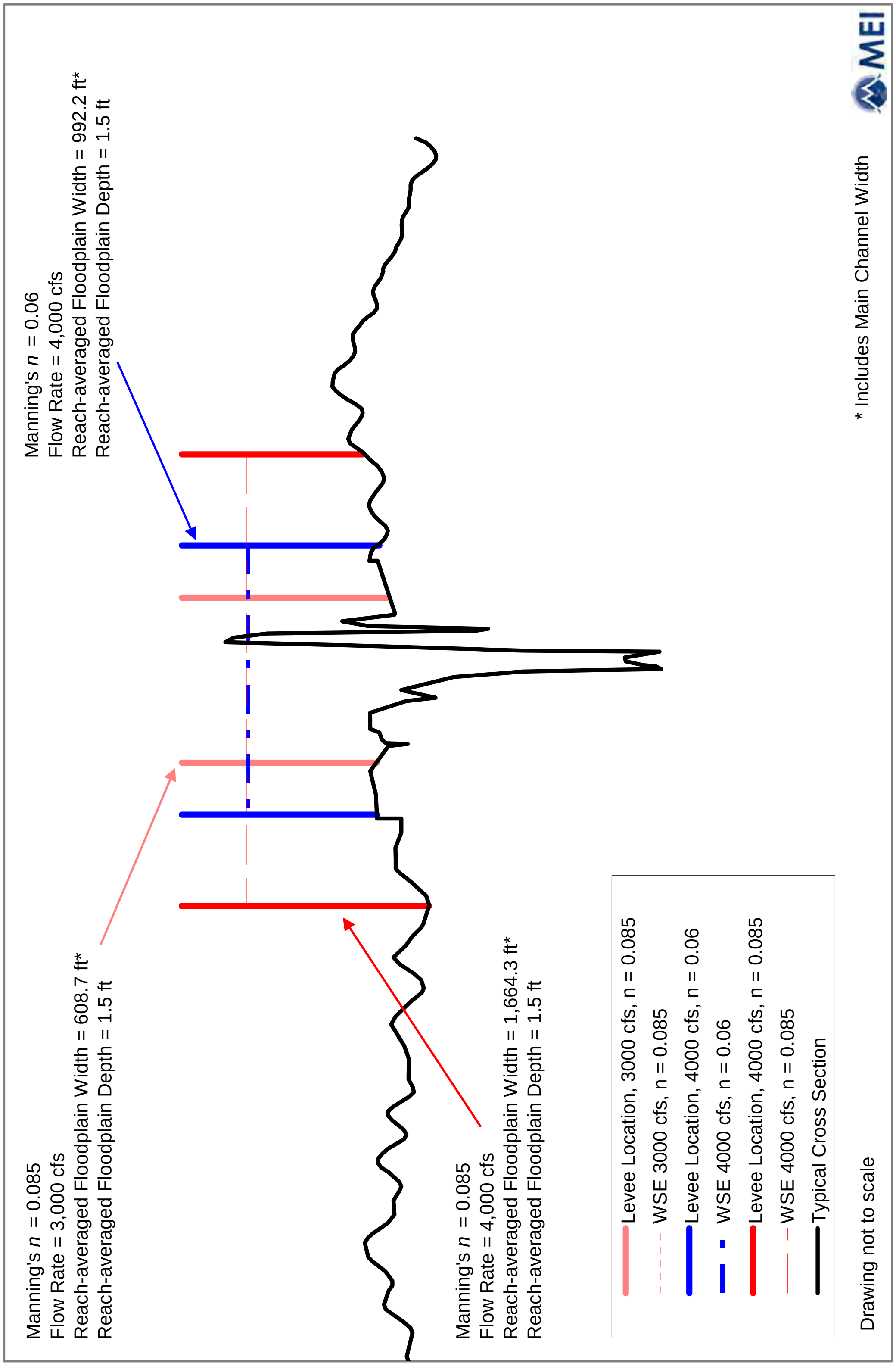

Figure 5-3.
Reach 2B Typical Cross Section (RM 213.82), Levee Locations, and Flows To achieve an Average 1.5-foot Overbank Depth with a Riparian Ribbon of Vegetation (*n* = 0.06 and 0.085)

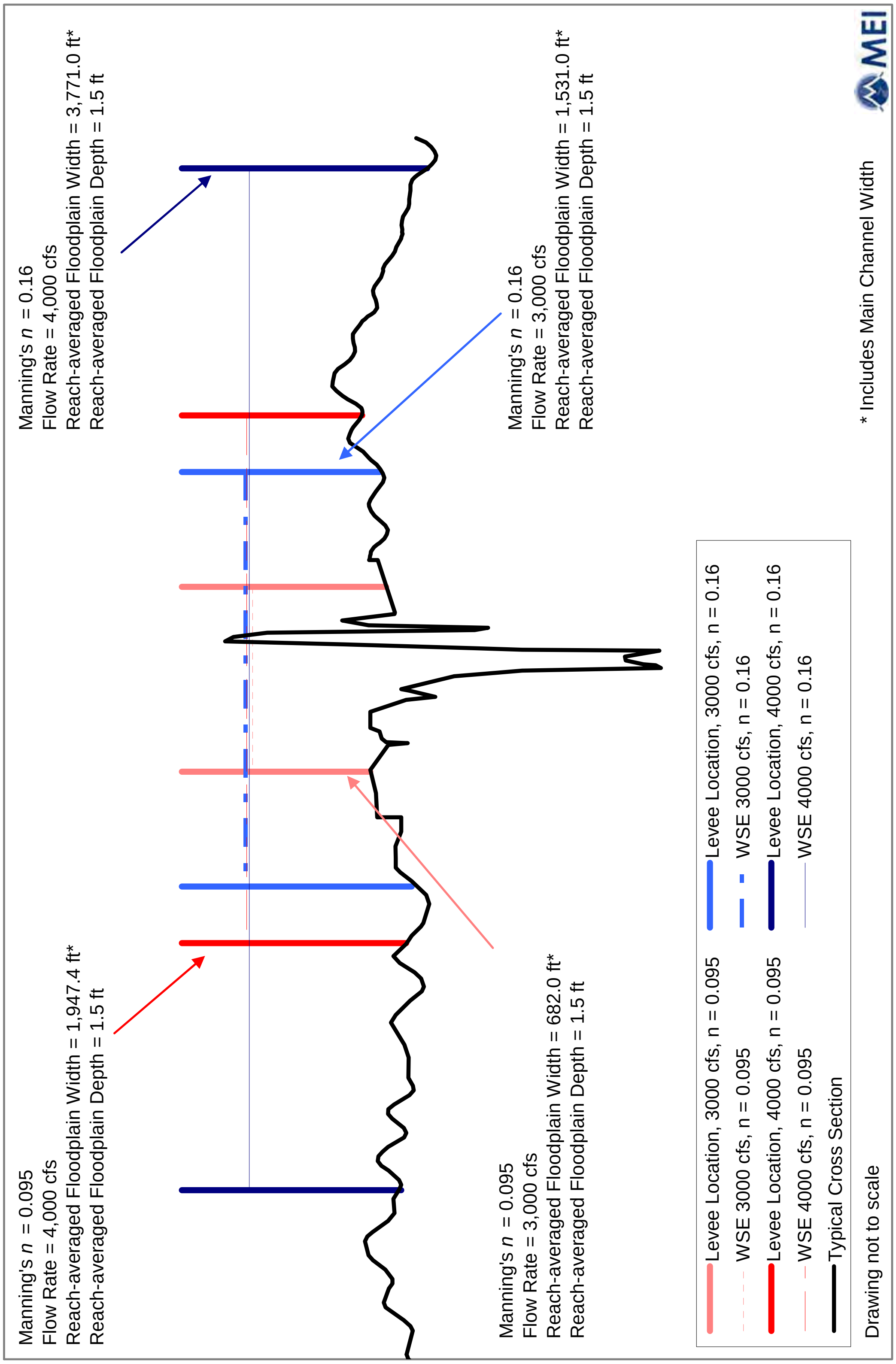

Figure 5-4.
Reach 2B Typical Cross Section (RM 213.82), Levee Locations, and Flows to Achieve an Average 1.5-foot Overbank Depth with a Riparian Forest (*n* = 0.095 and 0.16)

The maximum, minimum, and reach-averaged levee heights for the alignments and floodplain widths outlined in Table 5-1 are presented in Table 5-2. The indicated levee heights were designed to contain a discharge of 4,500 cfs with 3 feet of freeboard. Levee heights were not developed for alignments and scenarios where an average overbank flow depth of 18 inches was not possible. As discharge and roughness increases, the reported average levee heights in Table 5-2 tend to decrease because of the higher ground at wider levee setback alignments.

Table 5-2.
Levee Heights for Reach 2B at a Discharge of 4,500 cfs

Scenario		n	Levee Alignment (cfs)	LEFT Maximum Levee Height (ft)	LEFT Minimum Levee Height (ft)	LEFT Average Levee Height (ft)	RIGHT Maximum Levee Height (ft)	RIGHT Minimum Levee Height (ft)	RIGHT Average Levee Height (ft)
1	Grassy Floodplain	0.04	2,000	--	--	--	--	--	--
			3,000	--	--	--	--	--	--
			4,000	6.1	0.7	4.4	6.8	0.3	4.0
2	Grassy Floodplain	0.055	2,000	--	--	--	--	--	--
			3,000	--	--	--	--	--	--
			4,000	7.3	0.9	4.4	6.8	0.6	4.1
3	Riparian Ribbon	0.06	2,000	--	--	--	--	--	--
			3,000	--	--	--	--	--	--
			4,000	7.5	0.7	4.1	6.3	0.6	4.0
4	Riparian Ribbon	0.085	2,000	--	--	--	--	--	--
			3,000	7.4	1.8	5.3	8.1	1.4	4.8
			4,000	7.1	0.1	4.2	7.0	0.8	4.1
5	Riparian Forest	0.095	2,000	--	--	--	--	--	--
			3,000	7.5	1.9	5.4	8.9	1.6	5.0
			4,000	7.5	0.0	4.2	7.5	0.9	4.0
6	Riparian Forest	0.16	2,000	--	--	--	--	--	--
			3,000	8.2	0.9	5.0	7.9	1.9	4.9
			4,000	7.6	1.3	4.3	7.1	1.1	3.7

Note:
Table 5-2 reports the levee heights associated with a flow of 4,500 cfs through the levee alignments outlined in Table 2-1. Only the levee alignments where a 1.5-foot overbank depth was achieved were used.
Key:
cfs = cubic feet per second
ft = feet

5.2 Reach 4B

The reach-averaged results for Reach 4B for the six vegetation scenarios at three different flow rates are presented in Table 5-3. Similar to Reach 2B, the target average overbank depth was not achievable for all of the scenarios at the minimum floodplain width. It is possible that the overbank depth criteria could be met if the levees were placed closer to the river than for the minimum width scenario used for the analysis; however, this possibility was not specifically addressed in this analysis. The maximum levee setback alignment resulted in average overbank depths greater than 18 inches for the three roughest vegetation scenarios at 4,000 cfs; thus, levee setback alignments greater than the maximum setback would be necessary to produce average overbank depths of 18 inches for these scenarios. The currently available topographic data do not permit detailed evaluation of wider levees setbacks.

Table 5-3.
Reach-Averaged Results for Reach 4B

Scenario		*n*	Flow (cfs)	WSEL (ft)	Floodplain Width* (ft)	Floodplain Depth (ft)	Channel Velocity (ft/s)	Floodplain Velocity (ft/s)
1	Grassy Floodplain	0.04	2,000	95.2	1,680	1.2**	1.16	0.44
			3,000	95.7	2,090	1.5	1.24	0.56
			4,000	95.8	3,260	1.5	1.19	0.54
2	Grassy Floodplain	0.055	2,000	95.4	1,750	1.3**	1.18	0.35
			3,000	95.8	2,530	1.5	1.25	0.41
			4,000	95.8	4,270	1.5	1.20	0.40
3	Riparian Ribbon	0.06	2,000	95.4	1,760	1.3**	1.19	0.33
			3,000	95.8	2,670	1.5	1.25	0.38
			4,000	95.9	4,600	1.5	1.20	0.36
4	Riparian Ribbon	0.085	2,000	95.6	1,810	1.5	1.21	0.25
			3,000	95.8	3,720	1.5	1.24	0.27
			4,000	96.1	4,790	1.7**	1.26	0.29
5	Riparian Forest	0.095	2,000	95.7	1,880	1.5	1.22	0.23
			3,000	95.8	4,060	1.5	1.25	0.24
			4,000	96.2	4,840	1.8**	1.28	0.27
6	Riparian Forest	0.16	2,000	95.7	2,580	1.5	1.22	0.14
			3,000	96.1	4,770	1.7**	1.29	0.16
			4,000	96.7	5,030	2.2**	1.37	0.18

Notes:
* Including the main channel width.
** 1.5-foot overbank depth was not possible for all scenarios within the proposed minimum and maximum levee alignments.
Key:
cfs = cubic feet per second   ft = feet   ft/s = feet per second

The computed water-surface profiles for levee setback alignments yielding average overbank depths of 18 inches are shown in Figure 5-5. A discontinuity in the water-surface profile occurs near RM 157 at the Turner Island Road Bridge at high flows and high roughness conditions due to backwater associated with the bridge.

Figures 5-6 through 5-8 show typical cross sections in Reach 4B as with the average floodplain widths, water-surface elevations, and levee locations for the three vegetation scenarios. For the grassy flood plain scenarios, a discharge of 2,000 cfs did not achieve average overbank flow depths of 18 inches even at the minimum setback levee alignment for either roughness value. The reach-averaged floodplain widths required to meet the criteria at 3,000 cfs ranged from 2,087 feet (*n* = 0.04) to 2,527 feet (*n* = 0.055). At 4,000 cfs, the reach-averaged floodplain widths for the high and low overbank roughness value were wider and ranged from 3,263 to 4,267 feet.

For the riparian ribbon scenario, average overbank flow depths of 18 inches were not achieved at the minimum setback levee alignment at 2,000 cfs at the low roughness values, and a width of 1,810 feet necessary at the high roughness value. Floodplain widths ranging from 2,665 (low roughness) to 3,720 feet (high roughness) were necessary to meet the depth criteria at 3,000 cfs. At the increased roughness of *n* = 0.085, a discharge of 4,000 cfs produced average overbank flow depths greater than 18 inches at the maximum levee alignment.

For the riparian forest scenario, overbank flow depths at the maximum levee setback alignment exceeded the target overbank flow depth of 18 inches at 3,000 cfs for the high roughness conditions and at 4,000 cfs for both roughness conditions. Flow rates of 3,000 cfs produced mixed results. For 3,000 cfs, the depth criteria were met with an average floodplain width of 4,060 feet. At 2,000 cfs, the depth criteria were met with average floodplain widths ranging from 1,880 (low roughness) to 2,582 feet (high roughness).

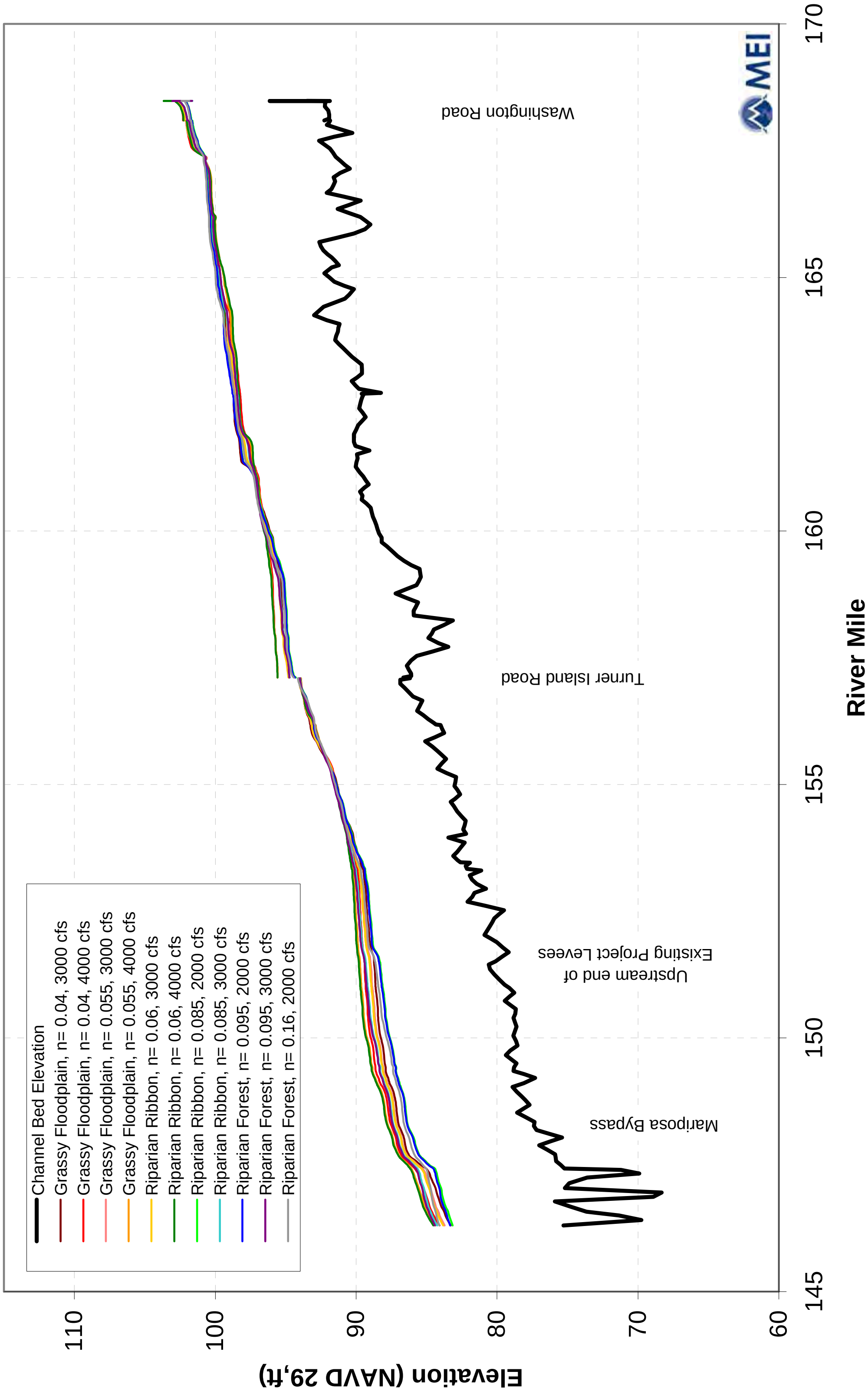

Figure 5-5.
Water-surface profiles for the range of flows, vegetation conditions, and associated levee alignments in Reach 4B.

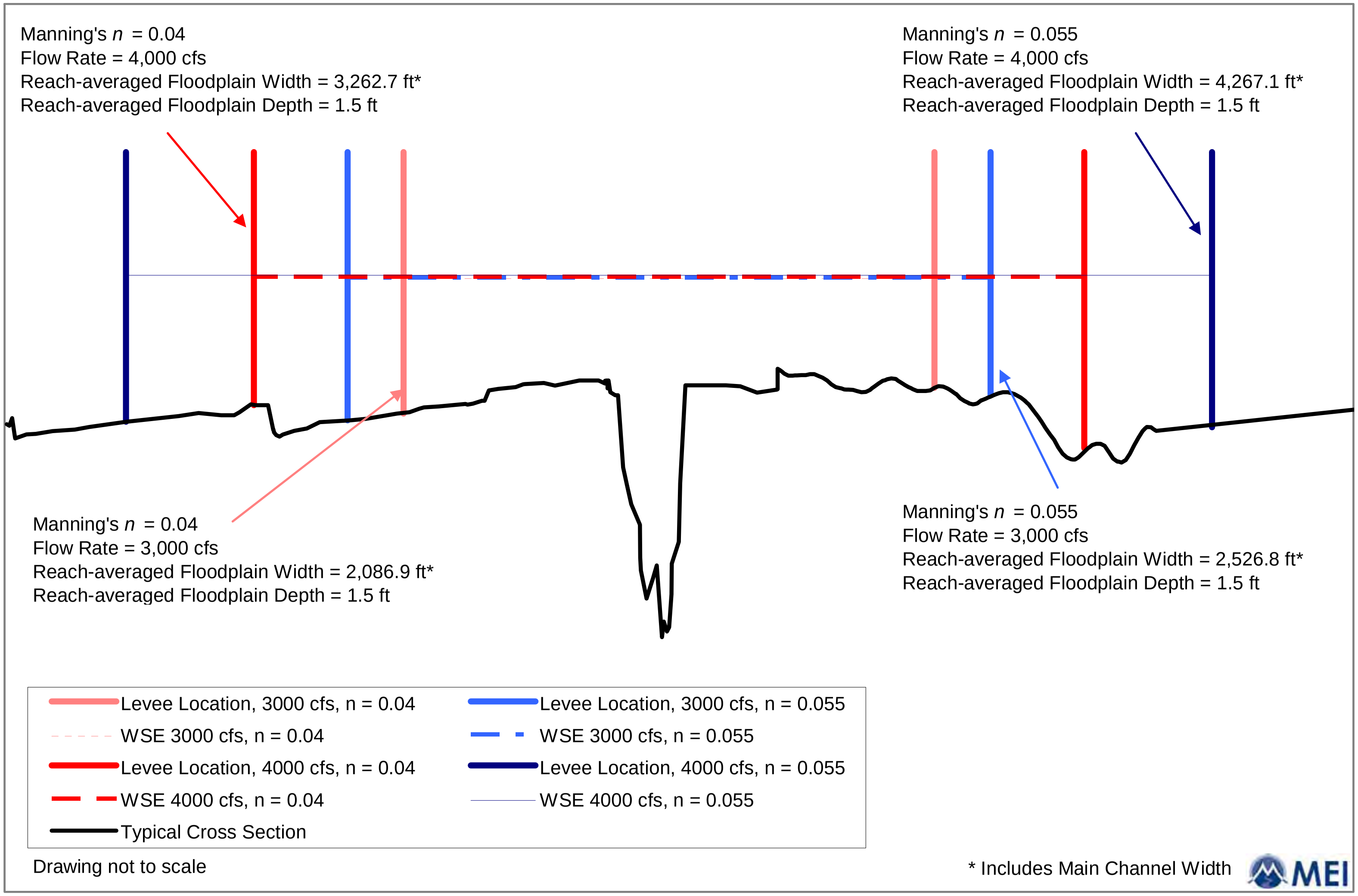

Figure 5-6.
Reach 4B Typical Cross Section (RM 162.5), Levee Locations, and Flows to Achieve an Average 1.5-foot Overbank Depth for a Grassy Floodplain (*n* = 0.04 and 0.055)

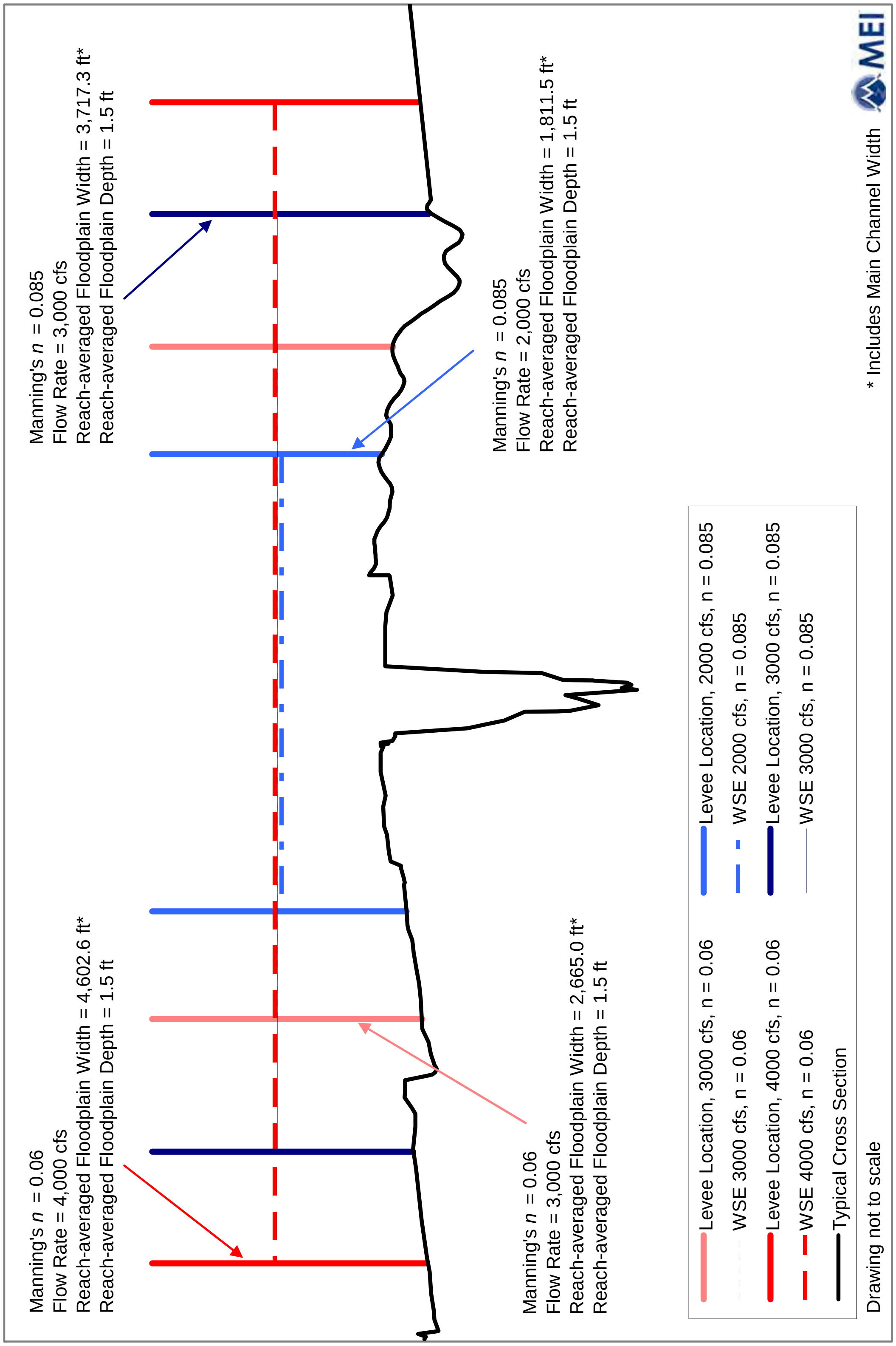

Figure 5-7.
Reach 4B Typical Cross Section (RM 162.5), Levee Locations, and Flows to Achieve an Average 1.5-foot Overbank Depth with a Riparian RIBBON of Vegetation (*n* = 0.06 and 0.085)

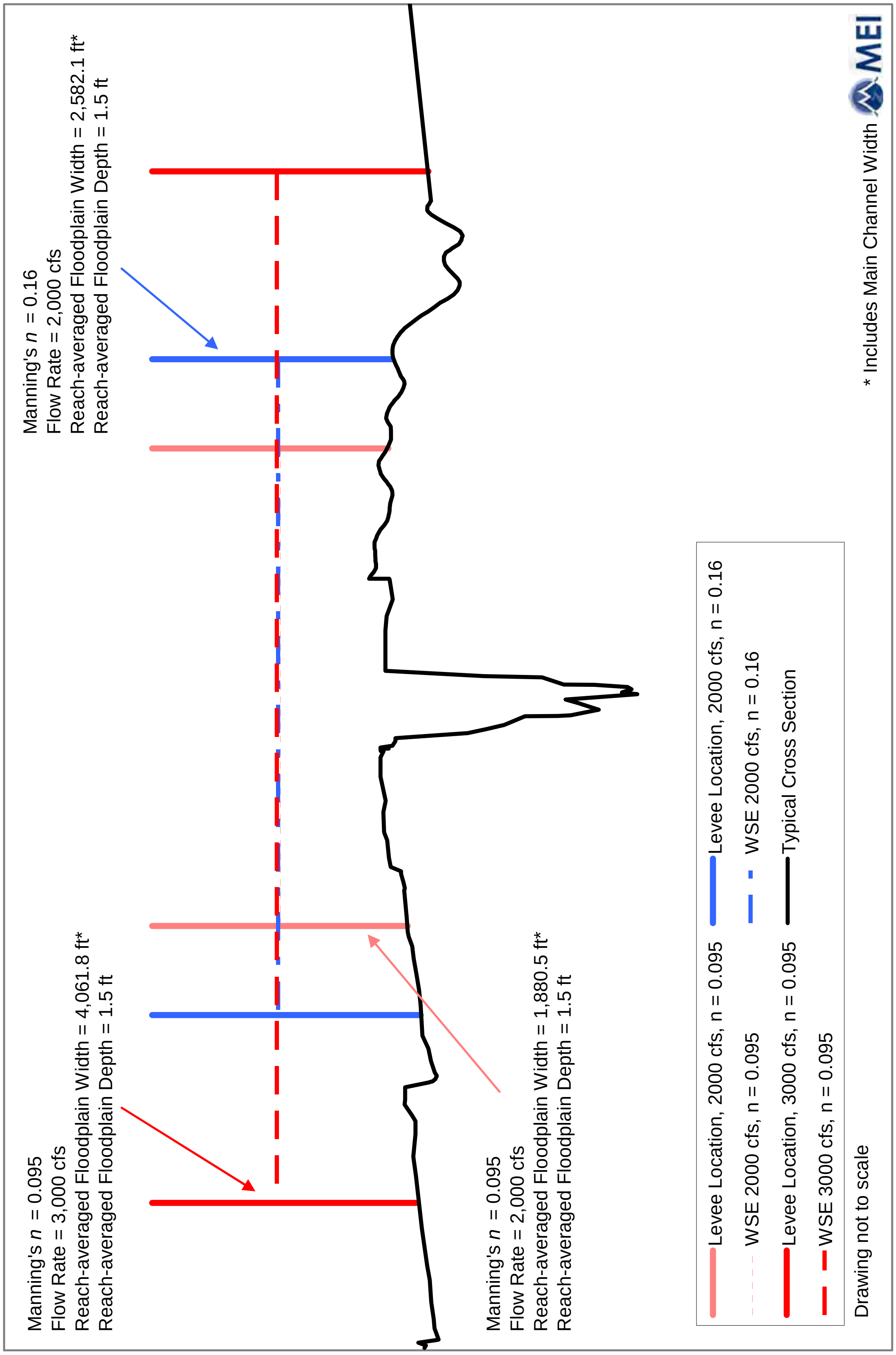

Figure 5-8.
Reach 4B Typical Cross Section (RM 162.5), Levee Locations, and Flows to Achieve an Average 1.5-foot Overbank Depth with a Riparian Forest (*n* = 0.095 and 0.16)

The maximum, minimum, and reach-averaged levee heights for Reach 4B for the alignments and floodplain widths outlined in Table 5-3 are presented in Table 5-4. The indicated levee heights were designed to contain a discharge of 4,500 cfs with 3 feet of freeboard. Levee heights were not developed for alignments and scenarios where an average overbank flow depth of 18 inches was not possible. As discharge and roughness increases, the reported average levee heights in Table 5-4 tend to decrease because of the higher ground at wider levee setback alignments.

Table 5-4.
Levee Heights for Reach 4B at a Discharge of 4,500 cfs

Scenario		*n*	Flow (cfs)	LEFT Maximum Levee Height (ft)	LEFT Minimum Levee Height (ft)	LEFT Average Levee Height (ft)	RIGHT Maximum Levee Height (ft)	RIGHT Minimum Levee Height (ft)	RIGHT Average Levee Height (ft)
1	Grassy Floodplain	0.04	2,000	--	--	--	--	--	--
			3,000	7.6	0.7	4.1	10.8	3.1	4.5
			4,000	7.1	0.4	3.9	7.6	2.5	4.3
2	Grassy Floodplain	0.055	2,000	--	--	--	--	--	--
			3,000	7.1	1.4	4.4	7.9	2.7	4.9
			4,000	7.4	0.2	4.2	7.8	3.0	4.4
3	Riparian Ribbon	0.06	2,000	--	--	--	--	--	--
			3,000	7.6	1.6	4.3	8.6	2.6	4.8
			4,000	7.3	0.1	4.1	7.7	3.1	4.4
4	Riparian Ribbon	0.085	2,000	8.6	2.8	5.2	9.1	2.8	5.4
			3,000	7.6	1.0	4.7	8.4	3.4	4.9
			4,000	--	--	--	--	--	--
5	Riparian Forest	0.095	2,000	8.6	2.4	5.2	11.4	3.4	5.5
			3,000	8.0	1.0	4.7	8.4	3.6	5.0
			4,000	--	--	--	--	--	--
6	Riparian Forest	0.16	2,000	8.6	2.8	5.4	9.6	4.0	5.9
			3,000	--	--	--	--	--	--
			4,000	--	--	--	--	--	--

Notes:
Table 5-4 reports the levee heights associated with a flow of 4,500 cfs through the levee alignments outlined in Table 2-1. Only the levee alignments where a 1.5-foot overbank depth was achieved were used.

Key:
cfs = cubic feet per second
ft = feet

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6.0 Summary

A sensitivity analysis of potential levee setback alignments over a range of floodplain roughness conditions was performed to provide information to the SJRRP Alternatives Formulation Group concerning floodplain width requirements to produce a target overbank depth of 18 inches at flow rates of 2,000, 3,000 and 4,000 cfs. The range of floodplain roughness represents the possible vegetated conditions from highly maintained with minimal woody vegetation to little or no maintenance that would result in a riparian forest. In general, as the floodplain roughness increased, the floodplain width required to achieve an average overbank flow depth of 18 inches increased. For a given roughness, as the discharge increased the floodplain width required to achieve the target flow depth increased. A discharge of 2,000 cfs was insufficient to create average overbank flow depths of 18 inches in Reach 2B and all but the roughest scenarios in Reach 4B. Additionally, in Reach 4B, overbank flow depths exceeding 18 inches occurred at 4,000 cfs for the maximum floodplain setback for the roughest vegetation conditions cfs.

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7.0 References

MEI. *See* Mussetter Engineering, Inc.

Mussetter Engineering, Inc. (MEI). 2002. Hydraulic Model of Mendota Pool Bypass. Prepared for Stillwater Sciences for the Friant Water Users Authority and Natural Resources Defense Council, September 18.

———. 2007. San Joaquin River Reach 2B Channel and Overbank Capacity Improvements. Technical Memorandum prepared for the California Dept. of Water Resources, Fresno, California, December 21.

———. 2008a. San Joaquin River Reach 4B Channel and Overbank Capacity Improvements. Technical Memorandum prepared for the California Dept. of Water Resources, Fresno, California, January 23.

———. 2008b. San Joaquin River Floodplain Sensitivity Analysis. Technical Memorandum prepared for the California Dept. of Water Resources, Fresno, California, August 27.

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Attachment

Friant Dam Releases for Restoration Flows

Draft
Plan Formulation Appendix

SAN JOAQUIN RIVER
RESTORATION PROGRAM

Draft
April 2011

Table of Contents

Tables

Figures

List of Abbreviations and Acronyms

°F	degrees Fahrenheit
cfs	cubic feet per second
cm	centimeter
CVP	Central Valley Project
Delta	Sacramento-San Joaquin Delta
DWR	California Department of Water Resources
FWA	Friant Water Authority
NRDC	Natural Resources Defense Council
PEIS/R	Program Environmental Impact Statement/Report
RA	Restoration Administrator
Reclamation	U.S. Department of the Interior, Bureau of Reclamation
RFG	Restoration Flow Guidelines
RWA	Recovered Water Account
Settlement	San Joaquin River Settlement
SJRRP	San Joaquin River Restoration Program
SWP	State Water Project
SWRCB	State Water Resources Control Board
TA	Technical Appendix
TAF	thousand acre-feet
TM	Technical Memorandum

1.0 Introduction

This Friant Dam Releases for Restoration Flows Attachment to the Plan Formulation Appendix was prepared in support of the San Joaquin River Restoration Program (SJRRP). This attachment provides context for describing the release of Restoration Flows from Friant Dam, and is intended to supplement the evaluation of program alternatives for the Program Environmental Impact Statement/Report (PEIS/R).

1.1 Purpose and Scope of this Attachment

This attachment 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 (Paragraphs13(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.

This attachment is organized as follows:

Section 1 introduces the attachment and presents its purpose and scope, and additional operations considerations.

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

Section 3 presents a digest of relevant expert testimony on ecological intentions.

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

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

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

Section 7 lists the remaining concepts and procedures needed for full implementation of the actions to reoperate Friant Dam for Restoration flow periods, which are summarized in Section 1.2.

Section 8 contains the sources used to compile this document.

1.2 Additional Operational Considerations

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

- Procedures and protocols for implementing recommendations from the Restoration Administrator (RA) and/or other advisory parties (Exhibit B). These are addressed in the *Restoration Flow Guidelines*, which will be an attachment to the *Operational Guidelines for Water Service – Friant Division Central Valley Project* (Reclamation 2005).

- Development of methodology and procedures for seepage evaluation (Paragraph 13(j)(iv)) and other measurement procedures and monitoring requirements (Paragraph 13(j)(ii)). These are addressed in the *Physical Parameters Monitoring Plan* and in four *Monitoring and Management Plan* documents for conveyance, seepage, sediment, and vegetation.

- Framework for developing a plan to achieve the Water Management Goal and details of plan components, including management of the Recovered Water Account (RWA) (Paragraph 16). These topics are addressed at a programmatic level within the PEIS/R and in the *Restoration Flow Guidelines*, and will be 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.

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

Line 25, Page 16

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

Line 5, Page 23

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

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

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

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3.0 Ecological Goals and Objectives for Restoration Flows

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

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

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

3.2.1 Chinook Salmon Life Stage Needs

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

3.2.2 Other Native and Nonnative Fish

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

3.2.3 Geomorphic Processes

The flow schedules are intended to achieve mobilization of spawning gravels to maintain gravel quality. Gravel should be movable by female salmon, have a loose texture, and be free of sediment so that eggs receive adequate intragravel flow and dissolved oxygen (Kondolf testimony, page 15). Gravel mobilization requires pulses of high discharge to transport bed material and entrained sediment. Such "flushing flows" are commonly considered to be needed approximately every 2 years on average (Kondolf and Wilcock 1996, Kondolf 1998; both cited in Kondolf testimony page 16).

3.2.4 Riparian Vegetation Recruitment and Maintenance

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

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

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	1,500	1,500	1,500	1,500	1,500
4/1–4/15	150	200	350	2,500	2,500	2,500
4/16–4/30	150	200	350	350	4,000	4,000

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.

Fish Goals

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

Geomorphic Goals

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

Riparian Vegetation Goals

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

3.3.3 Summer Base Flow

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

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	2,000
7/1–8/31	230	255	350	350	350	350

Key:
cfs = cubic feet per second

Ecological Objectives

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

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

Fish Goals

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

Riparian Vegetation Goals

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

3.3.4 Spring-Run Spawning Flow

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

Table 3-3.
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

Ecological Objectives

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

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

Fish Goals

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

3.3.5 Fall Base and Spring-Run Incubation Flows

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

Table 3-4.
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

Ecological Objectives

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

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

Fish Goals

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

3.3.6 Fall-Run Attraction Flow

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

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

Ecological Objectives

The following list summarizes ecological objectives identified in the next subsection.

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

Fish Goals

A 400–500 cfs pulse flow at the mouth of the Merced River, for 10 days, including 2 days for ramping up and down at each end, is designed to bring adult fall-run Chinook salmon upstream to spawn (USFWS 1994, cited in Kondolf testimony pages 15, 19–20; Moyle testimony page 47). The exact time of the pulse would be based on monitoring for the presence of fall-run Chinook at the Merced River. The duration of the release is based in part on estimated travel times of adult fall-run Chinook salmon to the potential spawning areas in Reach 1 (3–7 days). This pulse should also enable some spring-run Chinook salmon fry to emigrate (as they do in Butte Creek) (Moyle testimony page 47).

3.3.7 Fall-Run Spawning and Incubation Flow

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

Table 3-6.
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

Ecological Objectives

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

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

Fish Goals

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

3.3.8 Winter Base Flow

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

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
n/a = not applicable

Ecological Objectives

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

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

Fish Goals

Winter Base Flows were designed to achieve water temperatures of 48–55°F for fall-run Chinook salmon egg incubation and less than or equal to 68°F for fry/juvenile rearing of both runs of Chinook salmon in Reach 1 (Moyle et al. 1995, McCullough 1999, Moyle 2002, Ward et al. 2002, 2003, Stillwater Sciences 2003, Marine and Cech 2004, all cited in Moyle testimony pages 36–39, 58; Deas testimony page 27). A base flow of 350 cfs is also needed to maintain wetted spawning habitat in Reach 1 (i.e., flow over redds) throughout the incubation period (Moyle testimony page 48; McBain and Trush 2002, Cain et al. 2003, both cited in Kondolf testimony pages 20-21), as well as to provide 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 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 attachment) are “Critical-Low,” “Critical-High,” “Dry,” “Normal-Dry,” “Normal-Wet,” and “Wet.”

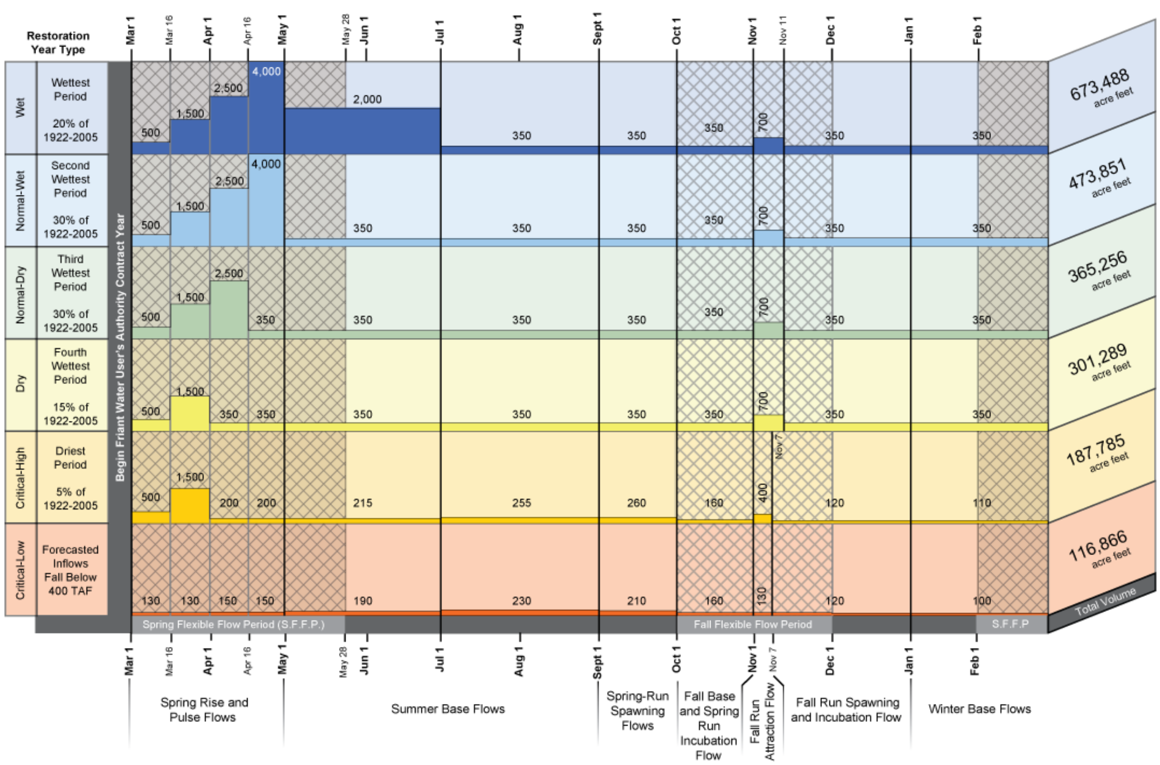


Figure 4-1.
Restoration Flow Schedules, by Restoration Year Type,
Exhibit B Stair-Step Allocation Method

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

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

- Classification thresholds
- Beginning date for year type application and corresponding Restoration Flows schedule

4.2 Classification Thresholds

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

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

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

San Joaquin River Settlement Restoration Year Type	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 Critial years, those with less than 400 TAF of unimparied 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; and
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.

Key: TAF = thousand acre-feet

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

For example, the Restoration Year Type classification changes from a Normal-Wet year type to a Wet year type between the historical runoff volumes associated with 1922 (2,355,000 acre-feet) and 1958 (2,631,000 acre-feet). Because hydrological conditions in the years after 2004 are not likely to be the same as those from1922 through 2004, it is necessary to define a set of thresholds for Restoration Year Type classification that is consistent with the classification in the Settlement.

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

- Wet equal to or greater than 2,500,000 acre-feet
- Normal-Wet equal to or greater than 1,450,000 acre-feet
- Normal-Dry equal to or greater than 930,000 acre-feet
- Dry equal to or greater than 670,000 acre-feet
- Critical-High equal to or greater than 400,000 acre-feet
- Critical-Low less than 400,000 acre-feet

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

4.3 Review of Hydrologic Forecasts

DWR uses a composite approach to produce 10-, 50- and 90-percent forecasts. The 50-percent forecast is produced from snow survey data, using correlations between historical flows and snow survey data. However, the 90- and 10-percent forecasts are produced by imposing a range of likely inflows around the 50-percent forecast.

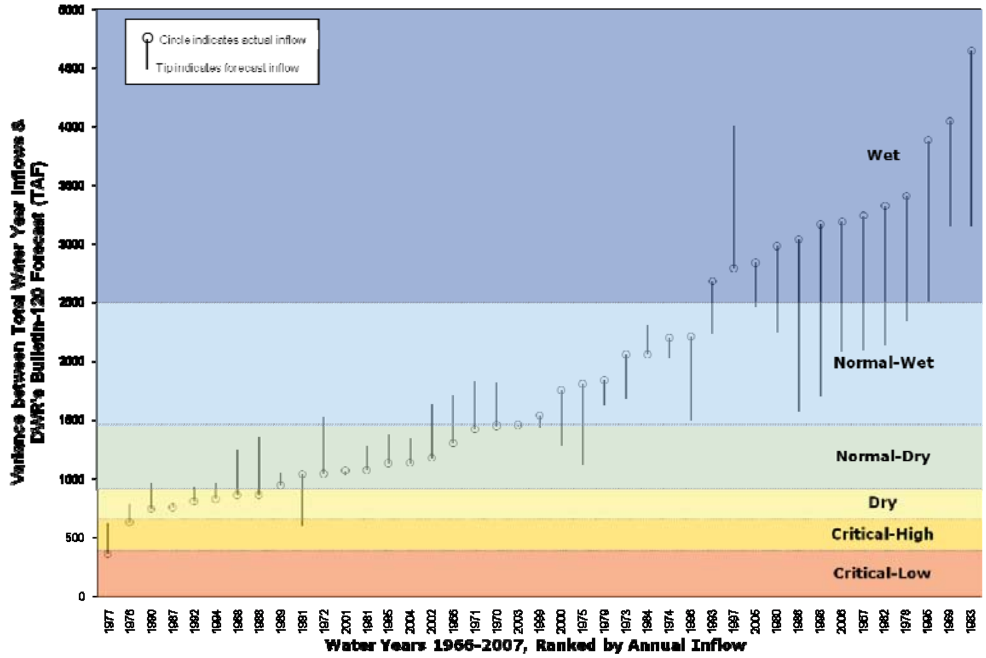
The envelope is defined with data from the previous 50 years, and reflects 10- and 90-percent deviations from the 50-percent forecast that have occurred during the remaining portions of the year. The timing and volumes of the 90^{th} and 10^{th} percentile forecasts are distributed across the forecast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

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

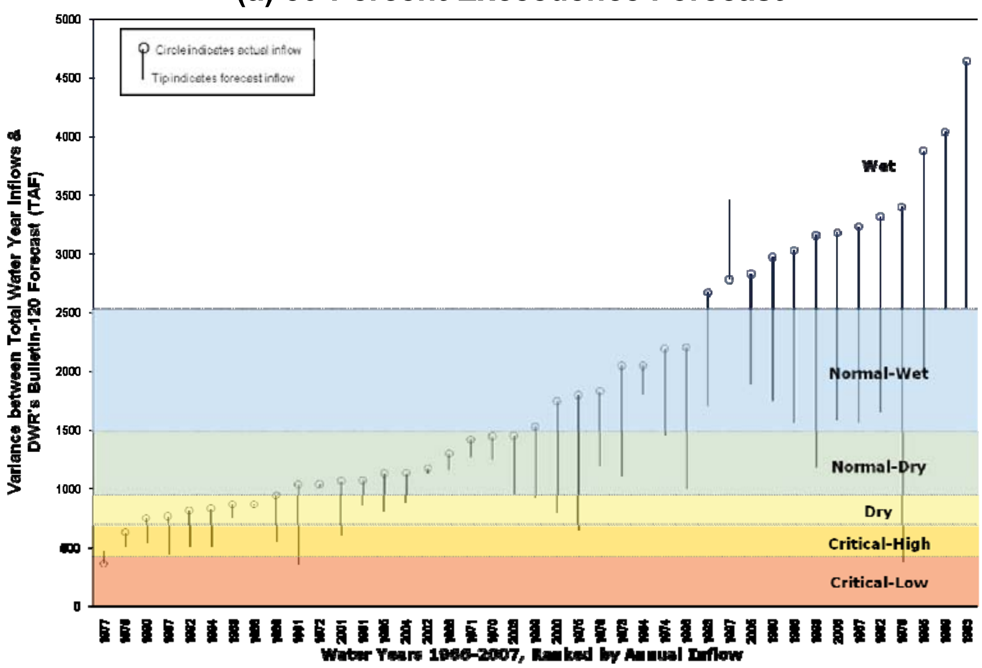
Figures 4-2 through 4-5 compare the historical annual unimpaired flow of 1966 through 2007, the common period for available 50-percent and 90-percent forecast data by DWR, with corresponding February, March, April, and May forecasts. Each page presents a comparison of a single month's 50-percent and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

Several observations on forecast quality are summarized as follows:

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

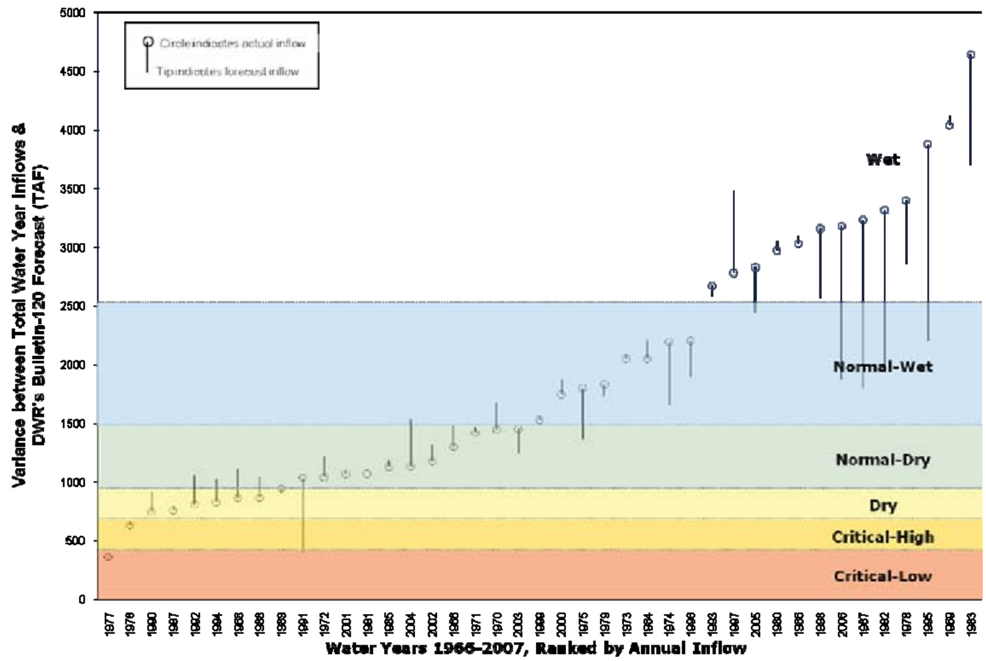


(a) 50-Percent Exceedence Forecast

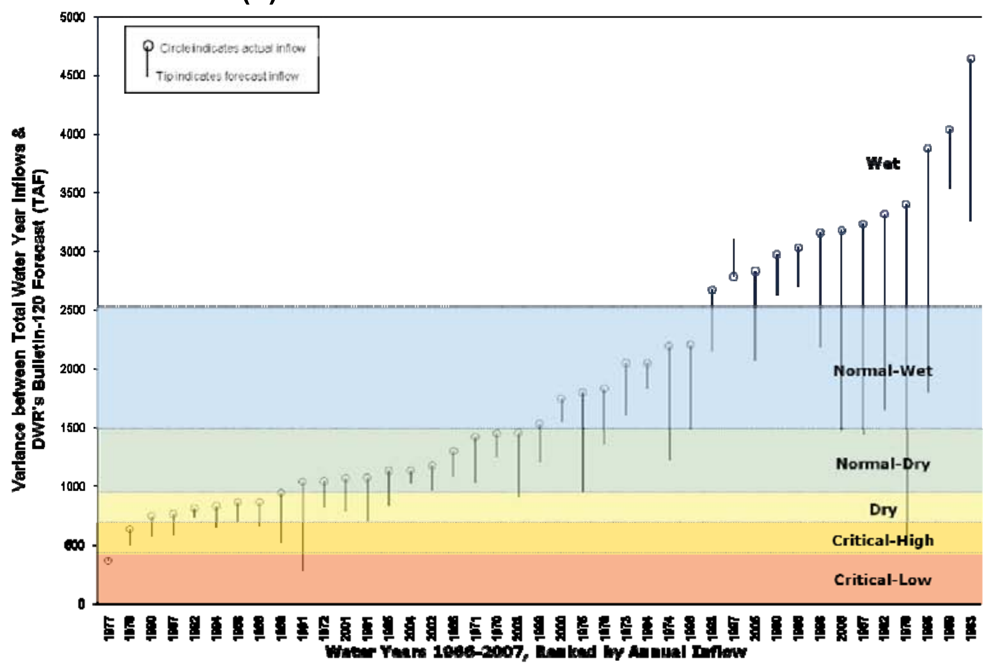


(b) 90-Percent Exceedence Forecast

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

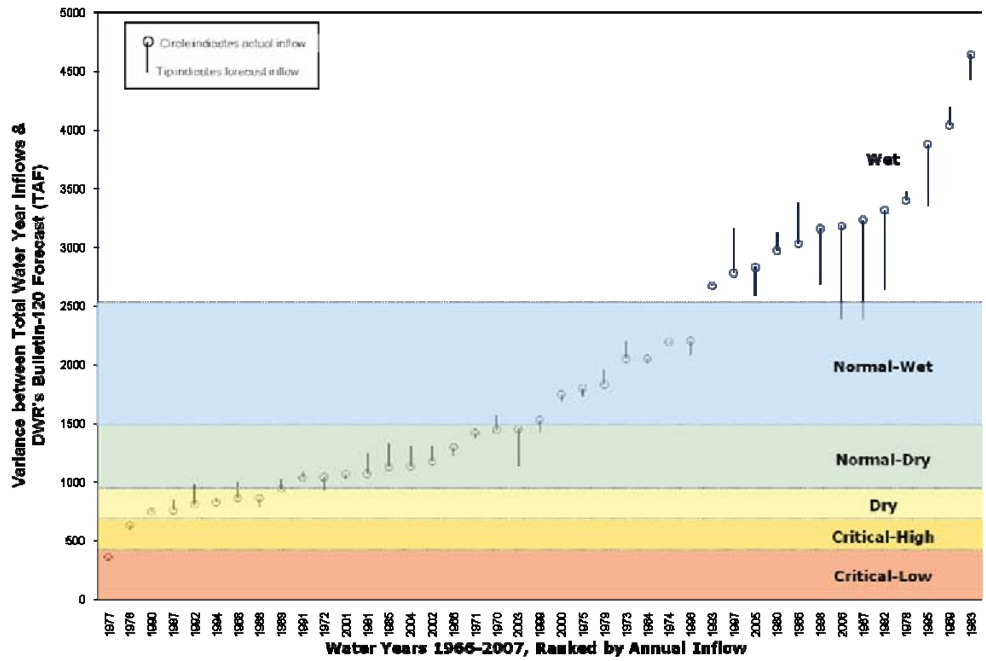


(a) 50-Percent Exceedence Forecast

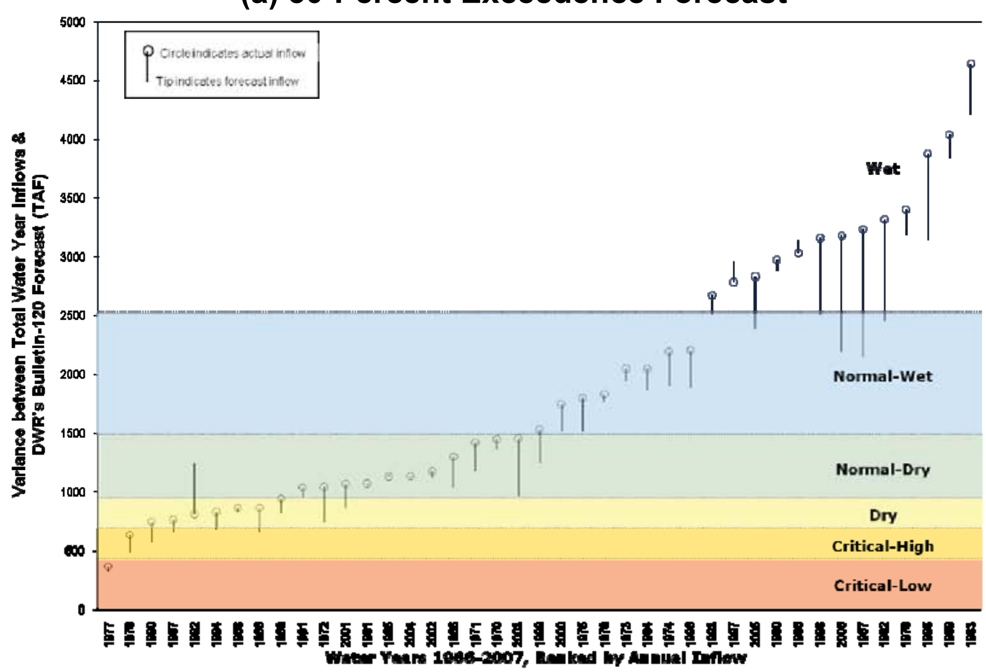


(a) 90-Percent Exceedence Forecast

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

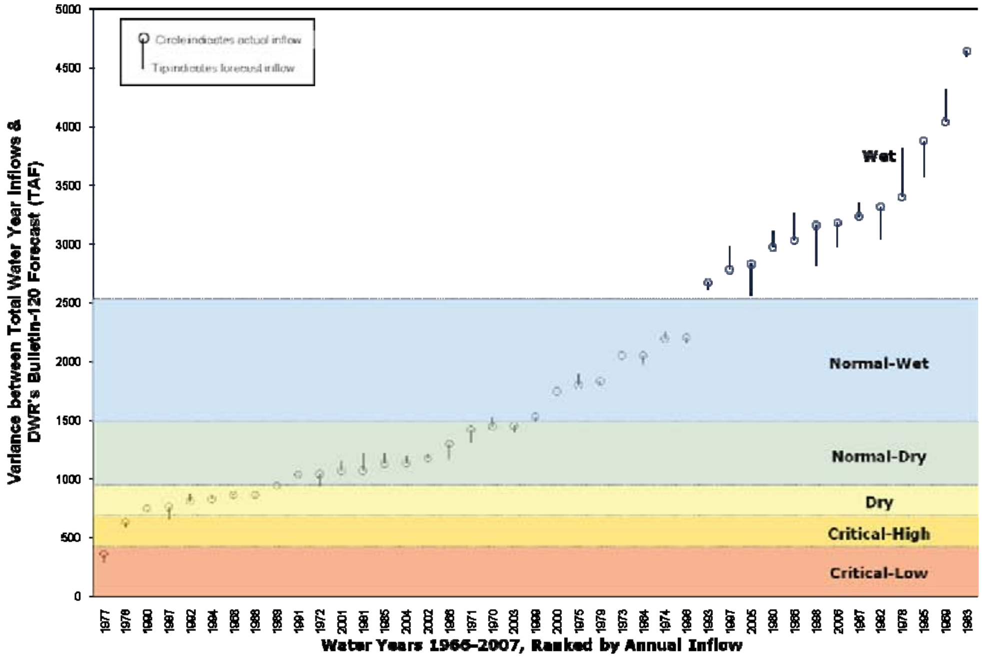


(a) 50-Percent Exceedence Forecast

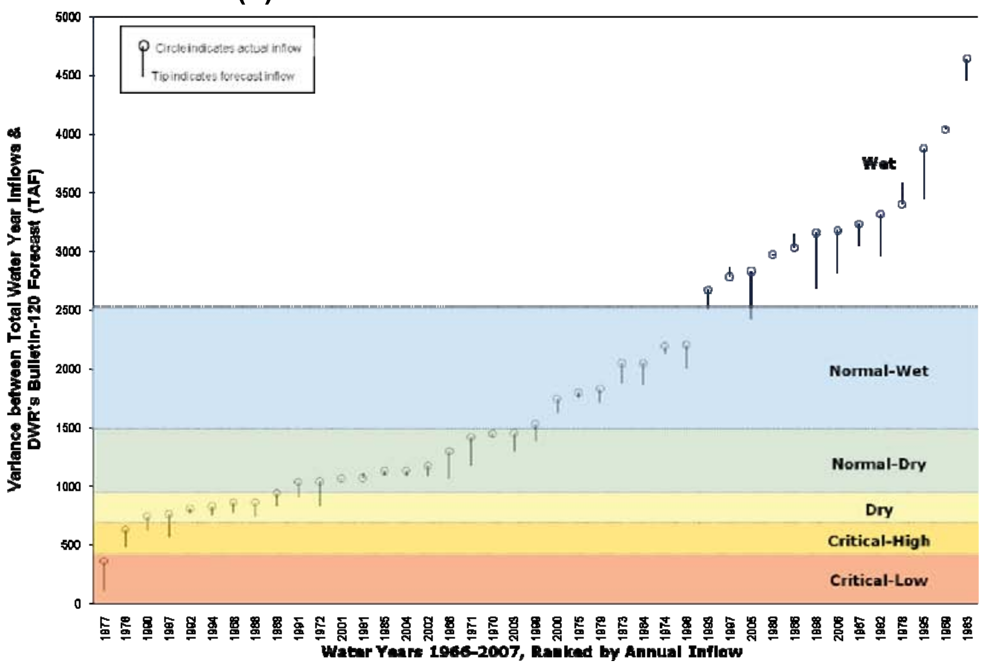


(b) 90-Percent Exceedence Forecast

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



(a) 50-Percent Exceedence Forecast



(b) 90-Percent Exceedence Forecast

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

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

Table 4-3.
Summary of Bulletin 120 Forecast for San Joaquin River Unimpaired Inflow Below Friant Dam from 2001 Through 2006 (in TAF)

	Forecast	Forecast Period															
Year	Month	Apr-Jul	% Error	Feb	% Error	Mar	% Error	Apr	% Error	May	% Error	Jun	% Error	Jul	% Error	Aug-Sept	% Error
2001	Feb	730	-8%	65	55%	105	-17%	190	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	870	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%	200	-19%	380	18%	280	26%	100	89%	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	67%
	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	-28%					240	52%	290	-33%	180	-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	1,050	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	-28%	565	-15%	250	-27%	90	0%
	Mar	1,720	-17%			200	-12%	310	21%	610	-25%	565	-15%	235	-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**	

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

4.4 Considerations for Restoration Flow Application

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

4.4.1 Existing Allocation Practice for Friant Division Contractors

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

The existing contract allocation practices for the Friant Division allow Reclamation to exercise its discretion in using a forecast within the range of 50 to 90 percent of exceedence (Reclamation 2005). Contract allocations are based on the review of several forecasts, which combine estimates of snow accumulation, antecedent conditions, and a statistical range of precipitation predictions. Using discretion, Reclamation tends to establish initial allocations in February by using higher probability forecasts (i.e., an expectancy that forecasted runoff would have a 90-percent exceedence) early in the year, and when dry conditions have prevailed. In years with wet conditions, with surplus water or possible flood control releases, an initial forecast might favor a lower percent of exceedence because the negative consequences of overestimating runoff and allocations are potentially great.

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

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

4.4.2 Availability of Hydrologic Forecasts

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

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

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

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

4.4.3 Considerations when Using Forecasts for Setting Restoration Flows

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

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

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

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

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

4.4.4 Consideration of Chinook Salmon

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

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

Spring-Run Life Cycle Timing

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

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

Fall-Run Life Cycle Timing

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

Restoration Flow Schedule Concerns Related to Chinook Timing

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

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

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

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

4.4.5 March 1 as Begin Date for Restoration Flow Scheduling

March 1 was selected as the beginning date for Restoration Year Type classification and, more importantly, the beginning date for the resulting annual Restoration Flow scheduling and accounting processes.

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

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

- From a practical viewpoint, the first determination of Restoration Year Type and flow schedules could be in mid-February, when DWR *Bulletin 120* forecast information becomes available. Before the February forecast, information is insufficient for a determination.

- Based on review of historical forecasts, February forecasts are subject to a much greater margin of error than preceding months, subjecting year type determinations to a greater risk of misclassification. From a fisheries management viewpoint, it is preferable to maintain established winter flows through March to avoid a risk of dewatering redds. Reviewing the Restoration Flow schedules in Figure 4-1, March Restoration Flows of all year types (except Critical-Low years) are higher than 350 cfs, the maximum of February Restoration Flows for all year types. Therefore, the risk of dewatering the redds due to misclassification of year type using early forecast information can be avoided completely by delaying the beginning point of the new year until March.

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

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

4.4.6 Consideration of Flood Releases

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

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

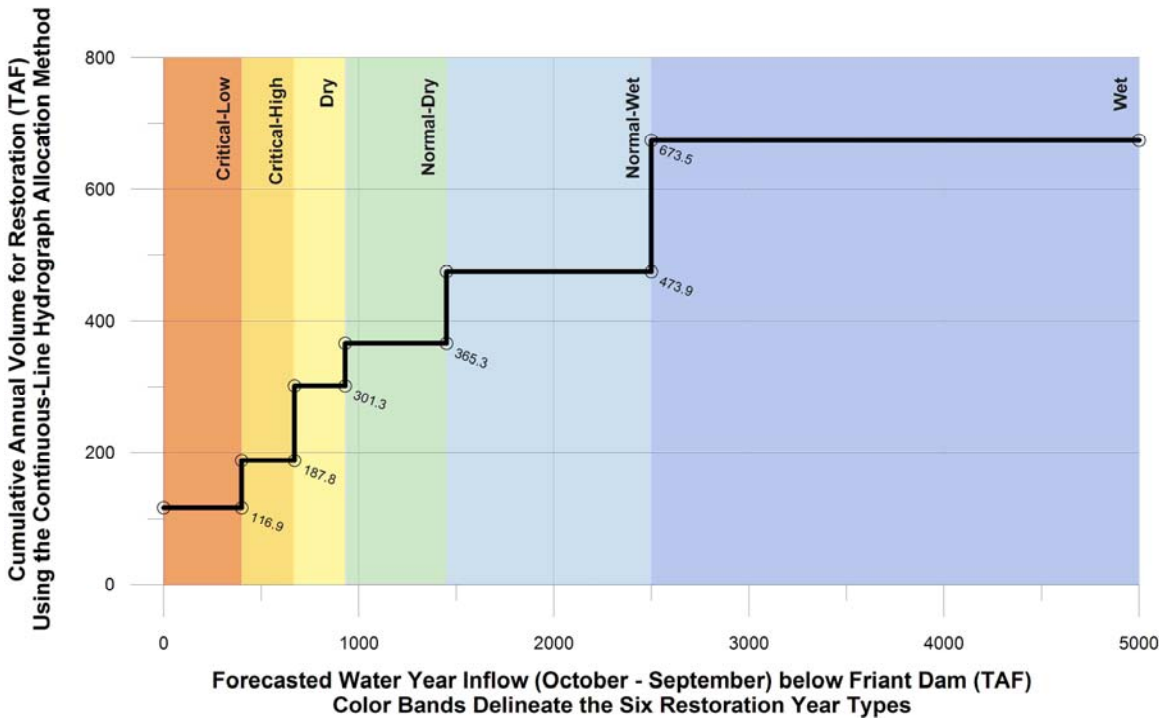


Figure 5-1.
Continuous Annual Allocation Method for Restoration Flows Following the Exhibit B Stair-Step Method

5.2 Continuous Methods Evaluation

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

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

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

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

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

- 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.

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

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

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

5.3 Annual Allocation Methods

5.3.1 Exhibit B Annual Allocation Method 1

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

Advantages

Advantages of Method 1 are as follows:

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

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

Disadvantages

Disadvantages of Method 1 are as follows:

- Potential significant changes in volume allocation could occur due to mid-year changes in hydrologic forecast and thus, year type classification.
- Rigid volume allocation for each year type could result in missed opportunities for improving overall accomplishments in both Restoration and Water Management goals from hydrologic variation within a year type.

5.3.2 Annual Allocation Method 2

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

- The Restoration Flow volume for Critical-Low years is the existing release from Friant Dam for downstream riparian water right diversions, and can be used as the starting point for developing the piece-wise linear function for annual volume.
- The Critical-Low year type was classified to be any year when unimpaired San Joaquin River flow below Friant Dam is less than 400,000 acre-feet (see Section 2). A Critical-High year type was classified to be any year when unimpaired San Joaquin River flow below Friant Dam is between 400,000 acre-feet and 670,000 acre-feet, with a midpoint unimpaired inflow of 535,000 acre-feet. Considering that the midpoint unimpaired inflow of 535,000 acre-feet is the representative condition for Critical-High years, it is assumed that the corresponding volume of Restoration Flows would be the volume of 187,000 acre-feet, as prescribed by the stair-step hydrograph for the Critical-High years.
- A line can be drawn through the following two points:
  - The point corresponding to the Critical-High midpoint unimpaired inflow (535,000 acre-feet) and Restoration Flow volume of 187,000 acre-feet
  - The boundary condition for Critical-Low years with unimpaired flow of 400,000 acre-feet and Restoration Flow requirements of 117,000 acre-feet
- The linear function for determining Restoration Flow volume for Critical-High year types can be completed by extending a line from the dry end of the Critical-High forecast/allocation (400 TAF/117 TAF), through the identified midpoint's forecast/allocation (535 TAF/187 TAF) , to the high-end range of the Critical-High years (670,000 acre-feet). The resulting Restoration Flow, for the high end of the Critical-High year type range, is 257,000 acre-feet.

- This mathematical procedure continues for the Dry, Normal-Dry, and Normal-Wet year type ranges.
- For Wet years, no median reference point exists for the above linear process. Therefore, it is recommended that the original stair-step hydrograph volume of 673,000 acre-feet be used whenever unimpaired inflow is estimated to equal or exceed 2,500 TAF. This would result in an abrupt change in hydrograph volume, at a much reduced scale, when the annual unimpaired flow forecast suggests a change from a Normal-Wet to a Wet Restoration Year Type. However, associated concerns over the abrupt change in Restoration Flow volume for water supply and fishery management are less in years of high runoff.

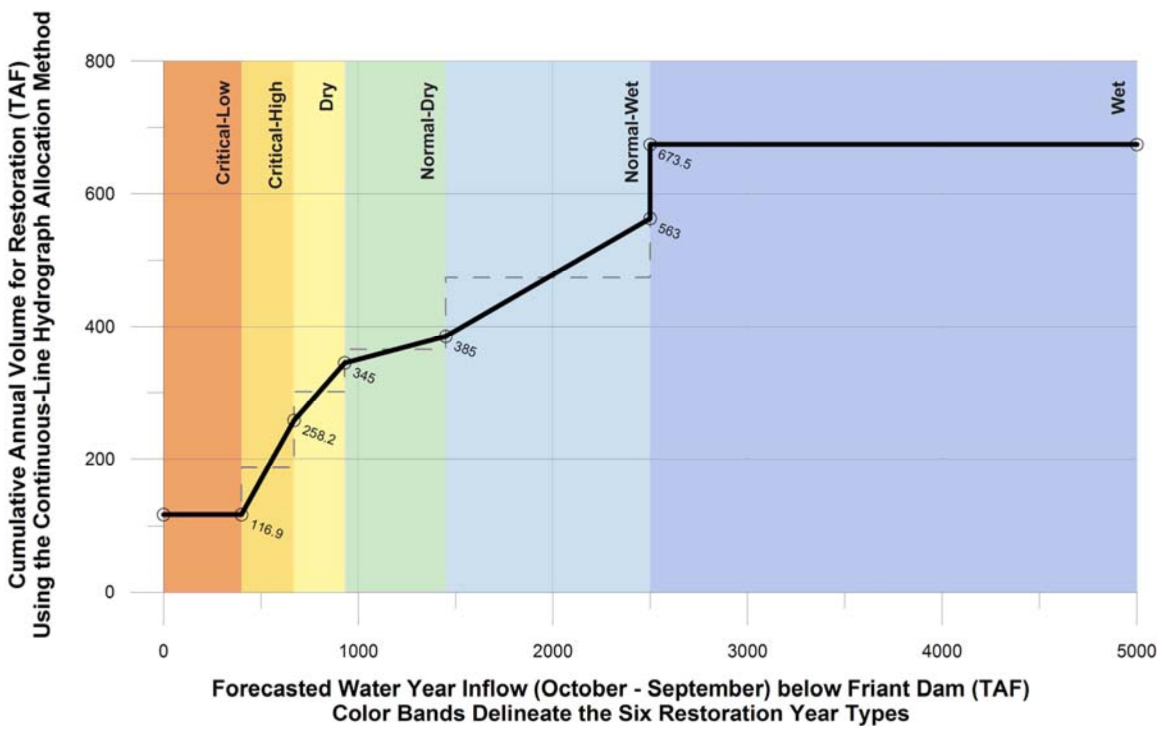


Figure 5-2.
Continuous Annual Allocation Method for Restoration Flows Following Method 2

Figure 5-2 illustrates the piece-wise linear function of Method 2. This function for annual Restoration Flow volume runs through the midpoint of each Restoration Year Type's range of indexed flows, with the continuous flow requirement being less than the explicit Restoration Flow volume for the lower half of the range, and higher than the explicit Restoration Flow volume for the higher half of the range.

Using the midpoint-driven volumes as connecting points between Restoration Year Types closely approximates the average Restoration Flow volume and potential water supply impacts within each classification, thereby maintaining consistency with the Settlement. The transformation should alleviate concerns over abrupt changes in the volume requirement for Restoration Flows, and enhance the correspondence between volumes of Restoration Flows and annual unimpaired flow.

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, 5-2).
- There is a smooth transition in annual allocations for each increment of change in hydrologic forecast.

Disadvantages

Disadvantages of Method 2 are as follows:

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.

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

Key:
TAF = thousand acre-feet

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

Key:
TAF = thousand acre-feet

5.3.3 Annual Allocation Method 3

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

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

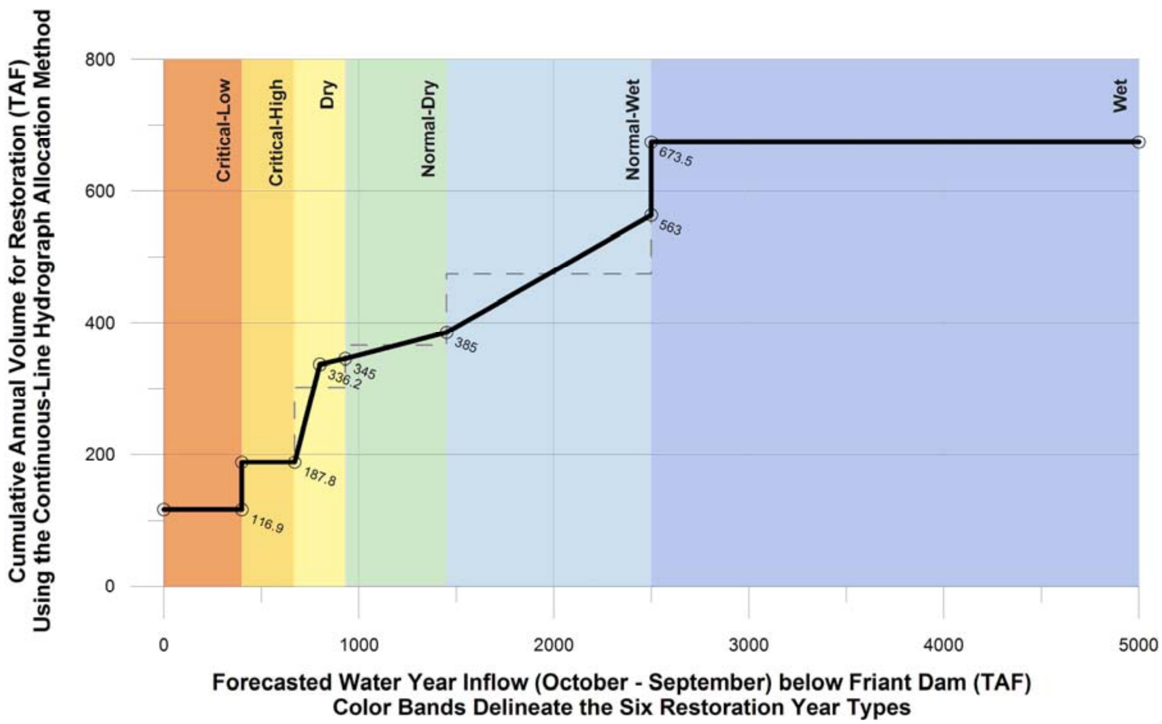


Figure 5-3.
Continuous Annual Allocation Method for Restoration Flows Following Method 3

Advantages

Advantages of Method 3 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 beginning the interpolation process at the forecast-boundary between Critical-High and Dry years.
- The long-term and year type average of allocation to Restoration Flow is preserved compared to those negotiated in the Settlement. (Table 5-3)
- There is a smooth transition in annual allocations for each increment of change in hydrologic forecast, except between Critical-High and -Low allocations.

Disadvantages

Disadvantages of Method 3 are as follows:

- 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.
- The long-term average reduction in water supply for Dry years was determined to be significant (Table 5-4).

Table 5-3.
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	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

Key: TAF = thousand acre-feet

Table 5-4.
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	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

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 (a) Restoration allocation and (b) the water supply reductions for Critical-High year types. To compensate for this, decreases are made to both (a) average allocation and (b) the water supply reductions for Dry year types.

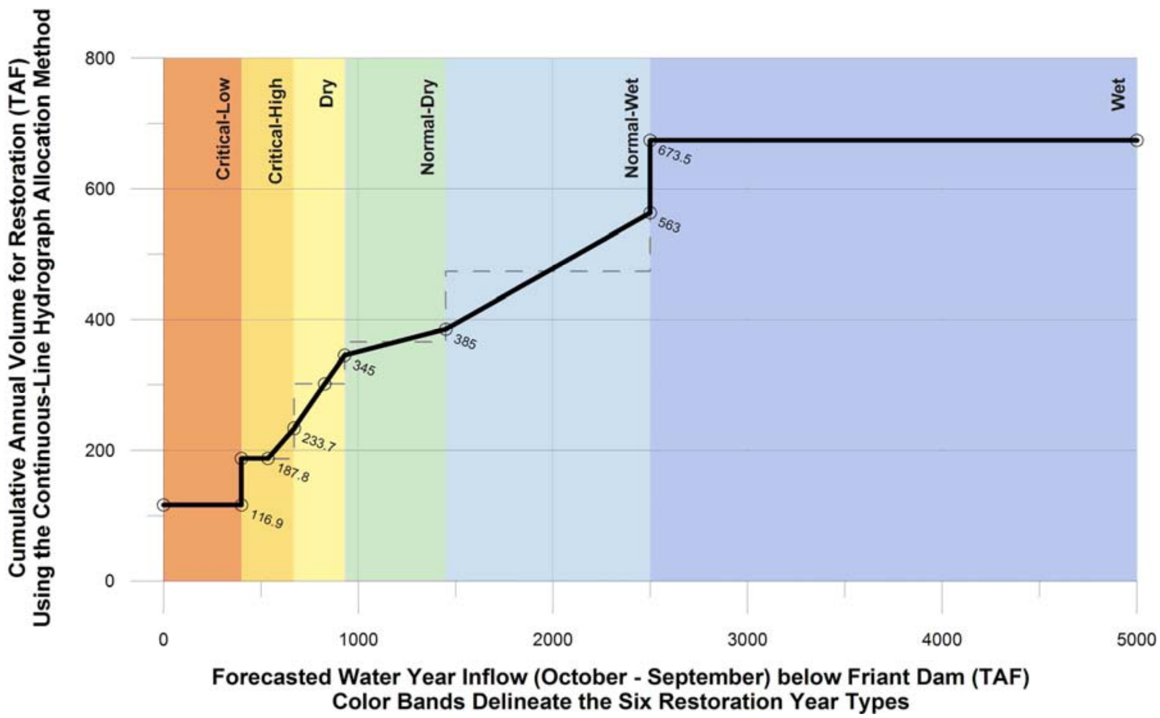


Figure 5-4.
Continuous Annual Allocation Method for Restoration Flows Following Method 4

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 beginning the interpolation process at the forecast-boundary between Critical-High and Dry years.

Disadvantages

Disadvantages of Method 4 are as follows:

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

Table 5-5.
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 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

Key: TAF = thousand acre-feet

Table 5-6.
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 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

Key: TAF = thousand acre-feet

5.4 Process of Refining Method 3

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

5.4.1 Adjustment for Normal-Wet Year Gravel Mobilization

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

5.4.2 Range of Dry Year Type Allocation Methods

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

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

Method 3.1 – Stair-Step Approach

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

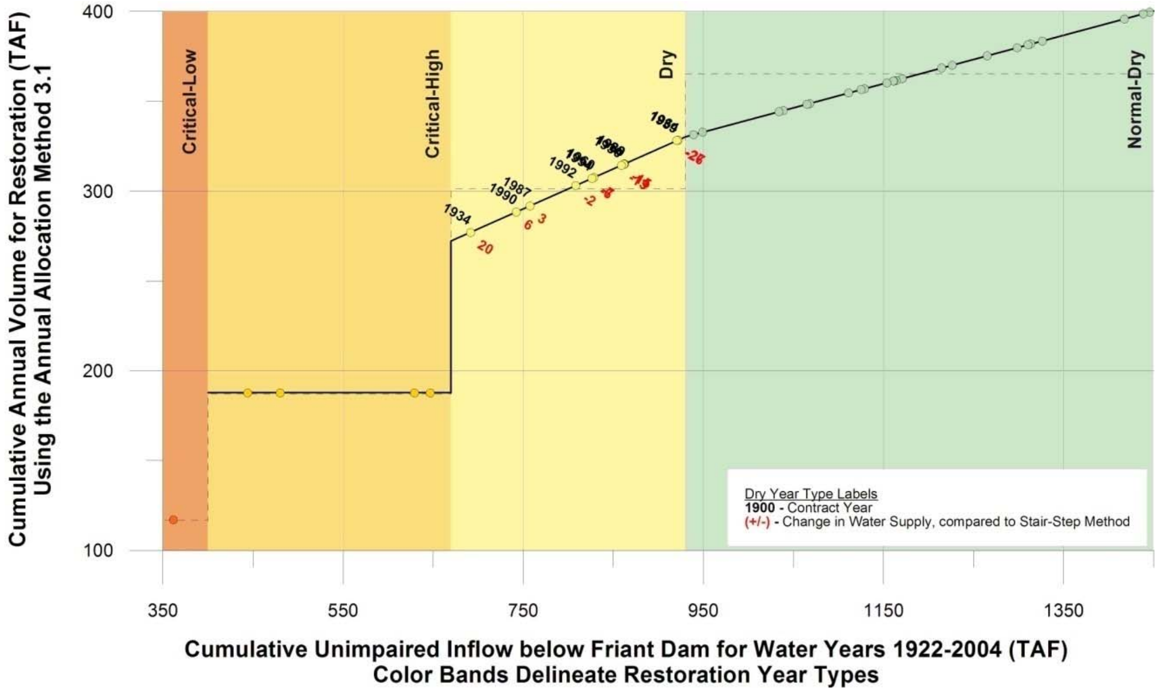


Figure 5-5.
Detail of Dry-Year Continuous Annual Allocation Method for Restoration Flows Following Method 3.1

Advantages

Advantages of Method 3.1 are as follows:

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

Disadvantages

Disadvantages of Method 3.1 are as follows:

- 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.

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

Key:
TAF = thousand acre-feet

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

Key:
TAF = thousand acre-feet

Method 3.2 – Plateau Approach

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

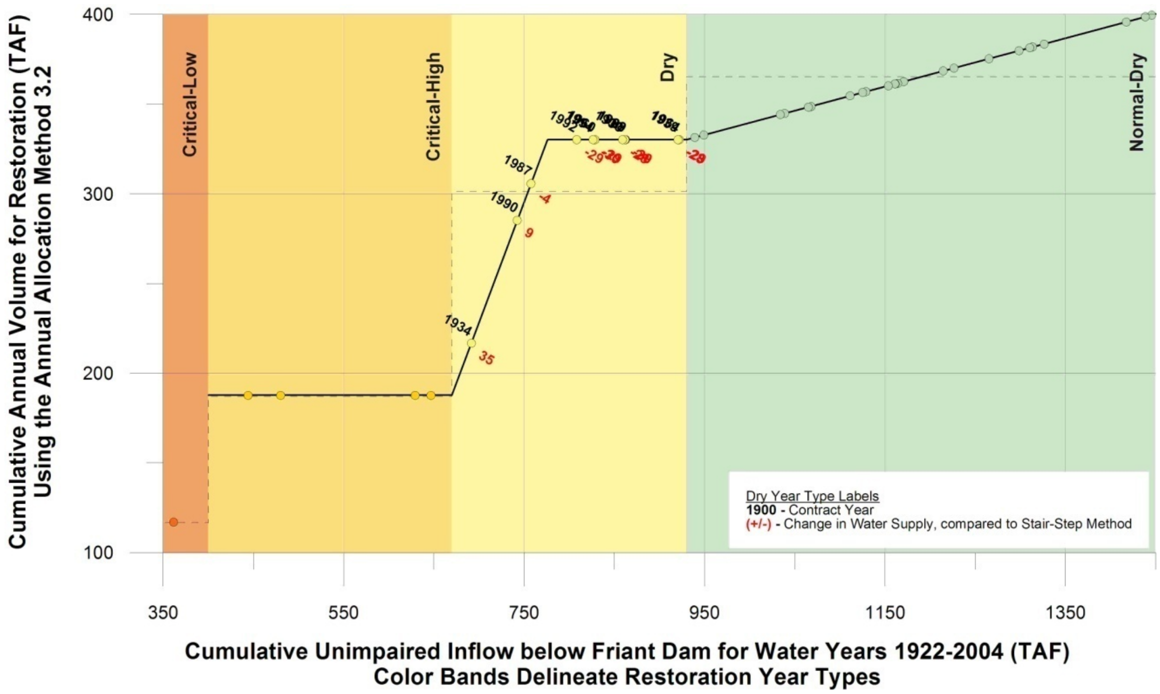


Figure 5-6.
Detail of Dry-Year Continuous Annual Allocation Method for Restoration Flows Following Method 3.2

Advantages

Advantages of Method 3.2 are as follows:

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

Disadvantages

Disadvantages to Method 3.2 are as follows:

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

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

Key:
TAF = thousand acre-feet

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

Key:
TAF = thousand acre-feet

Method 3.3 – Compromise Between Stair-Step and Plateau Approaches

Method 3.3 (Figure 5-7) was developed to present a compromise condition for implementing Method 3, wherein the "dogleg" inflection point is set on the stair-step, thus splitting the difference between the two previous methods.

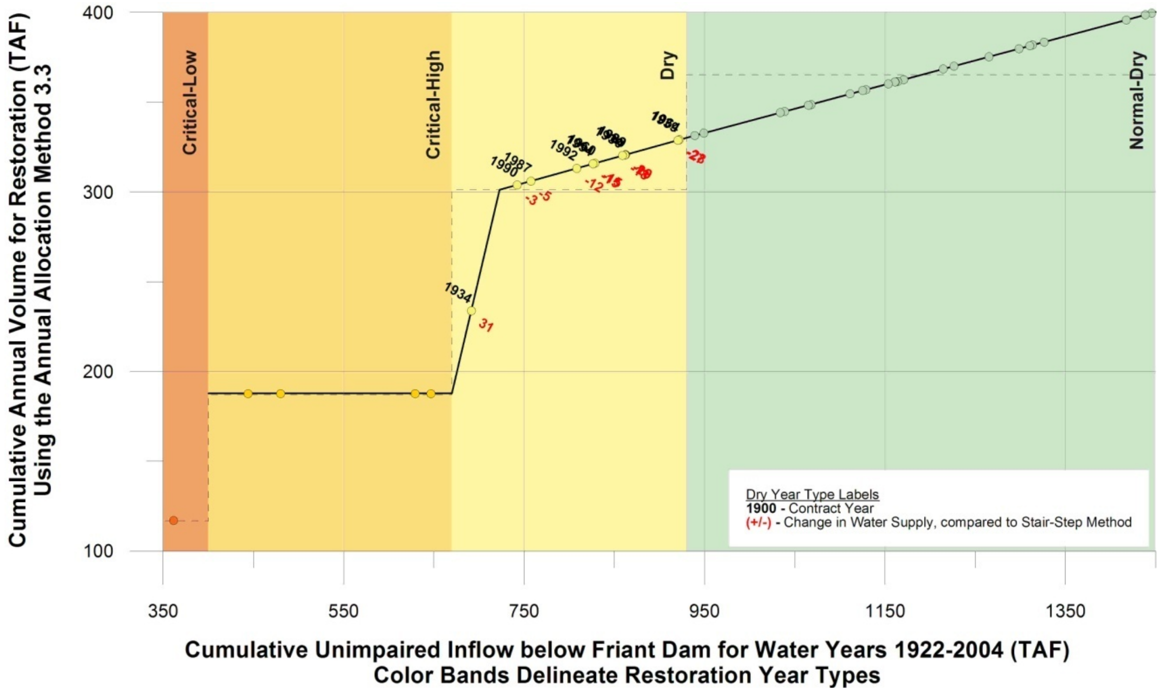


Figure 5-7.
Detail of Dry-Year Continuous Annual Allocation Method for Restoration Flows Following Method 3.3

Advantages

Advantages of Method 3.3 are as follows:

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

Disadvantages

Disadvantages to Method 3.3 are as follows:

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

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

Key:
TAF = thousand acre-feet

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

Key:
TAF = thousand acre-feet

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.

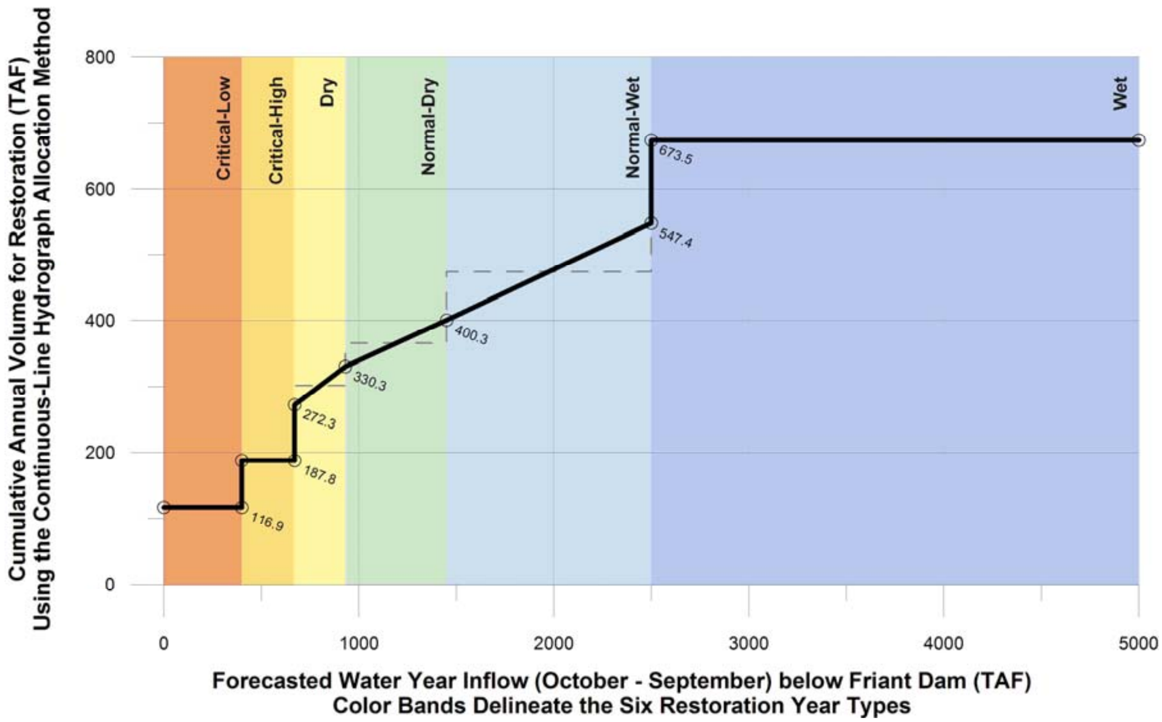


Figure 5-8.
Agreed-On Continuous Annual Allocation Method for Restoration Flows (formerly Method 3.1)

Table 5-13.
Critical-High to Dry Alpha Pathway – Prioritizes Spring-Run Chinook Salmon

Unimpaired Inflow Below Friant Dam (TAF)	Restoration Releases (TAF)
Below 400	116.9
at 400, and up to 670	187.8
at 670	272.3
at 930	330.3
at 1,450	400.3
at 2500	547.4
Above 2500	673.5

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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.

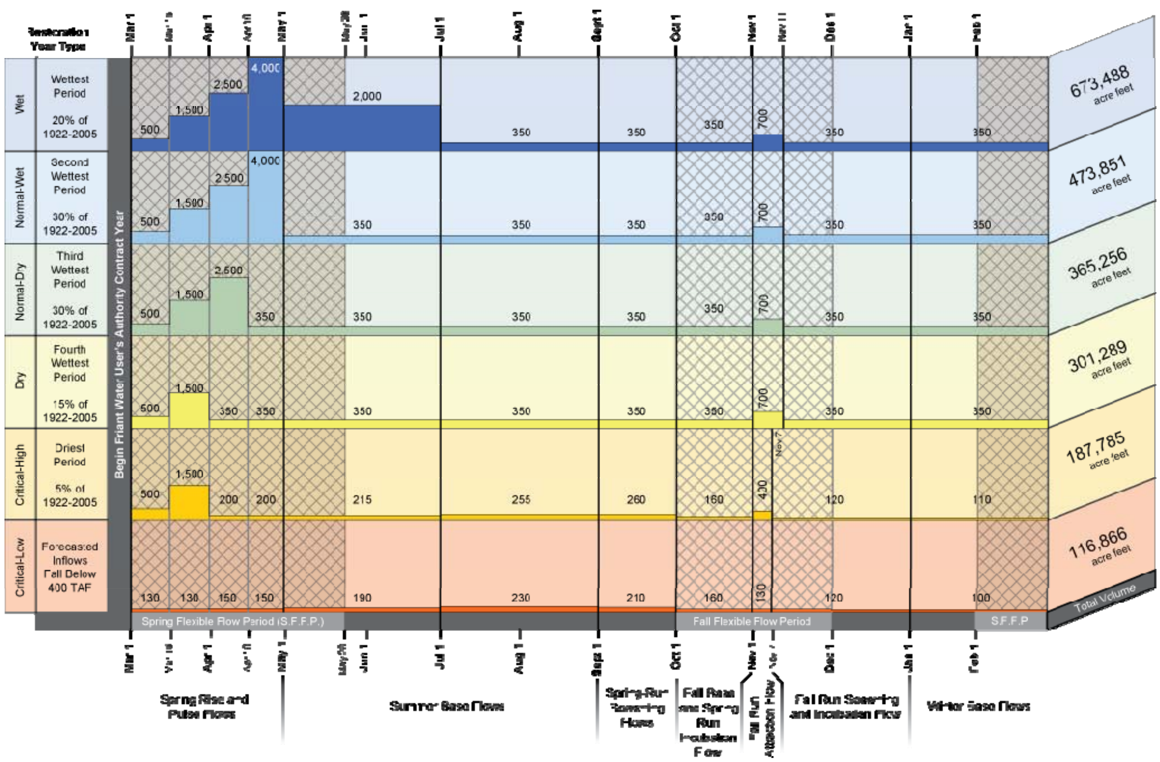

Figure 6-1.
Restoration Flow Schedules, by Restoration Year Type,
Using the Exhibit B Stair-Step Allocation Method

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

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

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

6.2.1 Critical-Low to Critical-High

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

6.2.2 Critical-High to Dry

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

Alpha Pathway: Spring-Run Chinook Prioritization

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

1. The first step in this pathway is to bring up the Spring Rise and Pulse Flows to 350 cfs to provide conditions suitable for spring-run Chinook salmon adult upstream migration and juvenile salmon outmigration of both runs.
2. The second step is to bring up both the fall base and spring-run incubation flow and the fall-run Spawning and Incubation Flow to 260 cfs to provide conditions suitable 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.

3. The next step is to increase the Spring-Run Spawning Flow, the Fall Base and Spring-Run Incubation Flow, and the Fall-Run Spawning and Incubation Flow to 350 cfs to improve conditions for spring-run Chinook salmon spawning and incubation.

4. The next step is to increase Winter Base Flows to 350 cfs to provide suitable conditions for fall-run Chinook salmon egg incubation.

5. The final step is to increase the Fall-Run Attraction Flow to 700 cfs to stimulate adult fall-run Chinook salmon upstream migration.

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

Priority	Action* (cfs)	Rationale
1 Spring rise and pulse flow	*A* to 350	• Spring-run Chinook adult upstream migration • Juvenile salmon outmigration of both runs
2 Fall base and spring-run incubation flow Fall-run spawning and incubation flow	*D* to 260 *F* to 260	• Spring-run Chinook incubation
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	• Spring-run Chinook spawning and incubation
4 Winter base flows	*G* to 350	• Fall-run Chinook incubation
5 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
6 Fall-run attraction flow	*E* to 700	• Fall-run Chinook upstream migration

Note:
* Letters A-G refer to the time periods shown in Figure 6-2.
Key:
cfs = cubic feet per second

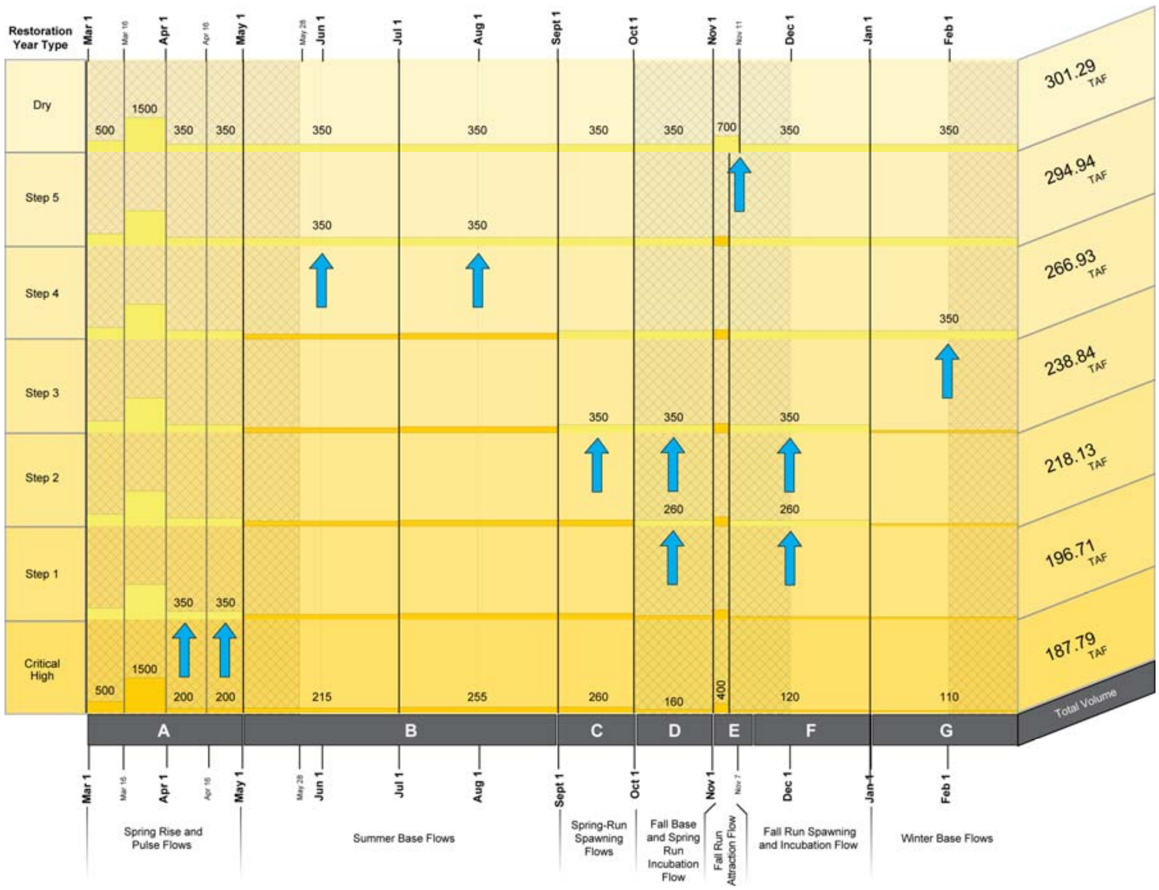

Figure 6-2.
Alpha Critical-High to Dry Pathway – Prioritizes Spring-Run Chinook Salmon

Beta Pathway: Spring- and Fall-Run Chinook Prioritization

The beta pathway, shown in Table 6-2 and Figure 6-3, prioritizes spring-run and fall-run Chinook salmon equally. The first step in this pathway is to bring up the Spring Rise and Pulse Flows to 350 cfs to provide conditions suitable for spring-run Chinook salmon adult upstream migration and juvenile salmon outmigration of both runs. The second step is to simultaneously bring up the Fall Base and Spring-Run Incubation Flow, the Fall-Run Spawning And Incubation Flow and the Winter Base Flows to 260 cfs to provide conditions suitable for spring-run Chinook salmon egg incubation and fall-run Chinook spawning and egg incubation. The next step is to 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 and incubation of both runs of salmon. The next step is to increase summer base flows to 350 cfs to provide spring-run Chinook adult holding and rearing habitat, other native fish habitat, and irrigation of riparian plants. The final step is to increase the Fall-Run Attraction Flow to 700 cfs to stimulate adult fall-run Chinook salmon upstream migration.

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	• Spring-run Chinook adult upstream migration • Juvenile salmon outmigration of both runs
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	• Spring-run Chinook incubation • Fall-run Chinook spawning and 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 • Spring-run Chinook incubation • Fall-run Chinook spawning and incubation
4	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
5	Fall-run attraction flow	*E* to 700	• Fall-run Chinook upstream migration

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

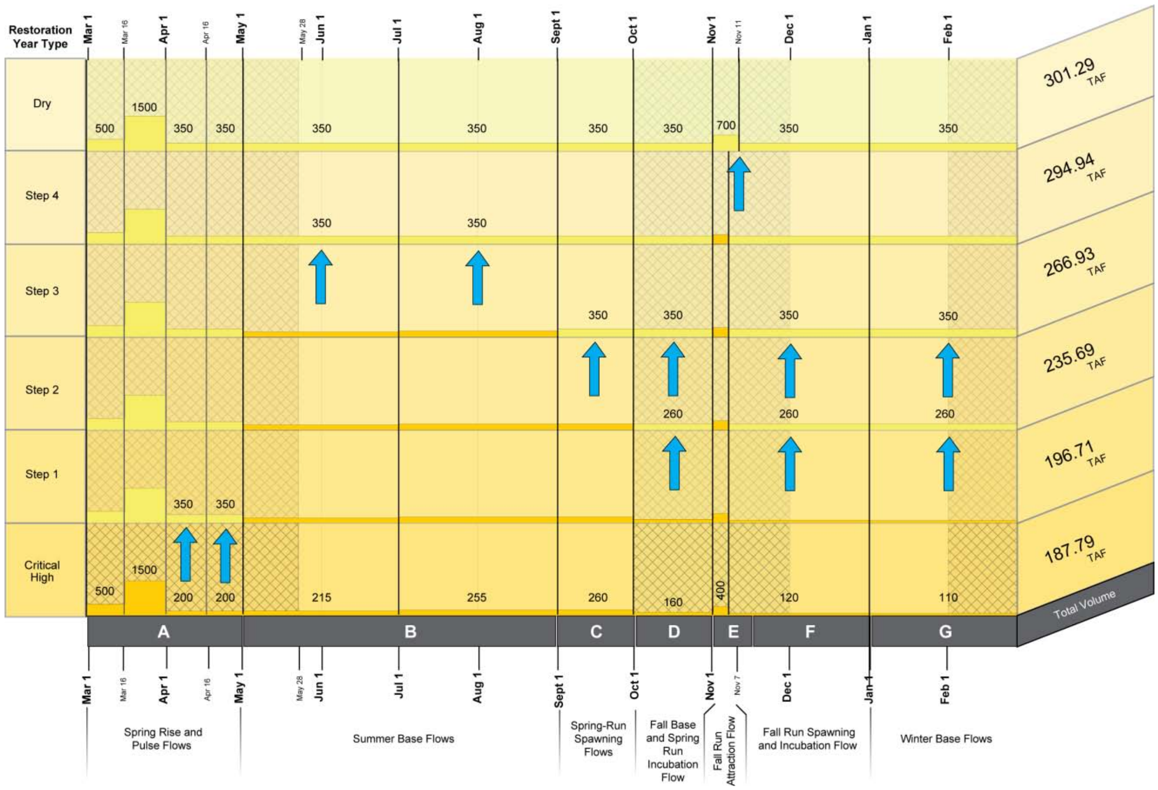

Figure 6-3.
Beta Critical-High to Dry Pathway – Equally Prioritizes Spring-Run and Fall-Run Chinook Salmon

Gamma Pathway: Spring-Run, then Fall-Run Chinook and Native Fish Prioritization

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

1. The first step in this pathway is to 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. The second step is to increase Winter Base Flows to 260 cfs to improve conditions for fall-run Chinook salmon egg incubation.

3. The next step is to bring up both the spring rise and pulse flows and the summer base flows to 260 cfs to improve conditions for juvenile salmon rearing and other native fish habitat.

4. The next step is to 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.

5. The next step is to increase the Spring Rise And Pulse Flows to 350 cfs to provide habitat for other native fish.

6. The next step is to increase the Fall-Run Attraction Flow to 700 cfs to stimulate adult fall-run Chinook salmon upstream migration.

7. The final step is to increase the Summer Base Flows to 350 cfs for spring-run Chinook adult holding and juvenile rearing, other native fish habitat, and maintenance of established riparian vegetation.

Table 6-3.
Gamma Critical-High to Dry Pathway – Spring-Run First Priority, then Fall-Run and Other 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 rise and pulse flows Summer base flows	*A* to 260 *B* to 260	• Other native fish habitat • Juvenile salmon rearing
4	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
5	Spring rise and pulse flows	*A* to 350	• Other native fish habitat
6	Fall-run attraction flow	*E* to 700	• Fall-run Chinook upstream migration
7	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 6-4.
Key:
cfs = cubic feet per second

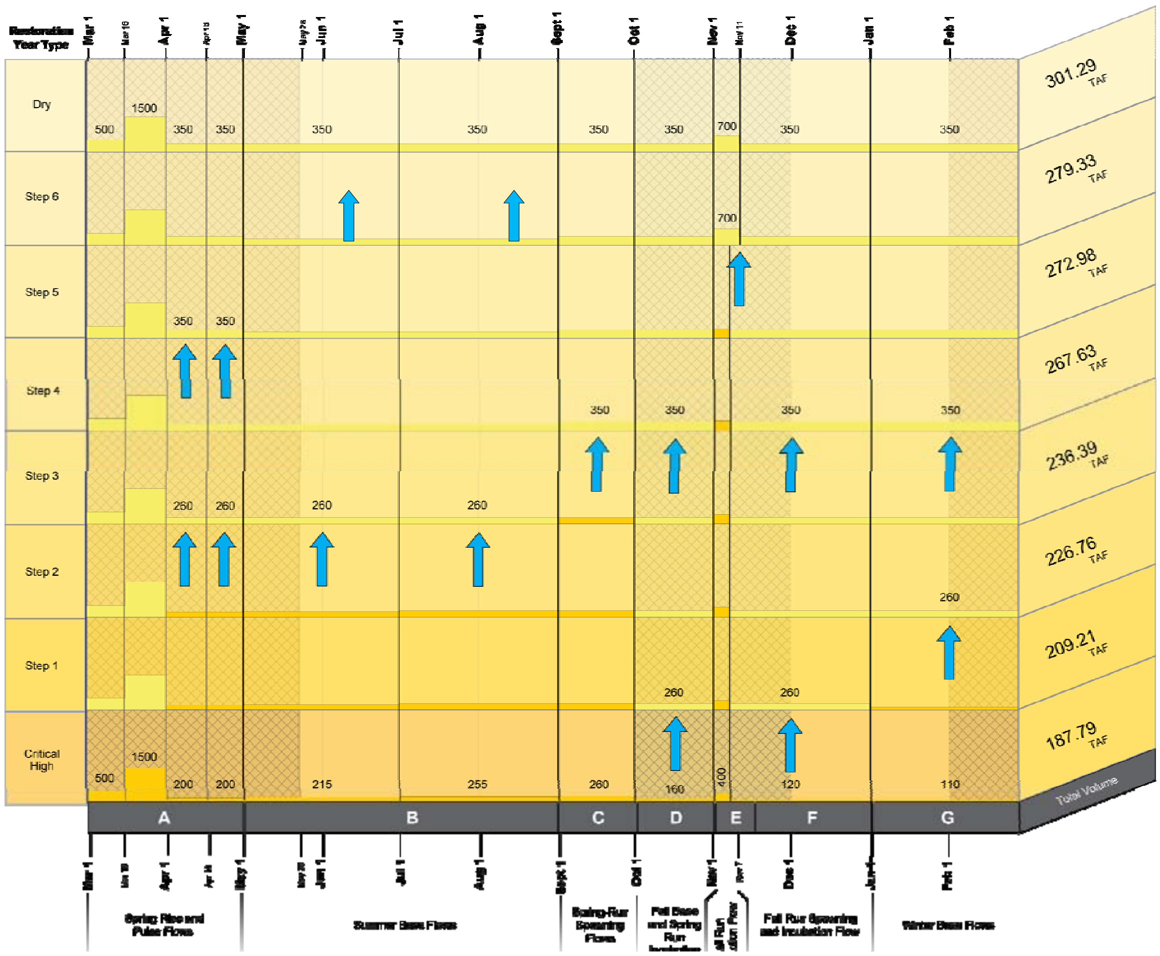

Figure 6-4.
Gamma Critical-High to Dry Pathway – Spring-Run First Priority, Then Fall-Run and Other Native Fishes

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. The first step is to 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.

2. 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.

3. The second step is to increase Winter Base Flows to 260 cfs to improve conditions for fall-run Chinook salmon egg incubation.

4. The next step is to 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.

5. The next step is to increase the Spring Rise and Pulse Flows to 350 cfs to provide habitat for other native fish.

6. The next step is to increase the Fall-Run Attraction Flow to 700 cfs to stimulate adult fall-run Chinook salmon upstream migration. The final step is to increase the Summer Base Flows to 350 cfs for spring-run Chinook 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

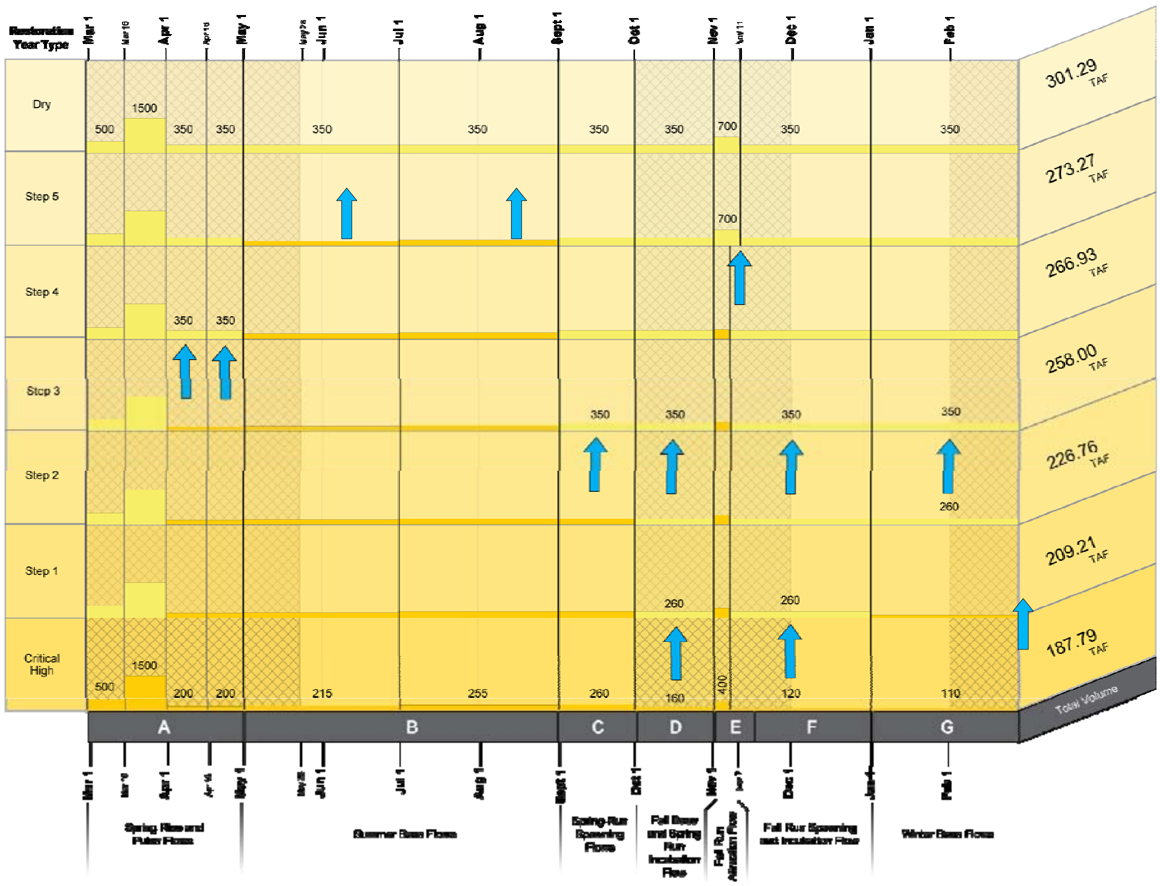

Figure 6-5.
Critical-High to Dry Delta Pathway – Prioritizes, in Order, Spring-Run Chinook Salmon, Fall-Run, Other Native Fishes

6.2.3 Dry to Normal-Dry

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

6.2.4 Normal-Dry to Normal-Wet

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

6.2.5 Normal-Wet to Wet

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

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

6.3 Retained Flow Schedule Transformation Pathways

The transformation pathways described in Section 4.2 were developed in parallel with the continuous line allocation method in Section 3. Unlike the annual allocation method, the result of the transformation pathway work was not a prescription for a singular technique. Instead, a range of possible flow scheduling outcomes was retained to bracket the identified range of priorities that were evident in the Settlement's expert testimony.

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

Table 6-5.
Retained Flow Schedule Transformation Pathways

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

Initial evaluations of all four alternative transformation pathways revealed that water supply impacts to Friant Division long-term contractors would not vary regardless of which pathway is chosen. In addition, it was concluded that the range of flows released from Friant Dam under any pathway would not differ with the application of any transformation pathway. Therefore, all four transformation pathways were retained for 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.
- Including 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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