Conservation Strategy Options Evaluation Report

Prepared for:

Steering Committee
Bay-Delta Conservation Plan
Sacramento, CA

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Acronym List

Banks Pumping Plant	Harvey O. Banks Delta Pumping Plant
BDCP	Bay-Delta Conservation Plan
CALFED	Joint Federal-State California Bay-Delta Program
CCWD	Contra Costa Water District
CDFG	California Department of Fish and Game
CEQA	California Environmental Quality Act
cfs	cubic feet per second
CVP	Central Valley Project
DRMS	Delta Risk Management Strategy
DWR	California Department of Water Resources
EC	electrical conductivity
FWS	U. S. Fish and Wildlife Service
Jones Pumping Plant	C.W. "Bill" Jones Pumping Plant
MAF/YR	million acre feet per year
maf	million acre feet
NEPA	National Environmental Policy Act
NMFS	National Marine Fisheries Service
NRDC	Natural Resources Defense Council
OCAP	Operating Criteria and Plan
Options	Conservation Strategy Options
SAIC	Science Applications International Corporation
SDIP	South Delta Improvements Program
SWP	State Water Project
SWRCB	State Water Resources Control Board
taf	thousand acre feet
TAF/YR	thousand acre feet per year
USBR	U. S. Bureau of Reclamation
USFWS	U.S. Fish and Wildlife Service
WGI	Washington Group International
YOY	Young-of-the-year

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EXECUTIVE SUMMARY

BACKGROUND AND PURPOSE

The Steering Committee for the Bay-Delta Conservation Plan (BDCP) is developing a comprehensive conservation plan for the Sacramento and San Joaquin Delta pursuant to a planning agreement that was executed on October 6, 2006. The BDCP planning area is the legal Delta (see Figure E-1). In the first half of 2007, the Steering Committee developed a list of ten conceptual conservation strategies, evaluated those strategies, and shortened that list to four Conservation Strategy Options (Options). Those four Options are evaluated in this report. The Steering Committee is intent on further narrowing the remaining Options to a single Option (derived from one or more of the evaluated Options) that will be carried forward into a detailed conservation planning process over the course of the next year. The Option chosen or created will serve as the nucleus for the larger conservation plan and other major elements of the strategy will be formulated around it. This larger, more comprehensive conservation plan will then be evaluated through a formal, public environmental review process under the National Environmental Policy Act (NEPA) and the California Environmental Quality Act (CEQA).

The purpose of this evaluation is to assist the Steering Committee in identifying which Option to carry forward into the planning process. This report describes how each of the four Options performs with respect to seventeen evaluation criteria identified by the Steering Committee for this purpose. It should be emphasized that this evaluation provides only an initial assessment of the relative performance of each of the four Options as described herein. It is likely that some elements of the selected Option will need to be refined further in light of information contained in this report and elsewhere. The Steering Committee may over the course of the fall elect to select one of the four Options to carry forward, or it may choose instead to modify or otherwise refine one of the Options and carry that modified Option into the planning process.

The evaluation is organized into seven sections. Section 1 explains the purpose of the report and includes descriptions of the Options evaluated. Section 2 describes the methods used in the evaluation. Sections 3 through 6 contain the detailed assessment on an Option-by-Option basis, starting with Option 1 (section 3) and ending with Option 4 (section 6). Section 7 provides a summary of the overall conclusions of the evaluation. Section 8 provides an overview of other key conservation elements not included in the four Options evaluated in the report. These other conservation elements, while important to the success of the conservation plan, do not help distinguish performance differences among the Options because they could be implemented with any of the four Options.

COVERED SPECIES

At this stage in development of the BDCP, the Steering Committee has identified nine fish species that are anticipated to be covered under Federal and State regulations by the BDCP. The Options Evaluation Report evaluates the relative ability of each of the four Options to meet the biological objectives for these nine potentially covered species:

- delta smelt,
- longfin smelt,
- winter-run Chinook salmon,
- spring-run Chinook salmon,
- fall- and late-fall-run Chinook salmon,
- Central Valley steelhead,
- green sturgeon,
- white sturgeon, and
- Sacramento splittail.

DESCRIPTIONS OF THE CONSERVATION STRATEGY OPTIONS

The four Options evaluated in the report were developed by the Steering Committee around two key components:

- Conveyance – the structural approach to conveyance of water to meet the goals for conservation of covered species and water supply reliability.
- Habitat restoration – the general type and location of habitat restoration opportunities in the Delta and in adjacent Suisun Marsh to address covered species conservation

The Options presented here represent a range of conveyance and habitat restoration approaches developed for the purpose of comparative evaluation. All of the Options could be refined, modified, or expanded to improve their performance in addressing the evaluation criteria.

Conservation Strategy Option 1: Existing Through-Delta Conveyance

Option 1 would involve the use of existing conveyance and pump facilities with operations focused on reducing take at the export facilities and improvement of hydrologic conditions for fish in the northern and western Delta; physical habitat restoration would be focused in the north and west Delta and Suisun Marsh (Figure E-2). The estimated area available for habitat restoration encompasses approximately 28% of the BDCP planning area.

Conservation Strategy Option 2: Improved Through-Delta Conveyance

Option 2 would involve improvement of through-Delta conveyance by (1) constructing operable barriers and levee improvements along Middle River; (2) constructing operable barriers on the San Joaquin and Old Rivers; (3) separating water supply conveyance flows from San Joaquin River flows with a siphon and pump facility connecting the Victoria Canal and Clifton Court Forebay; (4) operations focused on reducing take at the export facilities and improvement of hydrologic conditions for fish in the northern, western, central, and southern

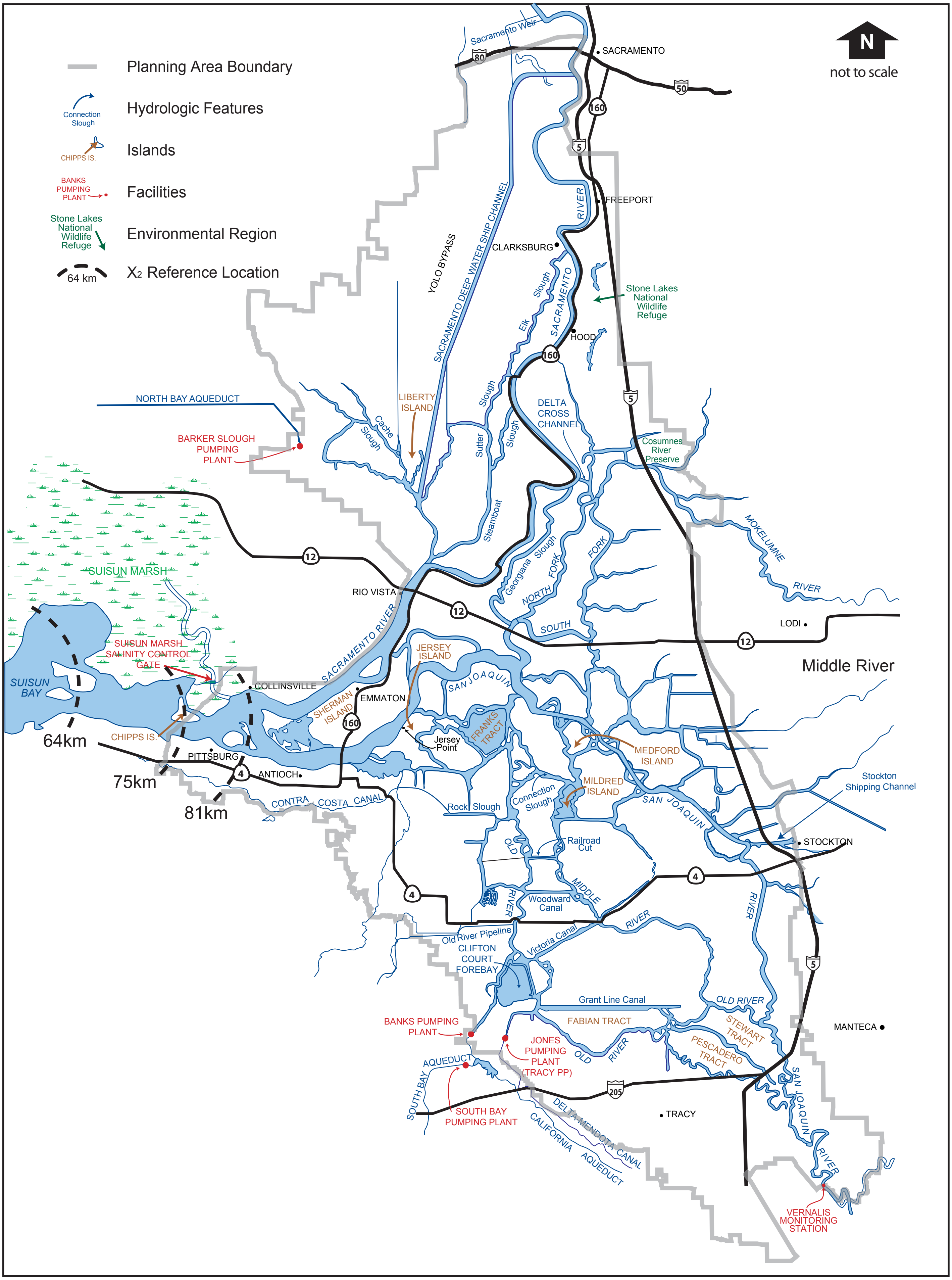

Figure E-1. Locator Map of Planning Area with Key Features Mentioned in Text

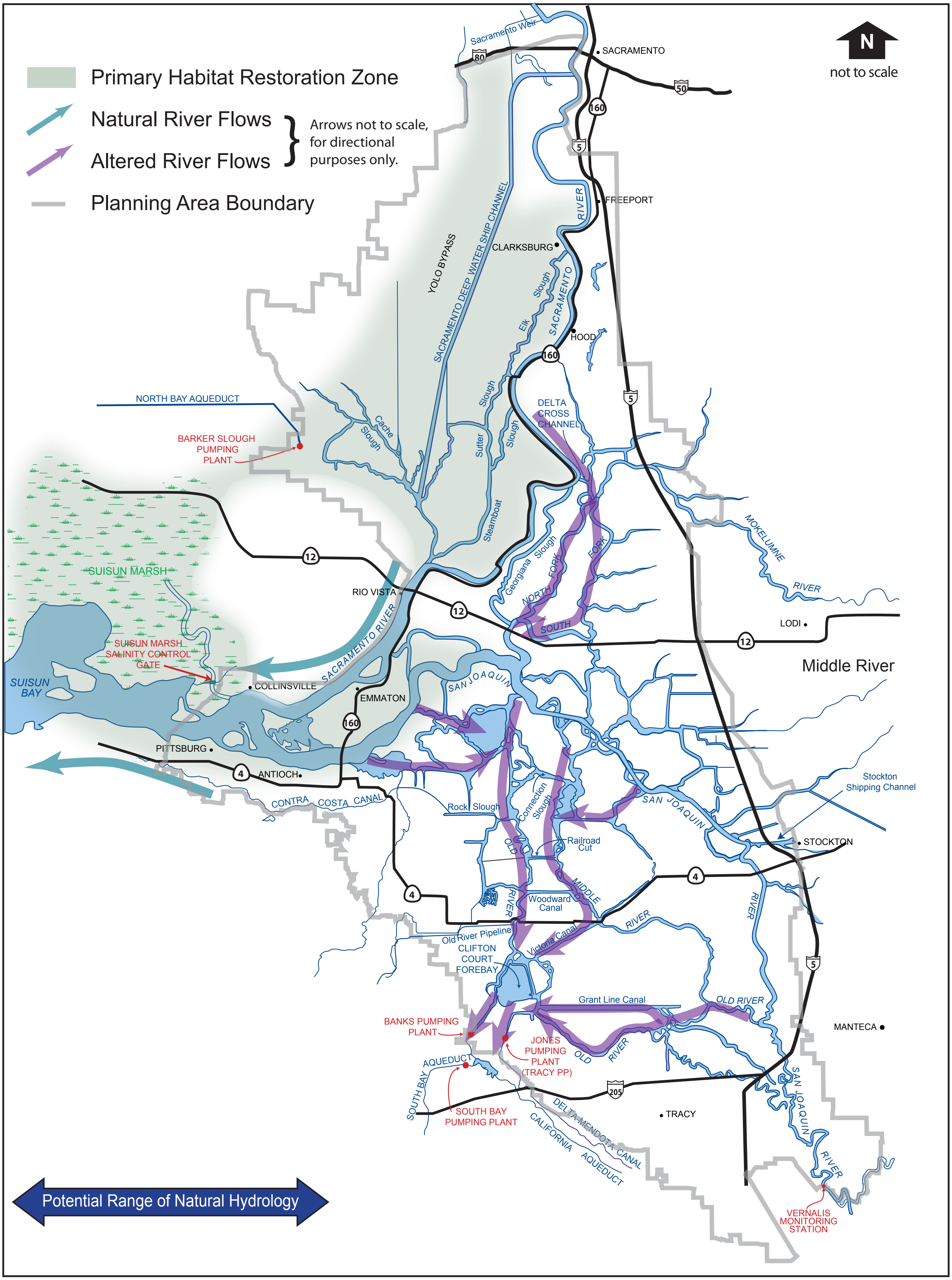

Figure E-2. Conservation Strategy Option 1

Delta; and (5) physical habitat restoration focused in the north, west, central, and south Delta and Suisun Marsh (Figure E-3). The estimated area available for habitat restoration encompasses approximately 35% of the BDCP planning area

Conservation Strategy Option 3: Dual Conveyance

Option 3 would involve dual conveyance facilities and physical and operational habitat restoration and enhancement (Figure E-4). Conveyance would be via: (1) a peripheral aqueduct with an intake on the Sacramento River and isolated connection at the SWP/CVP pump facilities, and (2) an improved through-Delta conveyance with operable barriers along Middle River and separated water supply flows from San Joaquin River flows by a siphon. Operations would focus on the use of the flexibility of dual conveyances to reduce take of covered fish species at the export facilities and improve hydrologic conditions for covered fish in the northern, western, central, and southern Delta. Physical habitat restoration and enhancement would be focused in the north, west, central, and south Delta and Suisun Marsh. The estimated area available for habitat restoration encompasses approximately 35% of the BDCP planning area.

Conservation Strategy Option 4: Peripheral Aqueduct

Option 4 would involve construction of a peripheral aqueduct with an intake on the Sacramento River and isolated connection at the SWP and CVP pump facilities (Figure E-5). Operations would provide the flexibility to improve hydrologic conditions for covered fish species throughout the Delta and to physically restore and enhance habitat opportunistically throughout the Delta and Suisun Marsh. The estimated area available for habitat restoration encompasses approximately 75% of the BDCP planning area.

APPROACH TO THE EVALUATION

The Options Evaluation Report is built around seventeen evaluation criteria developed by the Steering Committee for comparison of the Options (all criteria are included in the *Results of the Evaluation* section, below). The approach to the evaluation focused on the comparative ability of each Option to address each of the evaluation criteria. The evaluation identifies how the differing structural conveyance system and the habitat restoration opportunities among the Options distinguish the Options from each other. The seventeen evaluation criteria are grouped into four categories:

- biological criteria,
- planning criteria,
- flexibility/durability/sustainability criteria, and
- other resource impact criteria.

A combination of quantitatively or qualitatively approaches was used to score or rank the Options against each other or against base conditions (present conditions in the Delta). The evaluation criteria were designed to allow a comparison of the Options at this stage of the process. There are other criteria and issues, not included here because they did not appear to differentiate the Options that will need to be addressed in the future as the larger strategy is developed. In addition, the evaluation makes some assumptions that are acceptable at this level of analysis but that will need to be further evaluated as the larger strategy is developed. For example, in the biological evaluation, it is assumed that habitat restoration can be effective in alleviating some stressors on the species. For this coarse analysis, this should be a valid assumption but as planning for habitat restoration proceeds, more work will be needed on those specific stressors and the habitat conditions needed to address them.

Biological Criteria

For purposes of evaluating the relative ability of each of the four Options to meet the biological criteria, this report assesses the relative performance of each Option on a species-by-species basis. The comparative evaluation provided in this report is based on existing scientific information about environmental stressors affecting the nine covered fish species and Delta ecosystem processes important to supporting these species. The evaluation is largely qualitative, based on the best professional judgment of individuals who are knowledgeable about the covered species, the complex hydrology of the Delta, and the interplay of that hydrology with the ecological requirements of the individual species of fish. It includes the use of preliminary, coarse-level hydrodynamic modeling applying a broad range of input parameters to the four Options to enable a comparison of the Options' relative ability to provide flow and water quality conditions that benefit the species. For the purpose of evaluating the operating flexibility of each Option, hydrodynamic models CALSIM II and DSM 2 were applied using input parameters that spanned a range of potential operations for each Option. The results of these models were interpreted for anticipated effects on each fish species based on published and unpublished literature and best professional judgment. Each Option's effect on each species is based on an assessment of how the Option affects the species' stressors and the degree of those effects is compared among the Options using the metrics established for each of the biological criteria.

While the Options do not include any specific locations for habitat restoration, the evaluation identifies the relative opportunities and constraints of each Option for physical restoration of high functioning habitat that would improve ecological conditions for covered species. These opportunities and constraints are based on the assumption that physical habitat restoration located in areas with restored natural hydrology would be more effective than restoration in areas with hydrology controlled by water conveyance and export requirements.

Planning Criteria

The planning criteria focus on the ability of each Option to achieve the BDCP planning goals. This comparative evaluation is based on the results of hydrodynamic modeling to estimate the ability of each Option to achieve water supply goals; a cost comparison of both initial construction and long-term costs; and the relative practicability of the implementation.

Flexibility/durability/sustainability Criteria

These criteria address the flexibility, durability, and sustainability of each Option. These criteria focus primarily on the long-term ability of each Option to meet conservation and planning goals

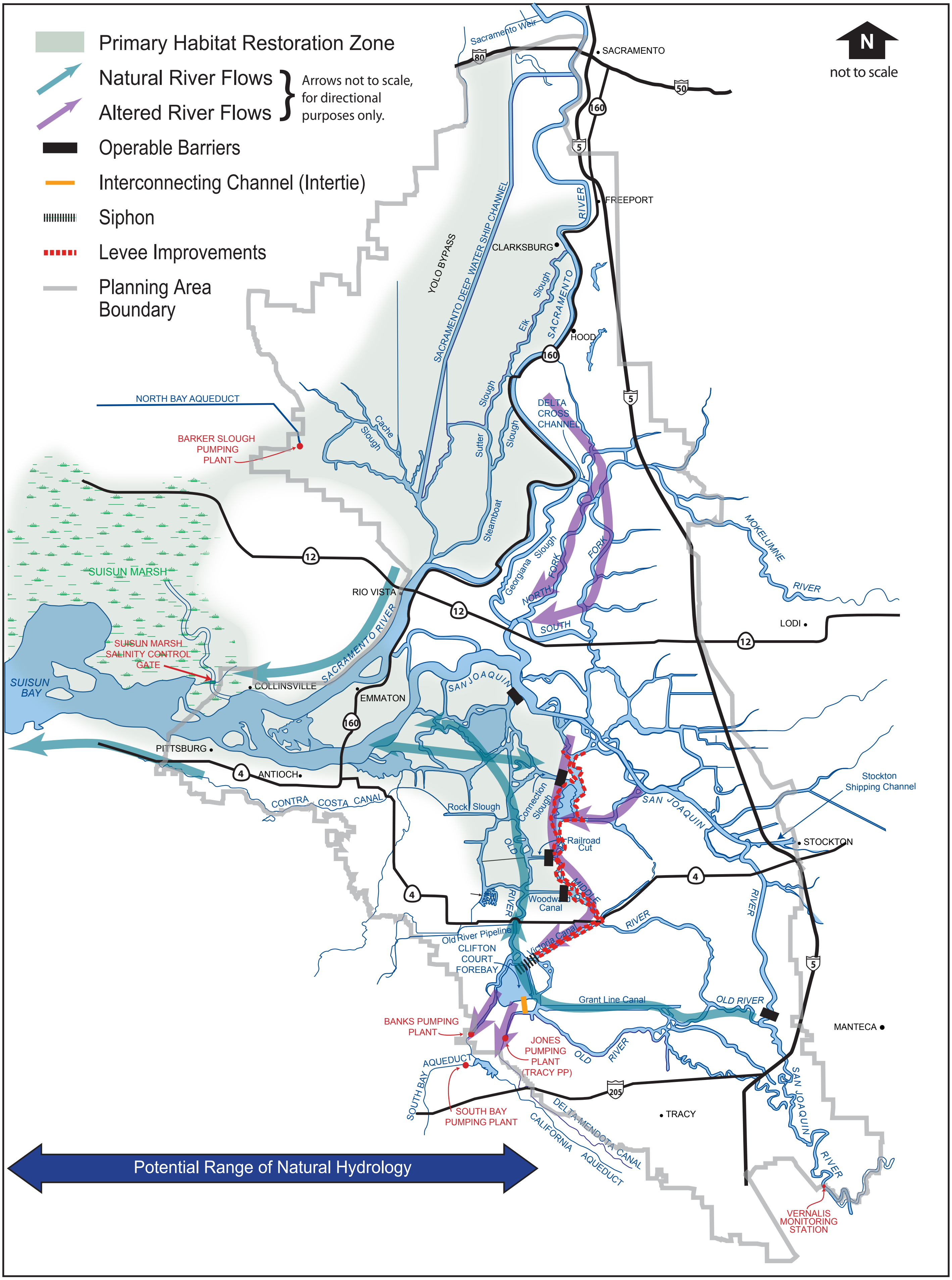

Figure E-3. Conservation Strategy Option 2

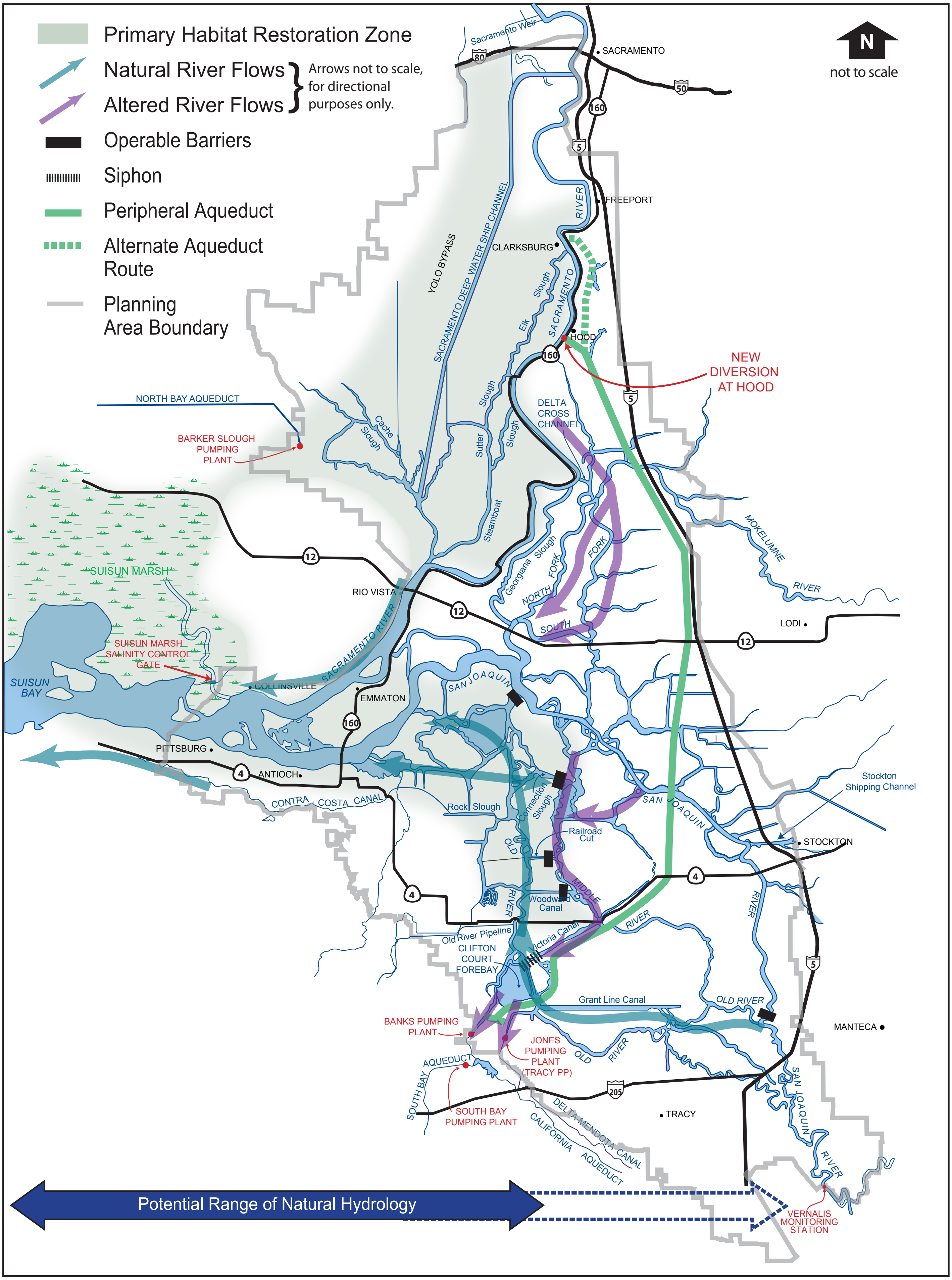

Figure E-4. Conservation Strategy Option 3

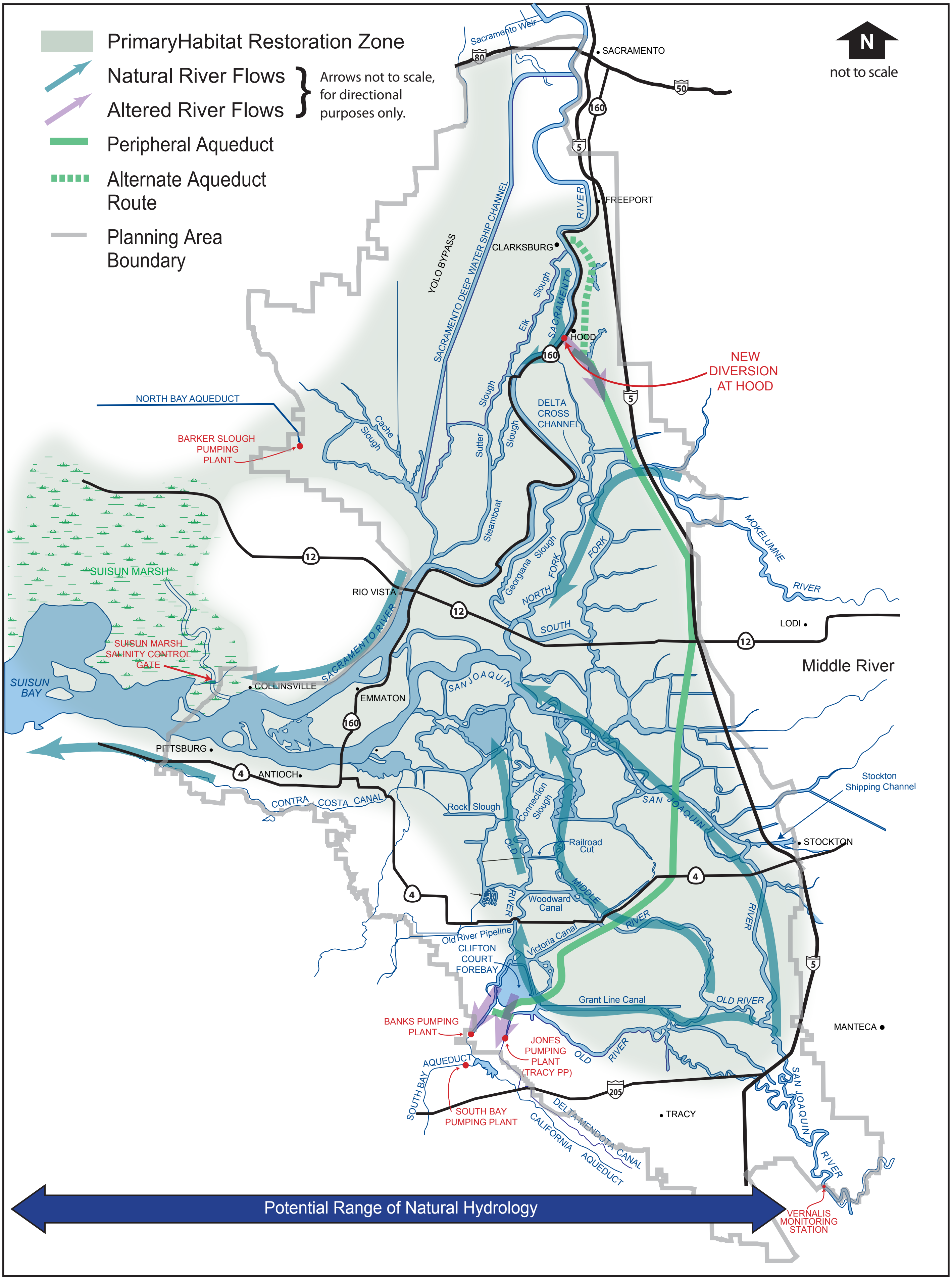

Figure E-5. Conservation Strategy Option 4

in the face of changing environmental conditions and expanding ecological knowledge. The report uses information from preliminary results of Delta Risk Management Strategy (DRMS) studies in evaluating the durability of the Options in response to catastrophic events in the Delta and long-term climate change.

Other Resource Impacts Criteria

The other resource impacts criteria focus on the unintended adverse effects of implementing each Option on the human environment and on other biological resources within and outside the Delta. This evaluation is based on prior environmental studies in the Delta that have evaluated actions similar to the four Options and on the outputs of the hydrodynamic modeling.

IMPORTANT CONSERVATION ACTIONS NOT INCLUDED IN THE EVALUATION

A number of potentially important ecological stressors on fish are not directly addressed by the Options as they are presently defined such as toxics, predation, competition, harvest, and turbidity. While the Options may indirectly address these stressors, there are many conservation elements that could be added to the Options that would more fully address them. These important stressors and the conservation elements that could address them and benefit specific covered species are discussed in Section 8 of the evaluation. Conservation elements addressing such stressors may be equally applicable under all Options and, therefore, do not serve to distinguish among the Options in the evaluation. Conservation elements addressing these other stressors may become important components of the larger conservation strategy as it is further developed.

RESULTS OF THE EVALUATION

The report presents the comparative evaluation of the Options in relation to the biological criteria by fish species as individual species (e.g., delta smelt) or groups of species (e.g., green and white sturgeon). The report presents the comparative evaluation of Options for the other groups of criteria by criterion (e.g., planning criteria #8). Table E-1 presents the comparative performance of each Option in addressing the needs of the covered fish species relative to the biological criteria. Table E-2 presents the comparison of the performance of each Option relative to the planning, flexibility/durability/sustainability, and other resource impacts criteria. Table E-3 presents the overall performance of the Options against the four criteria categories.

Comparison of the Options Relative to Biological Criteria (Presented by Species)

Criteria #1-7 for biological performance are evaluated separately in the report for each covered species. The seven biological criteria are:

1. Relative degree to which the Option would reduce species mortality attributable to non-natural mortality sources to enhance production (reproduction, growth, and survival), abundance, and distribution for each of the covered fish species.

2. Relative degree to which the Option would provide water quality and flow conditions necessary to enhance production (reproduction, growth, and survival), abundance, and distribution for each of the covered fish species.

3. Relative degree to which the Option would increase habitat quality, quantity, accessibility, and diversity to enhance and sustain production (reproduction, growth, and survival), abundance, and distribution, and to improve the resiliency of each of the covered species' populations to environmental change and variable hydrology.

4. Relative degree to which the Option would increase food quality, quantity, and accessibility (e.g., phytoplankton, zooplankton, macro-invertebrates, and forage fish) to enhance production (reproduction, growth, and survival) and abundance for each of the covered fish species.

5. Relative degree to which the Option would reduce the abundance of non-native competitors and predators to increase native species production (reproduction, growth, and survival), abundance, and distribution for each of the covered fish species.

6. Relative degree to which the Option improves ecosystem processes in the BDCP planning area to support aquatic and associated habitats

7. Relative degree to which the Option can be implemented within a timeframe to meet the near-term needs of each covered fish species (following BDCP authorization).

The summaries provided here roll up the criteria by species and present the overall biological affect of each Option on the species.

Table E-1. Comparison of Options by Covered Fish Species

Species	**Performance Rank[1]**			
	Option 1	**Option 2**	**Option 3**	**Option 4**
Delta smelt	●	●●	●●●	●●●●
Longfin smelt	●	●●	●●●	●●●●
Sacramento River Salmonids	●●●	●●●	●●●	●●●●
San Joaquin River Salmonids	●	●●	●●●	●●●●
White Sturgeon	●	●●●	●●●	●●●●
Green Sturgeon	●●●	●●●	●●●	●●●●
Sacramento splittail	●●	●●	●●●	●●●●

Notes:
1. Based on information presented in Tables H-1 to H-9 addressing Biological Criteria #1-7.

Species performance ranks are:
●●●● = Best performing,
●●● = Second best performing,
●● = Third best performing,
● = Lowest performing
Where ranks are equal the two Options receive same rank

Table E-2. Comparison of Options by Planning, Feasibility/ Durability/Sustainability, and Other Resource Impacts Criteria

Criterion	Performance Rank[1]			
	Option 1	Option 2	Option 3	Option 4
Planning Criteria				
8. Water supply goals	●●	●	●●●●	●●●
9. Feasibility/practicability	●●●●	●●●●	●●●●	●●●●
10. Minimize cost	●	●●	●●●	●●●●
Flexibility/Sustainability/Durability Criteria				
11. Durability to catastrophic events	●	●●	●●●●	●●●
12. Minimize ongoing resource input for long-term conservation	●	●●	●●●	●●●●
13. Flexibility/adaptability	●	●●	●●●	●●●●
14. Reversibility	●●●●	●●●	●●	●●
Other Resource Impacts Criteria				
15. Avoidance of impacts on other native species (in-Delta)	●●●●	●●	●	●●●
16. Avoidance of impacts on human environment (in-Delta)[2]	●●●●	●●●	●	●●
17. Avoidance of impacts on native species (outside Delta)	●●	●●	●●●●	●●●

Notes:
1. Derived from information presented in Sections 7.2, 7.3, and 7.4.
2. Does not include indirect effects in export service areas.

Criteria performance ranks are:
●●●● = Best performing,
●●● = Second best performing,
●● = Third best performing,
● = Lowest performing
Where ranks are equal the two Options receive same rank

Table E-3. Overall Comparison of Options by Criteria Category (Rank)[1]

Evaluation Criteria Category	Conservation Strategy Option			
	Option 1	Option 2	Option 3	Option 4
Biological	●	●●	●●●	●●●●
Planning	●	●	●●●●	●●●●
Flexibility/ Sustainability/Durability	●	●●	●●●	●●●●
Impacts on Other Resources	●●●●	●●●	●	●●

Notes:
1. Derived from information presented in Tables 7-1 and 7-2.

Criteria performance ranks are:
●●●● = Best performing
●●● = Second best performing;
●● = Third best performing
● = Lowest performing
Where ranks are equal the two Options receive same rank

Delta Smelt

Option 4 would provide the greatest benefit to delta smelt because it ranks consistently best in relieving highly important and moderately important stressors. Option 3 would provide the second greatest benefit to delta smelt, followed by Option 2. Option 1 would provide the lowest benefit to delta smelt because it consistently ranked lowest in relieving important stressors to delta smelt. All Options, however, provide benefits for delta smelt relative to base conditions.

Option 1 would provide the lowest benefit to delta smelt. Although Option 1 would relieve multiple stressors, it consistently ranks lowest in performance among the Options. Option 1 is ranked lowest in benefits to quantity and quality of food, rearing and spawning habitat, turbidity, predation, and CVP/SWP entrainment. Option 1 performs best among the Options in reducing exposure of delta smelt to toxics, though this effect does not differ from base conditions.

Option 2 would provide the third highest benefit to delta smelt. Like Option 3, Option 2 would need to maintain export water quality standards in the southern Delta, but, unlike Option 3, this need would extend to all flow conditions in all water year types under Option 2. As a result, the ability to increase food quantity and accessibility and increase turbidity would be reduced under Option 2. Further, entrainment at CVP/SWP pumps would be greater under Option 2 than under Options 3 and 4.

Option 3 would provide the second highest benefit to delta smelt. A primary difference between Option 3 and Option 4 is the need under Option 3 to meet export water quality standards in the south Delta, and the adverse effects of increased reverse flows within Middle River, when the south Delta export facilities are operating, resulting in a reduced area available for potential habitat restoration. Option 3 provides the best opportunity to increase turbidity and reduce CVP/SWP entrainment. Option 3 provides the second highest opportunity (after Option 4) to increase delta smelt rearing and spawning habitat, increase food quantity, quality, and accessibility, and reduce predation by non-natives.

Option 4 would perform best among the Options for delta smelt because it would provide the best opportunity to relieve four of the five highly important stressors. This Option provides the greatest increase in food quantity and quality by providing the largest area, with the greatest geographic distribution, in which to restore habitat that, if appropriately designed, would promote the growth and abundance of native prey species and reduce abundances of non-native competitors and predators. Food quantity would also likely improve under Option 4 by reducing exports of nutrients and organic carbon by CVP/SWP pumps and increasing hydraulic residence time throughout the Delta. Turbidity levels, which positively affect both risk of predation and foraging efficiency of delta smelt, would likely be highest under Option 4. The quantity, quality, and accessibility of probable spawning habitat would be the greatest under Option 4 by allowing the greatest area of the Delta to be available for restoration. CVP/SWP entrainment of delta smelt would be virtually eliminated under Option 4 because there would be no south Delta diversions and the Hood diversion is located upstream of the main distribution of the delta smelt population. One major stressor to delta smelt that Option 4 could increase is exposure to toxics as a result of reduced Sacramento River dilution flows and increased relative contribution of lower quality San Joaquin River water. Opportunities for pollutant source control to reduce the potential risk of toxicity effects would be equally applicable across all Options.

Longfin Smelt

Option 4 would allow the greatest benefit to longfin smelt because it performs best in relieving highly important and moderately important stressors. Option 3 would provide the second greatest benefit to longfin smelt, Option 2 would rank third, and Option 1 would provide the lowest benefit to longfin smelt because it relieved stressors the least amount. All Options, however, provide benefits for delta smelt relative to base conditions.

Option 1 would provide the lowest benefit to longfin smelt. Although Option 1 would relieve multiple stressors, it consistently ranks lowest in performance among the Options. Option 1 would rank lowest in potential benefits to longfin smelt in terms of quantity and quality of food, rearing and spawning habitat, turbidity, predation, and CVP/SWP entrainment. Option 1 performs best among the Options in reducing exposure of longfin smelt to toxics, though this effect is identical to base conditions.

Option 2 would provide the third highest benefit to longfin smelt. Like Option 3, Option 2 would need to rely on the use of the Middle River channel for water conveyance to the export facilities and maintain export water quality standards in the south Delta, but, unlike Option 3, this need would extend to all flow conditions in all water year types under Option 2. Therefore, the ability to increase food quantity and accessibility and increase turbidity would be reduced under Option 2. Entrainment at CVP/SWP pumps would increase under Option 2 when compared with operations under either Options 3 or 4.

Option 3 would provide the second highest benefit to longfin smelt. A primary difference between Option 3 and Option 4 is the requirement under Option 3 to meet export water quality standards in the south Delta when south Delta pump facilities are operating, resulting in a reduced area available for potential habitat restoration. In addition, operation under Option 3 would continue to use Middle River as the primary pathway for water conveyance from the Sacramento River to the south Delta export facilities and therefore would degrade opportunities for habitat enhancement in the Middle River area and east side tributaries. Along with Option 4, Option 3 provides the best opportunity to increase turbidity and reduce CVP/SWP entrainment. Option 3 provides the second highest opportunity (after Option 4) to increase longfin smelt rearing and spawning habitat, increase food quantity, quality, and accessibility, and reduce predation by non-natives.

Option 4 would provide the greatest benefit to longfin smelt among the Options because it would provide the best opportunity to relieve multiple highly important stressors. Option 4 provides the greatest increase in food quantity and quality by providing the largest area, with the greatest geographic distribution, in which to restore habitat that, if appropriately designed, would promote abundances native prey species and reduce abundances of non-native competitors. Option 4 also provide hydrodynamic conditions, including reduced channel velocities and increased residence times, that would be expected to result in greater phytoplankton and zooplankton production within the Delta. Food quantity would also likely increase under Option 4 by reducing exports of nutrients and organic carbon by CVP/SWP pumps and increasing hydraulic residence time throughout the Delta. Turbidity levels would likely be greatest under Option 4. The quantity, quality, and accessibility of probable spawning habitat would be the greatest under Option 4 by allowing the largest area of the Delta to be available for restoration. Option 4 would also rank highest in reducing the risk of predation by non-native species by providing the greatest area of the Delta to be available for restoration, which, if appropriately designed, would reduce conditions for non-native predators. CVP/SWP entrainment of longfin smelt would decrease under Option 4 because there would be no south Delta diversions and the Hood diversion is upstream of the main distribution of the longfin smelt population. In addition, the diversion at Hood would be equipped with a state-of-the-art positive barrier fish screen that would be expected to effectively exclude juvenile and adult longfin smelt, and other fish species, from being entrained as a result of diversion operations. One major stressor to longfin smelt that Option 4 could increase is exposure to toxics due to reduced Sacramento River dilution flows and increased relative contribution of lower quality San Joaquin River water.

Sacramento River Salmon and Steelhead

Option 4 would provide the greatest benefit to Sacramento River Chinook salmon and steelhead (salmonids) because it ranks consistently best in relieving highly important and moderately important stressors. Option 3 would provide the second greatest benefit to Sacramento River salmonids, followed by Option 2. Option 1 would provide the lowest benefit to Sacramento River salmonids because it consistently ranked lowest in relieving important stressors to Sacramento River salmonids.

The overall performances of Options 1, 2, and 3 for Sacramento River salmonids are largely indistinguishable. Each Option scores highly with respect to relieving some stressors and poorly with respect to relieving others. For example, Option 3 performs well with respect to CVP/SWP entrainment, but scores poorly with respect to exposure to toxics. Option 1 performs well in reducing rearing and spawning habitat, but has no other benefits to Sacramento River salmonids. Because of the high natural variability and resulting level of uncertainty associated with the Delta ecosystem, it is not possible to distinguish among these Options with reasonable confidence.

Option 4 would perform best among the Options for Sacramento River salmonids because it would relieve, to the greatest degree, all of the stressors identified as highly important including non-native predation, rearing and outmigration habitat, staging and spawning habitat, and CVP/SWP entrainment.

San Joaquin River Salmon and Steelhead

Option 4 is expected to provide the highest level of benefit for San Joaquin River salmonids relative to base conditions and the other Options. Options 1, 2, and 3 would all be expected to provide similar benefits.

Based on the evaluation of the potential effects of the Options on important San Joaquin River salmonid stressors, Option 1 is expected to provide the lowest level of benefits relative to base conditions and the other Options because it consistently provides the lowest benefit to reducing the effects of both very high and moderately high stressors. The only stressor for which Option

1 would provide the greatest benefit is the exposure of San Joaquin River salmonids to toxics, but this effect would be no greater than base conditions.

Option 2 is expected to provide the third highest benefit to San Joaquin River salmonids. Option 2 is expected to perform marginally better than Option 1 by providing increased rearing and outmigration habitat and reducing the risk to predation by non-native species. Option 2 would perform lower than Option 1 with respect to exposure to toxics. It is expected that the effects of Option 2 on all other stressors will be similar to Option 1.

Option 3 is expected to provide the second highest benefit to San Joaquin River salmonids. Option 3 is expected to perform marginally better than Option 2 by providing increased staging and spawning habitat and reducing entrainment risk. Option 3 would perform lower than Option 2 with respect to exposure to toxics. It is expected that the effects of Option 3 on all other stressors will be similar to Option 2.

Option 4 is expected provide the highest level of benefit relative to base conditions and the other Options because it is likely to be more effective than the other Options in:

- improving access to staging and spawning habitat,
- improving rearing and outmigration habitat conditions,
- reducing predation risk, and
- reducing SWP/CVP entrainment risk.

Green and White Sturgeon

Option 1 is expected to provide a low benefit for green sturgeon and a very low benefit for white sturgeon relative to base conditions. Options 2 and 3 would have a low beneficial effect relative to base conditions for both sturgeon species. Option 4 would be expected to have a moderate beneficial effect relative to base conditions and would be expected to provide the greatest benefit among the Options for green and white sturgeon.

The important stressors for green and white sturgeon that are addressed by each of the Options include exposure to toxics and reduced rearing habitat. The remaining important stressors for this species can only be addressed outside of the planning area. Based on the evaluation of the potential effects of the Options on these stressors, Options 1, 2, and 3 are expected to provide a low level of benefit for green sturgeon relative to base conditions. These Options provide a lower level of benefit than under Option 4 because they provide fewer geographic opportunities for restoring habitat in the range of the green sturgeon within the planning. Option 1 is expected to provide a very low level of benefit for white sturgeon relative to base conditions and the other Options because it provides the fewest opportunities for restoring habitat in the range of the white sturgeon within the planning area.

Options 2 and 3 are expected to provide a low level of benefit to white sturgeon relative to base conditions, a higher benefit relative to Option 1, and a lower level of benefit relative to Option 4 because these Options provide greater geographic opportunities for restoring habitats in the Delta relative to Option 1, but fewer opportunities relative to Option 4.

Option 4 is expected to provide a moderate benefit for green and white sturgeon relative to base conditions and the greatest benefit among the Options because it provides greater geographic opportunities for restoring aquatic shallow water subtidal and intertidal habitats. Unlike Options 1 and 2, there would be a reduction in Delta inflows under Options 3 and 4 that could have a low adverse affect on exposure of sturgeon to toxics because the ability of inflows to dilute toxic concentrations would be reduced.

Options 3 and 4 perform lower than Options 1 and 2 with regard to exposure of green sturgeon and white sturgeon to toxics because Sacramento River inflows to the Delta, which are assumed to dilute concentrations of toxics, are lower relative to base conditions and Options 1 and 2. However, the effects of reductions in Sacramento River inflows under Options 3 and 4 on increasing the exposure of sturgeon to toxics are highly uncertain. Allowing San Joaquin River water, which has a high selenium load, to discharge into the Delta with reduced dilution from the Sacramento River under Options 2, 3, and 4 could increase the bioaccumulation of selenium in sturgeon. This evaluation assumes that, because source control reductions in San Joaquin River selenium loads have been mandated by the Regional Water Quality Board to be in place by 2012, selenium concentrations would not become elevated from base conditions under Options 2, 3, and 4. If source controls are unsuccessful and selenium concentrations were to increase in the Delta, Options 2, 3, and 4 would be expected to have an overall adverse effect on sturgeon.

Sacramento Splittail

The important stressors on Sacramento splittail that are addressed by each of the Options include reduced juvenile rearing/adult habitat; reduced food availability; reduced spawning/larval rearing habitat; exposure to toxics; predation; and SWP/CVP entrainment. Based on the evaluation of the potential effects of the Options on important splittail stressors, Option 4 is expected provide the highest level of benefit relative to base conditions. Option 3 is expected to perform better than Options 1 and 2.

Options 1 and 2 would be expected to provide a low level of benefit relative to base conditions and lower levels of benefit compared to Options 3 and 4 primarily because they are not expected to improve food availability or address entrainment as effectively as those Options.

Option 3 is expected to perform better than Options 1 and 2, because it is more likely to improve habitat conditions and food availability and reduce the effects of entrainment losses to a greater extent than those Options.

Option 4 is expected to provide a greater level of benefit than the other Options because it is more likely to improve habitat conditions and food availability and reduce effects of predation and entrainment losses to a similar or greater degree than the other Options.

Comparison of the Options Relative to the Planning Criteria

Criterion #8. Relative degree to which the Option allows covered activities to be implemented in a way that meets the goals and purposes of those activities.

Criterion #8 addresses the ability of the Options to achieve the water supply goals of the CVP and SWP. For the purposes of this evaluation, CVP/SWP export water reliability, project operational flexibility, and export water quality were used for describing the relative capability of each Option to meet this criterion. Option 3 is expected to perform the best with regard to meeting the goals and purposes of the covered activities, with Option 4 second. Option 2 is ranked third and Option 1 fourth.

Option 1 has the lowest export water quality with highest salinity and organics. Although the existing engineered system of Option 1 allows for high export reliability, regulatory restrictions significantly reduce reliability with the Option 1 structural configuration of through-Delta conveyance and limited protection of fish from pump facilities.

Option 2 provides higher quality water than Option 1, but the gravity-fed siphon appears to be a design flaw that would need to be solved for Option 2 to provide reliable water supply. Assuming an engineered solution (i.e., a low-head pump facility) to the siphon limitation under Reconfigured Option 2, anticipated water supply reliability is expected to be equal to or higher than Option 1. Physical constraints to operations (i.e., channel capacity of Victoria Canal) would need to be address for Option 2 to function in meeting supply reliability goals.

Hydrodynamic modeling results suggest that Option 3 provides the greatest combination of water supply reliability, flexibility of operations, and water quality. The dual facility operation allows opportunistic use of the most effective and efficient facility when hydrologic, hydrodynamic, and regulatory conditions limit the use of the other facility.

Option 4 performs well in meeting the goals of the covered activities, but its water reliability is constrained by the reliance on Sacramento River water only with the intake isolated from using east side tributary and San Joaquin River waters. Export water quality under Option 4 is consistently the highest of all Options.

Criterion #9. The relative feasibility and practicability of the Option, including the ability to fund, engineer, and implement.

Criterion #9 addresses the feasibility and practicability of implementing each of the Options. The evaluation of this criterion was based on a qualitative assessment of the certainty of technologies for successfully engineering new facilities, likely level of regulatory uncertainties, implementation cost, and practicability of the Option to meet both planning and conservation goals. All Options were determined to be of equivalent feasibility and practicability with each Option having different strengths and constraints contributing to this conclusion.

While Option 1 could be considered the most feasible Option because it would be of lowest initial cost, would not test any new technologies, and would avoid the new regulatory compliance, this Option does not offer a strong solution to meeting the key goals of species conservation and water supply reliability and would continue to face regulatory uncertainty for Delta operations. Option 1 is considered of moderate feasibility.

Option 2 would require some technological challenges in developing a siphon and pump system, modifying channels to support high flows, and operating the barriers to maximize opportunities for both conservation and water supply conveyance. Option 2 is considered of moderate feasibility.

Option 3 provides a flexible approach to addressing the combined goals of species conservation and habitat restoration using practicable technologies. This Option has the highest initial construction costs and construction of the both peripheral aqueduct and in-Delta facilities would require challenging regulatory compliance. Option 3 is considered of moderate feasibility.

Option 4 provides a highly flexible approach to addressing the combined goals of species conservation and habitat restoration using practicable technologies. Construction of the peripheral aqueduct would require challenging regulatory compliance and substantial cost. Option 4 is considered of moderate feasibility.

Criterion #10. Relative costs (including infrastructure, operations, and management associated with implementing the Option.

The Options were evaluated in terms of expected construction costs, Delta conveyance disruption costs, and redirected water quality costs. Because this evaluation assumes that the overall amount of habitat restoration would be roughly the same for each Option, costs for habitat restoration were not used to differentiate the four Options and therefore were not calculated. It is important to emphasize that much of the data and information relied on for the cost evaluation was cursory in nature. In all cases professional judgment was used to assess order-of-magnitude and relative costs. Key parts of the evaluation relied on information developed for the Delta Risk Management Strategy, some of which may be revised or updated as work products from that effort are refined and finalized. As new information comes to light the ordering of relative costs presented here could be affected. Therefore findings regarding the relative costs of the four Options should be viewed as preliminary rather than definitive. For example, the cost analysis does not include an assumption that levee improvements might be conducted by other programs for other reasons with associated direct cost savings and economic benefits to in-Delta uses such as species conservation.

The evaluation concluded that Option 4 would have the lowest long-term costs with Option 3 slightly higher or equivalent to Option 4. Option 2 ranked third because the long-term cost savings were estimated to be less than Options 3 and 4. The cost of Option 1 was estimated to be the highest as a result of on-going costs over the long-term.

Option 1 is anticipated to have the highest overall cost of all Options over the long term. While the cost of construction is anticipated to be much lower[1] than the other Options, the periodic cost of recovery from seismic and flood events and the on-going cost of municipal water treatment are expected to overcome the construction cost savings over time. Anticipated risk and cost of catastrophic loss under Option 1 is much higher than other Options, possibly as much as $10-50 Billion in costs at a 50% chance of occurrence in the next 25 years. Option 1 is not expected to significantly improve water quality over existing conditions and therefore would not accrue the substantial water treatment cost savings as other Options – ranging from $1.0-2.5 Billion over the next 25 years.

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[1] Note, however, that additional construction cost under Option 1 to improve CVP and SWP screening and salvage facilities could be on the order of $1.3 billion and were not included in the cost comparison here.

Options 2 would have a higher overall cost than Options 3 and 4 and a lower overall cost than Option 1. While construction costs for Option 2 are $3 to $5 Billion less than Option 3 and $3 to $4.5 Billion less than Option 4, the risk of catastrophic loss of conveyance and the cost for recovery from such events under Option 2 is much higher than under Options 3 and 4 and the cost savings to water treatment in service area is less under Option 2 than under Options 3 and 4. For these reasons, Option 2 is anticipated to result in higher overall costs over the long term than Options 3 and 4. Option 2 would have lower overall cost than Option 1 because the savings over time in recovery costs from seismic or flood events and in water treatment costs under Options 2 is anticipated to overcome the initial $0.5-2.8 Billion higher construction costs.

Option 3 would be expected to have the second lowest overall cost over the long term. This low cost is the result of savings from lower frequency of catastrophic events shutting down the water supply system and lower per-event costs for recovery from catastrophic events, and from substantial on-going savings resulting from reduced costs for water treatment in service areas. These savings are expected to recover over time the construction cost differences between Option 3 and Options 1 and 2. Option 3, as configured, is considered more expensive than Option 4 because the initial construction costs would be higher, on-going operational costs would be higher (operating and maintaining 2 facilities rather than 1), and savings on water treatment costs would be less. The on-going cost of Option 3, however, could be reduced by the value of increased water delivery capability from the operational flexibility provided by multiple intakes. Option 3 may have a lower risk of supply cutoff from seismic or flood events and, therefore, a lower long-term cost for recovery following catastrophic events than Option 4, but it cannot be concluded whether this difference is substantial enough to offset other costs over time.

Option 4 would be expected to have the lowest overall cost over the long term. This low cost is the result of savings from lower frequency of catastrophic events shutting down the water supply system and lower per-event costs for recovery from catastrophic events, and from substantial on-going savings resulting from reduced costs for water treatment in service areas. These savings are expected to recover over time the construction cost differences between Option 4 and Options 1 and 2.

Comparison of the Options Relative to Flexibility/Durability/Sustainability Criteria

Criterion #11. Relative degree to which the Option will be able to withstand the effects of climate change (e.g., sea level rise, changes in runoff), variable hydrology, seismic events, subsidence of Delta islands, and other large-scale changes to the Delta

Criterion #11 addresses the ability of the Options to withstand predicted possible large-scale changes to the Delta. The evaluation of this criterion was based on a qualitative assessment of the durability of each Option to withstand the effects of catastrophic events, such as earthquake or flood and climate change-caused sea level rise, on habitat restoration and water supply conveyance. Options 3 and 4 afford the greatest protection from catastrophic disruption of water supply and Option 4 the greatest protection from loss of restored habitat. Option 1 offers the least protection from catastrophic events and sea level rise. Option 2 falls between Options 1 and Options 3 and 4 in avoiding these risks.

Option 1 is expected to be at the greatest risk of water supply disruption from catastrophic levee failures that could result from seismic and flood events because Option 1 does not include improvements to protect conveyance facilities. Option 1 would support the least durable habitat restoration sites because a smaller area (approximately 28% of the planning area) is available for locating these sites. Greater clustering of restoration sites results in more vulnerability to larger losses of habitat with localized levee failures. In addition, habitat restoration under Option 1 is less likely to be located at sites that could be adapted to address sea level rise because there are fewer locations from which to choose. All Options, however, include restoration outside the planning area at Suisun Marsh, an area that likely is less subject to habitat loss from seismic or flood events than much of the planning area.

Option 2 affords a better level of protection of water supply from catastrophic events, but is still at a higher risk than Options 3 and 4 because the levees that direct conveyance through the north Delta are at greater risk of failure from seismic and flood events than the peripheral aqueduct included in Options 3 and 4 (the aqueduct would be expected to be engineered to withstand probable seismic and flood events). Option 2 provides more area (approximately 35% of the planning area) than Option 1 to distribute restoration sites more broadly to avoid large losses from localized levee failures. Because Option 2 provides more area for habitat restoration than Option 1 it provides more flexibility to locate restoration sites in areas suitable to withstand sea level rise.

Option 3 would provide more protection to water supply from seismic and flood events than Options 1 and 2 because the peripheral aqueduct component of Option 3 is more durable in a seismic or flood event than through-Delta conveyance. Option 3 offers redundancy in the protection of water supply delivery through its dual system and each conveyance offers a back-up to the other should one fail. Option 3 is the only Option with this feature. Option 3 provides more area (approximately 35% of the planning area) than Option 1 to distribute restoration sites more broadly to avoid large losses from localized levee failures. Because Option 3 provides more area for habitat restoration than Option 1 it provides more flexibility to locate restoration sites in areas suitable to withstand sea level rise. Option 3 is comparable to Option 2 in the protection of restoration sites and less protective of restoration sites than Option 4.

Option 4 would provide more protection to water supply facilities from seismic or flood events than Options 1 and 2 because the peripheral aqueduct component is expected to be more durable than in-Delta levees. Option 4 does not have the conveyance redundancy that provides a back-up system for water supply that is part of Option 3. Relocating the intake to the vicinity of Hood reduces the potential for sea level rise to affect water quality. Option 4 provides substantially more area (approximately 75% of the planning area) than all other Options for habitat restoration and, therefore, the most flexibility to find sites suitable to address sea level rise and to better distribute sites to avoid large habitat losses from localized levee failures.

Criterion #12. Relative degree to which the Option could improve ecosystem processes that support the long term needs of each of the covered species and their habitats with minimal future input of resources

This criterion addresses the performance of each Option with regard to avoiding the need for future on-going input of resources to support the conservation of covered species. The evaluation determined that Option 4 would rank highest in sustainability and avoiding such costs. Option 3 ranked second and Options 1 and 2 lowest because of on-going costs of in-Delta facilities operations and fish salvage to achieve conservation objectives.

Options 1 and 2 would entail ongoing management actions (i.e., salvage and hauling) and costs to address entrainment of covered fish species at the SWP/CVP export facilities and provide limited flexibility for adaptively managing Delta flows to meet species needs in the future. Use of the Delta for both fish habitat and through-Delta conveyance often results in competing operational priorities. Options 1 and 2 are wholly dependent on through-Delta conveyance and therefore are more likely to incur the costs associated with export restrictions. Option 2 requires the on-going cost of barrier management and monitoring to maintain the conservation benefits the barriers provide for fish.

Option 3 would be more likely to sustain ecosystem processes into the future than Options 1 and 2. This Option's dual conveyance facilities provide opportunities to adjust the timing of through-Delta pumping to minimize the likelihood for fish entrainment and its associated salvage costs. Use of the Delta for both fish habitat and through-Delta conveyance often results in competing operational priorities. Option 3, therefore, is considered less likely than Option 4 to sustain ecosystem processes with minimal future inputs because of ongoing costs that would be associated with barrier management and monitoring.

Option 3 also may require ongoing management actions depending on operational rules and changes in fish status as a result of overall conservation actions.

Option 4 provides the greatest habitat sustainability with the lowest future input of resources of the Options because it allows for the largest area of the Delta to be used for physical and hydrological habitat restoration. Natural processes could be allowed to support fish habitat, as opposed to more engineered solutions required under Options that must balance within-Delta operations between habitat and water supply conveyance. Habitat management under Option 4 is expected to require less input of funds and other resources to sustain fish populations. In addition, the much reduced level of entrainment under Option 4 would avoid the need for funding ongoing fish salvage at CVP and SWP intake facilities or to incur the costs associated with export restrictions.

Criterion #13. Relative degree to which the Option can be adapted to address needs of covered fish species over time

Criterion #13 addresses the ability to which the Options can be adapted to address the potential future needs of the covered fish species. The evaluation of this criterion was based on a qualitative assessment of the likely flexibility under each Option to adaptively manage Delta flows and restore additional habitat areas to address current uncertainties and future needs of the covered fish species. Option 4 is the most flexible in allowing for adaptive management of both hydrologic patterns and location of habitat restoration in the Delta. Options 2 and 3 are ranked second because of constraints on adaptive management. Option 1 ranked last with the most limited flexibility.

Option 1 is considered to be the least adaptable of the Options because, to meet water supply objectives, opportunities to adaptively manage Delta flow patterns are minimal. This Option lacks the flexibility for restoring habitats in the central, south, and east Delta if needed to meet the future needs of covered fish species. Under Option 1, only about 28% of the Delta is available for restoration of natural hydrology.

Option 3 is more constrained than Option 4, but does provide opportunities to adaptively manage Delta flows, having the ability to opportunistically convey water through-Delta or via a peripheral aqueduct to maximize benefits for covered species. The operable barriers along Middle River under Option 3 and 2 limit the opportunities for managing Delta flows to a much smaller proportion of the Delta than under Option 4. Under Options 2 only about 35% of the Delta is available for restoration of natural hydrology. With the opportunity to use the peripheral aqueduct, Option 3 would have greater flexibility than Option 2 in the operation of the in-Delta barriers to manage hydrologic conditions east of Middle River for the benefit of covered fish species and other aquatic organisms. The extent of areas available for habitat restoration and adaptive management is more limited under Option 3 than under Option 4.

Option 4 is expected to provide the greatest flexibility among the Options to adaptively manage Delta flows and restored physical habitat for the benefit of covered fish species. Because it is not constrained by the need to maintain the export quality of water in a through-Delta conveyance, Option 4 provides for the greatest geographic extent and percentage of the Delta area available for habitat restoration should it be necessary to increase the extent of or redistribute restored habitat for covered species in the future. Under Option 4, approximately 75% of the Delta would be available for restoration of natural hydrology and therefore would provide the best locations for physical habitat restoration.

Criterion #14. Relative degree of reversibility of the Option once implemented

Criterion #14 addresses the relative ability to reverse each of the Options once they are implemented. The evaluation of this criterion was based on a qualitative assessment of the practicability for reversing the Options based on likely levels of engineering feasibility, public acceptance, and costs for doing so. Option 1 is expected to be the most reversible based on the assumption of limited new facilities. Option 2 would be more reversible than Options 3 and 4 because it does not involve the peripheral aqueduct. Option 4 ranked third because of greater limits on reversing a completed peripheral aqueduct. Option 3 ranked last because it includes the largest amount of initial capital investment.

Option 1 is considered to be the most easily reversed of the Options because no costs associated with the removal of infrastructure would be incurred relative to current conditions.

Option 2 is less reversible than Option 1, but is considered to be substantially more reversible than Options 3 and 4, which would entail removal or abandonment of a peripheral aqueduct at likely enormous cost and loss of capital investment. Likely costs associated with reversing Option 3, which would also include removal or abandonment of Delta barriers, would be somewhat higher than Option 4. Because costs associated with reversing Options 3 and 4 and the consequent loss of capital investment would be substantial, the probability for obtaining the level of public acceptance necessary to reverse these Options is considered low.

Comparison of the Options Relative to Other Resource Impacts Criteria

Criterion #15: Relative degree to which the Option avoids impacts on the distribution and abundance of other native species in the BDCP Planning Area

Criterion #15 addresses the degree to which each of the Options avoids potential impacts on native species (other than the covered species) in the planning area. The evaluation of this criterion was based on a qualitative assessment of the likely degree of impacts on native aquatic organisms and terrestrial species present in the Delta. Option 1 would have the least impact on terrestrial species but potentially the greatest impact on aquatic species. Ranked second, Option 4 avoids much of the impacts on aquatic species but has large effects on terrestrial species. Option 2 was ranked third because it has the largest effects on aquatic species and substantial effects on terrestrial species from levee construction. Ranked lowest, Option 3 impacts aquatic species and has large effects on terrestrial species.

Without new facilities, Option 1 would have no construction impacts on native terrestrial species, but on-going entrainment of native aquatic species at the pump facilities would continue. Option 1 would be expected to have greater entrainment of aquatic organisms than the other Options because of the location and more exposed condition of the pump facilities.

Option 2 would have minor impacts on terrestrial and aquatic species associated with construction of operable barriers and the siphon, but 34 miles of levee improvements could result in substantial impacts on riparian and terrestrial species on islands surrounding Middle River and Victoria Canal. Option 2 would have a higher probability for entraining aquatic organisms from the south Delta than Options 3 or 4 because south Delta exports under Option 3 would be much reduced and exports would not be taken from the south Delta under Option 4. The placement and operation of the barriers along Middle River under Options 2 could result in impacts on native aquatic organisms if the barriers sufficiently impede the movement of aquatic species to and from the east and central Delta. Because the barriers are expected to be operable, there is the opportunity to adjust operation of barriers to minimize these potential impacts.

Overall, Option 3 is anticipated to have the largest impacts on native species in the planning area as a result of the large construction impacts of the peripheral aqueduct and additional impact of the barriers and siphon. Options 3 would result in substantial impacts on terrestrial native species due to construction of a peripheral aqueduct across over 40 miles of upland, riparian, and wetland habitats. The placement and operation of the barriers along Middle River under Options 3 could result in impacts on native aquatic organisms if the barriers sufficiently impede the movement of aquatic species to and from the east and central Delta. Because the barriers are expected to be operable, there is the opportunity to adjust operation of barriers to minimize these potential impacts.

Options 4 would result in substantial impacts on terrestrial native species due to construction of a peripheral aqueduct across over 40 miles of upland, riparian, and wetland habitats. Option 4 is expected to have the least impacts on native aquatic organisms. Water would not be exported from the south Delta, thereby eliminating the probability of entrainment at the SWP/CVP pumping facilities. Operation of a state-of-the-art fish screen at the intake of the peripheral aqueduct is expected to minimize entrainment of aquatic organisms. The loss of food from the

Sacramento River may result in greater impacts on aquatic food supply in the Delta than under Options 1 and 2.

Criterion #16. Relative degree to which the Option avoids impacts on the human environment

Criterion #16 addresses the relative degree to which implementation of each Option could impact the human environment. The evaluation of this criterion was based on a qualitative assessment of likely impacts on NEPA/CEQA resource categories. The evaluation of Criterion #16 focuses on the likely range of adverse direct and indirect impacts of the Options in the planning area and not the indirect impacts to water quality and water supply reliability and in the service areas. These issues in the service areas are addressed in Criteria #8 and #11. Option 1 is expected to have the least adverse effects on the human environment with limited new construction. Option 2 was ranked second with more moderate construction impact due to the extent and location of new facilities. Option 4 ranked third and Option 3 last with the large amount of construction impacts associated with new facilities.

Option 1 would have the least overall impacts on the human environment because it would not entail any construction that could disrupt use of the Delta or degrade the human environment and water quality conditions for agriculture in the Delta would be similar to existing conditions. Although Option 1 would have the fewest direct impacts, it is expected to result in the lowest export water quality with consequent adverse effects on treatment costs, agricultural production, and human health. Option 1 is also the most vulnerable among the Options to future disruption of water supply to service areas as a result of catastrophic events.

Option 2 is expected to have fewer impacts than Options 3 and 4 because improvements of levees under Option 2 is anticipated to affect fewer resources and with less magnitude of impact than the peripheral aqueduct construction. Option 2, is expected to provide higher water quality and be less vulnerable to supply disruption than Option 1, but portions of the conveyance system would still be vulnerable to future disruption and loss of water supply to service areas.

Options 3 and 4 entail construction of a peripheral aqueduct which could lead to substantial permanent (e.g., removal of agricultural land from production; changes in land use) and temporary (e.g., noise, traffic, air quality) impacts. Because Option 3 includes construction of dual conveyance facilities, it would result in greater overall impacts on the human environment than the other Options. Options 3 and 4 are expected to be substantially less vulnerable than Options 1 and 2 to future disruption of water supply. Export water quality improvements would be successively greater and attendant impacts on treatment costs, agricultural production, and human health successively reduced under Options 2, 3, and 4 in that order.

Criterion #17. Relative degree of risk of the Option causing impacts on sensitive species and habitats in areas outside of the BDCP Planning Area

Other Resource Impacts Criterion #17 addresses the degree of risk for causing impacts on other sensitive species and habitats outside of the planning area. The evaluation of this criterion was based on hydrodynamic modeling results for Delta outflows and end-of-September reservoir storage volumes as indicators of how each of the Options may affect species and habitats downstream and upstream of the Delta, respectively. Option 3 ranked highest because it is most flexible in supporting both upstream and downstream operations beneficial to biological resources. Option 4 ranked second because of its ability to support greater Delta outflows than Options 1 and 2. Options 1 and 2 were considered similar in their effects on species outside the planning area.

Options 1 and 2 are expected to have a neutral affect relative to base conditions on species and habitats downstream of the Delta because outflows provided under Options 1 and 2 are expected to be similar to base conditions.

Options 3 and 4 would provide average annual Delta outflows higher than Options 1 and 2 and base conditions. Delta outflows during critical months of March and April in critical dry years are similar across all Options. Because they generally would provide for greater Delta outflows, Option 3 and 4 would be the less likely to impact species and habitats in Suisun Marsh and Bay and other downstream locations.

In most water year types, the capacity for providing cold water releases from Shasta, Folsom, and Oroville Reservoirs would be similar under each of the Options and to current conditions. Reservoir storage volumes under Option 4 may be less than under the other Options in dry and critical water years and therefore may be the least likely to provide for cold water releases in those years. If selected, operations under Option 4 would need to be refined so that cold water temperature requirements are met.

CONCLUSIONS - OVERALL COMPARISON OF OPTIONS

Biological Criteria

The comparison of overall biological benefits of the Options focused primarily on the estuarine species that are most dependent on the Delta (delta smelt, longfin smelt, and splittail). These species are at greater population-level vulnerability to in-Delta impacts than salmon, steelhead, and sturgeon.

Option 4 would provide the greatest benefits among all Options to the estuarine species most dependent on the Delta (Table E-3). Option 4 would provide the most opportunity to address important stressors to delta smelt, longfin smelt, and splittail. Option 4 also would perform well for salmonids relative to other Options.

Option 3 would provide the next greatest benefits to the most vulnerable estuarine fish and also would perform well for salmonids.

Option 2 would not perform as well as Options 4 for any species; it would provide comparable benefit to salmonids and sturgeon as Option 3, but provides lower benefit to the more vulnerable estuarine species. Option 2 would outperform or match Option 1 for all species.

Option 1 performs the poorest for covered fish species. Option 1 would be outperformed by all other Options for delta smelt, longfin smelt, San Joaquin River salmonids and white sturgeon. Option 1 is matched in performance by all other Options for Sacramento River salmonids, green sturgeon, and splittail.

Planning Criteria

Options 3 and 4 both address planning criteria well and rank higher than Options 1 and 2 in all cases (Table E-3). Option 4 may be slightly more cost effective and practicable than Option 3, but Option 3 provides greater flexibility to meet water supply goals. Overall Options 3 and 4 were tied for first rank.

Options 1 and 2 were both considered poor in meeting planning criteria. Option 1 was considered too limiting to meet dual habitat conservation and water supply goals and too expensive in the long term due to large on-going costs of low export water quality. Option 2 includes a number of technical challenges for both conservation and water supply objectives. Option 2 costs are relatively high because of levee construction, more limited improvement in export water quality, and additional high cost facilities likely to be necessary (e.g., pump facility and fish screens).

Flexibility/Durability/Sustainability Criteria

Option 4 has the most flexibility and adaptability to adjust conservation approaches both for physical habitat restoration and flow management with the least input of future resources (Table E-3). Options 3 and 4 both rank highest for durability in the face of sea level rise and catastrophic seismic and flood events. Options 3 and 4 are the least reversible as they involve the most input of resources. Overall Option 4 was ranked highest for flexibility, durability and sustainability. Option 3 ranked second because of its more limited adaptability due to smaller area available for restoration of natural hydrology and physical habitat restoration for covered fish species.

Option 2 is less durable than Options 3 and 4 and more durable than Option 1 in the face of catastrophic events and sea level rise. Option 2 is less flexible than Option 3 and much less flexible than Option 4 to conduct adaptive management to address the needs of covered fish species and with a minimum input of future resources.

Option 1 was ranked the lowest because of it high risk to loss of habitat and water supply from catastrophic events and sea level rise. While Option 1 is obviously the most reversible, it has the least flexibility to adapt water operations and physical habitat restoration to meet the future needs of species without substantial input of resources.

Other Resource Impacts Criteria

Option 1 ranked highest for avoiding direct impacts on other biological and human resources because of the minimal amount of new infrastructure required (Table E-3). The high indirect effects of Option 1 in service areas were not addressed in this category, but were addressed in the planning criteria under costs. If indirect effects on the human environment of Options 1 in water service areas over the long-term were included in the evaluation of other resource impacts criteria grouping rather than in the planning criteria, then Option 1 may have been ranked lowest for other resource impacts.

Option 2, with a smaller construction impact footprint than Options 3 or 4, ranked second in avoiding impacts. Impacts on biological resources both inside and outside the Delta would be higher than Option 4.

Option 4 ranked third in avoiding impacts. It was ranked behind Option 2 because of the greater direct impacts human environment and ahead of Option 3 because it does not include the new in-Delta facilities of Option 3.

Option 3 ranked last as it would involve the most new construction and would have the most direct impacts on biological resources and the human environment in the Delta. Options 3 and 4 allowed for the most Delta Outflow and would be expected to benefit aquatic species in Suisun Marsh and Bay.

Overall Conclusions

Each Option offers opportunities and constraints to meeting conservation and water supply goals. The conclusions presented in this evaluation regarding which Option would be most successful in meeting the various criteria are dependent on many assumptions used in the analysis, reflecting the uncertainties in the current state of knowledge. Drawing more general conclusions about how each option performs across all of the criteria compounds these assumptions and their uncertainties. Thus, hard and fast conclusions about the overall performance of any particular option should be approached cautiously.

With the above caveats in mind, the conclusion of this report is that both Options 3 and 4 appear to provide significant improvements over the first two options across the biological, planning and flexibility criteria, and both, in turn, score less well in the "other resource impacts" category.

Options 1, 2, and 3 all geographically split the Delta in some way to accommodate the dual use for water conveyance and species conservation. Option 1 focuses physical habitat restoration in the north and west Delta to avoid the conflict at sites in the central and south Delta between conveyance hydrology and the restoration of natural hydrology. Options 2 and 3 split the Delta through engineered structures to separate conveyance to the east and habitat conservation to the west. In doing so, Options 2 and 3 fall in between the extent of habitat opportunities provided by Option 1 (the lowest) and Option 4 (the highest).

Option 3 appears to perform better than all other options in its ability to meet water supply planning goals and objectives, and in its resiliency in response to catastrophic events. Its performance biologically is consistently superior to Options 1 and 2, but is less robust than Option 4. Its dual conveyance feature may provide significant operational flexibility over and above the other options.

Option 4 appears to provide the greatest opportunity to meet the greatest number of criteria. It allows for the most opportunities over a much larger proportion of the Delta to combine the restoration of natural hydrology beneficial to covered fish species with the restoration of physical habitat for those species. It separates geographically and hydrologically the frequently conflicting requirements (structural and operational) of export water conveyance and aquatic species conservation (allowing for the greatest flexibility in accomplishing habitat conservation). Finally, it provides high long-term water supply reliability with the highest export water quality at the lowest overall cost. A key constraint of Option 4 is the limitation of export capabilities to a single north Delta intake – a limitation which affects both water supply reliability and Delta inflows for conservation.

In summary, this evaluation describes how each of the Options performs in relation to a wide range of criteria. This information will assist the Steering Committee over the course of the fall in selecting an option to carry forward into the planning process. The Steering Committee may select of the four options as is, or it may further refine an option into a new hybrid to take into the planning process.

1.0 INTRODUCTION

1.1 BACKGROUND AND PURPOSE

The Steering Committee for the Bay-Delta Conservation Plan (BDCP) is developing a comprehensive conservation plan for the Sacramento and San Joaquin Delta pursuant to a planning agreement that was executed on October 6, 2006 (BDCP 2006). The BDCP planning area is the legal Delta (Figure 1-1). In first half of 2007, the Steering Committee developed a list of ten conceptual conservation strategies, evaluated those strategies, and shortened that list to four Conservation Strategy Options (Options). Those four Options are evaluated in this report. The Steering Committee is intent on further narrowing the remaining Options to a single Option (derived from one or more of the evaluated Options) that will be carried forward into a detailed conservation planning process over the course of the next year. The chosen Option will serve as the nucleus for the larger conservation plan and other major elements of the strategy will be formulated around it. This larger, more comprehensive conservation plan will then be evaluated through a formal, public environmental review process under the National Environmental Policy Act (NEPA) and the California Environmental Quality Act (CEQA).

The purpose of this report is to evaluate the four Options in order to assist the Steering Committee in identifying which Option to carry forward into the planning process. This report describes how each of the four Options performs with respect to seventeen evaluation criteria identified by the Steering Committee for this purpose. It should be emphasized that this evaluation provides only an initial assessment of the relative performance of each of the four Options as described herein. It is likely that some elements of the selected Option will need to be refined further in light of information contained in this report and elsewhere. The Steering Committee may over the course of the fall elect to select one of the four Options to carry forward, or it may choose instead to modify or otherwise refine one of the Options and carry that modified Option into the planning process.

1.2 APPROACH TO EVALUATION

A summary of the approach to the Options evaluation is provide here, with a more detailed description of the approach provided in Section 2, "Evaluation Methods." The approach to this evaluation focused on the comparative ability of each Option to address each of the evaluation criteria. The four Options center around two main elements: the structural conveyance system and the location of habitat restoration opportunities. Using performance metrics, the evaluation identifies how the differing structural conveyance system and the habitat restoration opportunities among the Options distinguish the Options from each other. The Options are describe in Section 1.3, "Descriptions of Conservation Strategy Options."

The seventeen evaluation criteria (see Section 1.5 "Evaluation Criteria" for full text of criteria) are grouped into four categories:

- biological criteria,
- planning criteria,

- flexibility/durability/sustainability criteria, and
- other resource impact criteria.

Specific metrics for use in the evaluation of each criterion were developed and scaling of the metrics, quantitatively or qualitatively, was used to score or rank the Options against each other or against base conditions (see Section 1.4 "Base Conditions" for the definition of base conditions used). The evaluation criteria were designed to allow a comparison of the Options at this stage of the process. There are other criteria and issues, not included here because they did not appear to differentiate the Options, that will need to be addressed in the future as the larger strategy is developed. In addition, the evaluation makes some assumptions that are acceptable at this level of analysis but that will need to be further evaluated as the larger strategy is developed. For example, in the biological evaluation, it is assumed that habitat restoration can be effective in alleviating some stressors on the species. This assumption should be valid for this coarse analysis, but as planning for habitat restoration proceeds, more work will be needed on those specific stressors and the habitat conditions needed to address them.

1.2.1 Biological Criteria

For purposes of evaluating the relative ability of each of the four Options to meet the biological criteria, this report assesses the relative performance of each Option on a species-by-species basis. At present, the BDCP has identified nine potentially covered species:

- delta smelt,
- longfin smelt,
- winter-run Chinook salmon,
- spring-run Chinook salmon,
- fall- and late-fall-run Chinook salmon,
- Central Valley steelhead,
- green sturgeon,
- white sturgeon, and
- Sacramento splittail.

The comparative evaluation provided in this report is based on existing scientific information about environmental stressors affecting the nine covered fish species and Delta ecosystem processes important to supporting these species. The evaluation is largely qualitative, based on the best professional judgment of individuals who are knowledgeable about the covered species, the complex hydrology of the Delta, and the interplay of that hydrology with the ecological requirements of the individual species of fish. It includes the use of preliminary, coarse-level hydrodynamic modeling applying a broad range of input parameters to the four

Options to enable a comparison of the Options' relative ability to provide flow and water quality conditions that benefit the species. For the purpose of evaluating the operating flexibility of each Option, hydrodynamic models CALSIM II and DSM 2 were applied using input parameters that spanned a range of potential operations for each Option. The results of these models were interpreted for anticipated effects on each fish species based on published and unpublished literature and best professional judgment. Each Option's effect on each species is based on an assessment of how the Option affects the species' stressors and the degree of those effects is compared among the Options using the metrics established for each of the biological criteria.

While the Options do not include any specific locations for habitat restoration, the evaluation also identifies the relative opportunities and constraints of each Option for physical restoration of high functioning habitat that would improve ecological conditions for covered species.

1.2.2 Planning Criteria

The planning criteria focus on the ability of each Option to achieve the BDCP planning goals. This comparative evaluation is based on the results of hydrodynamic modeling to estimate the ability of each Option to achieve water supply goals; a cost comparison of both initial construction and long-term costs; and the relative practicability of the implementation.

1.2.3 Flexibility/durability/sustainability Criteria

These criteria address the flexibility, durability, and sustainability of each Option. These criteria focus primarily on the long-term ability of each Option to meet conservation and planning goals in the face of changing environmental conditions and expanding ecological knowledge. The report uses information from preliminary results of Delta Risk Management Strategy (DRMS) studies in evaluating the durability of the Options in response to catastrophic events in the Delta and long-term climate change.

1.2.4 Other Resource Impacts Criteria

The other resource impacts criteria focus on the unintended adverse effects of implementing each Option on the human environment and on other biological resources within and outside the Delta. This evaluation is based on prior environmental studies in the Delta that have evaluated actions similar to the four Options and on the outputs of the hydrodynamic modeling.

1.2.5 Other Important Stressors and Conservation Elements

A number of potentially important ecological stressors on fish are not directly addressed by the Options as they are presently defined such as toxics, predation, competition, harvest, and turbidity. While the Options may indirectly address these stressors, there are many conservation elements that could be added to the Options that would more fully address them. These important stressors and the conservation elements that could address them and benefit specific covered species are discussed in Section 8 of the evaluation. Conservation elements addressing such stressors may be equally applicable under all Options and, therefore, do not serve to distinguish among the Options in the evaluation. Conservation elements addressing these other stressors may become important components of the larger conservation strategy as it is further developed.

1.3 DESCRIPTIONS OF CONSERVATION STRATEGY OPTIONS

The four Options evaluated in the report were developed by the Steering Committee around two key components:

- Conveyance – the structural approach to conveyance of water to meet the goals for conservation of covered species and water supply reliability.
- Habitat restoration – the general type and location of habitat restoration opportunities in the Delta and in adjacent Suisun Marsh to address covered species conservation

The Options presented here represent a range of conveyance and habitat restoration approaches developed for the purpose of comparative evaluation. All of the Options could be refined, modified, or expanded to improve their performance in addressing the evaluation criteria.

1.3.1 Conservation Strategy Option 1: Existing Through-Delta Conveyance

Option 1 would involve the use of existing conveyance and pump facilities with operations focused on reducing take at the export facilities and improvement of hydrologic conditions for fish in the northern and western Delta; physical habitat restoration would be focused in the north and west Delta and Suisun Marsh (Figure 1-2). The estimated area available for habitat restoration encompasses approximately 28% of the BDCP planning area (i.e., the legal Delta).

Facilities

Option 1 would use the existing C.W. "Bill" Jones Pumping Plant (Jones Pumping Plant) of the Central Valley Project (CVP) and Harvey O. Banks Delta Pumping Plant (Banks Pumping Plant) of the State Water Project (SWP) as export facilities in the South Delta, including continued use of Clifton Court Forebay.

Water operations

Water operations for Option 1 have not been characterized at this time. For the purpose of this evaluation, the Science Applications International Corporation (SAIC) consulting team developed and used key input parameters to the CALSIM II and DSM2 hydrologic models to assess the potential of this Option to meet specific biological and planning criteria. Two sets of parameter values were used to bracket a broad range of potential hydrologic and hydrodynamic conditions that could be associated with water operations under Option 1 (see Section 2.2). The operational inputs were developed solely for the purpose of this evaluation and do not represent any specific proposal for operations from any member of the Steering Committee or other entity. Model parameters and parameter values used to capture a range of water operations under Option 1 are presented in Appendices A and B.

Habitat restoration and enhancement

Based on anticipated hydrodynamic conditions within Delta channels associated with exports from the existing SWP and CVP export facilities, opportunities for habitat restoration and enhancement have been primarily identified within the northern and western regions of the Delta (Figure 1-2). Although water operations for exports would not preclude habitat restoration and enhancement within the central or southern Delta, potential biological benefits are anticipated to be lower due to increased water velocities and reduced residence time, as well as increased vulnerability to entrainment at SWP and CVP export facilities, when compared to enhanced habitat located further away from the potential zone of export influence. Potential habitat restoration and enhancement opportunities association with Option 1 could include:

- Increase spawning habitat for salmon and steelhead within the upstream reaches of the mainstem of the Sacramento River and major tributaries.
- Modify the existing channel configuration and levees on the mainstem of the Sacramento River to increase the frequency and duration of seasonal floodplain inundation over a wider range of flow conditions than currently exists.
- Provide an alternative migration route for Chinook salmon, steelhead, and other resident and migratory fish within the northern region of the Delta that would bypass the Delta Cross Channel and Georgiana Slough.
- Increase habitat diversity and complexity and food production for delta smelt and other resident fish species within the northern Delta by enhancing the area of freshwater tidal wetlands.
- Improve the hydraulic residence time and tidal exchange within sloughs and channels and consider relocating or modifying the Barker Slough pumping plant, as needed.
- Provide connectivity by securing a wildlife corridor between high-value habitat within the northern region of the Delta and Suisun Marsh.
- Increase the availability of brackish and freshwater tidal habitat in Suisun Marsh, including dendritic channels within both intertidal and subtidal areas by reconfiguring levees and water management along the channel margins adjacent to Suisun Bay and along interior channels.
- Protect and promote enhancements to tidal wetlands within the area adjacent to Sherman Lake.
- Construct interior levees, thus re-establishing tidal inundation and promoting tidal wetland development within the western portion of the Delta and Suisun Bay.
- Construct interior levees to allow tidal inundation along channel margins of the lower Sacramento River.

- Provide setback levees and other modifications to the channel adjacent to Suisun Bay and the lower Sacramento River to allow tidal inundation and promote tidal wetland vegetation colonization.

- Implement a management program at Clifton Court Forebay that may include actions such as predator removal, modification of radial gate operations, and adding facilities to promote fish passage from the radial gate to the salvage facility.

- Improve the collection, handling, transport, and release facilities and procedures at both the SWP and CVP salvage facilities.

Under Option 1, opportunities to establish more natural hydrologic conditions would primarily be limited to the region located west of the confluence of the Sacramento and San Joaquin Rivers.

1.3.2 Conservation Strategy Option 2: Improved Through-Delta Conveyance

Option 2 would involve improvement of through-Delta conveyance by (1) constructing operable barriers and levee improvements along Middle River; (2) constructing operable barriers on the San Joaquin and Old Rivers; (3) separating water supply conveyance flows from San Joaquin River flows with a siphon (and pump facility) connecting the Victoria Canal and Clifton Court Forebay; (4) operations focused on reducing take at the export facilities and improvement of hydrologic conditions for fish in the northern, western, central, and southern Delta; and (5) physical habitat restoration focused in the north, west, central, and south Delta and Suisun Marsh (Figure 1-3). The estimated area available for habitat restoration encompasses approximately 35% of the BDCP planning area and is the same area that is available for restoration under Option 3.

That the hydrodynamic modeling results for Option 2 indicated that a gravity siphon would not convey water at a sufficient rate to meet supply goals and, therefore, a low-head pump facility was assumed to be included at the siphon in the evaluation of Option 2. The addition of a pump facility to Option 2 allows for a comparative evaluation of all Options on an equal basis in which each Option is capable of achieving the planning objectives stated in the BDCP Planning Agreement (BDCP 2006).

Facilities

The new facilities under Option 2 are presented in Figure 1-3 and include:

- Operable physical channel barriers near the confluence of Middle River and the following channels:
    - Woodward Canal,
    - Railroad Cut, and
    - Connection Slough.

- Operable physical channel barriers on the Old River near the confluence with the San Joaquin River and on the San Joaquin River near the head of Old River.

- Siphon with low-head pump facility connecting Victoria Canal with Clifton Court Forebay under Old River, thus allowing direct conveyance of Middle River water through Victoria Canal to Clifton Court Forebay and the SWP pumping facility.

- Reinforcement of levees along Victoria Canal and along Middle River from Medford Island to Victoria Canal.

- Hydraulic intertie between Clifton Court Forebay and the CVP intake channel in the south Delta.

Water operations

Water operations for Option 2 have not been characterized at this time. For the purpose of this evaluation, key input parameters to the CALSIM II and DSM2 hydrologic models were developed and used for the purpose of assessing the potential of this Option to meet specific biological and planning criteria. Two sets of parameter values were used to bracket a broad range of potential hydrologic and hydrodynamic conditions that could be associated with water operations under Option 2 (see Section 2.2). The operational inputs were developed solely for the purpose of this evaluation and do not represent any specific proposal for operations from any member of the Steering Committee or other entity. Model parameters and parameter values used to capture a range of water operations under Option 2 are presented in Appendices A and B.

Habitat restoration and enhancement

Based on a consideration of the tidal hydrodynamics that would be anticipated in the Delta under Option 2, all of the habitat restoration and enhancement opportunities identified under Option 1 would be available under Option 2. Under Option 2, opportunities for habitat restoration and enhancement would be expanded to include the central and southern regions of the Delta, as shown in Figure 1-3. In addition, a siphon would be used to convey water from Victoria Canal to the export facilities without obstructing the Old River channel. The siphon would provide habitat restoration and enhancement opportunities within the San Joaquin River bypass and mainstem San Joaquin River (Figure 1-3). In addition to the features identified in Option 1, additional habitat enhancement under Option 2 may include:

- Increase habitat diversity and complexity by increasing the availability of tidally inundated shallow water wetland habitat through setback levees or the creation of additional berms associated with the channels west of the proposed Middle River barriers.

- Increase the availability of seasonal floodplain habitat inundation as well as tidal inundation along channels in the southern Delta.

Under Option 2, opportunities to establish more natural hydrologic conditions would be limited to the region located west of Middle River (Figure 1-3).

1.3.3 Conservation Strategy Option 3: Dual Conveyance

Option 3 would involve dual conveyance facilities and physical and operational habitat restoration and enhancement. Conveyance would be via: (1) a peripheral aqueduct with an intake on the Sacramento River and isolated connection at the SWP/CVP pump facilities; (2) an improved through-Delta conveyance with operable barriers on connecting channels along Middle River and on the San Joaquin and Old Rivers and (3) separated water supply flows from San Joaquin River flows by a siphon. Operations would focus on the use of the flexibility of dual conveyances to reduce take of covered fish species at the export facilities and improve hydrologic conditions for covered fish in the northern, western, central, and southern Delta. Physical habitat restoration and enhancement would be focused in the north, west, central, and south Delta and Suisun Marsh (Figure 1-4). The estimated area available for habitat restoration encompasses approximately 35% of the BDCP planning area and is the same area that is available for restoration under Option 2.

Facilities

The new facilities under Option 3 are presented in Figure 1-4 and include:

- Operable physical channel barriers near the confluence of Middle River and the following channels:
    - Woodward Canal,
    - Railroad Cut, and
    - Connection Slough.
- Operable physical channel barriers on the Old River near the confluence with the San Joaquin River and on the San Joaquin River near the head of Old River.
- Siphon under Old River connecting Victoria Canal with Clifton Court Forebay, thus allowing direct conveyance of Middle River water through Victoria Canal to Clifton Court Forebay and the SWP pumping facility.
- An intake facility with state-of-the-art positive barrier fish screens on the Sacramento River near Hood or Clarksburg.
- Peripheral aqueduct and associated appurtenant facilities (i.e., pumping plant and siphons) that would traverse from the new intake facility along the Sacramento River southerly along an alignment in the East Delta adjacent to, and west of, Interstate 5. The Peripheral aqueduct would terminate south of Clifton Court Forebay and tie into the existing SWP and CVP facilities.

Under this Option, the existing export facilities (Jones Pumping Plant and Banks Pumping Plant) in the south Delta may be used in addition to the new intake facility on the Sacramento River.

Water operations

Water operations for Option 3 have not been characterized at this time. For the purpose of this evaluation, key input parameters to the CALSIM II and DSM2 hydrologic models were developed and used for the purpose of assessing the potential of this Option to meet specific biological and planning criteria. Two sets of parameter values were used to bracket a broad range of potential hydrologic and hydrodynamic conditions that could be associated with water operations under Option 3 (see Section 2.2). The operational inputs were developed solely for the purpose of this evaluation and do not represent any specific proposal for operations from any member of the Steering Committee or other entity. Model parameters and parameter values used to capture a range of water operations under Option 3 are presented in Appendices A and B.

Habitat restoration and enhancement

Because Option 3 would include the same barriers as Option 2 and use the Middle River corridor for water conveyance, habitat restoration and enhancement opportunities under Option 3 (Figure 1-4) are anticipated to be comparable to habitat opportunities identified and described for Option 2 (Figure 1-3). To the extent that water exported through the peripheral aqueduct from the Sacramento River at Hood or Clarksburg, habitat restoration and enhancement opportunities could be extended to other areas of the northern Delta and eastern Delta tributaries and sloughs. As a result of the uncertainties regarding dual conveyance facility operations, the primary focus on habitat restoration and enhancement opportunities under Option 3 would be the same as Option 2 in the northern and western portions of the Delta and central and southern Delta channels located to the west of the barriers on Middle River (Figure 1-4).

Under Option 3, opportunities to establish more natural hydrologic conditions would, for the most part, be limited to the region west of Middle River (Figure 1-4).

1.3.4 Conservation Strategy Option 4: Peripheral Aqueduct

Option 4 would involve construction of a peripheral aqueduct with an intake on the Sacramento River and isolated connection at the SWP and CVP pump facilities. Operations would provide the flexibility to improve hydrologic conditions for covered fish species throughout the Delta and to physically restore and enhance habitat opportunistically throughout the Delta and Suisun Marsh (Figure 1-5). The estimated area available for habitat restoration encompasses approximately 75% of the BDCP planning area.

Facilities

The new facilities under Option 4 are presented in Figure 1-5 and include:

- An intake facility with state-of-the-art positive barrier fish screens on the Sacramento River near Hood or Clarksburg.

- A peripheral aqueduct and associated appurtenant facilities (i.e., pumping plant and siphons) that would traverse from the new intake facility along the Sacramento River southerly along an alignment in the East Delta adjacent to, and west of, Interstate 5. The conveyance canal would terminate south of Clifton Court Forebay and tie into the existing SWP and CVP facilities.

Water operations

Water operations for Option 4 have not been characterized at this time. For the purpose of this evaluation, key input parameters to the CALSIM II and DSM2 hydrologic models were developed and used for the purpose of assessing the potential of this Option to meet specific biological and planning criteria. Two sets of parameter values were used to bracket a broad range of potential hydrologic and hydrodynamic conditions that could be associated with water operations under Option 4 (see Section 2.2). The operational inputs were developed solely for the purpose of this evaluation and do not represent any specific proposal for operations from any member of the Steering Committee or other entity. Model parameters and parameter values used to capture a range of water operations under Option 4 are presented in Appendices A and B.

Habitat restoration and enhancement

Under Option 4, all of the SWP and CVP exports would occur through a state-of-the-art positive barrier fish screen located on the Sacramento River near Hood or Clarksburg. Hydrodynamic conditions within the Delta would be expected to have a net westerly flow, thus restoring more natural Delta conditions (Figure 1-5). Under the export and Delta hydrologic conditions expected to occur under Option 4, opportunities for habitat restoration and enhancement would include most of the Delta (Figure 1-5). Habitat restoration and enhancement opportunities under Option 4 would encompass all opportunities identified under Options 1, 2, and 3. Additionally, Option 4 would support opportunities to create floodplains, seasonal bypasses, corridors for migration, and shallow tidally inundated wetland areas extended geographically eastward to approximately Interstate 5.

Under Option 4, opportunities to establish more natural hydrologic conditions would occur throughout the Delta extending eastward to approximately Interstate 5 (Figure 1-5).

1.4 BASE CONDITIONS

Base Delta conditions are used in this evaluation to provide a common basis of comparison from which to assess the performance of each Option to each relevant criterion. Base conditions for the biological and physical environment are defined as the present state of the Delta ecosystem and supporting processes, including the present distribution and abundance of the covered fish species as of the most recent monitoring and research information available for the specific resource. For the Delta hydrodynamics used in the hydrodynamic modeling, base conditions for the Delta are defined as ongoing operation of existing facilities, current year water supply demands, and existing regulatory constraints as outlined in the State Water Resources Control Board (SWRCB) Water Rights Decision 1641 (D-1641) and the most recent U. S. Fish and Wildlife Service (FWS) and National Marine Fisheries Service (NMFS) biological opinions on coordinated operations of CVP and SWP and the Operating Criteria and Plan (OCAP) (SWRCB 1999; FWS 2005; NMFS 2004).

No attempt was made to identify a Delta environmental baseline under federal or state environmental regulations for use in this evaluation of the Options. The comparative evaluation of Options is an early screening-level planning process that does not require the level of detail or regulatory specificity that later, more detailed BDCP effects analyses will include.

1.5 EVALUATION CRITERIA

The evaluation of the four Options is based on the application of seventeen evaluation criteria adopted by the BDCP Steering Committee. The methods, metrics, and scales used to apply each of these criteria are presented in Section 2, "Evaluation Methods." These criteria are the same as those that were used to evaluate the BDCP Conservation Element Bundles (BDCP 2007). The criteria were developed based on the BDCP Planning Agreement planning goals (Section 3) and preliminary conservation objectives (Section 6), the draft BDCP conservation objectives approved by the BDCP Steering Committee, and previously developed criteria for evaluating approaches to conserving the Delta (Mount et al. 2006). The criteria are classified into four categories: biological, planning, flexibility/durability/sustainability, and other resource impacts.

Biological Criteria

1. Relative degree to which the Option would reduce species mortality attributable to non-natural mortality sources to enhance production (reproduction, growth, and survival), abundance, and distribution for each of the covered fish species (BDCP Conservation Objective).

2. Relative degree to which the Option would provide water quality and flow conditions necessary to enhance production (reproduction, growth, and survival), abundance, and distribution for each of the covered fish species (BDCP Conservation Objective).

3. Relative degree to which the Option would increase habitat quality, quantity, accessibility, and diversity to enhance and sustain production (reproduction, growth, and survival), abundance, and distribution, and to improve the resiliency of each of the covered species' populations to environmental change and variable hydrology (BDCP Conservation Objective).

4. Relative degree to which the Option would increase food quality, quantity, and accessibility (e.g., phytoplankton, zooplankton, macro-invertebrates, and forage fish) to enhance production (reproduction, growth, and survival) and abundance for each of the covered fish species (BDCP Conservation Objective).

5. Relative degree to which the Option would reduce the abundance of non-native competitors and predators to increase native species production (reproduction, growth, and survival), abundance, and distribution for each of the covered fish species (BDCP Conservation Objective).

6. Relative degree to which the Option improves ecosystem processes in the BDCP planning area to support aquatic and associated habitats (BDCP Conservation Objective).

7. Relative degree to which the Option can be implemented within a timeframe to meet the near-term needs of each covered fish species (assumed following BDCP authorization).

Planning Criteria

8. Relative degree to which the Option allows covered activities to be implemented in a way that meets the goals and purposes of those activities.

9. The relative feasibility and practicability of the Option, including the ability to fund, engineer, and implement.

10. Relative costs (including infrastructure, operations, and management) associated with implementing the Option.

Flexibility/Durability/Sustainability Criteria

11. Relative degree to which the Option will be able to withstand the effects of climate change (e.g., sea level rise and changes in runoff), variable hydrology, seismic events, subsidence of Delta islands, and other large-scale changes to the Delta.

12. Relative degree to which the Option could improve ecosystem processes that support the long-term needs of each of the covered species and their habitats with minimal future input of resources.

13. Relative degree to which the Option can be adapted to address the needs of covered fish species over time.

14. Relative degree of reversibility of the Option once implemented.

Other Resource Impacts Criteria

15. Relative degree to which the Option avoids impacts on the distribution and abundance of other native species in the BDCP planning area.

16. Relative degree to which the Option avoids impacts on the human environment.

17. Relative degree the Option avoids impacts on sensitive species and habitats in areas outside of the BDCP planning area.

1.6 REPORT ORGANIZATION

The sections and content of this Options Evaluation Report are described below:

Section 1, "Introduction," describes the background and purpose this report and the approach to the evaluation, provides descriptions of the conservation strategy options, lists the current conditions of the site, and presents the evaluation criteria used to compare the Options.

Section 2, "Evaluation Methods," describes the species stressors and hydrodynamic modeling methods and results that were used to evaluate the Options and the metrics and assumptions used to evaluate the performance of each Option for each evaluation criterion.

Section 3, "Conservation Strategy Option 1 Evaluation," presents the evaluation results for Option 1 by evaluation criteria category.

Section 4, "Conservation Strategy Option 2 Evaluation," presents the evaluation results for Option 2 by evaluation criteria category.

Section 5, "Conservation Strategy Option 3 Evaluation." presents the evaluation results for Option 3 by evaluation criteria category.

Section 6, "Conservation Strategy Option 4 Evaluation." presents the evaluation results for Option 4 by evaluation criteria category.

Section 7, "Comparison of the Options," compares the relative performance of each of the Options based on the metrics and scales established for each of the evaluation criterion.

Section 8, "Opportunities for Conservation Elements Available Under all Options," describes additional conservation elements that could be implemented within the planning area under all of the Options and identifies species stressors that are not addressed by the Options, but which could be addressed by additional conservation elements implemented inside or outside of the planning area.

Section 9, "References," lists the references and personal communications cited in this Options Evaluation Report.

Figure 1-1 identifies features in of the BDCP planning area that are mentioned in this report. The contents of appendices to this Options Evaluation Report are described below:

Appendix A, "Description of Hydrologic/Hydrodynamic Analytical Tools and Summary of Modeling Results," describes the CALSIMII and DSM2 models used in the evaluation and summarizes the modeling results.

Appendix B, "Flow Parameters and Parameter Values used in CALSIM2 and DMS2 Modeling of the Options," presents the range of flow parameter values used in the CALSIM2 and DMS2 models.

Appendix C, "Covered Fish Species Stressors," presents the highly and moderately important stressors for each of the covered fish species and the process used to identify the stressors.

Appendix D, "CALSIM2 and DMS2 Modeling Results for Option 1," presents the hydrodynamic modeling results for Option 1.

Appendix E, "CALSIM2 and DMS2 Modeling Results for Option 2," presents the hydrodynamic modeling results for Option 2 as originally described with a gravity siphon.

Appendix F, "CALSIM2 and DMS2 Modeling Results for Option 3," presents the hydrodynamic modeling results for Option 3.

Appendix G, "CALSIM2 and DMS2 Modeling Results for Option 4," presents the hydrodynamic modeling results for Option 4.

Appendix H, "Options Scores by Evaluation Criteria Metrics," presents the evaluation scores for each Option by metrics used to assess Option performance relative to each of the evaluation criterion.

FIGURES

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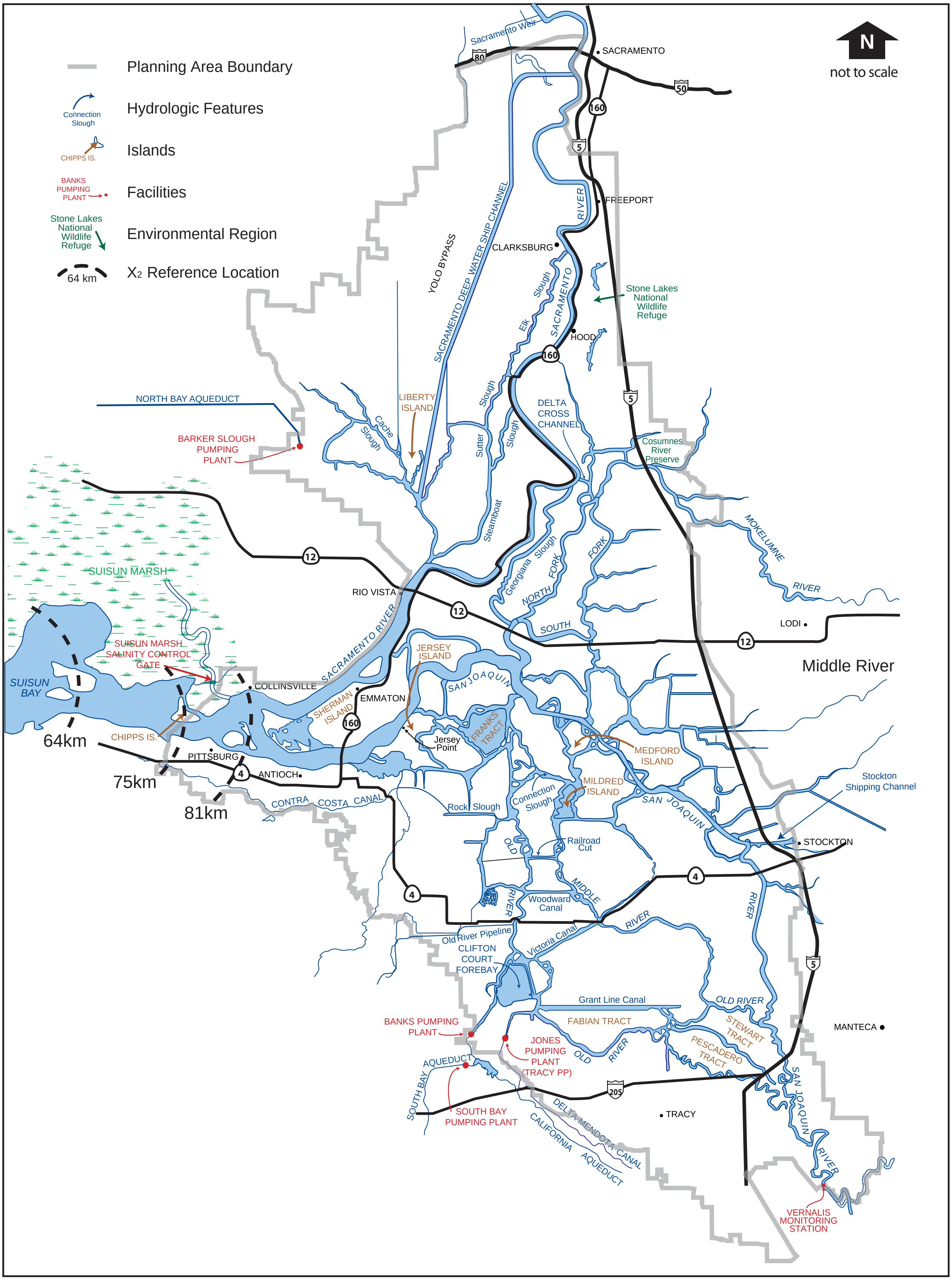

Figure 1-1. Locator Map of Planning Area with Key Features Mentioned in Text

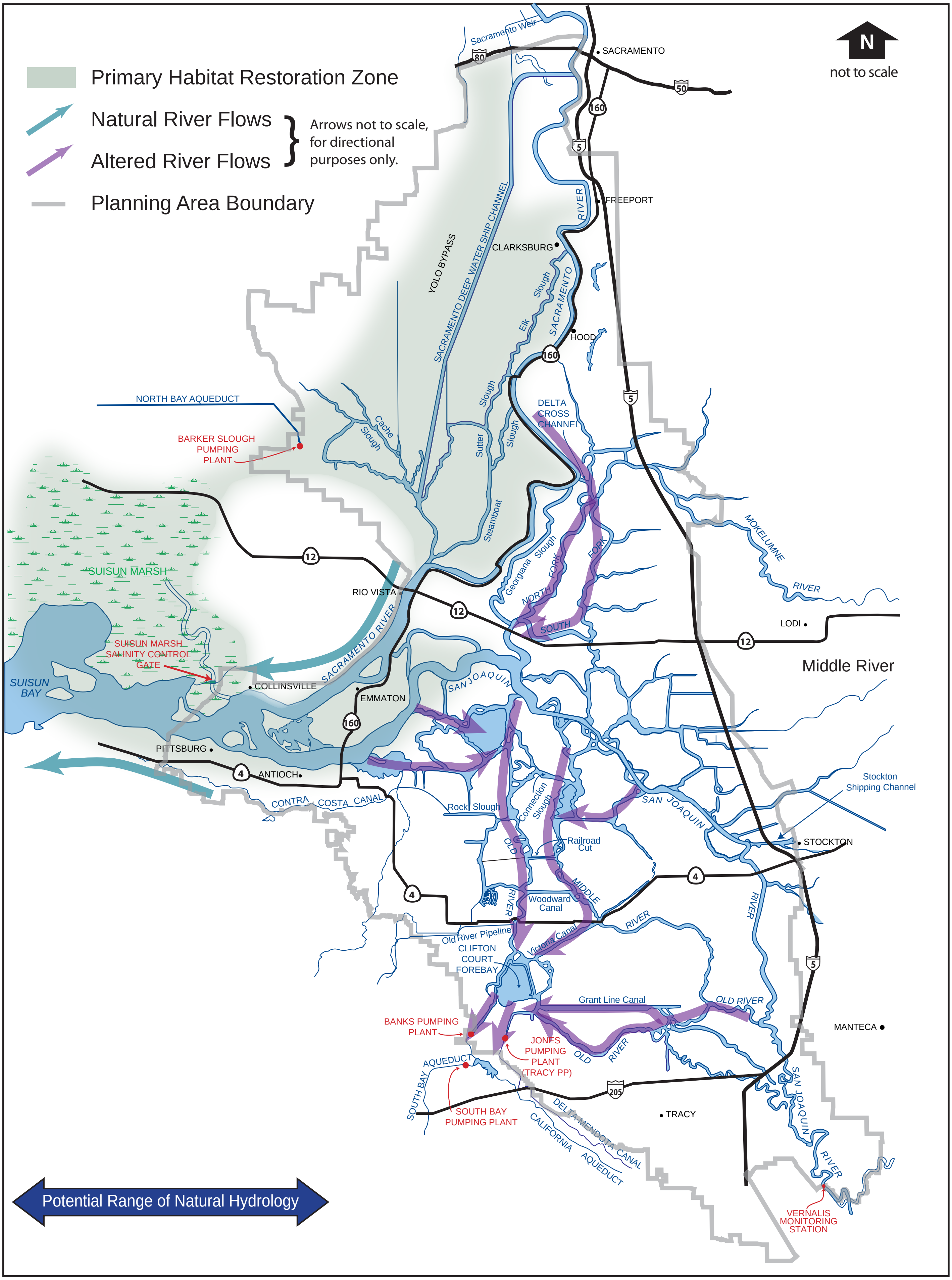

Figure 1-2. Conservation Strategy Option 1

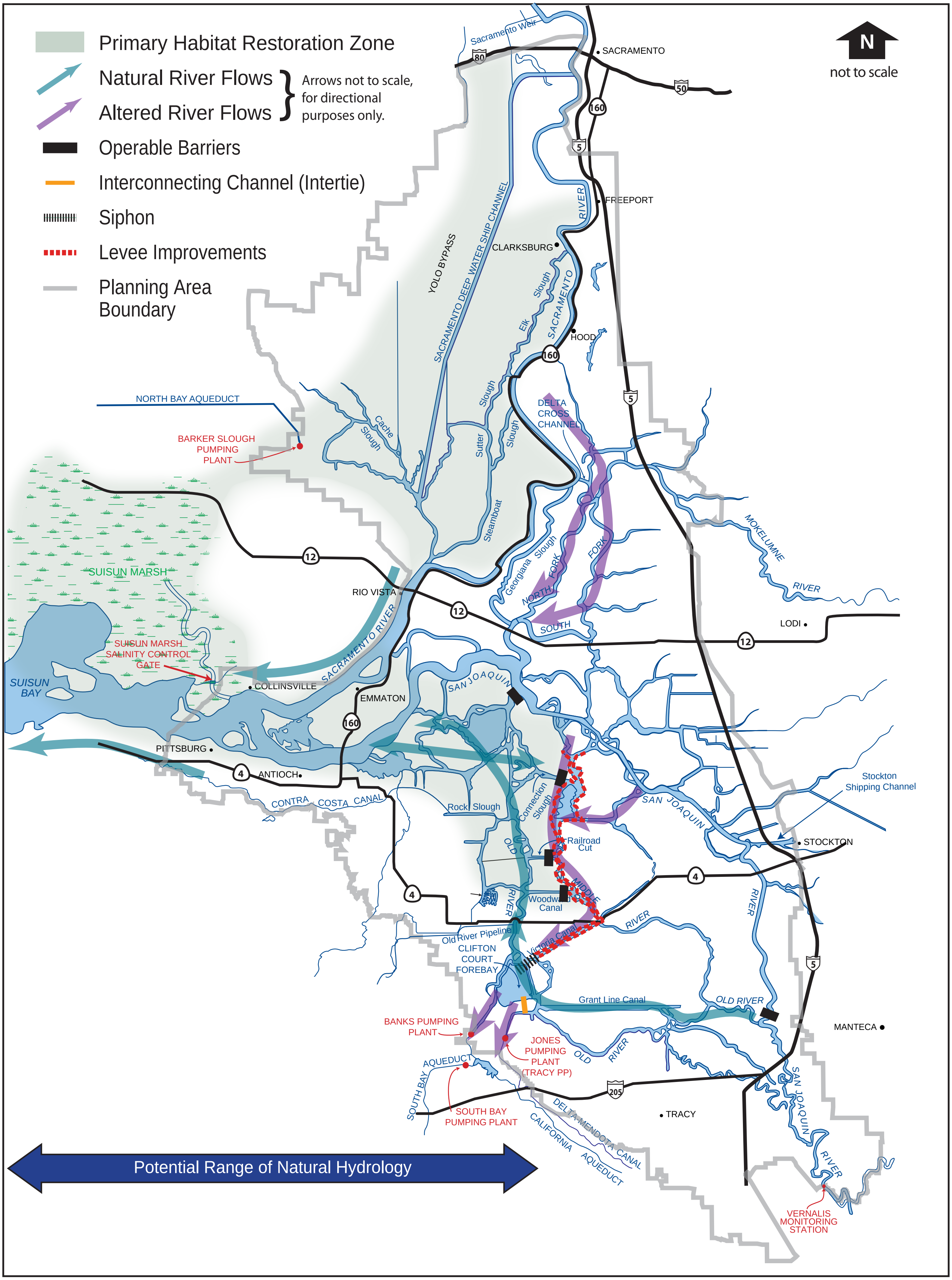

Figure 1-3. Conservation Strategy Option 2

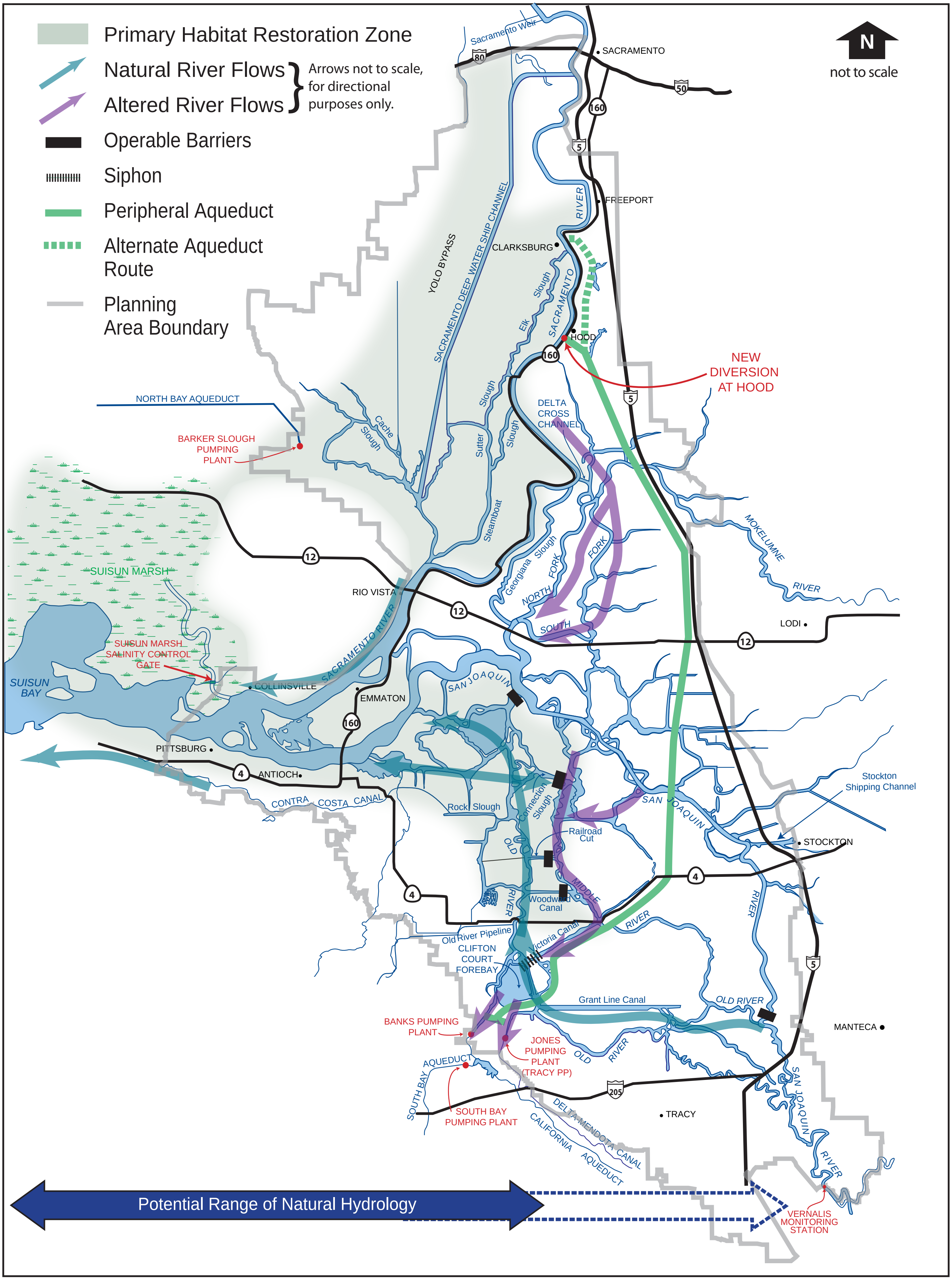

Figure 1-4. Conservation Strategy Option 3

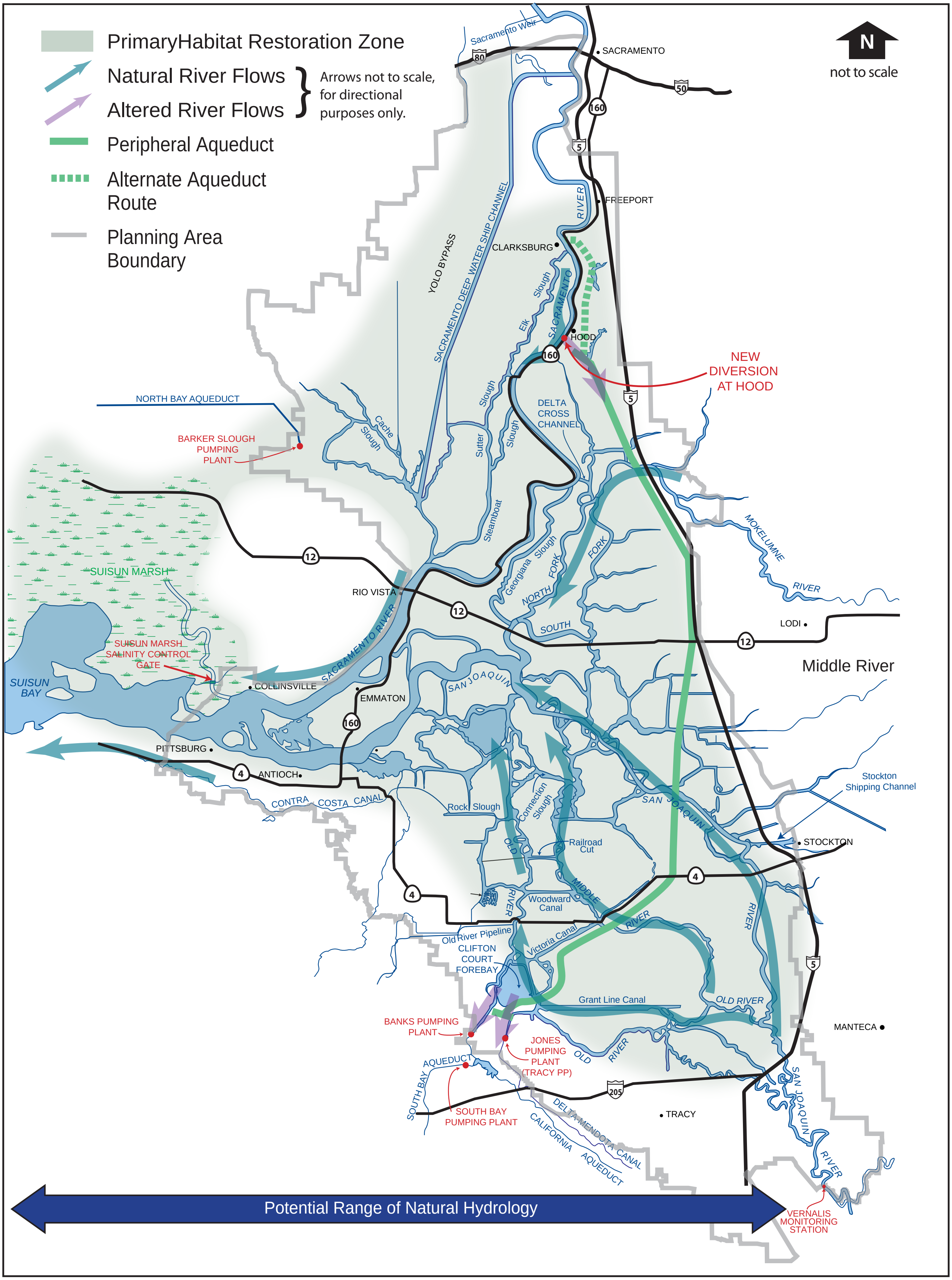

Figure 1-5. Conservation Strategy Option 4

2.0 METHODS

This section describes the methods and analytical tools used to evaluate each of the four Options in relation to each of the 17 evaluation criteria (see Section 1.5). This section includes a description of how ecological stressors and impact mechanisms on fish were defined, ranked, and used in the evaluation of the Options and how the level of certainty was defined; a description of methods for conducting the hydrodynamic modeling of each of the Options and rationale for addition of pump facility to Option 2; description of the methods used to evaluate the performance of Options in addressing biological criteria, including descriptions of the metrics, tools, scales, and assumptions used; and methods used to evaluate the performance of Options in addressing the planning, flexibility/durability/sustainability, and other resource impacts criteria.

2.1 COVERED FISH SPECIES STRESSORS

Stressors and stressor impact mechanisms were the primary tool used to conduct the evaluation of each Option relative to the biological criteria. The BDCP uses the following definitions of species stressors and impact mechanisms:

- **Species Stressor –** An ecological/environmental condition that reduces the production (reproduction, growth, and survival), abundance, or distribution of the species.
- **Species Stressor impact mechanism** – A physical or biological process that triggers a species stressor. If the magnitude of an impact mechanism is changed (positively or negatively), the effect of the stressor on the species would change (positively or negatively).

The stressors were identified for the covered fish species through the BDCP process. The stressors and their underlying impact mechanisms were derived from information gathered in BDCP technical sessions with species experts during the spring and summer of 2007. Based on published and unpublished literature and best professional judgment of species experts, the stressors for each species were ranked in the following categories:

- **Highly important stressors:** Stressors that, if reduced or eliminated, would likely result in a sustained increase in species production, abundance, or distribution throughout a large segment of the species range.
- **Moderately important stressors:** Stressors that, if reduced or eliminated, would likely result in increased species production, abundance, or distribution, but at a lesser scale than for the highly important stressors.
- **Other stressors:** Stressors that are currently known or for which the available information indicate are likely to adversely affect individuals of the species, but which are not likely to affect the species at a population level.

- **Stressors that could be manifested in the future:** Environmental attributes or conditions that might affect the abundance and distribution of the species in the future. These stressors, which are applicable to each of the covered species, include:
  - future establishment of non-native competitor/predator populations,
  - disease,
  - climate change (e.g., increased temperature, change in the hydrologic cycle, sea level rise), and
  - catastrophic change in the configuration of the Delta (e.g., extensive levee failures resulting from seismic events).

The degree to which each Option would increase or decrease each of the stressors for each fish species was the key element of the evaluation. A description of the impact mechanism(s) by which effects would occur is provided in the narrative section of the evaluation. The evaluation focused on highly important and moderately important stressors. The cause-and-effect linkages between the impact mechanisms and the stressors were used to evaluate the anticipated range of responses of the covered fish species under each of the Options in relation to the seven biological evaluation criteria. The primary focus of the evaluation was on how each of the Options affected the highly important and moderately important stressors for each of the species because reductions in these stressors are expected to result in population-level benefits. The relationship among highly and moderately important stressors, their primary impact mechanisms, and the certainty of the cause and effect linkage between impact mechanisms and stressors are illustrated in Figures 2-1 to 2-9 for each of the covered species. Detailed descriptions of the stressors, their impact mechanisms, and other supporting information are presented in Appendix C.

The certainty of the predicted effects of each Option on species was also evaluated, and is provided in the narrative discussion and summary tables. Level of certainty was based on the following definitions[1]:

4 = High certainty: Understanding of the stressor and its impact mechanisms is high based on information provided in the scientific literature and input provided by species experts. Stressor effects are well-understood and largely predictable.

3 = Moderate certainty: Understanding of the stressor and its impact mechanisms is high but the nature of stressor effects is dependent on other highly variable ecosystem processes or uncertain external factors, or understanding of the stressor and its impact mechanisms is moderate. Stressor effects are well-understood and largely predictable. Certainty assessment is based on information provided in the scientific literature and input provided by species experts.

[1] Adapted from certainty categories for ecological outcomes presented in the draft DRERIP Vetting Worksheet dated July 30, 2007.

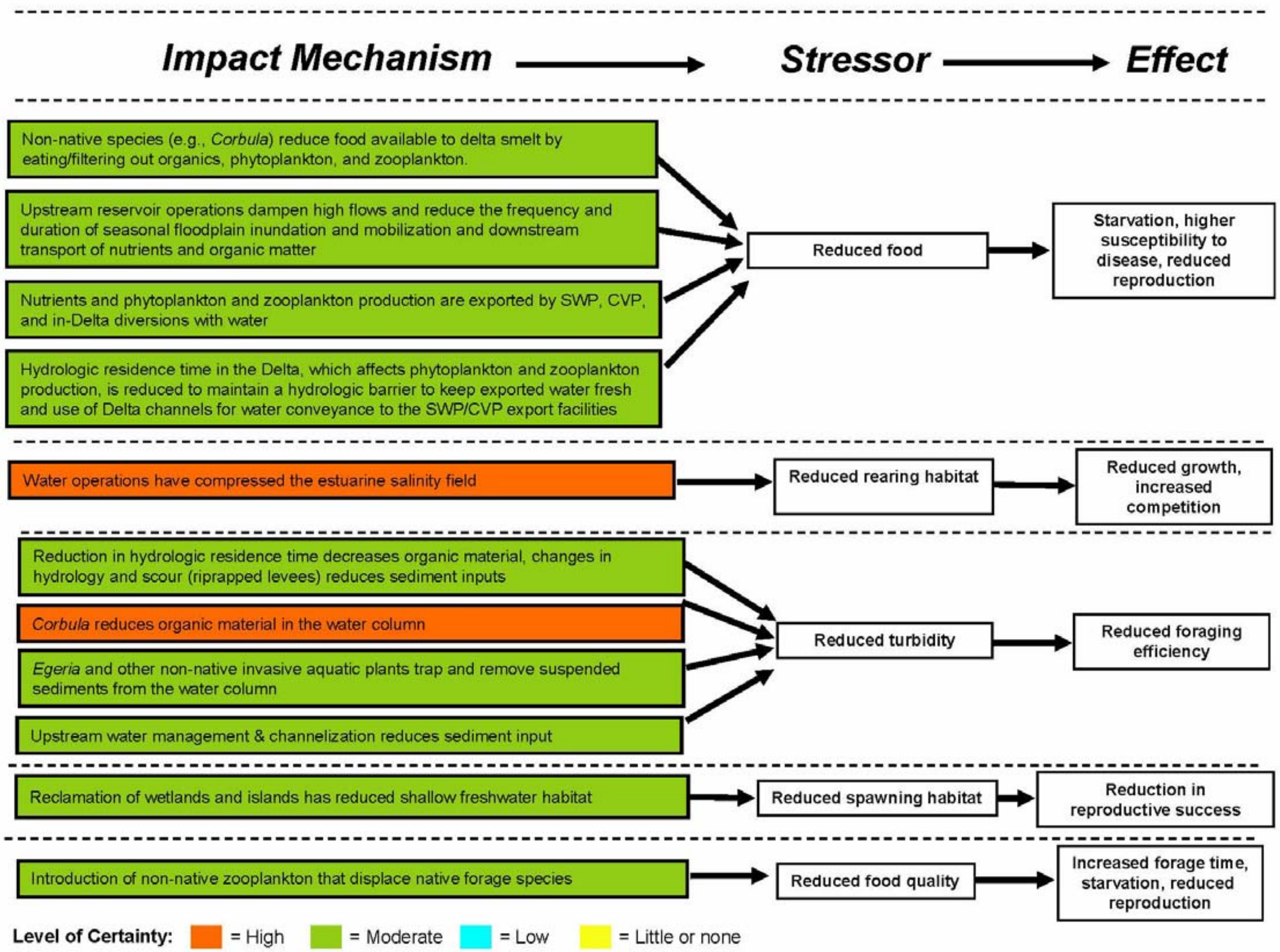

Figure 2-1a. Highly Important Delta Smelt Impact Mechanisms, Stressors, and Effects

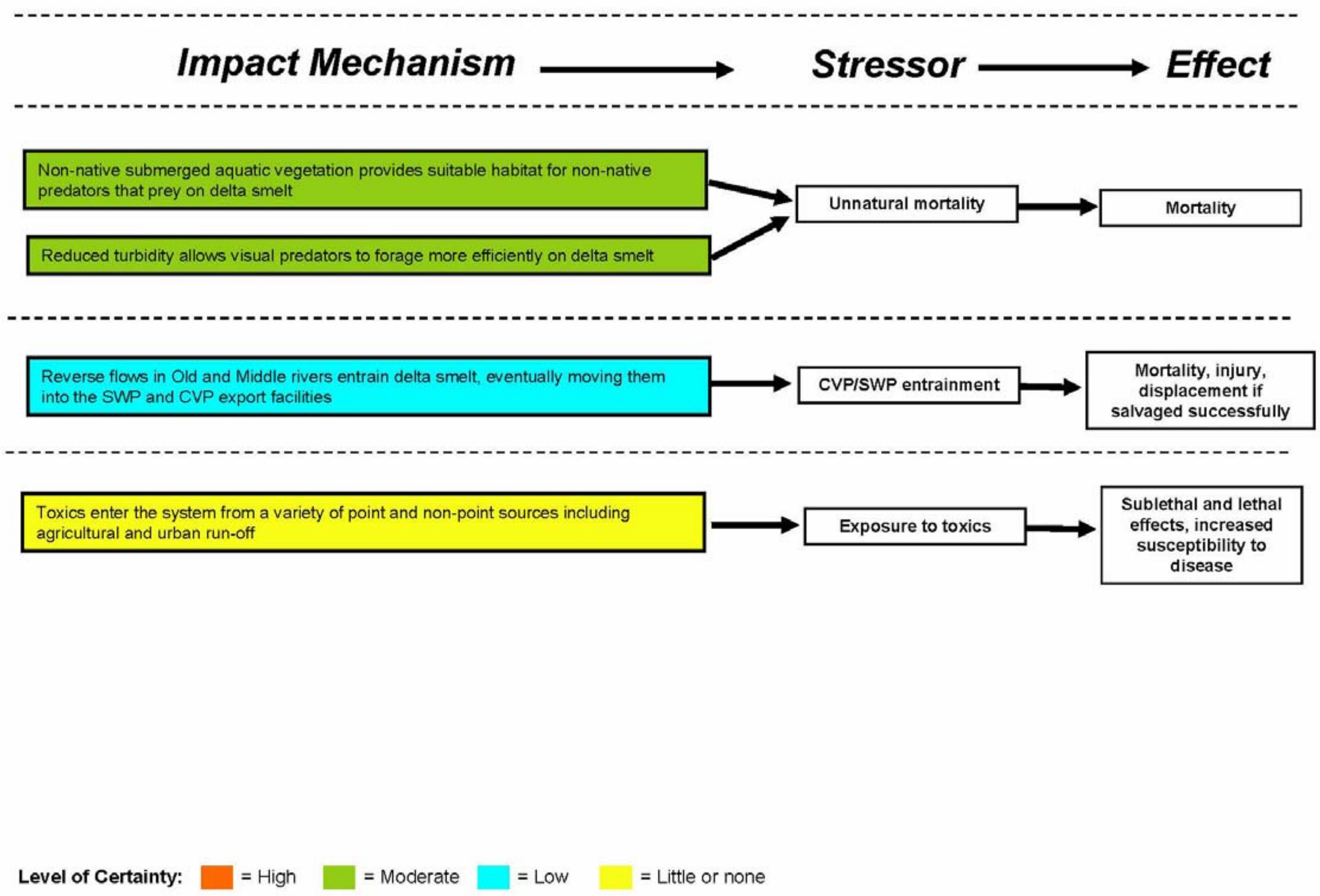

Figure 2-1b. Moderately Important Delta Smelt Impact Mechanisms, Stressors, and Effects

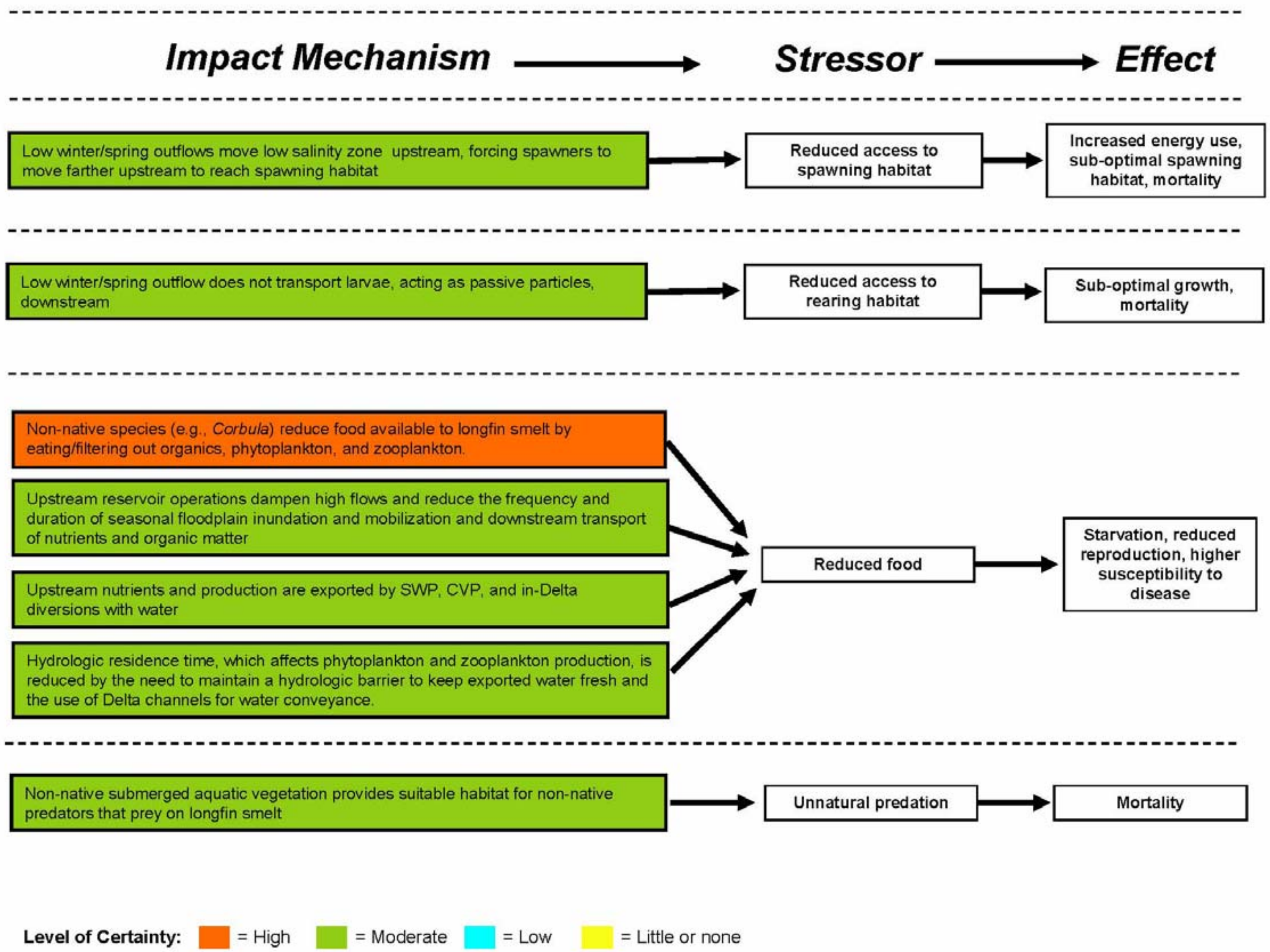

Figure 2-2a. Highly Important Longfin Smelt Impact Mechanisms, Stressors, and Effects

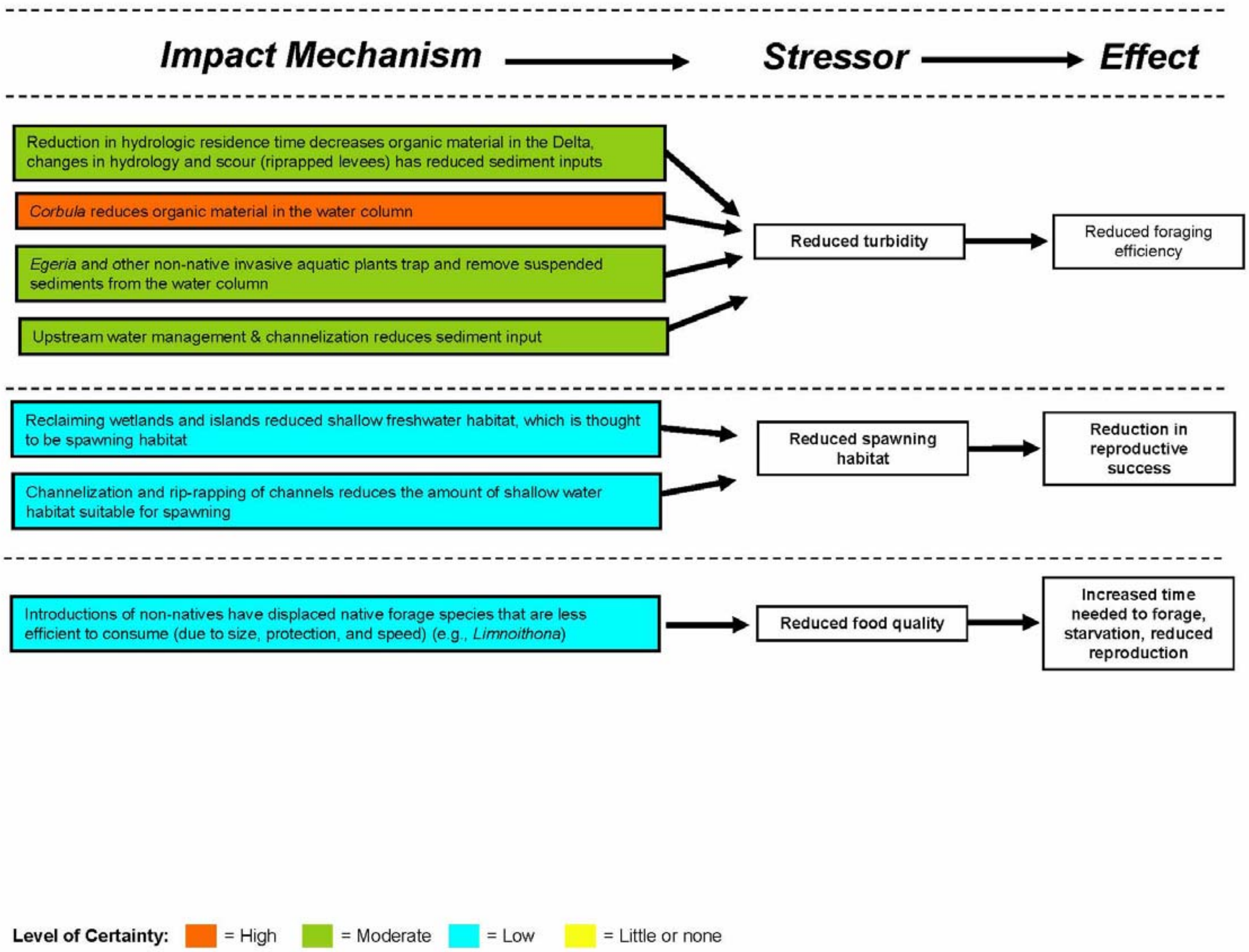

Figure 2-2b. Highly Important Longfin Smelt Impact Mechanisms, Stressors, and Effects

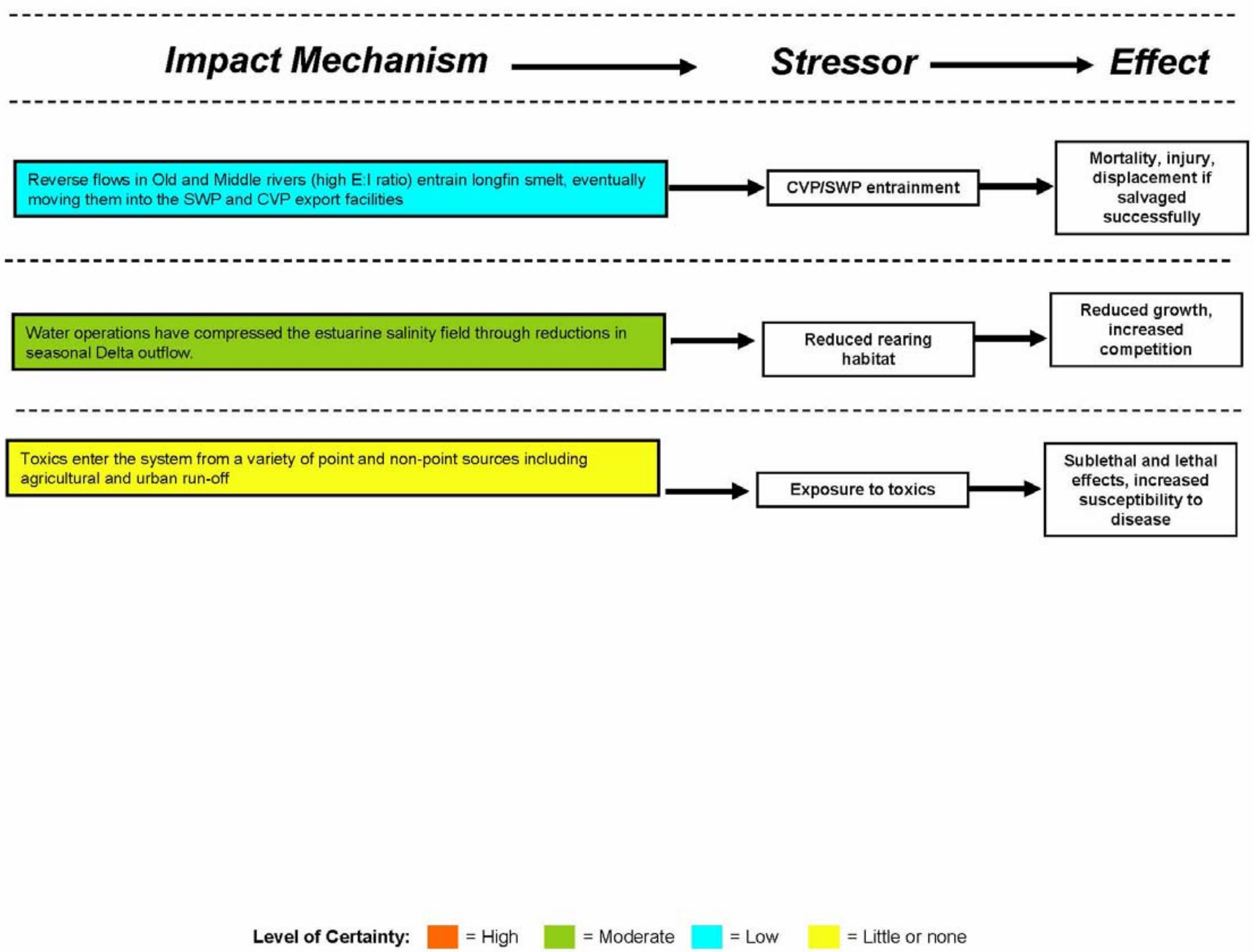

Figure 2-2c. Moderately Important Longfin Smelt Impact Mechanisms, Stressors, and Effects

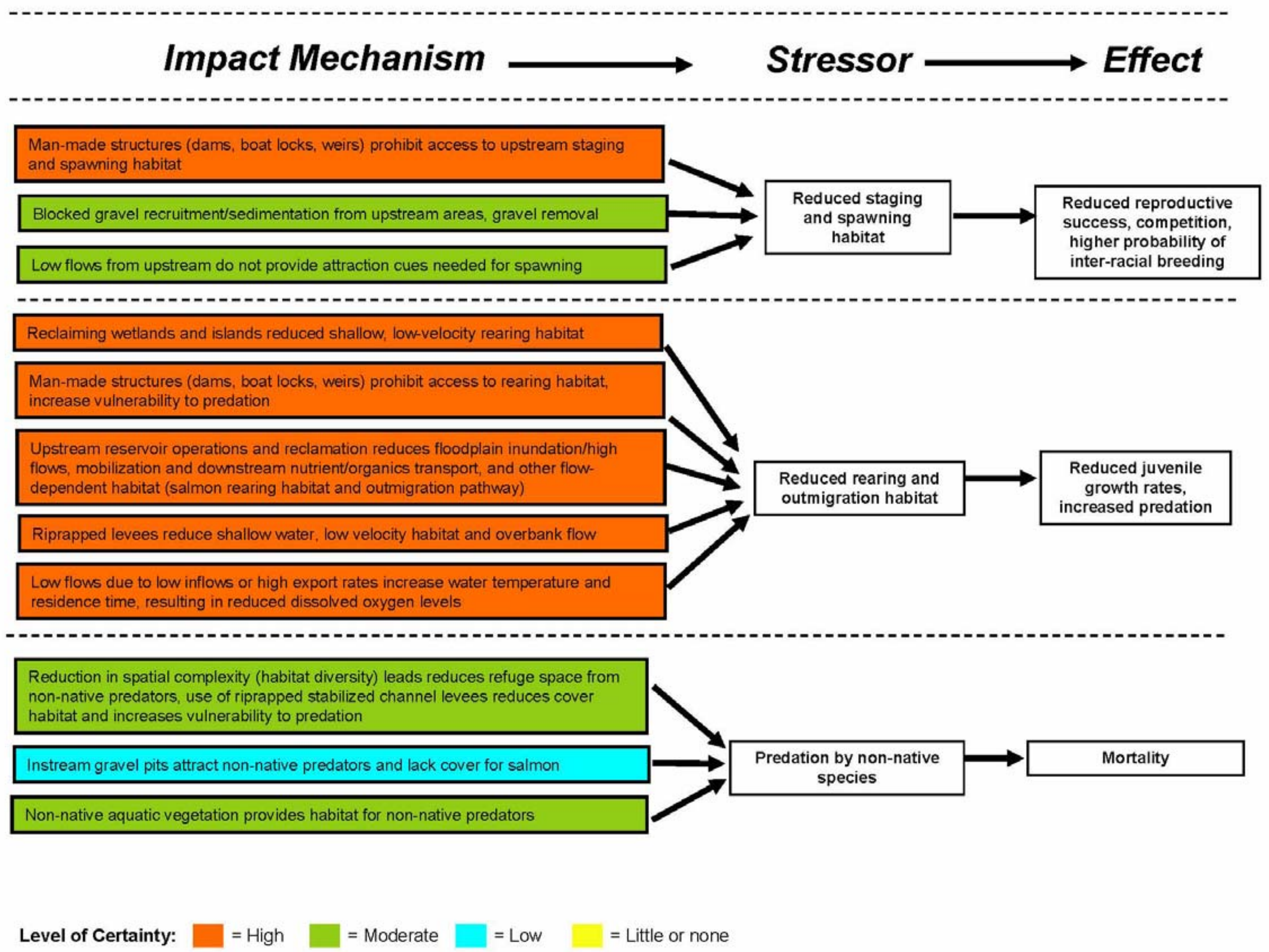

Figure 2-3a. Highly Important Sacramento River Chinook Salmon Impact Mechanisms, Stressors, and Effects

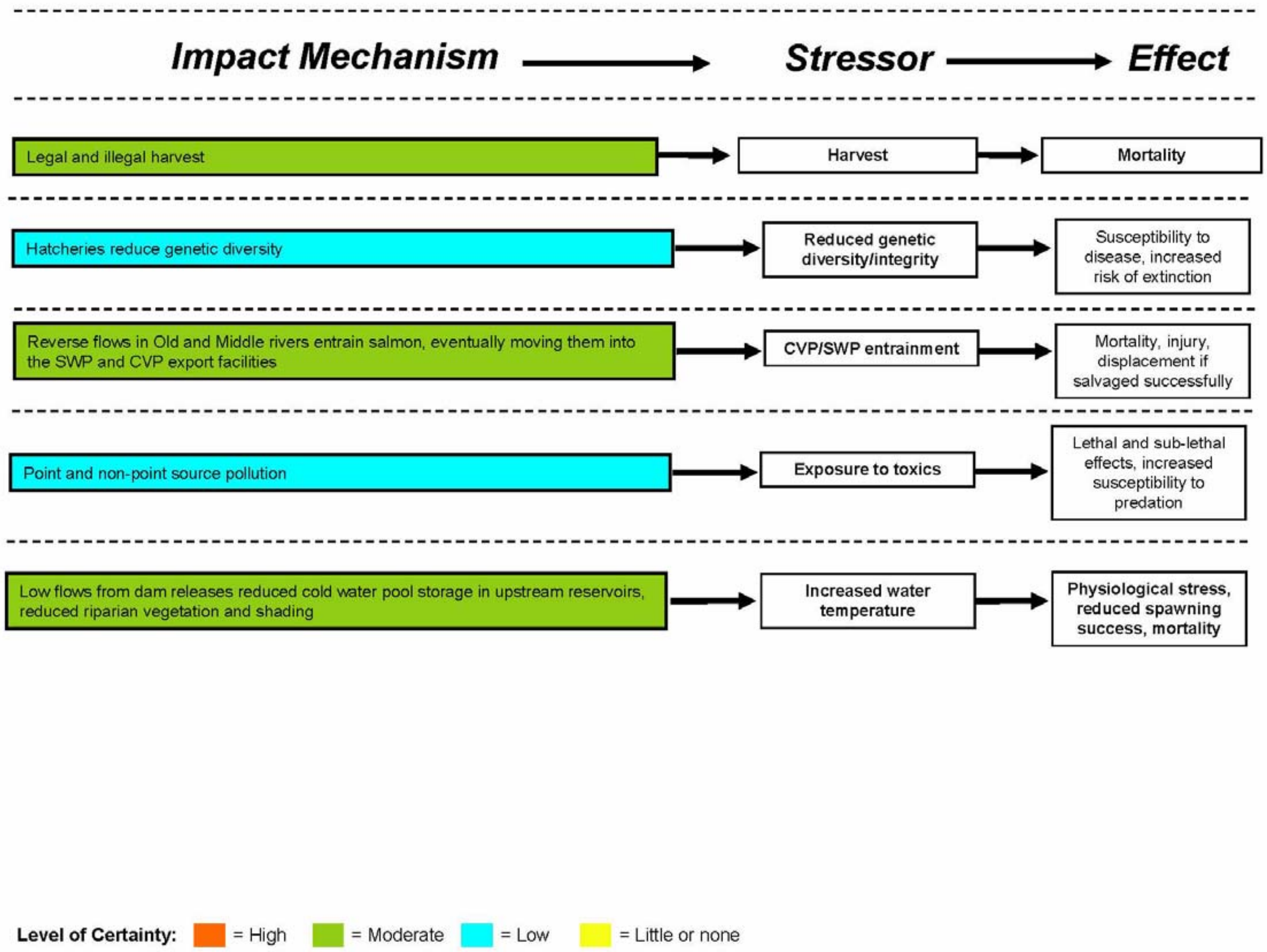

Figure 2-3b. Moderately Important Sacramento River Chinook Salmon Impact Mechanisms, Stressors, and Effects

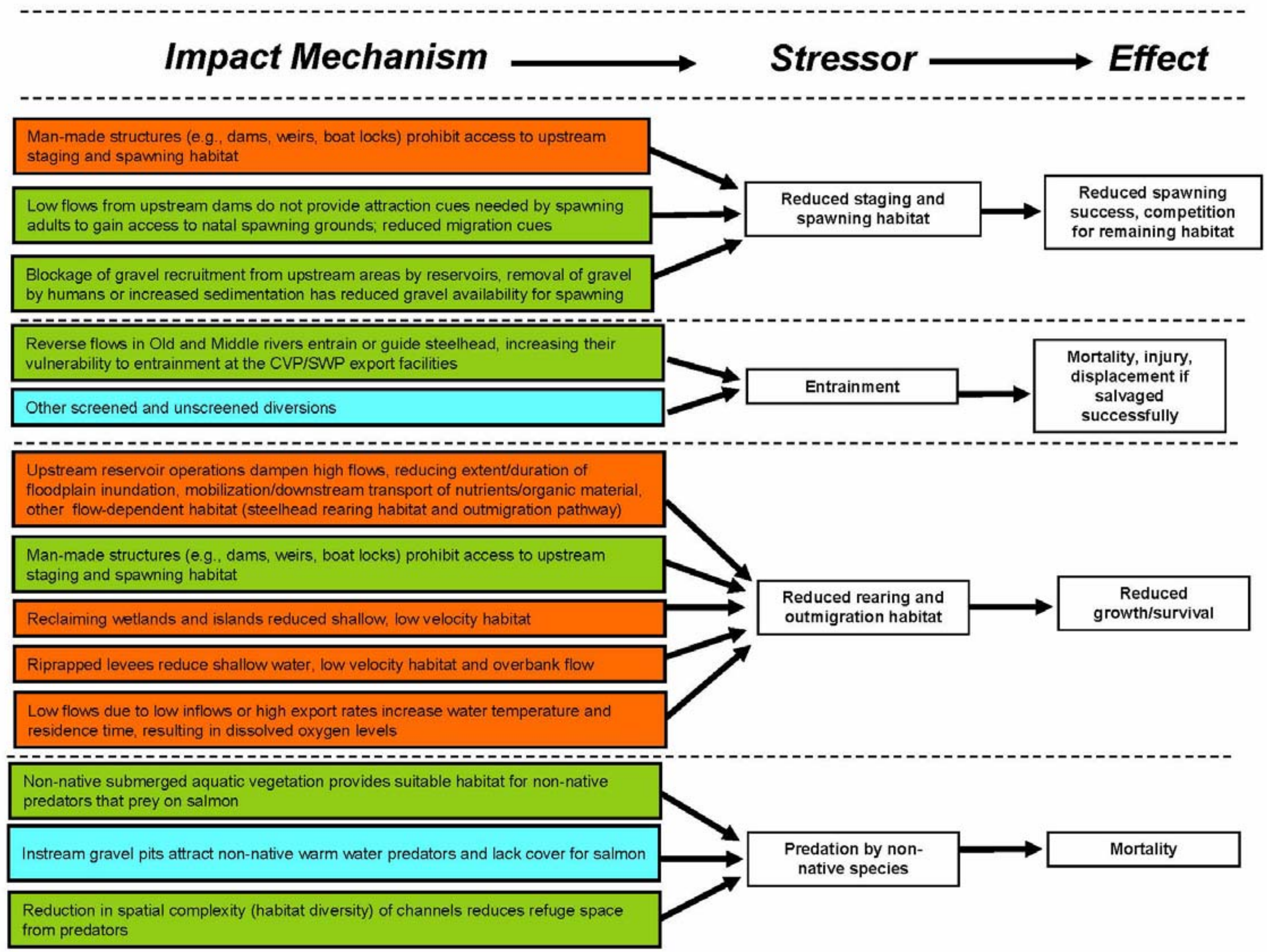

Figure 2-4a. Highly Important Sacramento River Steelhead Impact Mechanisms, Stressors, and Effects

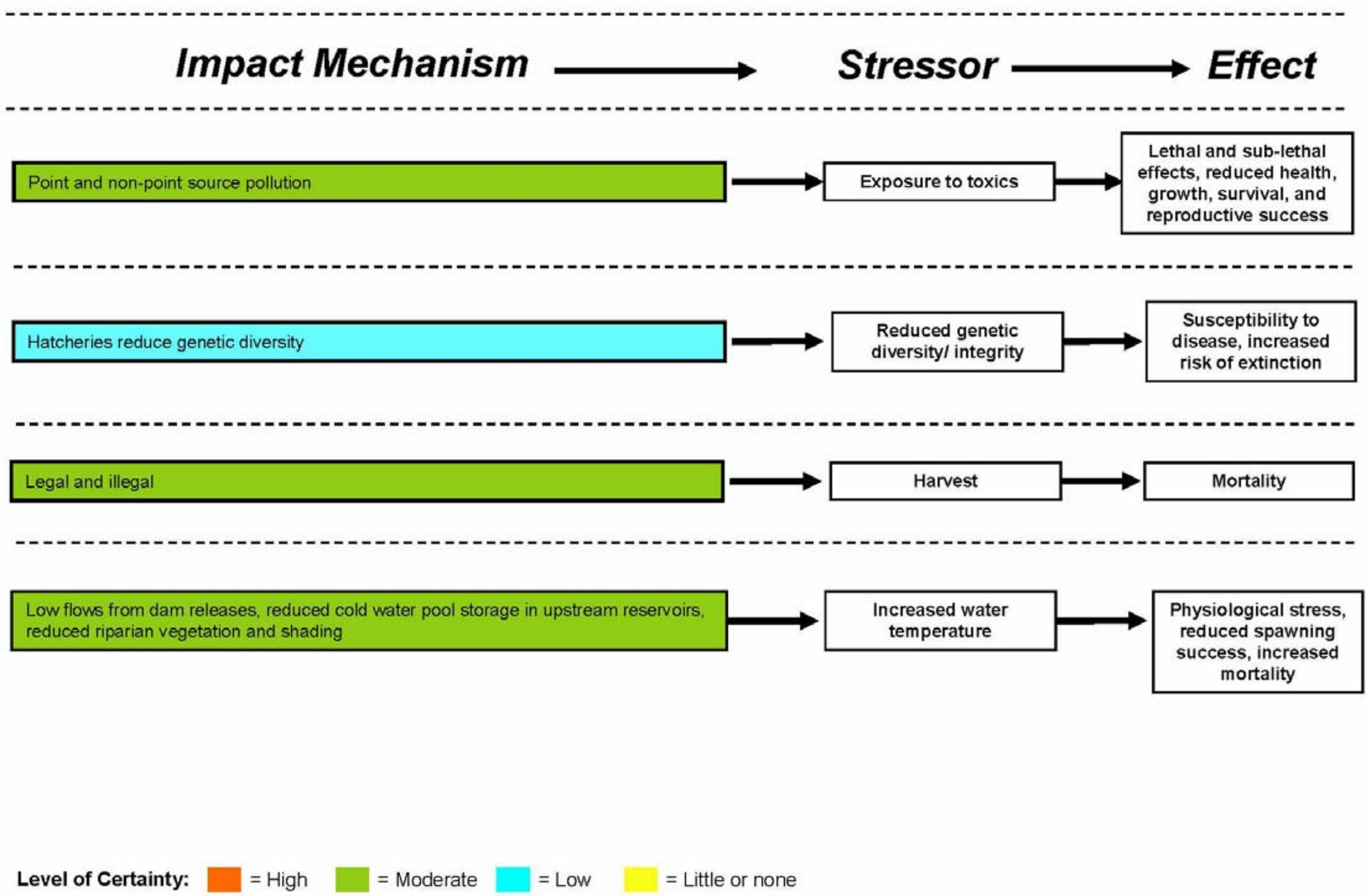

Figure 2-4b. Moderately Important Sacramento River Steelhead Impact Mechanisms, Stressors, and Effects

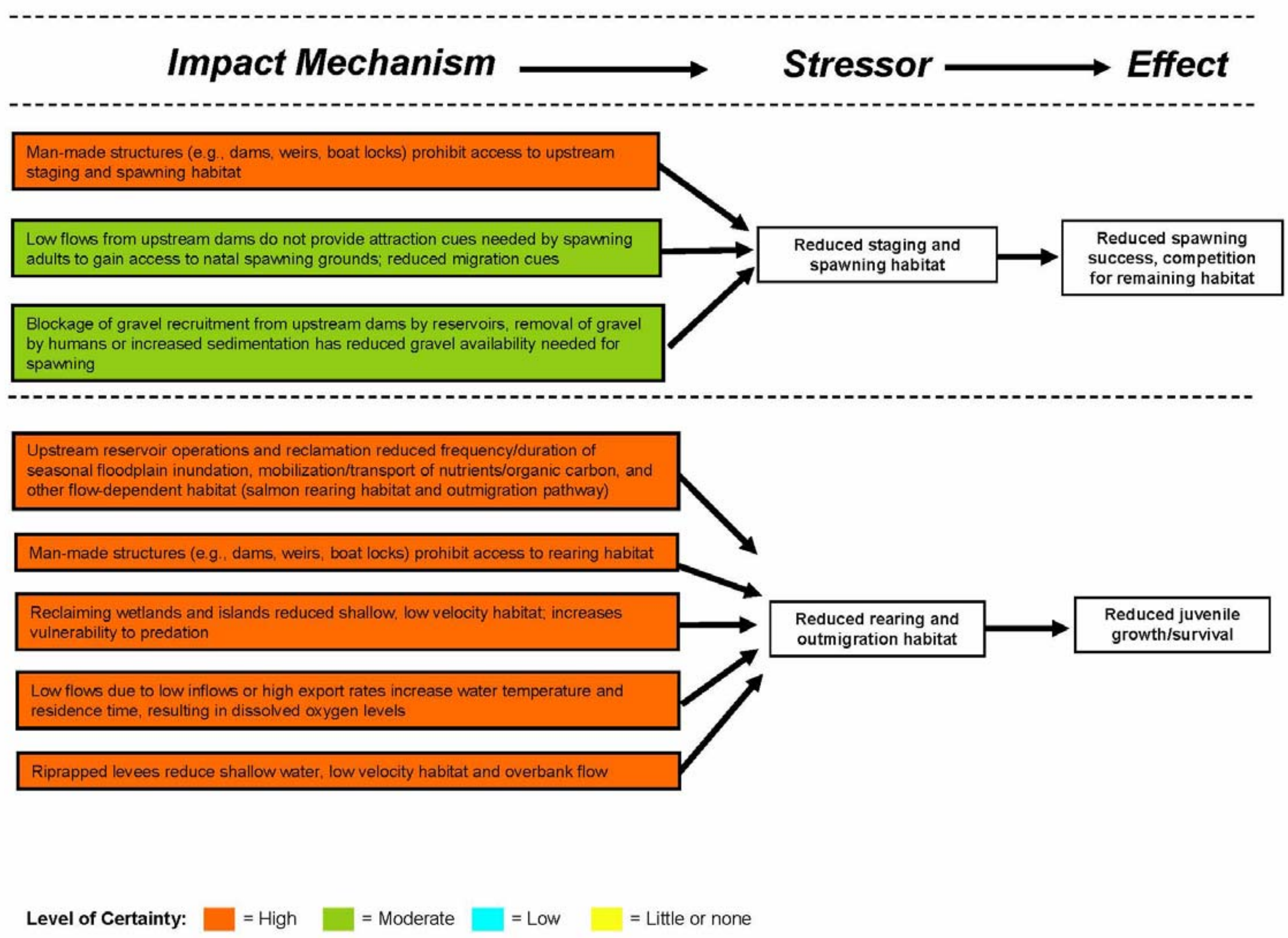

Figure 2-5a. Highly Important San Joaquin River Chinook Salmon Impact Mechanisms, Stressors, and Effects

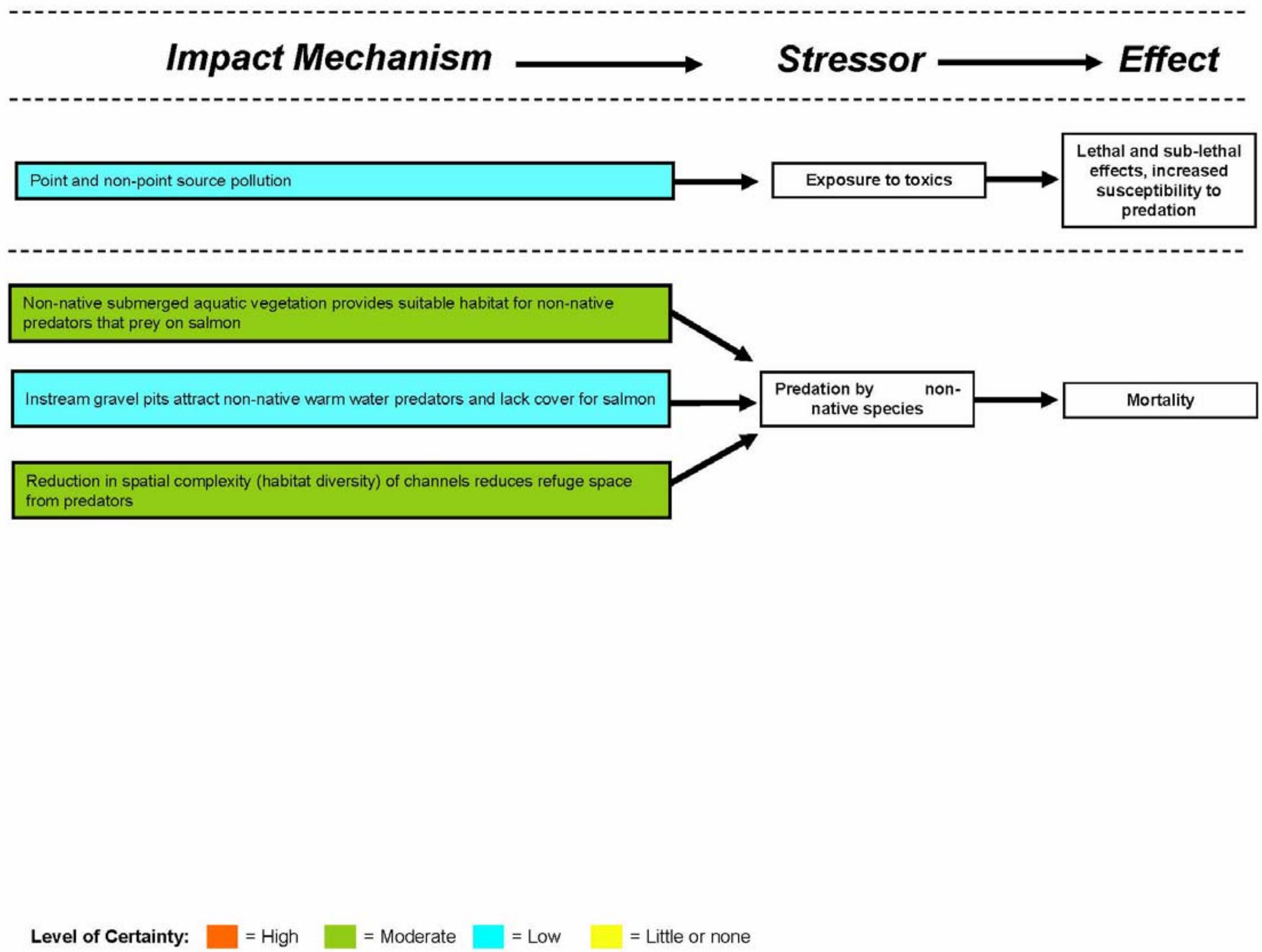

Figure 2-5b. Highly Important San Joaquin River Chinook Salmon Impact Mechanisms, Stressors, and Effects

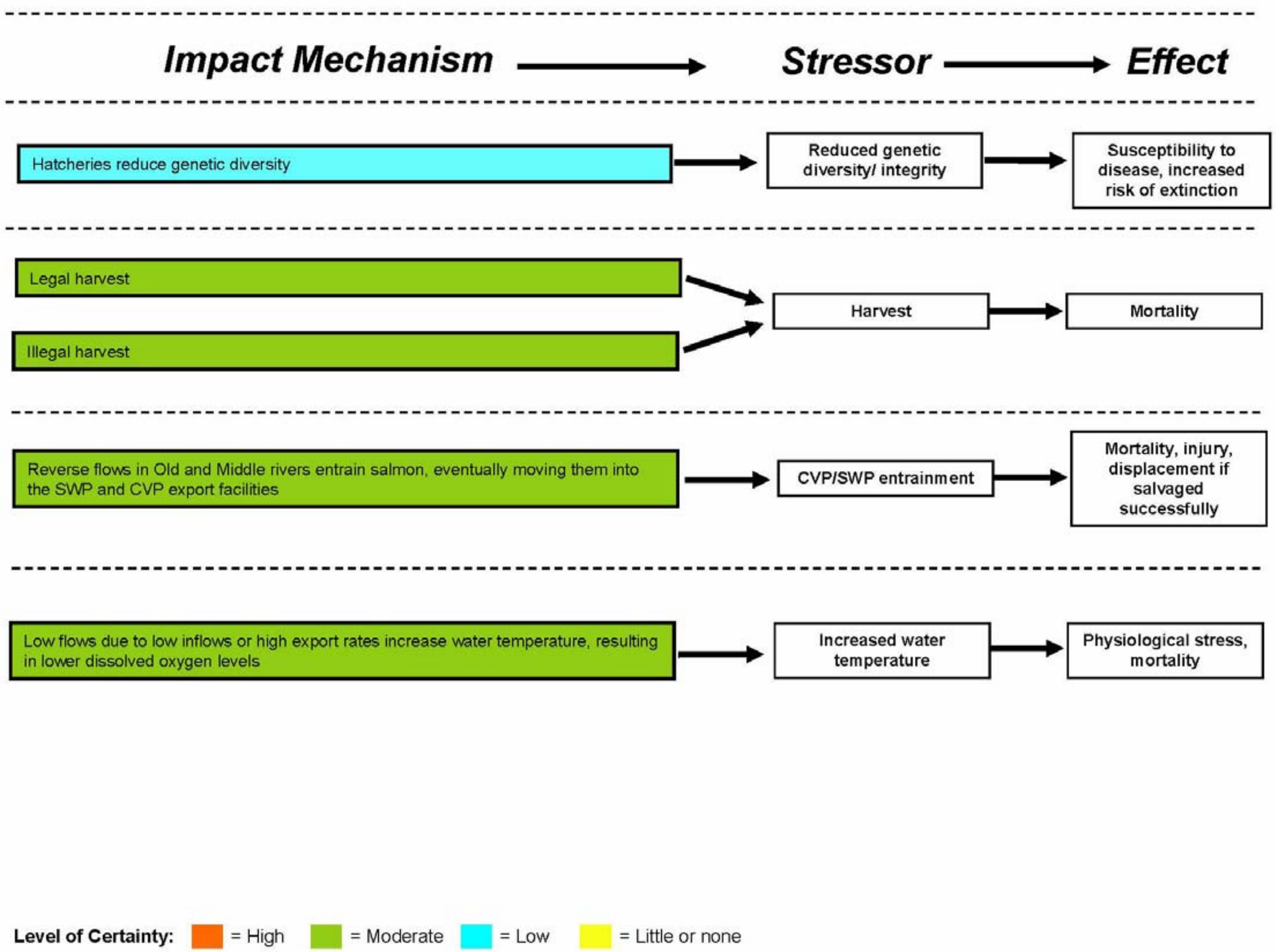

Figure 2-5c. Moderately Important San Joaquin River Chinook Salmon Impact Mechanisms, Stressors, and Effects

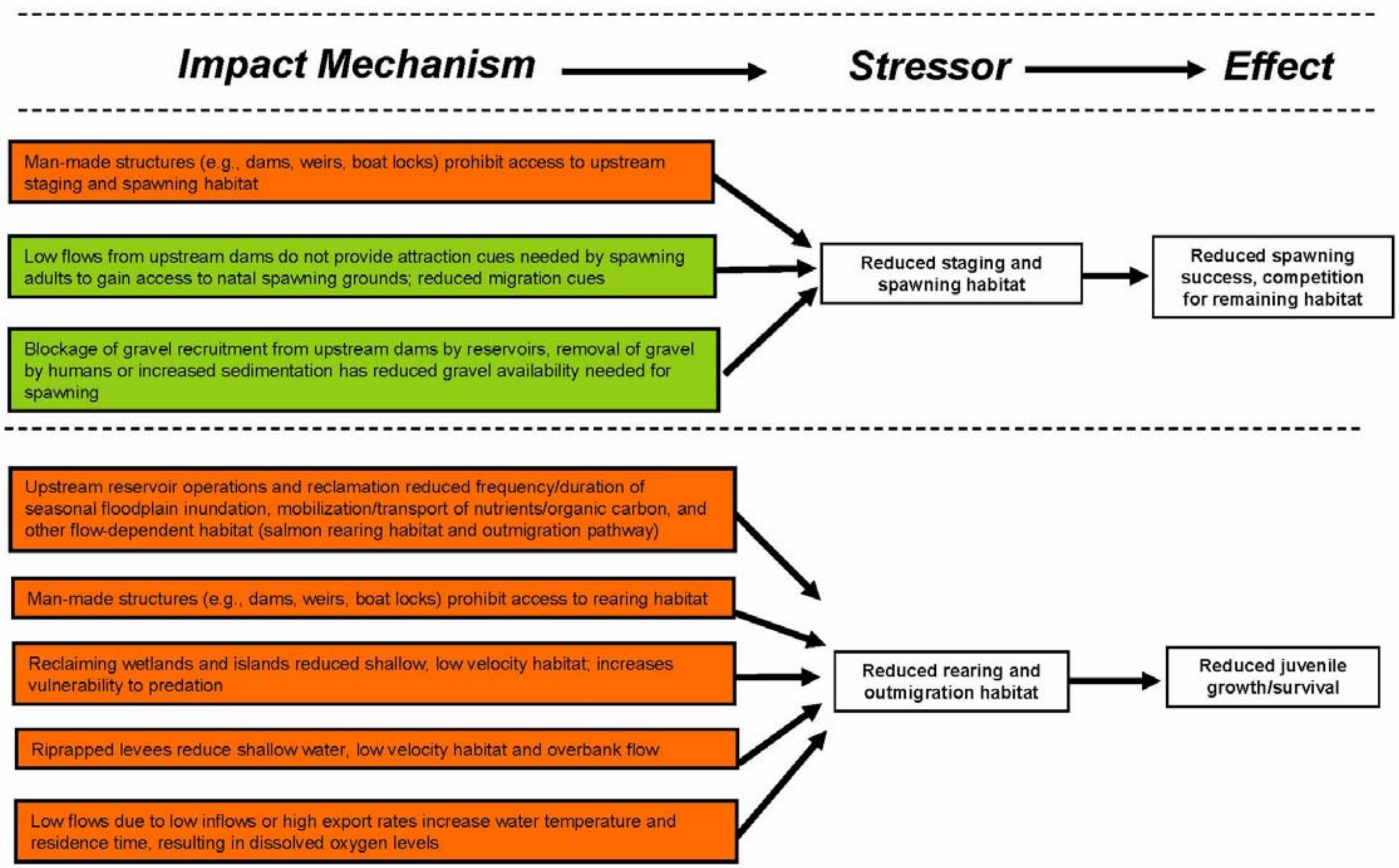

Figure 2-6a. Highly Important San Joaquin River Steelhead Impact Mechanisms, Stressors, and Effects

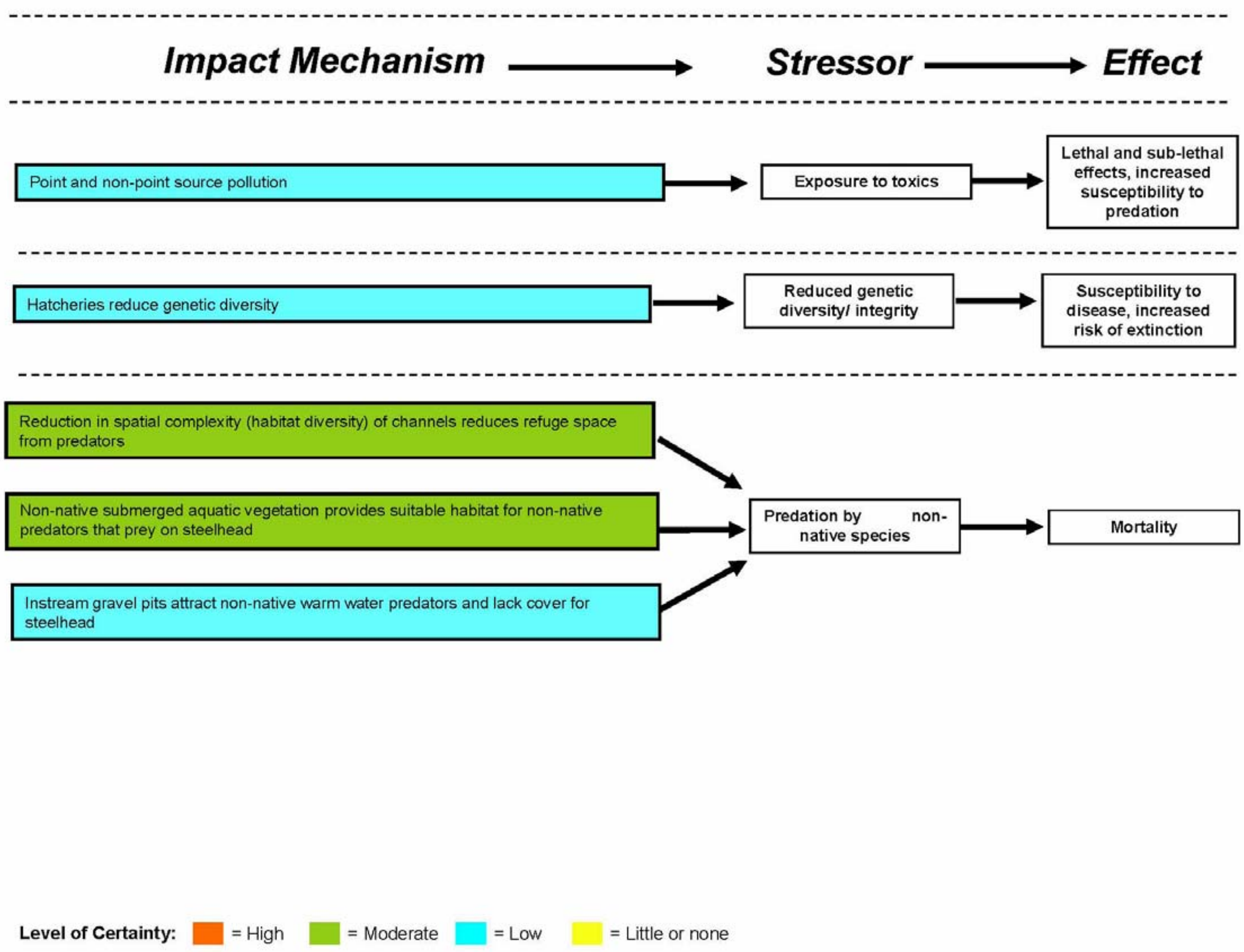

Figure 2-6b. Highly Important San Joaquin River Steelhead Impact Mechanisms, Stressors, and Effects

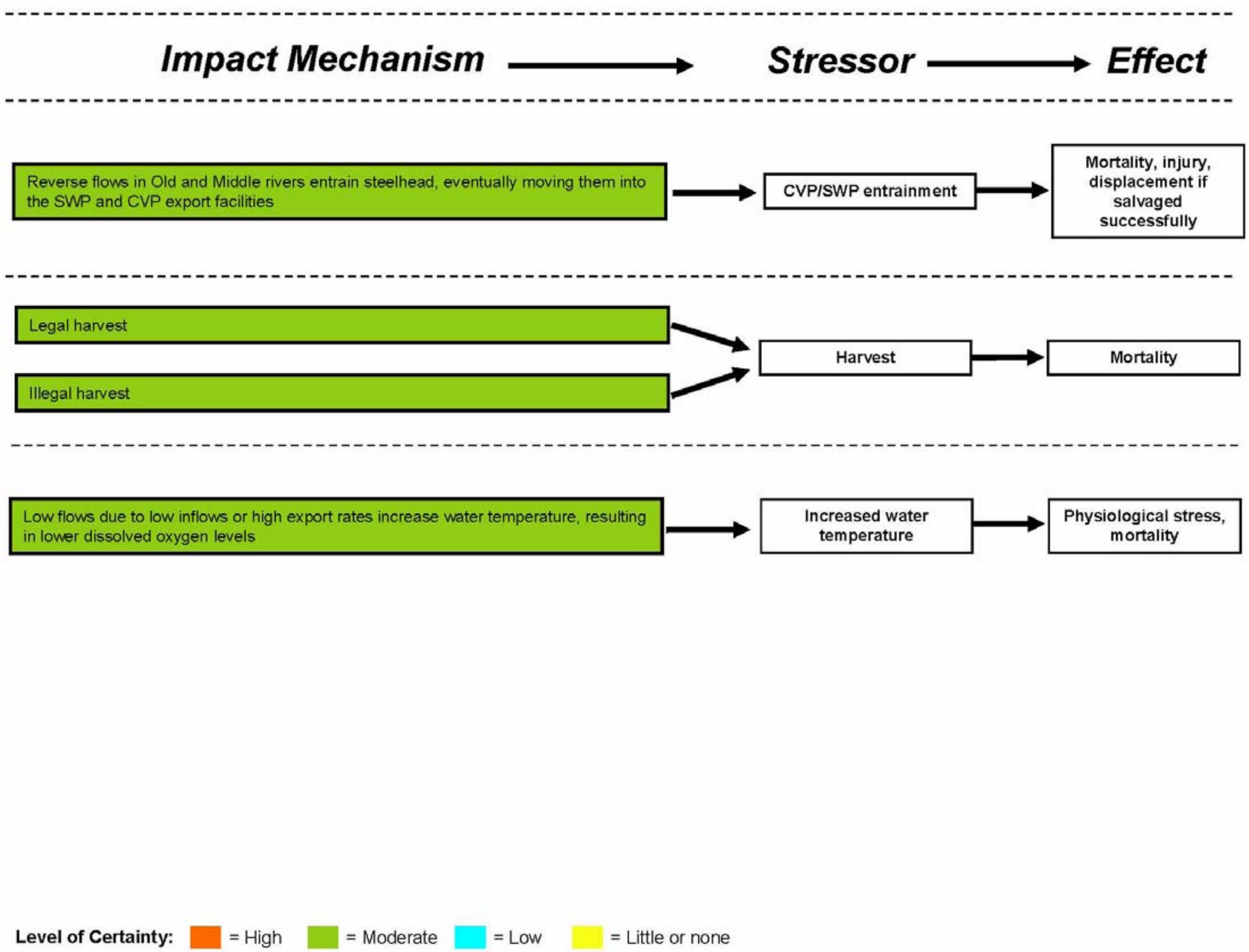

Figure 2-6c. Moderately Important San Joaquin River Steelhead Impact Mechanisms, Stressors, and Effects

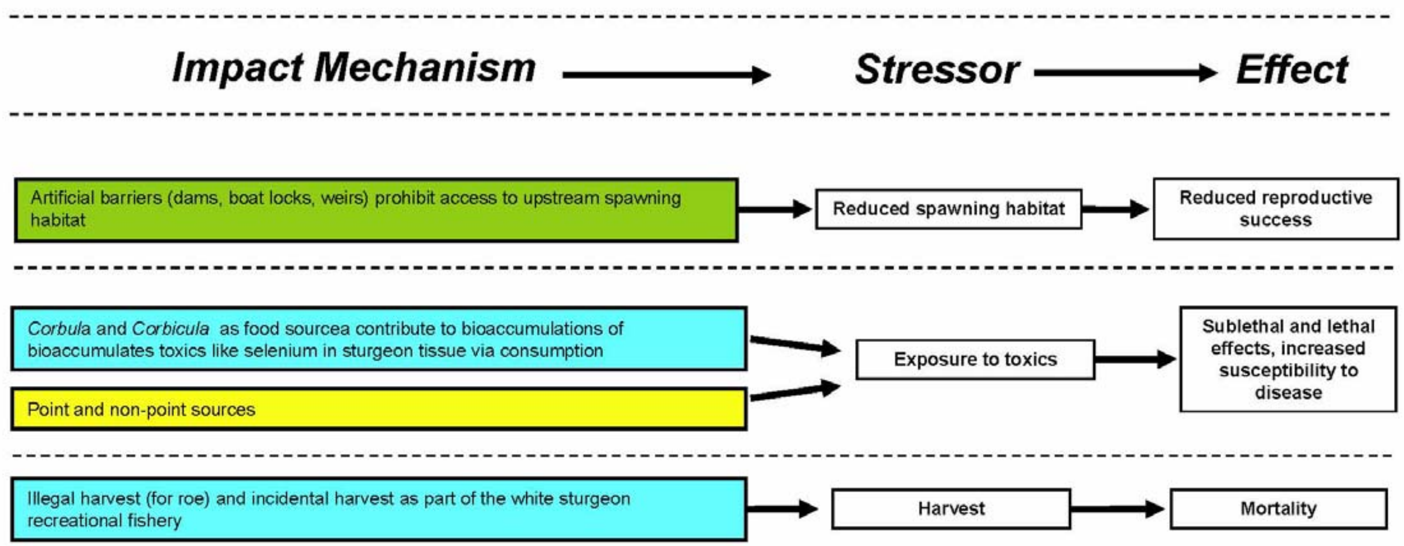

Figure 2-7a. Highly Important Green Sturgeon Impact Mechanisms, Stressors, and Effects

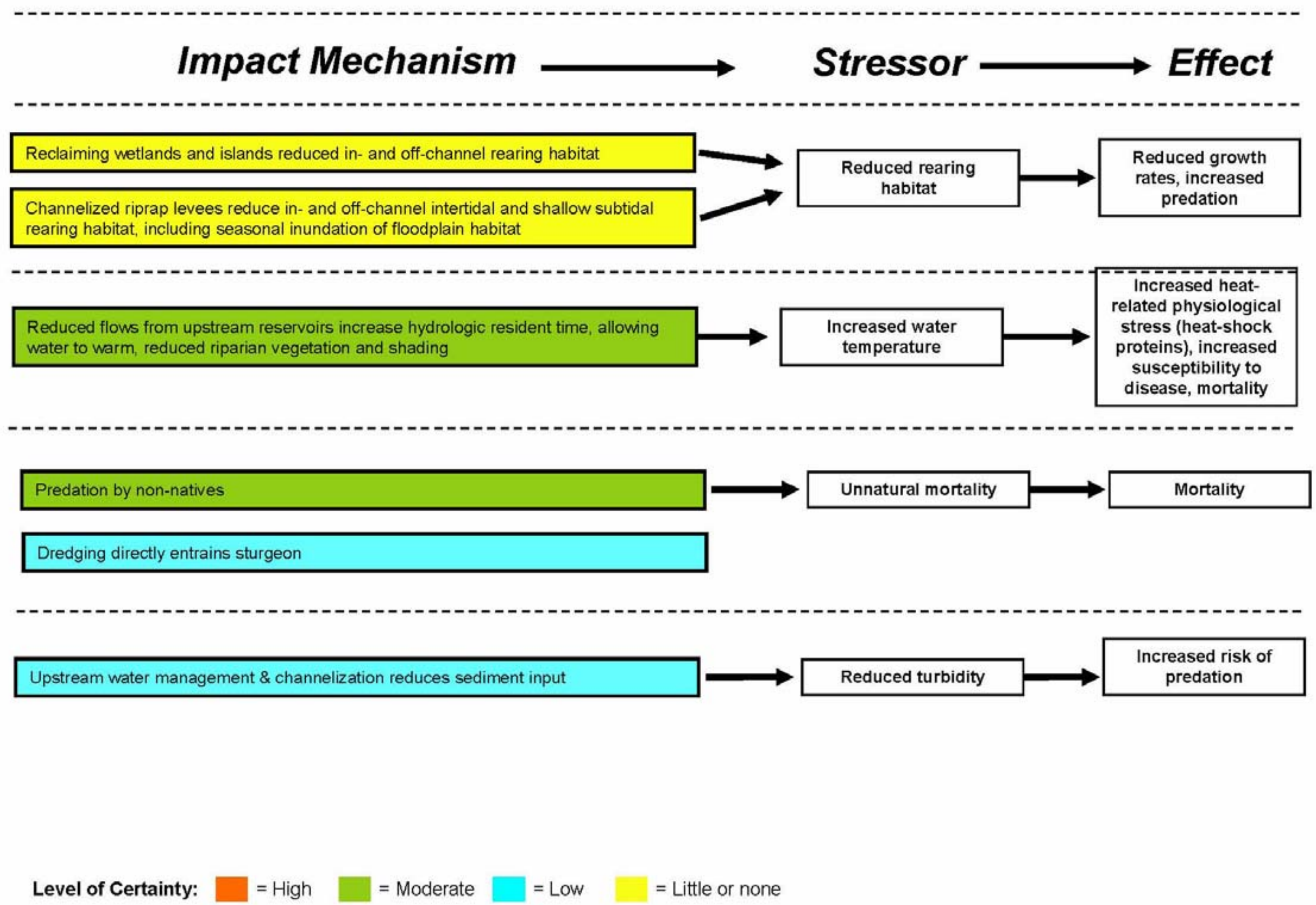

Figure 2-7b. Moderately Important Green Sturgeon Impact Mechanisms, Stressors, and Effects

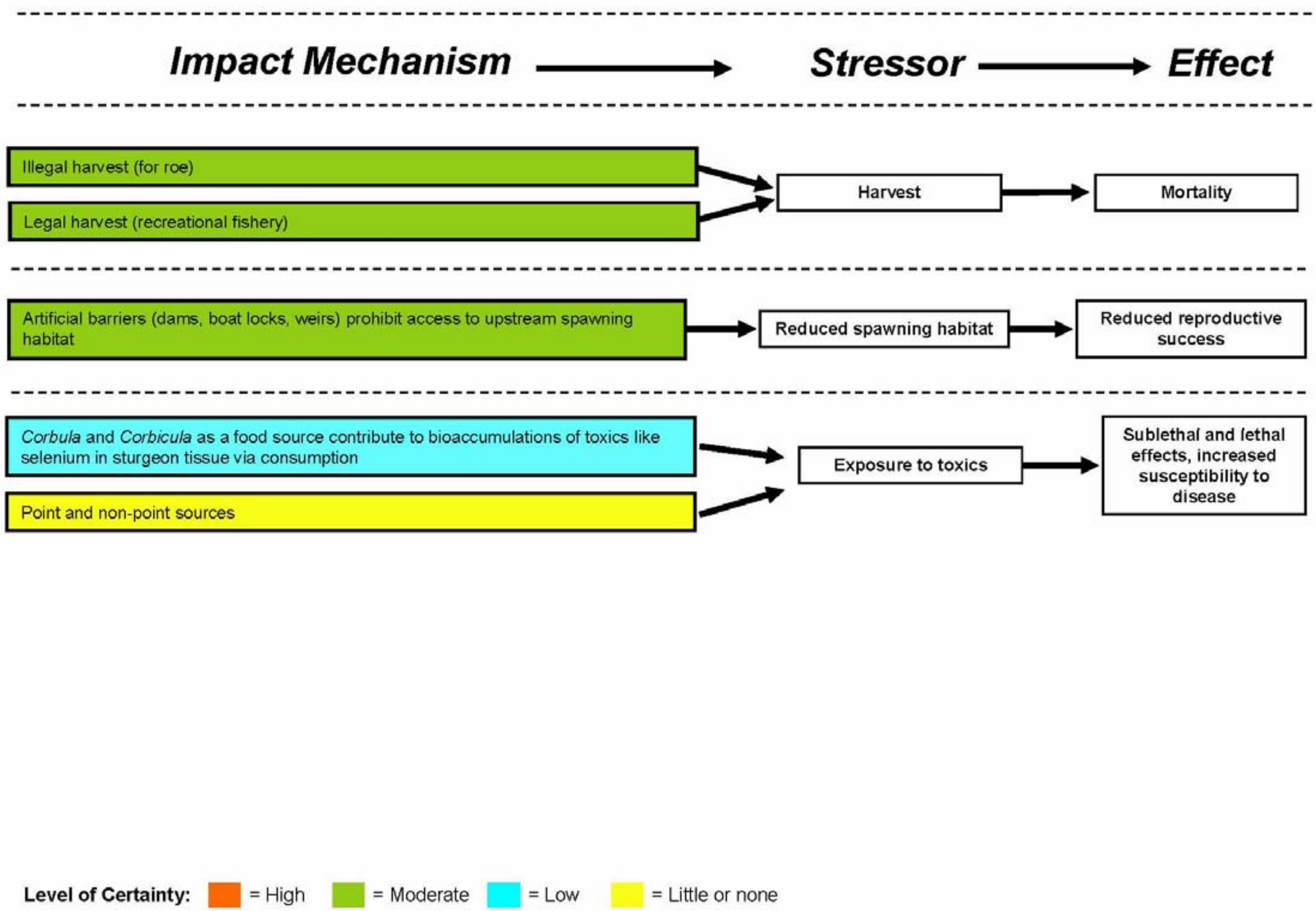

Figure 2-8a. Highly Important White Sturgeon Impact Mechanisms, Stressors, and Effects

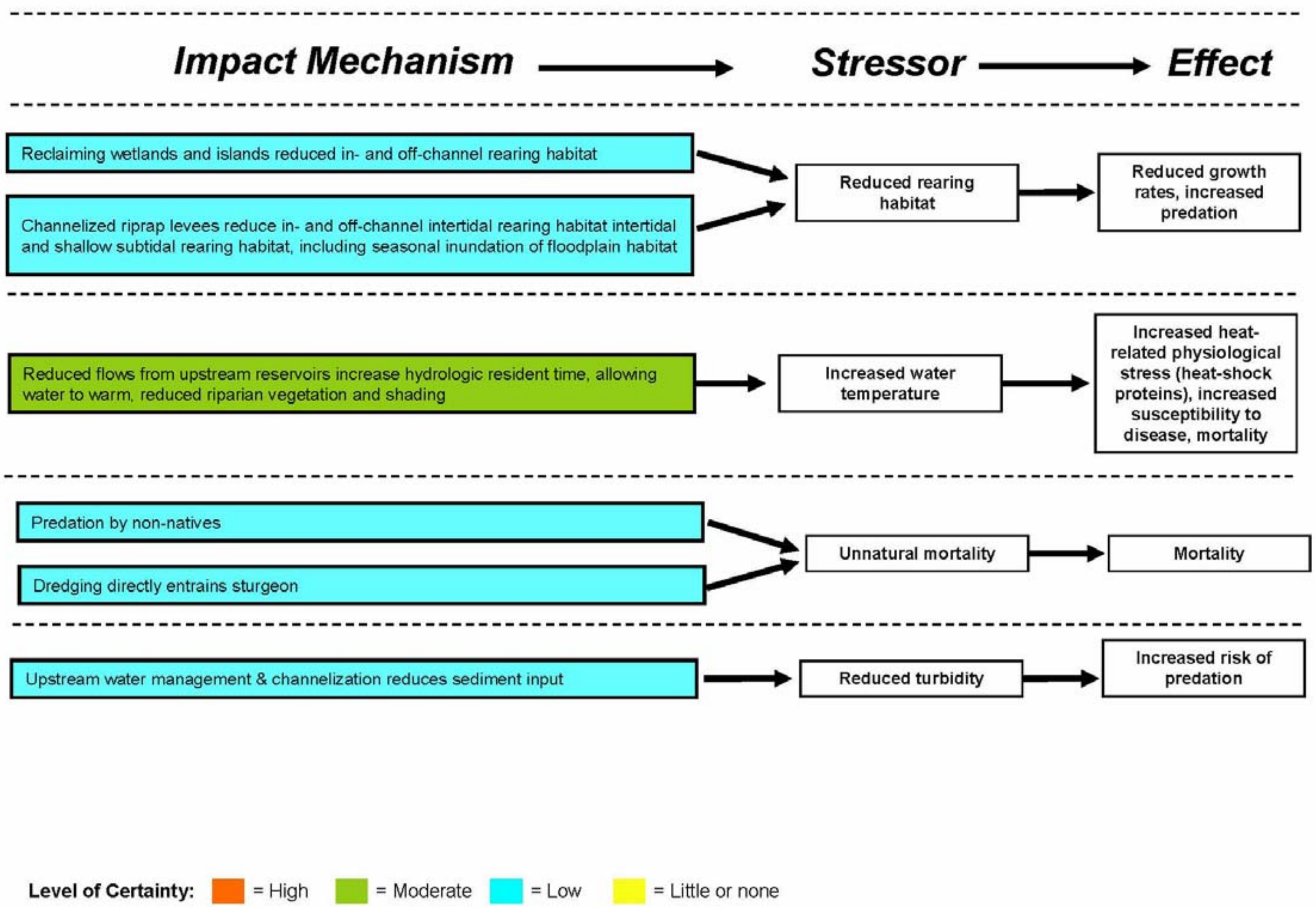

Figure 2-8b. Moderately Important White Sturgeon Impact Mechanisms, Stressors, and Effects

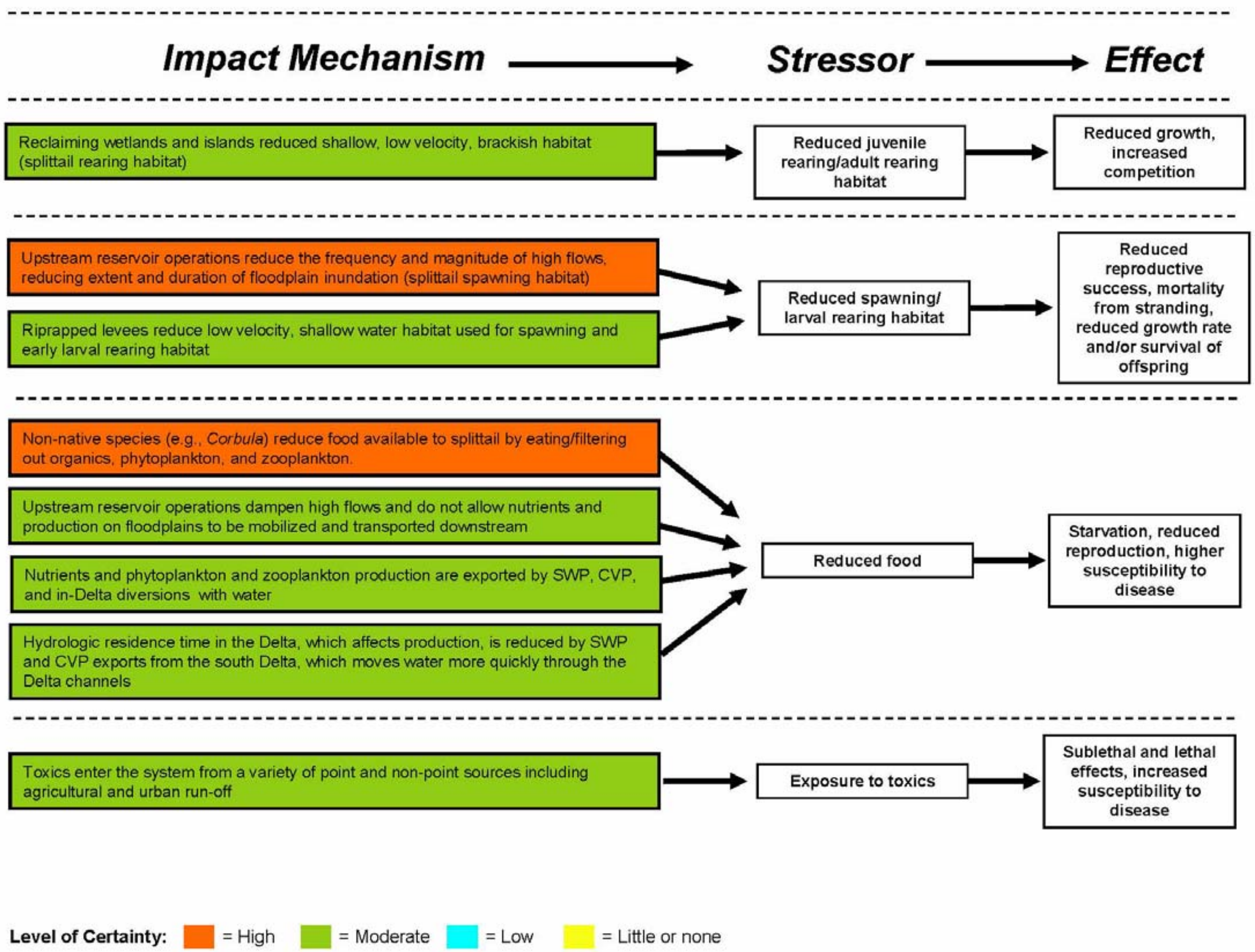

Figure 2-9a. Highly Important Sacramento Splittail Impact Mechanisms, Stressors, and Effects

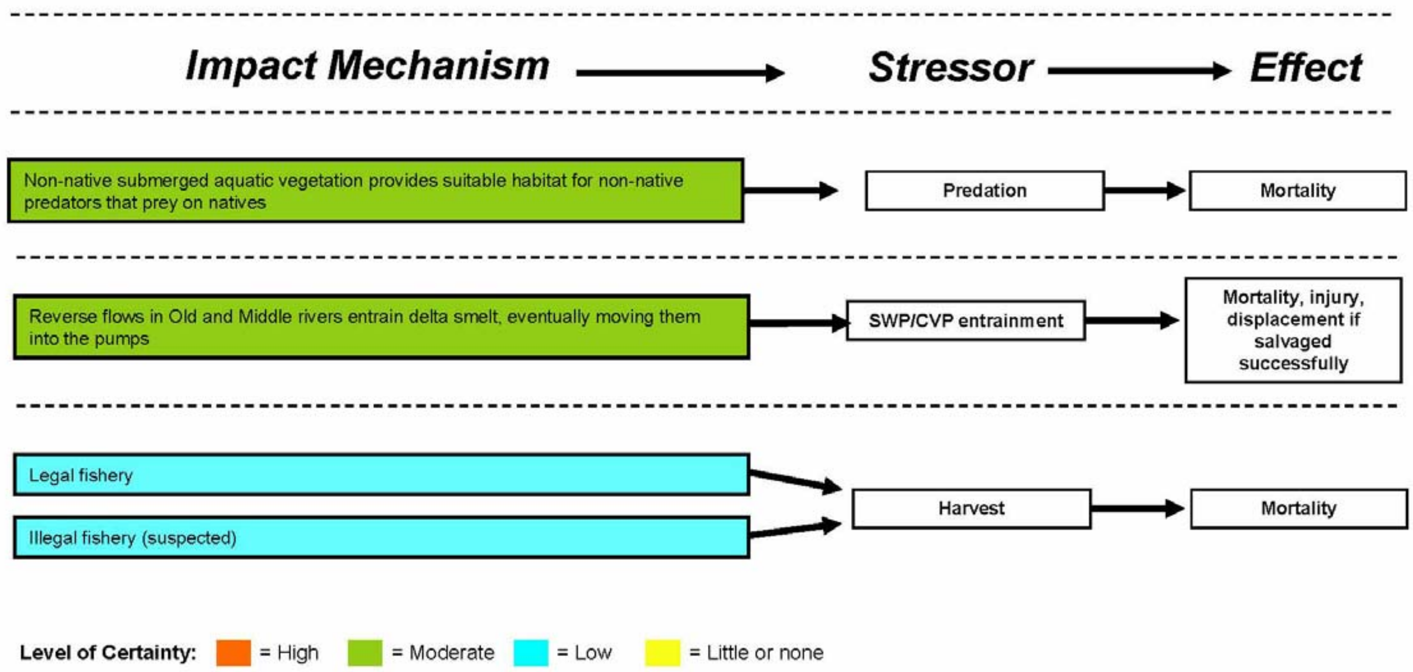

Figure 2-9b. Moderately Important Sacramento Splittail Impact Mechanisms, Stressors, and Effects

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2 = Low certainty: Understanding of the stressor and its impact mechanisms is moderate. Stressor effects generally cannot be predicted, or understanding of the stressor and its impact mechanisms is low. The nature of stressor effects is largely predictable based on information provided in the scientific literature and input provided by species experts.

1 = Little or no certainty: Understanding of the stressor and its impact mechanisms is lacking (scientific basis unknown or not widely accepted), or understanding of the stressor and its impact mechanisms is low. The nature of stressor effects is generally not predictable.

2.2 HYDROLOGIC/HYDRODYNAMIC MODELING

This section describes the hydrologic and hydrodynamic modeling approach, tools, and assumptions that were applied to provide information for evaluation of the Options. Hydrologic/system operations, hydrodynamic, and water quality modeling was performed to provide information on Delta flows, CVP/SWP operations and exports, Delta circulation patterns, and water quality effects in a response to the assumptions and criteria applied under each of the Options. The modeling information was used, in part, to assist in the overall evaluation of the Options. The modeling performed for this evaluation report should be considered "screening-level", consistent with the objectives and timeframe for this report.

2.2.1 Analytical Process and Modeling Approach

The overall analytical process applied in the hydrodynamic modeling evaluation of the Options is shown in Figure 2-10. Two main models, CALSIM II and DSM2, were used to evaluate a range of operations and response within each Option. These models and their applications and uses are described in Appendix A. Operational parameter assumptions, consisting of flow requirements/restrictions, water quality targets, and facility operational criteria, were developed by the consultant team, in consultation with the Steering Committee, to provide a range of responses within each Option. The range of operations under each Option is represented in the modeling as "A" and "B" scenarios. The "A" scenario generally represents the less restrictive conditions for water supply while the "B" scenario represents a more restrictive condition for water supply. Parameter values for scenarios A and B used in the modeling for each of the Options is presented in Appendix B.

The CALSIM II model was used to evaluate the hydrologic and system response of each Option over a wide range of hydrologic conditions. CALSIM II was simulated on a monthly time step for 82 years (water years 1922 to 2003) to provide output for parameters such as river flows, exports, water supply impacts, reservoir storage conditions, and system controls. The output from the CALSIM II modeling, in addition to other necessary boundary conditions, was used to drive the DSM2 set of models to evaluate the hydrodynamic, water quality, and particle transport and fate conditions. The DSM2-HYDRO and DSM2-QUAL models were simulated on a 15-minute time step for a 16 year period (water years 1976 to 1991) to provide output of channel flows, velocities, stage, and water quality (electrical conductivity). Finally, the DSM2-PTM model was simulated for three distinct months to evaluate particle transport and fate assuming particle insertions at five different locations in the Delta.

2.2.2 Base Study Assumptions

A base condition for Delta operations was established as a reference point to specify modeling assumptions common to all Options. The base condition selected for the evaluation was current operating conditions. Current conditions were defined based on the "Existing Condition" models and assumptions currently envisioned (as of CALSIMII version 9A) in the "Common Assumptions" process. The Common Assumptions process represents a concerted effort by the California Bay Delta Authority (CBDA), the U.S. Bureau of Reclamation (Reclamation), and the California Department of Water Resources (DWR) to coordinate and implement an evaluation framework to support the common needs of the surface storage investigations.

The base condition models and assumptions include all facilities, policies, regulations, and programs in place as of June 1, 2004. Appendix B includes a detailed list of assumptions incorporated in this study. Some minor modifications to the Common Assumptions models were made as part of this evaluation report to provide for a single-step study with D-1641 Delta standards and to include QWEST and Old and Middle River flow estimates.

2.2.3 Options Assumptions

Operational parameter assumptions, consisting of flow requirements/restrictions, water quality targets, and facility operation criteria, were developed by the consultant team to provide a range of responses within each option (see Appendix B). These operational parameters were reviewed by the BDCP Steering Committee and revised based on their input. However, final model parameter inputs were developed by the consultant team to ensure that each operational scenario could function within the modeling analyses, to the extent possible, without violating upstream regulatory controls or to reconcile conflicting controls determined after initial draft simulations.

Each Option included structural and operational assumptions that were incorporated into the modeling analyses. In general the operational assumptions were based on Sacramento River flow at Rio Vista, San Joaquin River flow at Vernalis, San Joaquin River flow estimate near Jersey Point (QWEST), Middle River flow, combined Old and Middle River flow, Delta Cross Channel gate operations, X_2 position, and Delta salinity objectives.

Assumptions Common to All Options

Unless noted, the modeling assumptions for each Option are the same as those applied in the Base study. Several assumptions that differ from the Base study and that were common to all Options and are listed below for clarity:

- Export/Inflow ratio standard was not imposed
- X_2 standards for "A" scenarios were identical to the Base study, but the "B" scenarios were restructured as a function of water year type (dry, moderate, wet).
- QWEST restrictions were not included in the "A" scenarios, but were included in all "B" except for Option 4 where no south Delta diversions would be permitted

- San Joaquin River flow requirements at Vernalis are consistent across options, but differ between the "A" and "B" scenarios

In addition, particle tracking model (PTM) simulations consist of an insertion of 1000 particles spread over 5 days and a simulation period of 45 days. The number of particles that were drawn into the SWP and CVP export pumps, exited into Suisun Bay, exited into agricultural intakes, and those that remained within the Central Delta were counted. The five particle insertion locations included Old River at Quimby Island, Middle River at Mildred Island, San Joaquin River near Big Break, Sacramento River near Cache Slough, San Joaquin River near Head of Old River (see Figure 2-11). Three different simulation periods were identified. In selecting the periods for PTM simulations, the probability of exceedance was computed on the monthly average QWEST flow (San Joaquin River flow at Jersey Point) from the BDCP base DSM2 study. The three months corresponding approximately to the 50%, 70% and 90% probability of exceedance values, as measured in the Base study, were identified as the three simulation periods. These months are September 1977 (50%), March 1990 (70%), and January 1981 (90%).

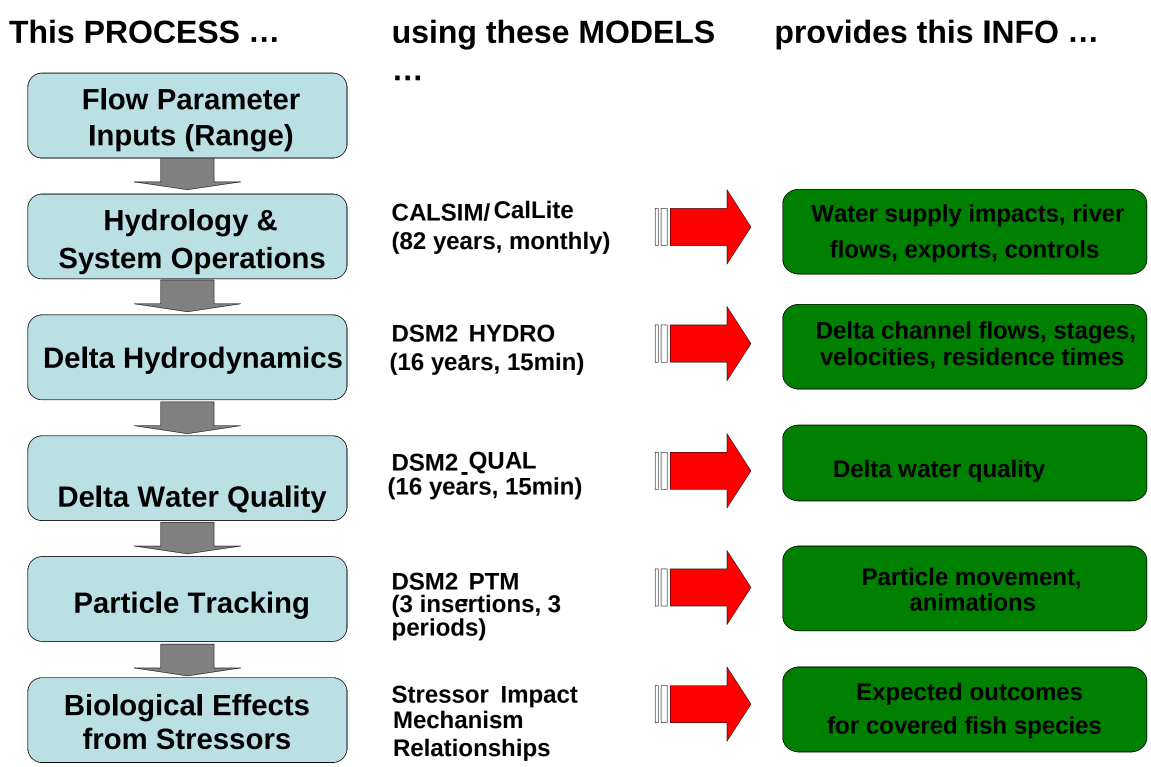

Figure 2-10. Analytical Process and Modeling Approach

The following sections provide brief descriptions of the key additional assumptions included in each of the four Options. For a more detailed description and a comparison of the assumptions refer to Appendix B.

Option 1 Assumptions

Option 1 consists of existing facilities and Delta configuration. Changes from current conditions are due to Delta standards and operational criteria. Under Option 1 (Scenario A), in addition to removal of the D-1641 export-inflow ratio standard, the Fish and Wildlife salinity standard at Collinsville is removed and the Delta Cross Channel gate operations are modified. Those gates are assumed to be closed from February through June and open between July and January.

Under Option 1 (Scenario B), the D-1641 Agricultural water quality objectives completely removed, and higher Rio Vista minimum flow requirements are specified. The Delta Cross Channel gates remain open at all times. The most significant operational criteria change in this scenario is the addition of Old and Middle River and QWEST flow restrictions limiting the magnitude of reverse flows in these channels.

Option 2 Assumptions

Under Option 2, a siphon (with pump facility – see discussion below) would be constructed between Victoria Canal and Clifton Court Forebay to convey Middle River water under Old River. In addition, five new barriers would be constructed. Three of the five barriers at Woodward Cut, Railroad Cut and Connection Slough would prevent interaction between Middle River and Old River through the cuts. The fourth barrier at the Mouth of Old River would prevent or delay fish entrainment into Middle River. The fifth barrier would be constructed in San Joaquin River just downstream of Head of Old River, in lieu of the Head of Old River Barrier. The San Joaquin River Barrier is operated to direct San Joaquin River flow into Old River and provides approximately 400 cfs in downstream flow at all times for downstream consumptive use and water quality needs.

In addition to the new barriers, the operation of the existing temporary agricultural barrier on Middle River was modified. This barrier would prevent ebb flows, permit flood flows over the barrier, and hydraulically isolate Old River from Middle River.

Under Option 2, in addition to the common assumption of removal of the D-1641 export-inflow ratio standard, only the D-1641 Agricultural water quality objectives were included. Contra Costa Water District was assumed to draw water from Middle River in this Option.

In Option 2 Scenario A (the less restrictive scenario) the flow and operational restrictions are the same as those described in Option 1 Scenario A. In Option 2 Scenario B (the more restrictive scenario) no D-1641 water quality objectives are specifically simulated and Rio Vista minimum flow requirements and DCC operations are the same as the Option 1 Scenario B. The most significant operational criteria change in this scenario is the addition of Middle River and QWEST flow restrictions limiting the magnitude of reverse flows in these channels.

Victoria Canal Siphon Capacity

The operation of Option 2 is dependent on the flow capacity of the Victoria Canal siphon. Hydraulic calculations and hydrodynamic model simulations indicate that use of a gravity siphon at this location would limit conveyance to approximately 4,500 cfs (however, see

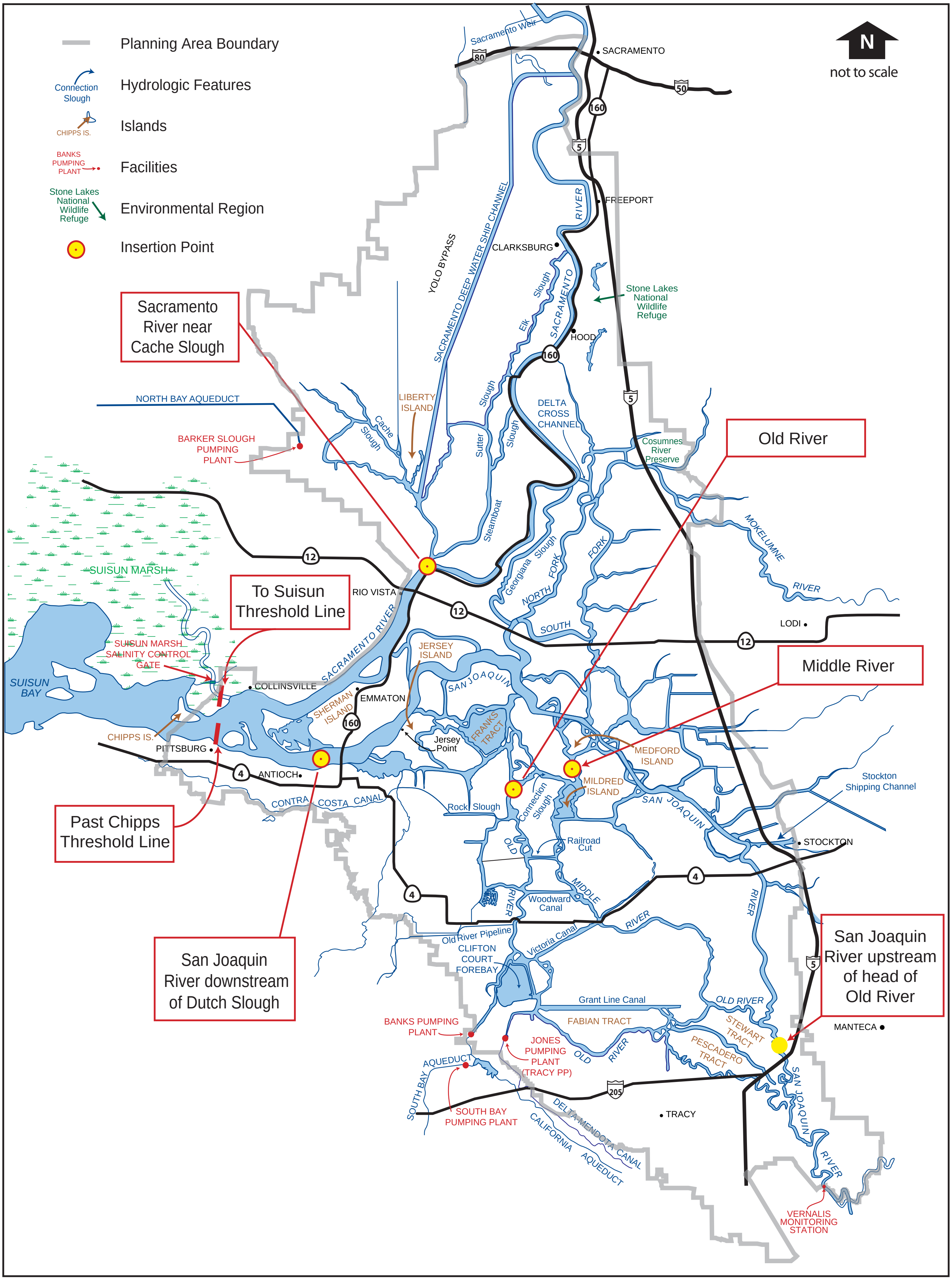

Figure 2-11. DSM2 - Particle Tracking Model Particle Insertion Points

discussion below regarding addition of a pump facility). This section provides detail on the methods used for determining Victoria Canal siphon capacity.

To determine the capacity of the Victoria Canal siphon, a combination of DSM2 model simulations and hydraulic calculations were performed. The siphon was modeled in DSM2 through the use of a gate structure at the southwestern end of Victoria Canal. The gate structure was defined as containing a number of 24′ diameter pipes. The number of pipes was varied during a sensitivity analysis to determine if the flow through the pipes was limited by the driving stage in Victoria Canal or the number of pipes. Results indicate that flows through the siphon are primarily a function of stage in Victoria Canal, and not the number of pipes.

Water flow through a siphon is controlled by the stage difference across the siphon (driving head) and the head losses associated with the siphon. In DSM2, the driving head is provided by tidally-varying stages in Victoria Canal (upstream head), and a user specified elevation on the downstream side of the siphon representative of operable water surface elevations in Clifton Court Forebay. For this study, it was assumed that Clifton Court Forebay could be operated at -1 ft MSL (NGVD 1929). Checks against historic water levels in Clifton Court Forebay indicate that on a daily basis, the minimum stage was below 0 ft MSL more than 80 percent of the time for the past six years, and below -1.0 ft six percent of the time. This indicates the ability of the facility to operate at these levels, but a refined assessment should be conducted if this Option is carried forward.

The head loss across the siphon also influences the siphon capacity. The DSM2 application utilized a broad-crested weir downstream of the siphon to approximate the head loss through the siphon, since DSM2 does not explicitly account for friction losses through pipes. By setting the weir crest elevation at 0 ft and assuming an operable water level in Clifton Court Forebay of -1 ft, a constant head loss of 1 foot is applied to the siphon.

DSM2 predictions of flow through the siphon were used to back calculate the head loss, given the velocity and assumptions for friction and siphon length. Results indicate that the average head loss through a range in tidal flows is 0.8 ft, and thus the assumed 1 ft of loss is conservative, and will result in an underestimation of the potential flow through the siphon.

To determine a more appropriate value for the head loss through the siphon, the standard energy equation was used to solve for velocity, head loss, and flow through the proposed siphon, given water stages from the DSM2 model. Two head loss components were used, the loss at the entrance and the loss along the length of the siphon, assumed to be 2000 feet. The friction coefficient for the pipe was set at 0.015.

Given a time series of upstream stage, taken from the DMS2 model predictions in Victoria Canal with the siphon in place, the velocity and thus flow through the siphon were solved via the energy equation. Flows calculated from the energy equation were averaged on a monthly basis, yielding a long term average of approximately 4,500 cfs through the siphon.

Addition of Pump Facility to the Victoria Canal Siphon

Hydrodynamic modeling outputs indicate that the export capacity under Option 2 is constrained by a gravity siphon connecting Victoria Canal and Clifton Court Forebay (Appendix E). Option 2 in that configuration would not meet water supply objectives (Figure 2-12) because the ability to gravity siphon water is hydraulically constrained to 4,500 cfs. Consequently, the evaluation of Option 2 relative to applicable evaluation criteria was conducted with the addition of a low-head pump at the siphon that would increase the flow capacity from Victoria Canal to Clifton Court Forebay to levels that could meet water supply objectives. Preliminary results of Option 2 with the pump facility indicate that water supply reliability would exceed base conditions under operational Scenario A (Figure 2-13).

The assessment of Option 2 was conducted based on the full model outputs with the gravity siphon interpreted for expected results with a pump facility. Model outputs for Option 2 with the pump facility were not available in time to incorporate into the full evaluation, though, some preliminary outputs of that model run are included as appropriate (e.g., Figure 2-13). Option 2 was evaluated using professional judgment and understanding of Delta hydrodynamics to determine the hydrologic and water quality conditions that would likely result with a pump facility to increase siphon capacity. This professional judgment is based on experience with results of previous CALSIMII and DSM2 studies of numerous operational scenarios conducted by DWR, Reclamation, and state and federal water contractors. Hydrodynamic modeling outputs under Option 2 for the following modeled parameters would be expected to substantively change with addition of a pump facility:

- Volume of water exported
- Delta outflow
- Delta inflow
- Quality of water exported
- Quality of in-Delta water
- Position of X_2
- Hydraulic residence time and Delta flow pattern (from the PTM model)

Numeric values for these parameters under Option 2 with pump facility cannot be determined without running the CALSIMII and DSM2, which could not be accommodated within the Options Evaluation Report schedule. Consequently, the likely performance of Option 2 for these parameters is qualitatively described in Section 4 relative to the model results presented in Appendices D-G for the base condition and each of the Options. The estimated performance of Option 2 relative to the base condition and the other Options for each parameter is described in Table 2-1.

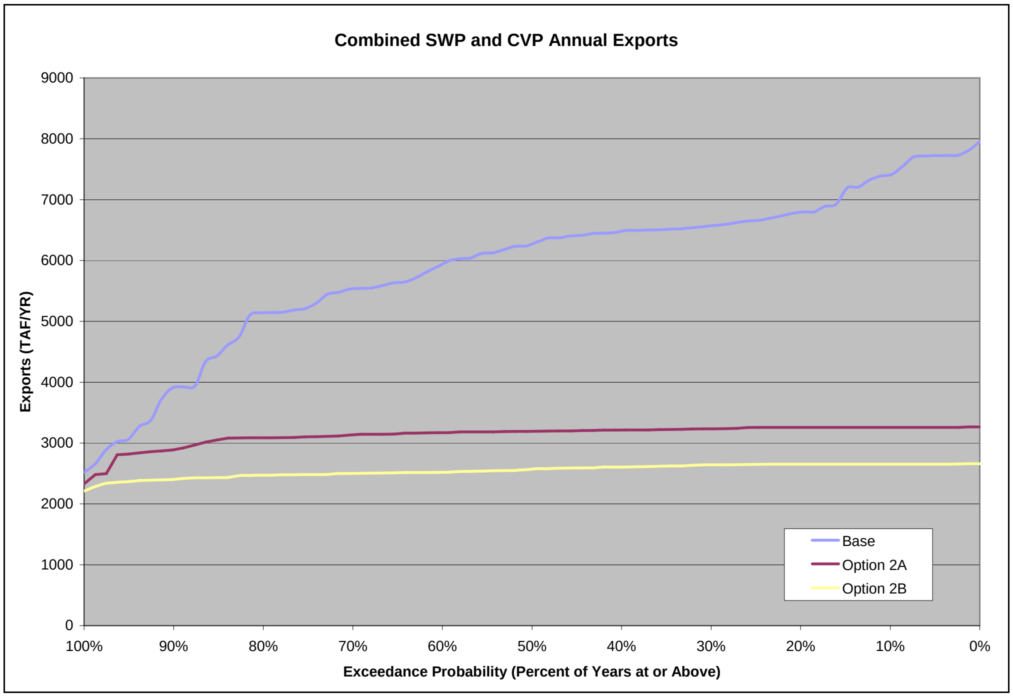

Figure 2-12. Water supply reliability curves for Option 2 without pump facility (gravity siphon, only) under operational scenarios A and B and base conditions

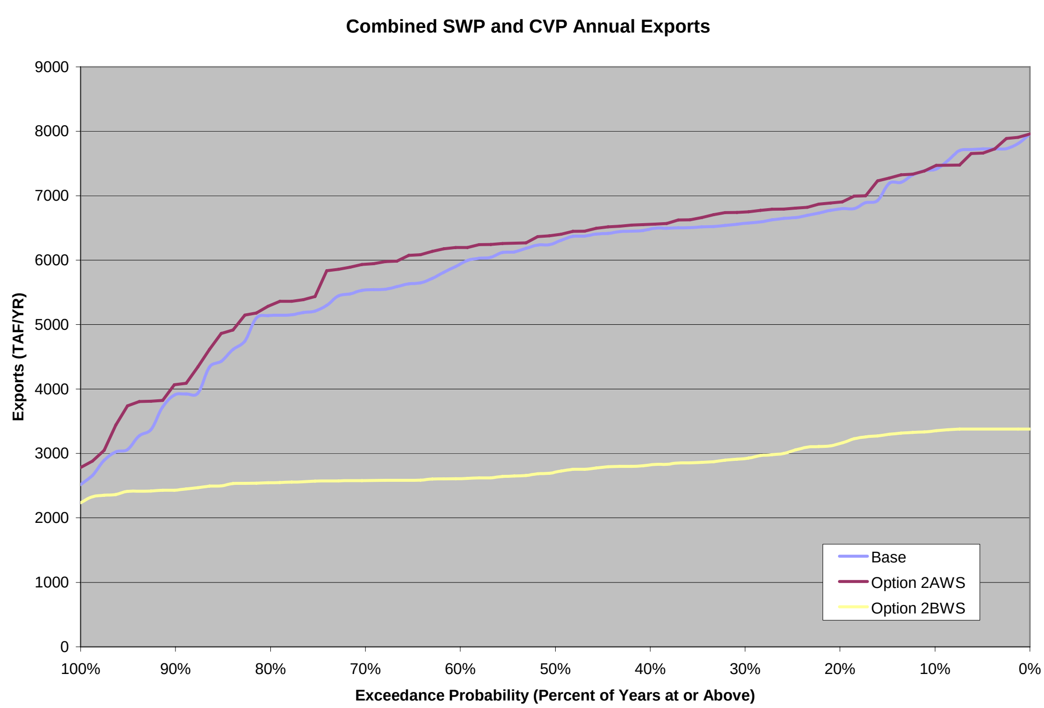

Figure 2-13. Water supply reliability curves for Option 2 with pump facility at the siphon under operational scenarios A and B and base conditions

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Table 2-1. Assumed Performance of Option 2 with a Pump Facility at the Siphon for Important CALSIMII and DSM2 Parameters Relative to the Base Condition and the Options 1-4

	Comparison to Option 2 with Pump Facility[1]				
Model Parameter	**Base Condition**	**Option 1**	**Option 2 without pump facility**	**Option 3**	**Option 4**
Export volume	Less than	Similar to	Greater than	Similar to	Similar to
Delta outflow	Greater than	Similar to	Less than	Similar to	Similar to
Delta inflow	Less than	Similar to	Greater than	Similar to	Similar to
X_2	Less than	Similar to	Greater than	Similar to	Similar to
Export water quality	Greater than	Greater than	Greater than	Less than	Less than
In-Delta water quality	Greater, except for OR	Less than	Less than, higher EC	Uncertain	Uncertain
Particle tracking fate					
Export	Less than	Less than	Greater than	Greater than	Greater than
Downstream	Greater than	Similar to	Greater than	Less than	Uncertain
Central	Greater than	Greater than	Greater than	Uncertain	Uncertain

Notes:

1. "Less than" means Option 2 with pump would have a lower value than the base condition or other Option for that parameter. "Greater than" means Option 2 with pump would have a greater value for that parameter. Determined by best professional judgment based experience with running models under a wide range of input conditions.

Option 3 Assumptions

Option 3 incorporates a dual set of conveyance facilities. The south Delta diversion facility and barrier modifications are as described under Option 2. A second diversion facility is included in this Option for a Sacramento River diversion at Hood or Clarksburg to divert water into a peripheral aqueduct as described in Option 4. Thus, this Option is a hybrid of facilities included in Option 2 and 4. The assumptions specific to the Middle River corridor concept included in Option 2 were carried forward for this option. Similarly, the assumptions specific to the Hood diversion facility included in the Option 4 were carried forward for this option.

In Option 3, the peripheral aqueduct diversion facility was operated preferentially to the south Delta diversion at all times. The Hood diversion was set to a maximum of 15,400 cfs. Under the more restrictive scenario modeled under this option, a maximum diversion of 6,000 cfs was assumed from March to May. Banks Pumping Plant capacity was assumed to operate at a maximum of 8,500 cfs in all months, although the ability to operate continuously at 10,300 cfs should be further evaluated if this option is carried forward. In both scenarios, it was assumed that the Contra Costa Water District intake would be relocated to draw water directly from the peripheral aqueduct.

Rio Vista minimum flow requirements during January through June were increased significantly over the Base condition, Option 1, or Option 2 to reflect the primary downstream control on the peripheral aqueduct diversion. Under both scenarios of this Option, the Delta Cross Channel gates are closed year-round.

Option 4 Assumptions

Under Option 4, the peripheral aqueduct diversion described above for Option 3 is included as a replacement for the current south Delta diversions of the SWP and CVP. Because there is no direct diversion from the south Delta, the VAMP export, Middle River flow, and QWEST flow restrictions are assumed not to be applicable. As in Option 3, Rio Vista minimum flow requirements were increased significantly over the Base, Option 1, and Option 2 and reflect the primary control on the Isolated Facility diversion. Several levels of Rio Vista minimum flow standards in Dry and Critical years were modeled to reduce the impact on upstream storage conditions.

2.3 EVALUATION OF THE BIOLOGICAL CRITERIA

This section describes the overall approach to conducting the evaluation of the Options in relation to the biological criteria and includes descriptions of the metrics, tools, scales and important assumptions used to conduct the evaluation in relation to each of the covered fish species. Metrics are defined as specific standards against which the performance of each Option is evaluated. Tools are defined as the methods and information used to evaluate performance of each Option in relation to the metric. Scales are the quantitative or qualitative measures used to express the performance of each Option relative to the tools.

The process used to conduct the evaluation of each criterion for each of the covered species is described below:

- identification of the stressors for each covered species (from Appendix C) that could be affected by the conveyance configuration and habitat restoration opportunities for each Option;
- development of metrics that address the likely effects (positive or negative) of each Option on the impact mechanisms for each of the identified stressors and identify the tools for measuring those effects;
- use of the metric tools to evaluate the likely performance of each Option for each covered fish species relative to each metric. Tools are based on CALSIM II and DSM2 modeling results, published results of species studies and other credible sources of relevant information, and professional judgment; and
- summarization of the relative performance of each Option for each species relative to the biological criteria, based on the scaled metrics.

The metrics, tools, and scales for the biological criteria are presented in Table 2-2.

Table 2-2. Metrics, Tools, and Scales for Biological Criteria

Metric	Relationship	Tools	Scale
Criterion #1. Relative degree to which the Option would reduce species mortality attributable to non-natural mortality sources, in order to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species (BDCP Conservation Objective)			
B1. Opportunity for restoration of aquatic and intertidal habitat under the Option	Improving the quality and extent of aquatic and intertidal habitat in the Delta is hypothesized to reduce mortality by: • Improving the abundance and availability of food that is more nutritious than non-native species; • Create conditions that are less favorable for supporting non-native species that compete for food; and • Create conditions that are less favorable to non-native predators and that reduce the susceptibility of covered fish species to predation. **Certainty:** 2	A. Proportion of the planning area available for restoration of high-function aquatic and intertidal habitats	**<u>Proportion of the Delta (%)</u>** 5 = 80 to 100% 4 = 51% to 79% 3 = 31% to 50% 2 = 11% to 30% 1 = 0 to 10%
B2. Opportunity for improving inflows into the Delta	Changes in peak total Delta inflows during peak runoff periods change the frequency and duration of floodplain inundation and affect: • Inputs of nutrients to the Delta, which affects food production and availability, • Turbidity, which affects the foraging efficiency and predation vulnerability of delta and longfin smelt, • Extent of food available for Sacramento splittail rearing. **Certainty:** 3	A. Change from base conditions in hydrologic modeling results for peak total Delta inflows during January-March	**<u>Change (%)</u>** 5 = > +5% 4 = +1% to +4% 3 = 0 to -4% 2 = -5% to -9% 1 = < -10%

Table 2-2. Metrics, Tools, and Scales for Biological Criteria (continued)

Metric	Relationship	Tools	Scale
	The potential range of spring Delta inflow is indicative of the ability of the Option to dilute contaminants that could result in mortality **Certainty:** 3	B. Change from base conditions in hydrologic modeling results for Sacramento River flows at Rio Vista during March and April	**Change (%)** 5 = > +10% 4 = +10% to -9% 3 = -10% to -19% 2 = -20% to -29% 1 = < -30%
	The potential range of spring Delta inflow is indicative of the ability of the Option to dilute contaminants that could result in mortality **Certainty:** 3	C. Change from base conditions in hydrologic modeling results for total Delta inflow during March and April	**Change (%)** 5 = > +10% 4 = +10% to -9% 3 = -10% to -19% 2 = -20% to -29% 1 = < -30%
B3. Opportunities to improve hydraulic residence time	Changes in hydraulic residence time within the central Delta affect food production and turbidity which affects the foraging efficiency and vulnerability to predation of all species but splittail (splittail are addressed separately below). The particle tracking model approximates the likelihood of nutrients and food remaining in the central Delta **Certainty:** 3	A. Change from base conditions in particle tracking modeling results for percentage of particles after 14 days with "central" fate for the three hydrology conditions (50%, 70%, and 90% exceedance)	**Change (%)** 5 = > 75% 4 = 51% to 75% 3 = 26% to 50% 2 = 0% to 25% 1 = < 0%
		B. Change from base conditions in particle tracking modeling results for percentage of particles after 28 days with "central" fate for the three hydrology conditions (50%, 70%, and 90% exceedance)	**Change (%)** 5 = > 75% 4 = 51% to 75% 3 = 26% to 50% 2 = 0% to 25% 1 = < 0%

Table 2-2. Metrics, Tools, and Scales for Biological Criteria (continued)

Metric	Relationship	Tools	Scale
	Changes in hydraulic residence time within the central Delta affect food production and turbidity which affects the foraging efficiency and vulnerability to predation of splittail. The particle tracking model approximates the likelihood of nutrients and food remaining in the central Delta under drier conditions, when food is limiting to splittail **Certainty:** 4	A. Change from base conditions in particle tracking modeling results for percentage of particles after 14 days with "central" fate for the 50% exceedance hydrology	**Change (%)** 5 = > 75% 4 = 51% to 75% 3 = 26% to 50% 2 = 0% to 25% 1 = < 0%
		B. Change from base conditions in particle tracking modeling results for percentage of particles after 28 days with "central" fate for the 50% exceedance hydrology	**Change (%)** 5 = > 75% 4 = 51% to 75% 3 = 26% to 50% 2 = 0% to 25% 1 = < 0%
B4. Ability to reduce the export of nutrients and food from the Delta	The SWP/CVP export facilities and agricultural diversions entrain food and nutrients from the Delta that can affect food production and availability to all fish species but splittail. The particle tracking model approximates the likelihood for entrainment of nutrients and food of these diversions. **Certainty:** 3	A. Change from base conditions in particle tracking modeling results for percentage of particles after 14 days with either "SWP/CVP exports" or "agricultural diversions" fate for the three hydrology conditions (50%, 70%, and 90% exceedance)	**Change (%)** 5 = < -75% 4 = -51% to -75% 3 = -26% to -50% 2 = 0% to -25% 1 = > 0%
		B. Change from base conditions in particle tracking modeling results for percentage of particles after 28 days with either "SWP/CVP exports" or "agricultural diversions" fate for the three hydrology conditions (50%, 70%, and 90% exceedance)	**Change (%)** 5 = < -75% 4 = -51% to -75% 3 = -26% to -50% 2 = 0% to -25% 1 = > 0%

Table 2-2. Metrics, Tools, and Scales for Biological Criteria (continued)

Metric	Relationship	Tools	Scale
	The SWP/CVP export facilities and agricultural diversions entrain food and nutrients from the Delta that can affect food production and availability to splittail. The particle tracking model approximates the likelihood for entrainment of nutrients and food of these diversions under drier conditions, when food is limiting to splittail. **Certainty:** 4	C. Change from base conditions in particle tracking modeling results for percentage of particles after 14 days with either "SWP/CVP exports" or "agricultural diversions" fate for the 50% exceedance hydrological condition	**Change (%)** 5 = < -75% 4 = -51% to -75% 3 = -26% to -50% 2 = 0% to -25% 1 = > 0%
		D. Change from base conditions in particle tracking modeling results for percentage of particles after 28 days with either "SWP/CVP exports" or "agricultural diversions" fate for the 50% exceedance hydrological condition	Change (%) 5 = < -75% 4 = -51% to -75% 3 = -26% to -50% 2 = 0% to -25% 1 = > 0%
B5. Ability to reduce entrainment at the SWP/CVP export facilities	Entrainment of particles using the particle tracking model approximate the likelihood for entrainment of larval delta smelt and longfin smelt at the SWP/CVP facilities **Certainty:** 2	B. Change from base conditions in particle tracking modeling results for percentage of particles after 14 days for with "CVP/SWP exports" fate for the three hydrology conditions (50%, 70%, and 90% exceedance)	**Change (%)** 5 = < -75% 4 = -51% to -75% 3 = -26% to -50% 2 = 0% to -25% 1 = > 0%
		C. Change from base conditions in particle tracking modeling results for percentage of particles after 28 days with "CVP/SWP exports" fate for the three hydrology conditions (50%, 70%, and 90% exceedance)	Change (%) 5 = < -75% 4 = -51% to -75% 3 = -26% to -50% 2 = 0% to -25% 1 = > 0%

Table 2-2. Metrics, Tools, and Scales for Biological Criteria (continued)

Metric	Relationship	Tools	Scale
	There is evidence that the degree of reverse flow in Old and Middle Rivers is positively correlated to entrainment levels of juvenile and adult fish **Certainty:** 3	D. Change from base conditions in Old and Middle River reverse flows in modeling results during January	**Change (cfs)** 5 = > 0 4 = 0 to -1999 3 = -2000 to -3999 2 = -4000 to -5999 1 = < -6000
		E. Change from base conditions in Old and Middle River reverse flows in modeling results during April	**Change (cfs)** 5 = > 0 4 = 0 to -1999 3 = -2000 to -3999 2 = -4000 to -5999 1 = < -6000
Criterion #2. Relative degree to which the Option would provide water quality and flow conditions necessary to enhance production (reproduction, growth, survival) , abundance, and distribution for each of the covered fish species (BDCP Conservation			
B6. Ability to improve the location of the low salinity zone during sensitive periods **Objective)**	The location of X_2 during April is related to the production, growth, and survival of delta smelt and longfin smelt **Certainty:** 3	A. Change in modeling results for the location of X_2 during April from base conditions	**<u>Change (km)</u>** 5 = < -6 4 = -5.9 to -3 3 = -2.9 to 0 2 = 0.1 to +2.9 1 = >3
B7. Ability to improve turbidity of Delta waters	Changes in turbidity of Delta waters affects foraging efficiency and predation vulnerability of delta and longfin smelt. The particle tracking model approximates the likelihood for entrainment of algae and other particles	A. Change from base conditions in particle tracking modeling results for percentage of particles after 14 days with "central" fate for the three hydrology conditions (50%, 70%, and 90% exceedance)	**Change (%)** 5 = > 75% 4 = 51% to 75% 3 = 26% to 50% 2 = 0% to 25% 1 = < 0%

Table 2-2. Metrics, Tools, and Scales for Biological Criteria (continued)

Metric	Relationship	Tools	Scale
	that contribute to turbidity at the SWP/CVP facilities. **Certainty:** 3	B. Change from base conditions in particle tracking modeling results for percentage of particles after 28 days with "central" fate for the three hydrology conditions (50%, 70%, and 90% exceedance)	**Change (%)** 5 = > 75% 4 = 51% to 75% 3 = 26% to 50% 2 = 0% to 25% 1 = < 0%
	Changes in peak total Delta inflows during peak runoff periods affects sediment inputs that govern turbidity in Delta waters which affects the foraging efficiency and vulnerability to predation. **Certainty:** 3	C. Change from base conditions in hydrologic modeling results for peak total Delta inflows during January-March	**<u>Change (%)</u>** 5 = > +5% 4 = +1% to +4% 3 = 0 to -4% 2 = -5% to -9% 1 = < -10%
	Reduction in abundance of non-native species like filter-feeding clams (*Corbula, Corbicula*) and aquatic vegetation (*Egeria*, water hyacinth) could result in an increase in turbidity, **Certainty:** 2	D. Proportion of the planning area available for restoration of high-function aquatic and intertidal habitats	**<u>Proportion of the Delta (%)</u>** 5 = 80 to 100% 4 = 51% to 79% 3 = 31% to 50% 2 = 11% to 30% 1 = 0 to 10%
B8. Ability to improve net downstream flow	Changes in net downstream flow affects downstream transport of larval and juvenile fish. The particle tracking model approximates downstream transport of larvae and young juveniles from all Covered Species of fish except green and white sturgeon. **Certainty:** 2	A. Change from base conditions in particle tracking modeling results for percentage of particles after 14 days with either "past Chipps Island" or "to Suisun Marsh" fate for the three hydrology conditions (50%, 70%, and 90% exceedance)	**Change (%)** 5 = > 75% 4 = 51% to 75% 3 = 26% to 50% 2 = 0% to 25% 1 = < 0%

Table 2-2. Metrics, Tools, and Scales for Biological Criteria (continued)

Metric	Relationship	Tools	Scale
		B. Change from base conditions in particle tracking modeling results for percentage of particles after 28 days with either "past Chipps Island" or "to Suisun Marsh" fate for the three hydrology conditions (50%, 70%, and 90% exceedance)	**Change (%)** 5 = > 75% 4 = 51% to 75% 3 = 26% to 50% 2 = 0% to 25% 1 = < 0%
	Changes in spring Sacramento River flow at Rio Vista affects downstream transport of larval and juvenile fish and upstream migration cues for adult salmonids. **Certainty:** 2	C. Change from base conditions in hydrologic modeling results for Sacramento River flows at Rio Vista during March and April	**Change (%)** 5 = > +10% 4 = +10% to -9% 3 = -10% to -19% 2 = -20% to -29% 1 = < -30%
	Changes in spring total Delta outflow affects downstream transport of larval and juvenile fish and upstream migration cues for adult salmonids. **Certainty:** 3	D. Change from base conditions in hydrologic modeling results for total Delta outflow during March and April	**Change (%)** 5 = > +10% 4 = +10% to -9% 3 = -10% to -19% 2 = -20% to -29% 1 = < -30%
B9. Ability to provide cool water flows in the Sacramento, American, and Feather Rivers	The temperatures of water released from Shasta, Oroville, and Folsom Reservoirs may vary under the Options and, therefore, have differing effects on Sacramento River salmonids and sturgeon **Certainty:** 3	A. Change from base conditions in hydrologic modeling results for Shasta Reservoir storage volume	**Change (%)** 5 = > +10% 4 = +6% to +10% 3 = -5% to +5% 2 = -6% to -10% 1 = < -10%

Table 2-2. Metrics, Tools, and Scales for Biological Criteria (continued)

Metric	Relationship	Tools	Scale
		B. Change from base conditions in hydrologic modeling results for Oroville Reservoir storage volume	**Storage (maf)** 5 = > 1.5 4 = 1.49 to 1.4 3 = 1.39 to 1.3 2 = 1.29 to 1.2 1 = < 1.2
		C. Change from base conditions in hydrologic modeling results for Folsom Reservoir storage volume	**Storage (maf)** 5 = > 0.4 4 = 0.39 to 0.35 3 = 0.34 to 0.3 2 = 0.29 to 0.25 1 = < 0.25
Criterion #3. Relative degree to which the Option would increase habitat quality, quantity, accessibility, and diversity in order to enhance and sustain production (reproduction, growth, survival), abundance, and distribution; and to improve the resiliency of each of the covered species' populations to environmental change and variable hydrology (BDCP Conservation Objective).			
B10. Opportunity for restoration of aquatic and intertidal habitat under the Option	Improving the quality and extent of aquatic and intertidal habitat in the Delta for covered species will increase the production, abundance, and distribution of covered species. **Certainty:** 2	A. Proportion of the planning area available for restoration of high-function aquatic and intertidal habitats	**Proportion of the Delta (%)** 5 = 80 to 100% 4 = 51% to 79% 3 = 31% to 50% 2 = 11% to 30% 1 = 0 to 10%
B11. Improve accessibility to spawning and rearing habitat	Changes in peak total Delta inflows during peak runoff periods change the frequency and duration of floodplain inundation that provides splittail spawning and larval rearing habitat. **Certainty:** 4	B. Change from base conditions in modeling results for peak total Delta inflows during January-March	**Change (%)** 1 = > +5% 2 = +1% to +4% 3 = 0 to -4% 4 = -5% to -9% 5 = < -10%

Table 2-2. Metrics, Tools, and Scales for Biological Criteria (continued)

Metric	Relationship	Tools	Scale
	The location of X_2 during April determines the extent of rearing habitat available for delta and longfin smelt **Certainty:** 3	A. Change from base conditions in modeling results for the location of X_2 during April	**Change (km)** 1 = < -6 2 = -5.9 to -3 3 = -2.9 to 0 4 = 0.1 to +2.9 5 = >3
B12. Ability to improve turbidity of Delta waters	Changes in turbidity of Delta waters affects foraging efficiency and predation vulnerability of delta and longfin smelt. The particle tracking model approximates the likelihood for entrainment of algae and other particles that contribute to turbidity at the SWP/CVP facilities. **Certainty:** 3	A. Change from base conditions in particle tracking modeling results for percentage of particles after 14 days with "central" fate for the three hydrology conditions (50%, 70%, and 90% exceedance)	**Change (%)** 5 = > 75% 4 = 51% to 75% 3 = 26% to 50% 2 = 0% to 25% 1 = < 0%
		B. Change from base conditions in particle tracking modeling results for percentage of particles after 28 days with "central" fate for the three hydrology conditions (50%, 70%, and 90% exceedance)	**Change (%)** 5 = > 75% 4 = 51% to 75% 3 = 26% to 50% 2 = 0% to 25% 1 = < 0%
	Changes in peak total Delta inflows during peak runoff periods affects sediment inputs that govern turbidity in Delta waters which affects the foraging efficiency and vulnerability to predation. **Certainty:** 3	C. Change from base conditions in hydrologic modeling results for peak total Delta inflows during January-March	**Change (%)** 5 = > +5% 4 = +1% to +4% 3 = 0 to -4% 2 = -5% to -9% 1 = < -10%

Table 2-2. Metrics, Tools, and Scales for Biological Criteria (continued)

Metric	Relationship	Tools	Scale
	Reduction in abundance of non-native species like filter-feeding clams (*Corbula, Corbicula*) and aquatic vegetation (*Egeria*, water hyacinth) could result in an increase in turbidity, **Certainty:** 2	D. Proportion of the planning area available for restoration of high-function aquatic and intertidal habitats	**Proportion of the Delta (%)** 5 = 80 to 100% 4 = 51% to 79% 3 = 31% to 50% 2 = 11% to 30% 1 = 0 to 10%
B13. Ability to improve net downstream flow	Changes in net downstream flow affects downstream transport of larval and juvenile fish to rearing habitat. The particle tracking model approximates downstream transport of larvae and young juveniles from all Covered Species of fish except green and white sturgeon. **Certainty:** 2	A. Change from base conditions in particle tracking modeling results for percentage of particles after 14 days with either "past Chipps Island" or "to Suisun Marsh" fate for the three hydrology conditions (50%, 70%, and 90% exceedance)	**Change (%)** 5 = > 75% 4 = 51% to 75% 3 = 26% to 50% 2 = 0% to 25% 1 = < 0%
		B. Change from base conditions in particle tracking modeling results for percentage of particles after 28 days with either "past Chipps Island" or "to Suisun Marsh" fate for the three hydrology conditions (50%, 70%, and 90% exceedance)	**Change (%)** 5 = > 75% 4 = 51% to 75% 3 = 26% to 50% 2 = 0% to 25% 1 = < 0%
	Changes in spring Sacramento River flow affects downstream transport of larval and juvenile delta smelt, longfin smelt and splittail to rearing habitat. **Certainty:** 3	E. Change from base conditions in hydrologic modeling results for Sacramento River flows at Rio Vista during March and April	**Change (%)** 5 = > +9% 4 = +10% to -9% 3 = -10% to -19% 2 = -20% to -29% 1 = >-30%

Table 2-2. Metrics, Tools, and Scales for Biological Criteria (continued)

Metric	Relationship	Tools	Scale
	Changes in total spring Delta outflow affects downstream transport of larval and juvenile delta and longfin smelt to rearing habitat. **Certainty:** 3	D. Change from base conditions in hydrologic modeling results for total Delta outflow during March and April	**<u>Change (%)</u>** 5 = > +9% 4 = +10% to -9% 3 = -10% to -19% 2 = -20% to -29% 1 = < -30%
Criterion #4. Relative degree to which the Option would increase food quality, quantity, and accessibility (e.g., phytoplankton, zooplankton, macro-invertebrates, forage fish) to enhance production (reproduction, growth, survival) and abundance for each of the covered fish species (BDCP Conservation Objective).			
B14. Opportunities for restoration of aquatic and intertidal habitat	Improving the quality and extent of aquatic and intertidal habitat in the Delta is hypothesized to reduce mortality by: • Improving the abundance and availability of native prey species that are more nutritious than non-native species; and • Create conditions that are less favorable for supporting non-native species that compete for food. • **Certainty:** 2	A. Proportion of the planning area available for restoration of high-function aquatic and intertidal habitats	**<u>Proportion of the Delta (%)</u>** 5 = 80 to 100% 4 = 51% to 79% 3 = 31% to 50% 2 = 11% to 30% 1 = 0 to 10%

Table 2-2. Metrics, Tools, and Scales for Biological Criteria (continued)

Metric	Relationship	Tools	Scale
B15. Opportunities for improving peak inflows into the Delta	Changes in peak total Delta inflows during peak runoff periods change the frequency and period of floodplain inundation affect: • Inputs of nutrients to the Delta, which affects food production and availability, • Turbidity, which affects the foraging efficiency and predation vulnerability of delta and longfin smelt, • Extent of food available for Sacramento splittail rearing. **Certainty:** 3	A. Change from base conditions in modeling results for peak total Delta inflows during January-March	**Change (%)** 5 = > +5% 4 = +1% to +4% 3 = 0 to -4% 2 = -5% to -9% 1 = < -10%
B16. Opportunities to improve hydraulic residence time	Changes in hydraulic residence time within the central Delta affect food production and turbidity which affects the foraging efficiency to all fish species but splittail (splittail are addressed separately below). The particle tracking model approximates the likelihood for particles remaining in the central Delta. **Certainty:** 3	A. Change from base conditions in particle tracking modeling results for percentage of particles after 14 days with "central" fate for the three hydrology conditions (50%, 70%, and 90% exceedance)	**Change (%)** 5 = > 75% 4 = 51% to 75% 3 = 26% to 50% 2 = 0% to 25% 1 = < 0%
		B. Change from base conditions in particle tracking modeling results for percentage of particles after 28 days with "central" fate for the three hydrology conditions (50%, 70%, and 90% exceedance)	**Change (%)** 5 = > 75% 4 = 51% to 75% 3 = 26% to 50% 2 = 0% to 25% 1 = < 0%

Table 2-2. Metrics, Tools, and Scales for Biological Criteria (continued)

Metric	Relationship	Tools	Scale
	Changes in hydraulic residence time within the central Delta affect food production and turbidity which affects the foraging efficiency to all fish species but splittail. The particle tracking model approximates the likelihood for particles remaining in the central Delta under drier conditions, when food is limiting to splittail **Certainty:** 4	C. Change from base conditions in particle tracking modeling results for percentage of particles after 14 days with "central" fate for the 50% exceedance hydrological condition	**Change (%)** 5 = > 75% 4 = 51% to 75% 3 = 26% to 50% 2 = 0% to 25% 1 = < 0%
		D. Change from base conditions in particle tracking modeling results for percentage of particles after 28 days with "central" fate for the 50% exceedance hydrological condition	**Change (%)** 5 = > 75% 4 = 51% to 75% 3 = 26% to 50% 2 = 0% to 25% 1 = < 0%
B17. Ability to reduce the export of nutrients and food from the Delta	The SWP/CVP export facilities and agricultural diversions entrain food and nutrients from the Delta that can affect food production and availability to all fish species but splittail. The particle tracking model approximates the likelihood for entrainment of nutrients and food of these diversions. **Certainty:** 3	A. Change from base conditions in particle tracking modeling results for percentage of particles after 14 days with either "SWP/CVP exports" or "agricultural diversions" fate for the three hydrology conditions (50%, 70%, and 90% exceedance)	Change (%) 5 = < -75% 4 = -51% to -75% 3 = -26% to -50% 2 = 0% to -25% 1 = > 0%
		B. Change from base conditions in particle tracking modeling results for percentage of particles after 28 days with either "SWP/CVP exports" or "agricultural diversions" fate for the three hydrology conditions (50%, 70%, and 90% exceedance)	Change (%) 5 = < -75% 4 = -51% to -75% 3 = -26% to -50% 2 = 0% to -25% 1 = > 0%

Table 2-2. Metrics, Tools, and Scales for Biological Criteria (continued)

Metric	Relationship	Tools	Scale
	The SWP/CVP export facilities and agricultural diversions entrain food and nutrients from the Delta that can affect food production and availability to splittail. The particle tracking model approximates the likelihood for entrainment of nutrients and food of these diversions under drier conditions, when food is limiting to splittail. **Certainty:** 4	C. Change from base conditions in particle tracking modeling results for percentage of particles after 14 days with either "SWP/CVP exports" or "agricultural diversions" fate for the 50% exceedance hydrological condition	Change (%) 5 = < -75% 4 = -51% to -75% 3 = -26% to -50% 2 = 0% to -25% 1 = > 0%
		D. Change from base conditions in particle tracking modeling results for percentage of particles after 28 days with either "SWP/CVP exports" or "agricultural diversions" fate for the 50% exceedance hydrological condition	Change (%) 5 = < -75% 4 = -51% to -75% 3 = -26% to -50% 2 = 0% to -25% 1 = > 0%
Criterion #5. Relative degree to which the Option would reduce the abundance of non-native competitors and predators to increase native species production (reproduction, growth, survival), abundance and distribution for each of the covered fish species (BDCP Conservation Objective).			
B18. Opportunity for restoration of aquatic and intertidal habitat under the Option	Improving the quality and extent of aquatic and intertidal habitat in the Delta is hypothesized to: • Create conditions that are less favorable for supporting non-native species that compete for food; and • Create conditions that are less favorable to non-native predators and that reduce the vulnerability of covered fish species to predation. **Certainty:** 2	A. Proportion of the planning area available for restoration of high-function aquatic and intertidal habitats	**Proportion of the Delta (%)** 5 = 80 to 100% 4 = 51% to 79% 3 = 31% to 50% 2 = 11% to 30% 1 = 0 to 10%

Table 2-2. Metrics, Tools, and Scales for Biological Criteria (continued)

Metric	Relationship	Tools	Scale
Criterion #6. Relative degree to which the Option improves ecosystem processes in the BDCP planning area to support aquatic and associated habitats (BDCP Conservation Objective).			
B19. Opportunities for restoration of aquatic and intertidal habitat under the Option	Improving the quality and extent of aquatic and intertidal habitat in the Delta is hypothesized to contribute to higher levels of ecosystem function **Certainty:** 2	A. Proportion of the planning area available for restoration of high-function aquatic and intertidal habitats	**Proportion of the Delta (%)** 5 = 80 to 100% 4 = 51% to 79% 3 = 31% to 50% 2 = 11% to 30% 1 = 0 to 10%
B20. Opportunity to improve hydraulic residence time	Changes in hydraulic residence time within the central Delta affect food production and turbidity, which should contribute to higher levels of ecosystem function to all fish species but splittail (splittail are addressed separately below). The particle tracking model approximates the likelihood for particles remaining in the central Delta. **Certainty:** 3	A. Change from base conditions in particle tracking modeling results for percentage of particles after 14 days with "central" fate for the three hydrology conditions (50%, 70%, and 90% exceedance)	**Change (%)** 5 = > 75% 4 = 51% to 75% 3 = 26% to 50% 2 = 0% to 25% 1 = < 0%
		B. Change from base conditions in particle tracking modeling results for percentage of particles after 28 days with "central" fate for the three hydrology conditions (50%, 70%, and 90% exceedance)	**Change (%)** 5 = > 75% 4 = 51% to 75% 3 = 26% to 50% 2 = 0% to 25% 1 = < 0%
Criterion #7. Relative degree to which the Option can be implemented within a timeframe to meet the near-term needs of each covered fish species (post BDCP authorization).			
B21. Likelihood that the Option can be implemented before populations decline sufficiently to inhibit the likelihood for their future recovery	The longer the period required for implementation of the Option the less likely the Option will meet the near-term needs of covered fish species **Certainty:** Definitions not applicable.	Estimated time post-BDCP approval required to complete planning, design, and construction phases of Option implementation infrastructure	**Estimated Time to Completion** 5 = 0-5 years 4 = 6-10 years 3 = 11-15 years 2 = 16-20 years 1 = > 20 years

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Important assumptions used to conduct the analysis for biological criteria are presented in Table 2-3.

Table 2-3. Important Assumptions used to Evaluate the Biological Criteria

Criterion #1.	**Relative degree to which the Option would reduce species mortality attributable to non-natural mortality sources, in order to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species (BDCP Conservation Objective).**
1.	When combined reverse flows in Old and Middle rivers exceeded -5000 cfs in January and February of 1993-2006, salvage of delta smelt increased dramatically (Smith et al. 2006). This assessment assumes that the risk of entrainment for larval, juvenile, sub-adult, and adult delta smelt would increase as reverse flows in Old and Middle rivers increase. Although delta smelt are vulnerable to entrainment at the export facilities at various times during the year, the analysis of hydrologic conditions was simplified by analyzing results for only January (pre-spawning delta smelt) and April (larval and early juvenile delta smelt). As part of Options 3 and 4 water diversions would be made from the Sacramento River at a location in the vicinity of Hood. The diversion would be equipped with a positive barrier fish screen, designed and operated in accordance with current criteria, has been assumed to be 95% effective in avoiding entrainment losses of all but the smallest fish eggs and larvae.
2.	Adverse effects of legal and illegal harvest on covered fish species would not be affected with implementation of any of the Options. Consequently, these stressors are described as contributing to the reduction in covered fish species production, distribution, and abundance, but are not evaluated under this criterion.
3.	The CALSIMII modeling results indicate that major CVP and SWP reservoirs could be drawn down to levels that could adversely affect the temperature of water released from reservoirs, which could have an adverse effect on salmonids and sturgeon in upstream of Delta habitats. In actuality, releases from these reservoirs would only be operated to provide for cold water releases to maintain conditions for these species as mandated under permit conditions. Although not reflected in the hydrologic modeling results for the various Options, under actual operating conditions modifications to reservoir releases and/or exports would be modified to the extent possible to avoid or minimize depletion of the cold water pool. Consequently, the evaluation assumes that the Options would have no adverse effects related to changes in upstream water temperatures on salmonids and sturgeon.
4.	Although risk for entrainment at the CVP/SWP export facilities for sturgeon would be reduced under some of the Options and not increased under any of the Options, it is not considered to be an important stressor for sturgeon and, therefore, effects of the Options on sturgeon entrainment risk are not evaluated under this criterion.
5.	Predation on sturgeon within the planning area is not considered to be an important stressor on sturgeon, although predation on larval and small juvenile sturgeon in spawning and rearing habitats upstream of the planning area is considered to be an important stressor. Because the Options would not affect sturgeon predation risk outside of the planning area, this stressor is not evaluated under the biological criteria.

Table 2-3. Important Assumptions used to Evaluate the Biological Criteria (continued)

Criterion #2.	**Relative degree to which the Option would provide water quality and flow conditions necessary to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species (BDCP Conservation Objective).**

1. For purposes of this assessment it was assumed that the transport of larval delta smelt, nutrients, phytoplankton, zooplankton, and other planktonic organisms can be modeled using the PTM. This model provides a useful tool for determining the percentage of larval fish and their potential food supplies that would move downstream towards Chipps Island and Suisun Bay.
2. Changes in the configuration of the Delta channels under Option 2 and 3 would include a series of operable barriers to isolate the Old River area and central Delta from the hydraulic influence of the SWP and CVP exports, and construction of a gravity or pumped siphon to convey water from Middle River to the export facilities while allowing the flow from the San Joaquin River to pass downstream into the central Delta. Under these conditions, residence time within the central Delta would be increased, flushing would be reduced, and nutrient loading may stimulate phytoplankton blooms. Under severe conditions large phytoplankton blooms could result in a diel depletion of dissolved oxygen concentrations within the central Delta. These diel depressions in dissolved oxygen could adversely impact habitat conditions for resident and migratory fish and other aquatic resources. For purposes of this analysis it has been assumed that if monitoring showed evidence of a potentially severe depression in dissolved oxygen, the operable gates on the barriers would be opened to increase flushing and maintain suitable dissolved oxygen levels in the central Delta to support fish. Therefore, no adverse impacts would be expected from dissolved oxygen depressions within the Delta.
3. Water quality within the Delta is influenced by point and non-point source discharges of pollutants and toxics. The watershed tributary to the Delta supports extensive agricultural, municipal, and industrial uses. The Delta also supports extensive agriculture and urban populations. Pesticides, herbicides, salts, and other chemicals enter the Delta from these sources and potentially affect covered species directly (chronic or acute exposure resulting in reduced health, growth, reproduction, survival) or indirectly through changes in food supplies. For purposes of these analyses, it has been assumed that the most efficient method for reducing exposure to toxics is through source control and enforcement that would apply equally across all Options. Operations under the various Options included in this analysis have the potential to also affect dilution flows, primarily from the Sacramento River, that would be expected to change the concentrations of toxics within the Delta.
4. Reduced turbidity is an important stressor for sturgeon that can increase predation risk for larval and small juvenile sturgeon in spawning and rearing habitats upstream of the planning area and is not an important stressor within the planning area. Consequently, this stressor is not evaluated under the biological criteria for sturgeon.
5. Concern has been expressed that allowing San Joaquin River water, which has a high selenium load, to discharge into the Delta under Options 2, 3, and 4 could increase the bioaccumulation of selenium in sturgeon and splittail. This evaluation assumes that, because source control reductions in selenium San Joaquin River selenium loads have been mandated the Regional Water Quality Board to be in place by 2012, selenium concentrations would not become elevated from base conditions under Options 2, 3, and 4 and, therefore, would not increase the risk for bioaccumulation of selenium in sturgeon and splittail beyond existing conditions. However, if source controls were to be unsuccessful such that selenium concentrations were to increase in the Delta, these Options would be expected to have an overall adverse effect on sturgeon and splittail.

Table 2-3. Important Assumptions used to Evaluate the Biological Criteria (continued)

	6. Water passing downstream from the upper Sacramento River is typically in thermal equilibrium with atmospheric conditions by the time it enters the northern Delta. As a result, seasonal water temperatures within the Delta are expected to be the same under all options evaluated.
Criterion #3.	**Relative degree to which the Option would increase habitat quality, quantity, accessibility, and diversity in order to enhance and sustain production (reproduction, growth, survival), abundance, and distribution; and to improve the resiliency of each of the covered species' populations to environmental change and variable hydrology (BDCP Conservation Objective).**
	1. The BDCP has not yet determined the extent of habitat that would need to be restored or enhanced to achieve BDCP planning objectives; therefore, the evaluation of this criterion assumes that there would be an equal amount of intertidal and subtidal aquatic habitat restored and enhanced under each of the Options. The geographic area that is considered highly suitable for restoration and enhancement of habitat, however, differs among the Options (see Figures 1-2 to 1-5). Consequently, the evaluation of this criterion focuses on identifying the varying degrees of benefits that could be afforded to each of the covered species based on the opportunities presented under each of the Options for restoring physical habitat in different locations within the Delta. 2. Though there is considerable uncertainty regarding spawning habitat requirements, this assessment assumes that spawning habitat for species such as delta smelt can be successfully restored under each of the Options. 3. Upstream dams and weirs are an impact mechanism for preventing access of salmonids and sturgeon to historical spawning habitats. Physical features that may serve as barriers to upstream movement to spawning habitats within the planning area can be addressed be addressed equally under the Options and, therefore, the effects of the Options on this stressor are not addressed further in this evaluation.
Criterion #4.	**Relative degree to which the Option would increase food quality, quantity, and accessibility (e.g., phytoplankton, zooplankton, macro-invertebrates, forage fish) to enhance production (reproduction, growth, survival) and abundance for each of the covered fish species (BDCP Conservation Objective).**
	1. The evaluation of this criterion assumes that restoration of aquatic subtidal and intertidal habitats under the Options would improve habitat conditions for the covered fish species and reduce habitat conditions for some non-native competitors such that adverse effects of non-native competitors on food availability would be reduced from base conditions (Matern et al. 2002, Lund et al. 2007b) 2. The evaluation of this criterion assumes that restoration of shallow water subtidal and intertidal habitats under the Options would improve habitat conditions for native zooplankton and thus increase food quality for species such as delta smelt, longfin smelt, and other fish species (POD Action Plan 2007) 3. The evaluation of this criterion assumes that results of the PTM modeling for the fate of particles that are removed from the Delta by the SWP/CVP export facilities and in-Delta diversions are an indicator of the potential for the Options to remove nutrients, organic material, phytoplankton, and zooplankton from the Delta aquatic system, thus affecting food production and availability.

Table 2-3. Important Assumptions used to Evaluate the Biological Criteria (continued)

Criterion #5.	**Relative degree to which the Option would reduce the abundance of non-native competitors and predators to increase native species production (reproduction, growth, survival), abundance and distribution for each of the covered fish species (BDCP Conservation Objective).**
1.	The evaluation of this criterion assumes that restoration of aquatic subtidal and intertidal habitats under the Options would improve habitat conditions for the covered fish species such that their vulnerability to predation would be reduced and reduce habitat conditions for some non-native competitors such that adverse effects of non-native predators/competitors would be reduced from base conditions (Matern et al. 2002, Lund et al. 2007b). The response of predatory species to restored habitats, however, is uncertain and therefore the degree to which habitat restoration under each of the Options would reduce vulnerability to predation is uncertain. For example, the central Delta currently supports a population of largemouth bass and increasing intertidal and subtidal habitats could contribute to a further increase in the abundance of these non-native predators, which may or may not outweigh the benefits of reducing predation vulnerability provided by habitat restoration.
2.	This evaluation assumes that restoration of habitat could be implemented such that production of nutrients and native zooplankton could be improved and thereby improve food availability and quality for delta smelt, longfin smelt, juvenile salmon, and other covered fish species. The response of these fish and the species they rely on as a food supply is dynamic and complex. There is a relatively high degree of uncertainty in predicting the effectiveness of many of the actions in reducing the adverse effects of non-native species on delta smelt and other covered fish species.
Criterion #6.	**Relative degree to which the Option improves ecosystem processes in the BDCP planning area to support aquatic and associated habitats (BDCP Conservation Objective).**
1.	The degree that an Option would contribute to improvements in ecosystem processes would depend on two primary factors: (1) opportunities to enhance or restore subtidal and intertidal aquatic habitat over a wide geographic area within the Delta, and (2) degree that changes in the conveyance facilities and their operations restore natural hydrologic flow patterns within Delta channels. For example, hydrologic flow patterns under base conditions include reverse flows in channels such as Old and Middle rivers and the lower San Joaquin River, as well as high flows and water velocities within Delta channels currently used to convey water from the Sacramento River across the Delta to the south Delta export facilities. Restoring flow patterns to reflect a net westerly flow, reductions in channel velocities and increased hydraulic residence times, and avoid reverse flows are all expected to contribute positively to improvements in ecosystem processes.
Criterion #7.	**Relative degree to which the Option can be implemented within a timeframe to meet the near-term needs of each covered fish species (post BDCP authorization).**
1.	Because the extent of habitat that would be restored among the Options has not yet been determined, the time required to implement habitat restorations and enhancements (e.g., securing lands for restoration and enhancement, planning, NEPA/CEQA and other regulatory compliance, design, construction) is assumed to be the same among the Options and, therefore, are not addressed in the evaluation of this criterion.

2.4 EVALUATION OF THE PLANNING CRITERIA, FLEXIBILITY/ DURABILITY/SUSTAINABILITY, AND OTHER RESOURCE IMPACTS CRITERIA

This section includes descriptions of the metrics, tools, and scales used to conduct the evaluation of planning, flexibility/sustainability/durability, and other resource impacts criteria. Metrics are the specific standards against which the performance of each Option is evaluated. Tools are the methods and information used to evaluate performance of each Option in relation to the metric. Scales are the quantitative or qualitative measures used to express the performance of each Option relative to the tools.

The process used to conduct the evaluation of each criterion included:

- development of metrics that address each criterion and identification of the tools and scales for measuring the performance of each Option for each metric;
- use of the tools to evaluate the likely relative performance of each Option for each metric, based on the best available information and professional judgment
- summarization of the relative performance of each Option for each criterion based on the scaled metrics.

The metrics, tools, and scales for the planning criteria, flexibility/sustainability/durability, and other resource impacts are presented in Tables 2-4, 2-5, and 2-6, respectively.

Table 2-4. Metrics, Tools, and Scales for Evaluation of Planning Criteria

Metric	Tools	Scale
Criterion #8: Relative degree to which the Option allows covered activities to be implemented in a way that meets the goals and purposes of those activities		
P1. Water supply reliability	Change in annual combined CVP/SWP exports at 50% exceedance probability from the base condition	**High** = >+5% **Moderate** = <+5% to >-5% **Low** = <-5% to >-10% **Very Low** = <-10%
P2. Operational flexibility	Number of pathways available for exporting water from the Delta and qualitative assessment of the potential for regulatory constraints to exporting water	**High** = more than one pathway and reduction in regulatory constraints **Moderate** = one pathway and substantial reduction in regulatory constraints **Low** = more than one pathway and limited or no reduction in regulatory constraints **Very Low** = one pathway and limited or no reduction in regulatory constraints
P3. Quality of water exported from the SWP/CVP facilities	Hydrologic modeling results for exported water quality expressed as mean annual EC	**High** = EC <200 umhos/cm **Moderate** = EC 200 to 300 umhos/cm **Low** = EC 300 to 400 umhos/cm **Very Low** = EC >400 umhos/cm
Criterion #9: The relative feasibility and practicability of the Option, including the ability to fund, engineer, and implement		
P4. Relative feasibility and practicability to address habitat conservation and water supply goals	Estimated number and level of technological issues and uncertainty and capability to address conservation and water supply goals simultaneously	**High** = few technological challenges, flexibility to achieve dual goals **Moderate** = some technological challenges, flexibility to achieve dual goals **Low** = some technological challenges and some constraints to achieving dual goals **Very Low** = many technological challenges and substantial constraints to achieving dual goals

Table 2-4. Metrics, Tools, and Scales for Evaluation of Planning Criteria (continued)

Metric	Tools	Scale
Criterion #10: Relative costs (including infrastructure, operations, and management) associated with implementing the Option		
P5. Ability to control construction costs for implementing the Option	Cost estimates prepared for construction of component elements and for similar projects under other programs (e.g., DRMS and CALFED)	**High** = cost likely <$1 billion **Moderate** = cost likely $1 to 3 billion **Low** = cost likely $3 to 5 billion **Very Low** = cost likely >$5 billion
P7. Ability to avoid redirected costs to service area from adverse effects of low water quality on municipal treatment, agricultural production, and human health	Rough estimate of cost savings by urban water treatment facilities due to lowered salinity of export water over the next 25 years	**High** = >$2.0 billion **Moderate** = $1.5 to 2.0 billion **Low** = $1.0 to 1.5 billion **Very Low** = >$1.0 billion
P7. Ability to avoid costs for extensive and frequent recovery and repair following catastrophic events	Qualitative assessment of frequency of catastrophic events, costs associated with repair following such events, and effects of disrupted water delivery	**High** = low costs because relatively low risk for infrastructure damage and water supply disruption from seismic and flood events **Moderate** = moderate costs because some infrastructure is at risk of damage from seismic and flood events, but a low risk of disruption of water supply **Low** = high costs because some infrastructure is at risk of damage from seismic and flood events and a high risk for disruption of water supply **Very Low** = very high costs because most or all infrastructure is at risk of damage from seismic and flood events and a high risk for disruption of water supply

Table 2-5. Metrics, Tools, and Scales for Evaluation of Feasibility/ Durability/Sustainability Criteria

Metric	Tools	Scale
Criterion #11: Relative degree to which the Option will be able to withstand the effects of climate change (e.g., sea level rise and changes in runoff), variable hydrology, seismic events, subsidence of Delta islands, and other large-scale changes to the Delta		
F1. Ability of infrastructure supporting conveyance to avoid disruption in water supply resulting from effects of seismic and flood events and sea level rise	Qualitative probability assessment of the conveyance facilities to withstand the effects of future seismic and flood events and sea level rise that would disrupt water supply export. Based on relative risk for seismic and flood events and exposure to sea level rise at Delta locations where facilities may be located	**High** = relatively low risk of disruption in water supply resulting from infrastructure damage following seismic and flood events **Moderate** = relatively moderate risk of disruption in water supply resulting from infrastructure damage following seismic and flood events **Low** = relatively high risk of disruption in water supply resulting from infrastructure damage following seismic and flood events **Very Low** = relatively very high risk of disruption in water supply resulting from infrastructure damage following seismic and flood events
F2. Ability of the Option to avoid loss of restored habitat from future seismic and flood events and sea level rise	Proportion of the planning area that is available for restoration as an indicator of the range of opportunities to locate restoration sites such that the risk of loss to seismic and flood events and sea level rise would be minimized	**High** = 51 to 100% **Moderate** = 31 to 50% **Low** = 11 to 30% **Very Low** = 0 to 10%

Table 2-5. Metrics, Tools, and Scales for Evaluation of Feasibility/ Durability/Sustainability Criteria (continued)

Metric	Tools	Scale
Criterion #12: Relative degree to which the Option could improve ecosystem processes that support the long-term needs of each of the covered species and their habitats with minimal future input of resources		
F3. Ability of the Option to support species conservation without continual input of large amounts of resources to maintain conservation benefits	Estimate of the proportion of the planning area in which Delta flow patterns can be adaptively managed to avoid the need for future remedial habitat restoration; the ability to avoid ongoing mitigation costs (e.g., fish salvage and export restrictions) associated with entrainment of covered fish species	**High** = opportunities to adaptively manage Delta flow patterns in 51 to 100% of the planning area and substantially reduce entrainment mitigation costs **Moderate** = opportunities to adaptively manage Delta flow patterns in 25 to 50% of the planning area and substantially reduce entrainment mitigation costs <u>or</u> opportunities to adaptively manage Delta flow patterns in 50 to 100% of the planning area, but little or no reduction in entrainment mitigation costs **Low** = opportunities to adaptively manage Delta flow patterns in 0 to 24% of the planning area and substantially reduce entrainment mitigation costs <u>or</u> opportunities to adaptively manage Delta flow patterns in 25 to 50% of the planning area, but little or no reduction in entrainment mitigation costs **Very Low** = opportunities to adaptively manage Delta flow patterns in 0 to 24% of the planning area, but little or no reduction in entrainment mitigation costs
Criterion #13: Relative degree to which the Option can be adapted to address the needs of covered fish species over time		
F4. Flexibility to experiment with and adjust water management to address current and future ecological uncertainties to benefit covered fish species	Coarse estimate of the proportion of the planning area in which Delta flow patterns can be adaptively managed to address current and future ecological uncertainties	**High** = 75 to 100% **Moderate** = 50 to 74% **Low** = 25 to 49% **Very Low** = 0 to 24%

Table 2-5. Metrics, Tools, and Scales for Evaluation of Feasibility/ Durability/Sustainability Criteria (continued)

Metric	Tools	Scale
F5. Spatial flexibility for restoring additional physical habitat for covered fish species	Relative proportion of the Delta with high suitability for restoration of physical habitat	**High** = 75 to 100% **Moderate** = 50 to 74% **Low** = 25 to 49% **Very Low** = 0 to 24%
Criterion #14: Relative degree of reversibility of the Option once implemented		
F6. Relative practicability to reverse the Option	Estimated loss of capital investment (based on cost estimates for Option infrastructure provided in the evaluation of Criterion #10) and qualitative assessment of the political feasibility for reversing a Option	**High** = <$0.5 billion in lost capital and likely to be politically feasible to reverse **Moderate** = $0.5 to 3 billion and likely to be politically feasible to reverse **Low** = $3 to 5 billion in lost capital and likely politically difficult to reverse **Very Low** = >$5 billion in lost capital and reversal may be politically unacceptable

Table 2-6. Metrics, Tools, and Scales for Evaluation of Impacts on Other Resource Impacts Criteria

Metric	Tools	Scale
Criterion #15: Relative degree to which the Option avoids impacts on the distribution and abundance of other native species in the BDCP planning area		
O1. Ability to avoid temporary and permanent impacts on terrestrial habitat in the planning area	Coarse estimate of the relative extent of habitat for terrestrial native species that could be removed or degraded with construction of new facilities or modification of existing facilities	**High** = 0 to 250 acres **Moderate** = 251 to 500 acres **Low** = 501 to 1,000 acres **Very Low** = >1,000 acres
O2. Ability to avoid entrainment of other native aquatic species at SWP/CVP pumps under the Option	Coarse estimate of potential change in entrainment of native aquatic organisms SWP/CVP pumps relative to current conditions (based on evaluation results of Criterion #1)	**High** = greater than 50% reduction **Moderate** = 25 to 49% reduction **Low** = 0 to 25% reduction **Very Low** = increase in entrainment from current conditions

Table 2-6. Metrics, Tools, and Scales for Evaluation of Impacts on Other Resource Impacts Criteria (continued)

Metric	Tools	Scale
Criterion #16: Relative degree to which the Option avoids impacts on the human environment		
O3. Ability to avoid disruption of transportation/traffic patterns	Broad-level comparison of the location of new or improved infrastructure under the Option to the location of existing energy and transportation infrastructure	**High** = no substantive disruption to transportation/traffic patterns **Moderate** = local county roads could be closed for a cumulative duration of no more than one year **Low** = local county roads and state highways could be closed for a cumulative duration of no more than one year **Very Low** = local county roads or state highways for a cumulative duration greater than one year
O4. Ability to avoid removal of agricultural land for construction of new facilities under the Option	Coarse estimate of the relative extent of agricultural land that could be removed or degraded with construction new facilities or modification of existing facilities	**High** = 0 to 250 acres **Moderate** = 251 to 500 acres **Low** = 501 to 1,000 acres **Very Low** = >1,000 acres
O5. Ability to avoid reductions in irrigation water quality for agriculture in the Delta	Hydrologic modeling results for Delta water quality expressed as mean annual EC at State Highway 4 Old River crossing and qualitative assessment of selenium loading in the south Delta	**High** = EC <200 umhos/cm **Moderate** = EC 200 to 300 umhos/cm **Low** = EC 300 to 400 umhos/cm **Very Low** = EC >400 umhos/cm
O6. Ability to provide high quality export water for use in service areas	Hydrologic modeling results for exported water quality expressed as mean annual EC	**High** = EC <200 umhos/cm **Moderate** = EC 200 to 300 umhos/cm **Low** = EC 300 to 400 umhos/cm **Very Low** = EC >400 umhos/cm

Table 2-6. Metrics, Tools, and Scales for Evaluation of Impacts on Other Resource Impacts Criteria (continued)

Metric	Tools	Scale
O7. Ability to avoid impacts on other CEQA/NEPA resources (e.g., cultural resources, air quality, noise, and environmental justice)	Qualitative assessment of likely relative extent of effect on each of the resource categories that could occur under the Option based on information available for similar Options previously evaluated (e.g., CALFED) and best professional judgment	**High** = no significant impacts expected **Moderate** = potential for significant impacts in up to two resource categories **Low** = potential for significant impacts in multiple resource categories, but mitigation costs expected to be relatively low **Very Low** = potential for significant impacts in multiple resource categories and mitigation costs expected to be relatively high
Criterion #17: Relative degree to which the Option avoids impacts on sensitive species and habitats in areas outside of the BDCP planning area		
O8. Ability to provide outflows beneficial to species in Suisun Marsh and Bay	Change in average annual Delta outflow during March and April relative to current conditions	**High** = >+10% **Moderate** = +9% to -5% **Low** = –4% to -10% **Very Low** = >-10%
O9. Provides potential for Sacramento, American, and Feather River water temperatures beneficial to native fish species	Shasta Reservoir storage volumes at the end of September	**<u>Storage (maf)</u>** **High** = >1.9 **Moderate** = 1.9 to 1.8 **Low** = 1.8 to 1.7 **Very Low** = <1.6
	Folsom Reservoir storage volumes at the end of September	**<u>Storage (maf)</u>** **High** = >1.5 **Moderate** = 1.5 to 1.4 **Low** = 1.4 to 1.3 **Very Low** = <1.2
	Oroville Reservoir storage volumes at the end of September	**<u>Storage (maf)</u>** **High** = >.4 **Moderate** = 0.4 to 0.35 **Low** = 0.35 to 0.3 **Very Low** = <0.25

3.0 CONSERVATION STRATEGY OPTION 1 EVALUATION

Using the methods described in Section 2, this section presents an evaluation of Option 1. Option 1 is evaluated based on how it addresses each of the evaluation criteria and how it performs relative to the other Options and base conditions. While Option 1 as described does not include new facilities, there are a number of facilities that may be necessary to allow Option 1 to achieve BDCP planning and conservation goals. Such facilities as fish screens and new or reinforced levees are mentioned in the discussion of individual criteria where applicable, but for the purposes of the comparative evaluation they are not included as part of Option 1.

3.1 BIOLOGICAL CRITERIA

Option 1 includes operational modifications to the existing SWP and CVP export facilities in the south Delta. Modifications of existing export operations have the potential to reduce aquatic species vulnerability to entrainment at the export facilities as well as to modify hydrodynamic conditions in the Delta that may affect habitat conditions for covered fish species. To accommodate through-Delta water conveyance under Option 1 the primary location of potential physical habitat restoration and enhancement measures is expected to occur in the northern and western reaches of the Delta (e.g., Cache Slough area, Yolo Bypass, and Sutter and Steamboat Sloughs), and in Suisun Marsh (Figure 1-2). Results of the assessment of biological criteria and potential benefits to the covered fish species under Option 1 are described in this section.

The evaluation of biological criteria for Option 1 is based on the hydrodynamic parameter values modeled for operational Scenarios A and B. The evaluation discussions presented below for each species and criterion, however, focus on Scenario A because:

- the type of effects of Scenario B on stressors and stressor impact mechanisms for each of the covered fish species are the same as described for Scenario A and a description of the performance of Scenario B would be repetitious;
- Scenario A would be more likely to achieve water supply objectives than Scenario B and, therefore, comparison of hydrodynamic outputs for scenario A across the Options puts each Option on an equivalent basis; and
- the magnitude of the effects of the Option on covered fish species differs between Scenarios A and B and, consequently, CALSIM II and DSM2 modeling results for Scenario B provided information useful in determining the range of flexibility within the Option to improve performance of the Option relative to achieving each of the biological criteria.

Though not described in the criteria evaluation text, the expected performance of Scenario B on each of the important stressors for each of the covered fish species relative to the performance of Scenario A is presented in summary tables at the beginning of each species evaluation section below.

3.1.1 Delta Smelt

Based on the evaluation presented below of the expected performance of Option 1 for addressing important delta smelt stressors, Option 1 would be expected to have a very low beneficial effect on delta smelt production, distribution, and abundance relative to base conditions when operated to meet water supply objectives (Scenario A). If water supply exports are reduced (Scenario B), Option 1 would be expected to provide a low beneficial effect on delta smelt production, distribution, and abundance relative to base conditions. Option 1 would be expected to provide the lowest benefits for delta smelt compared to the other Options.

Stressors that affect delta smelt are presented in Figures 2-1 and are described in Appendix C. The effect of these stressors on the delta smelt population vary among years in response to environmental conditions (e.g., seasonal hydrology) and may also interact with each other in additive or synergistic ways. The effects of these stressors include both the incremental contribution of a stressor to the population as well as the cumulative effects of multiple stressors over time. The assessment of Option 1 evaluates the degree to which Option 1 would be expected to address these stressors.

Table 3-1 summarizes the expected effects of implementing Option 1 under Scenarios A and B on important delta smelt stressors relative to base conditions.

Table 3-1. Summary of Expected Effects of Option 1 on Highly and Moderately Important Delta Smelt Stressors

Stressors[1]	Applicable Criteria	Option Effects on Important Species Stressors Relative to Base Conditions	
		Scenario A	Scenario B
Highly Important Stressors			
Reduced food availability	1,3,4,5	Very low benefit	Moderate benefit
Reduced rearing habitat	2,3	Very low benefit	Low benefit
Reduced turbidity	1,2,3,5	Very low benefit	Low benefit
Reduced spawning habitat	3	Low benefit	Low benefit
Reduced food quality	1,4,5	Low benefit	Low benefit
Moderately Important Stressors			
Predation	1,5	Low benefit	Low benefit
CVP/SWP entrainment[2]	1	No net effect	Moderate benefit
Exposure to toxics	1,2	No net effect	Very low adverse effect

Notes:

1. See Appendix C for descriptions of stressors, stressor impact mechanisms, and stressor effects.
2. It is recognized that the risk of entrainment at the SWP and CVP export facilities may be a high level stressor to delta smelt in some years and a very low level stressor to delta smelt in other years. For purposes of this analysis, the risk of delta smelt entrainment has been characterized, on average, as a moderate level stressor to the population.

3.1.1.1 Criterion #1. Relative degree to which the Option would reduce species mortality attributable to non-natural mortality sources, in order to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species.

Important stressors that cause non-natural mortality of delta smelt (see Appendix C) are:

- Reduced food availability,
- Reduced turbidity,
- Reduced food quality,
- Predation,
- Entrainment by CVP/SWP facilities, and
- Exposure to toxics.

Based on the following evaluation of Option 1 effects on applicable delta smelt stressors, Option 1 is expected to provide very low benefits relative to base conditions by reducing the effects of non-natural sources of mortality on delta smelt.

Reduced Food Availability and Quality

Reduced food availability and quality can result in non-natural levels of mortality. The effects of Option 1 on delta smelt food availability and quality are evaluated under Criterion #4 below. As described in the Criterion #4 evaluation, Option 1 would be expected to provide a very low beneficial effect on food availability and a low beneficial effect on food quality for the delta smelt relative to base conditions.

Reduced Turbidity

Reduced turbidity increases the vulnerability of delta smelt to predation. The effects of Option 1 on turbidity are evaluated under Criterion #2 below. As described in the Criterion #2 evaluation, Option 1 would be expected to provide no to very low beneficial increases in turbidity conditions relative to base conditions.

Predation

Predation by non-native species (e.g., striped bass, largemouth bass) on delta smelt can result from at least two impact mechanisms: 1) the establishment of non-native submerged aquatic plants and introduction of man-made structures that provide habitat for non-native predators and 2) reduced turbidity that increases the vulnerability of delta smelt to predation.

As described below under Criterion #2, Option 1 would be expected to have no effect on turbidity conditions relative to base conditions. Although there is a high degree of uncertainty, restoration of high quality aquatic habitat under Option 1 could reduce the vulnerability of delta smelt to predation. Under Option 1, opportunity areas for physical habitat restoration would encompass Suisun Bay and Marsh and approximately 28% of the Delta (in the northern and western portions) to provide high quality aquatic habitat under this Option (Figure 1-2), which encompasses a large segment of the delta smelts range. Benefits associated with this habitat restoration relative to predation vulnerability, however, would be expected to be tempered because turbidity and hydrological conditions (e.g., flow rates at multiple Delta locations; see Appendix D) would not change substantially from base conditions, which currently benefit non-native predators. Consequently, the potential to reduce the impact of non-native predators on delta smelt is expected to very low under Option 1.

Entrainment by CVP/SWP facilities

Operation of the SWP and CVP export facilities results in the entrainment and salvage of delta smelt. Delta smelt entrained into the export facilities are expected to experience increased risk of predation mortality, entrainment through the louvers, and direct loss from the Delta, and increased levels of stress and mortality during collection, handling, transport, and release in fish salvage operations.

The vulnerability of delta smelt to export-related losses varies in response to a number of factors including the geographic distribution of smelt within the estuary, hydrodynamic conditions occurring within the central and southern regions of the Delta (e.g., Old and Middle rivers), and the export rate. Measurements used to assess entrainment risk by the SWP/CVP pumps included (1) hydrodynamic model results of the magnitude of reverse flows in Middle and Old Rivers under each Option and (2) PTM results of CVP/SWP export fate.

Results of these measurements indicate that the hydrodynamics of the Delta and the risk for entrainment of delta smelt would both remain similar to base conditions (see Appendix D and H).

Exposure to Toxics

Exposure of delta smelt to toxic substances can result in mortality of delta smelt. The effects of Option 1 on exposure to toxics are evaluated under Criterion #2 below. As described in the Criterion #2 evaluation, Option 1 would be expected to have a similar risk for exposure to toxics relative to base conditions.

3.1.1.2 Criterion #2. Relative degree to which the Option would provide water quality and flow conditions necessary to enhance production (reproduction, growth, survival) , abundance, and distribution for each of the covered fish species.

Important stressors that affect water quality and flow conditions for delta smelt (see Appendix C) are:

- Reduced rearing habitat,
- Reduced turbidity, and
- Exposure to toxics.

Based on the following evaluation of Option 1 effects on applicable delta smelt stressors, Option 1 is expected to provide very low benefits for water quality and flow conditions that support delta smelt relative to base conditions.

Reduced Rearing Habitat

Reduced rearing habitat for delta smelt can result from at least three impact mechanisms: compression of the estuarine salinity field (X_2), reduced net downstream flows that impede access to rearing habitat, and reduced turbidity that can reduce foraging efficiency of juvenile smelt (see Figure 2-1 and Appendix C). Measurements used to assess effects of Option 1 on rearing habitat included (1) hydrologic model results for the position of X_2 in April, (2) PTM modeling results for particle fate past Chipps Island and particle residence time in the central Delta, (3) Sacramento River flows at Rio Vista, and (4) Delta outflow during March and April, when larval delta smelt are transported downstream.

The location of X_2 affects the location of the low salinity zone, where delta smelt juveniles and adults rear (Bennett 2005). Higher outflows tend to locate X_2 farther downstream, which provides more and better rearing habitat (defined as open water) for delta smelt and makes them less vulnerable to reverse flows in Old and Middle Rivers and, therefore, entrainment. Modeling results for Option 1 show that the change in location of X_2 in April relative to base conditions is 0.5 km upstream (see Appendix H).

Net downstream flows are important for transporting planktonic larval delta smelt towards suitable rearing habitat in the western Delta and Suisun Bay. PTM modeling results indicate that the percentage of particles that moved past Chipps or into Suisun Bay would generally be equal to or marginally greater under Option 1 relative to base conditions, indicating Option 1 would be unlikely to affect downstream movement of larval delta smelt (see Appendices D and H).

Based on PTM modeling results, Option 1 would be expected to maintain turbidity conditions similar to base conditions (see discussion below) and thus would not be expected to affect foraging conditions in rearing habitats.

Modeling results for Sacramento River flows and total Delta outflow indicate that in all water year types larval fish from the Cache Slough/Yolo Bypass area, which is thought to be high quality delta smelt spawning habitat, would be transported downstream to the low salinity zone similar to base conditions. Once these fish are in the Delta, however, there is a moderate beneficial effect on larval transport because flow rates (i.e., Delta Outflow) greatly increase and fish are transported towards the low salinity zone much more effectively than under base conditions (see Appendices D and H).

Reduced Turbidity

Reduced turbidity can result from at least four impact mechanisms: reduction in hydraulic residence time, filtering of organic material from the water column by *Corbula*, filtering of suspended sediments from the water column by non-native aquatic plants (e.g., *Egeria*), and reduction in upstream inputs of sediments from a range of causes. Reduced turbidity reduces foraging efficiency and increases vulnerability of delta smelt to predation (see Appendix C).

Measurements used to assess performance of Option 1 for reducing turbidity included (1) hydrologic model results for peak Delta inflows from January through March, (2) PTM modeling results for hydraulic residence time for the central Delta, and (3) the proportion of the Delta expected to be suitable for restoration of aquatic and intertidal habitat.

There is increased evidence that delta smelt have specific turbidity requirements that can influence their survival and foraging efficiency (Basker-Bridges et al. 2004, POD Action Plan 2007, Feyrer et al. 2007). Results of laboratory studies indicate that, in low turbidity waters, delta smelt move to the edge of aquaria, presumably to reduce vulnerability to predation and reduce feeding. Fullerton (unpubl. data) found that movement patterns of sub-adults suggest that they prefer waters with increased levels of turbidity. One of the primary factors affecting turbidity during winter in the Delta is storm water runoff within the upstream watershed that is carried into the Delta by Delta inflows. Model results indicates that peak Delta inflows during January through March under Option 1 were similar to base conditions on average (see Appendices D and H), indicating that peak flows will not be expected to change turbidity levels under Option 1 relative to base conditions.

Increasing hydraulic residence time increases turbidity by allowing primary producers (phytoplankton) and primary consumers (zooplankton) to increase in the Delta (Feyrer et al. 2007). Generally, residence time under Option 1 would be expected to be highly variable, but on average similar to base conditions.

Non-native clams that filter phytoplankton and zooplankton from the water column (i.e., *Corbula*) and extensive submerged beds of non-native aquatic vegetation (e.g., *Egeria*) can reduce water velocity and increase settling rates of sediments thereby reducing turbidity (Kimmerer and Orsi 1996, Jassby et al. 2002, Kimmerer 2002; Nestor et al. 2003, Hobbs et al. 2006). Under Option 1, habitat could be restored at sites in Suisun Bay and Marsh and approximately 28% of the planning area to provide high quality aquatic habitat under this Option (Figure 1-2). These potential restoration areas under Option 1 encompass a smaller proportion of the delta smelt's range than the proportion of the Delta within which habitat could be restored under the other Options. Therefore, this Option has the lowest potential among the four Options to increase turbidity by reducing the potential effects of non-native species and would be expected to provide a very low beneficial improvement in turbidity.

Exposure to Toxics

Exposure of delta smelt to toxic substances can result from point and non-point sources associated with agricultural, urban, and industrial land uses. There was a reported toxic event in the winter of 2007 that coincided temporally and spatially with delta smelt spawning in the Cache Slough region of the Delta and was also detected further downstream in the lower Sacramento River near Sherman Island (DWR unpubl. data). Additional indications of toxicity have been detected within Suisun Bay during the summer 2007 (S. Ford pers comm.). Although no specific causal link has been established, these toxic events coincided with low abundance indices of larval and juvenile delta smelt observed in the 2007 CDFG 20 mm townet and summer townet surveys. There is little evidence that toxics impact delta smelt directly and, in fact, there is a growing body of evidence that toxics have little direct effect on delta smelt (Bennett, unpubl. data, Werner 2007, Herbold pers. comm., POD Action Plan 2007). There is inconsistent evidence that the invertebrate prey of delta smelt is affected by toxics (Weston et al.

2004, POD Action Plan 2007). Although there is little research to date on the direct or indirect effects of toxics on delta smelt, this stressor is identified as a concern for delta smelt because of large and rapid potential impact on the species should one or more common toxics prove an important stressor.

Differences in dilution flow rates from the Sacramento River and other Delta tributaries relative to base conditions among the Options are one measure of the potential concentrations of toxics and their potential to effect delta smelt. Measurements used to assess the dilution potential of Option 1 included (1) Sacramento River flows at Rio Vista and (2) Delta outflow during March and April, when larval delta smelt are transported downstream. Modeling results indicate that the toxics dilution potential of Option 1 would be similar to base conditions (see Appendices D and H).

3.1.1.3 Criterion #3. Relative degree to which the Option would increase habitat quality, quantity, accessibility, and diversity in order to enhance and sustain production (reproduction, growth, survival), abundance, and distribution; and to improve the resiliency of each of the covered species' populations to environmental change and variable hydrology.

Important stressors that affect delta smelt habitat quality, quantity, accessibility, and diversity (see Appendix C) are:

- Reduced food availability,
- Reduced rearing habitat,
- Reduced turbidity, and
- Reduced spawning habitat.

Within the planning area, delta smelt habitat conditions are governed by hydrodynamic conditions and the extent and quality of habitat within the planning area. Under Option 1, these conditions relative to base conditions would be affected by the conveyance configuration of Option 1 and restoration of physical habitat that could be sited within Suisun Bay and Marsh and within 28% of the planning area in the north and west Delta.

Based on the following evaluation of Option 1 effects on applicable delta smelt stressors, Option 1 is expected to provide low benefits relative to habitat conditions for the delta smelt.

Reduced Food Availability

Habitat conditions can affect the availability and quality of delta smelt food. The effects of Option 1 on delta smelt food availability are evaluated under Criterion #4 below. As described in the Criterion #4 evaluation, Option 1 would be expected to provide a very low beneficial effect on food supply for the delta smelt relative to base conditions.

Reduced Rearing Habitat

Under Option 1, in addition to the flow benefits for rearing habitat conditions described above under Criterion #2, habitat could be restored within Suisun Bay and Marsh and approximately 28% of the Delta to provide high quality shallow aquatic subtidal and intertidal habitat (Figure 1-2), which encompasses a smaller proportion of the delta smelt rearing range than restoration that could be implemented under the other Options. Consequently, relative to base conditions and the other Options, Option 1 would be expected to provide a very low benefit for delta smelt rearing habitat.

Reduced Turbidity

Habitat conditions that support non-native filter feeders and aquatic plants can reduce turbidity. The effects on turbidity associated with these impact mechanisms are evaluated under Criterion #2 above. As described in the Criterion #2 evaluation, restoring habitat under Option 1 would be expected to have very low beneficial effects on turbidity conditions for delta smelt relative to base conditions.

Reduced Spawning Habitat

Spawning habitat for delta smelt is upstream of the low salinity zone. Although spawning has never been observed in nature, it is generally agreed that the location of young delta smelt larvae is not far from where they hatched. This habitat is thought to be in shallow, low salinity upstream areas with sand or gravel substrate available on which to deposit their sticky egg sacs, such as that habitat found on floodplains (Moyle et al. 2004).

The primary impact mechanism believed to affect spawning habitat is the reclamation and channelization of historical intertidal wetlands that has presumably reduced the amount of habitat available for spawning by delta smelt. Under Option 1, habitat could be restored within Suisun Bay and Marsh and approximately 28% of the Delta to provide high quality aquatic habitat under this Option (Figure 1-2). Habitat restoration opportunities under Option 1 encompass a smaller proportion of the likely spawning range of delta smelt than restoration that could be implemented under the other Options. Consequently, relative to the other Options and to the extent that functioning delta smelt spawning habitat can be successfully restored based on current understanding of its habitat requirements, restoration under Option 1 would be expected to provide a low level of benefit (see Appendix H).

3.1.1.4 Criterion# 4. Relative degree to which the Option would increase food quality, quantity, and accessibility (e.g., phytoplankton, zooplankton, macro-invertebrates, forage fish) to enhance production (reproduction, growth, survival) and abundance for each of the covered fish species.

Important stressors that affect delta smelt food quality, quantity, and accessibility (see Appendix C) are:

- reduced food availability, and
- reduced food quality.

Based on the following evaluation of Option 1 effects on applicable delta smelt stressors, Option 1 is expected to provide very low benefits relative to food quality, quantity, and accessibility for the delta smelt.

Reduced Food Availability

Reduced food availability for delta smelt can result from at least five impact mechanisms: competition with non-native species, reduced frequency of floodplain inundation, nutrient and food exports from CVP/SWP pumps and in-Delta agricultural diversions, hydraulic residence time, and effects of toxics (e.g., pesticides/herbicides) on zooplankton abundance (see Figure 2-1 and Appendix C). Measurements used to assess effects on food availability included (1) PTM modeling results for CVP/SWP for particle fate in the central Delta, (2) change in peak total Delta inflows from January through March, and (3) the proportion of the Delta expected to be suitable for restoration of aquatic and intertidal habitat.

Restoration of tidal and intertidal habitats could create conditions that disfavor non-native species that indirectly or directly affect food abundance (e.g., *Corbula* and threadfin shad), thereby improving food availability for delta smelt. Under Option 1, habitat could be restored within Suisun Bay and Marsh and approximately 28% of the Delta to provide high quality aquatic habitat (Figure 1-2). This is a smaller proportion of the delta smelt range than restoration that could be implemented under the other Options. Delta smelt abundance in recent years, however, has been greatest in the lower Sacramento River near Decker Island, the Cache Slough region, and within Suisun Bay and Marsh (DFG 2007), all of which are within the potential habitat restoration area of Option 1. Because the overall hydrologic conditions (e.g., flow rates at multiple locations; see Appendix D) do not differ substantially from base conditions in most water years (conditions which are believed to favor competitor species), the effect of restoring habitat on reducing competition may be limited. Consequently, the potential benefits for reducing competition to increase food availability for delta smelt under Option 1 are considered low.

Floodplains are highly productive and are thought to be a source of high amounts of allochthonous nutrient and organic carbon production from the terrestrial community that inhabits the floodplain and upland areas during the remainder of the year (Sommer et al. 2001, Harrell and Sommer 2003). One of the major floodplains in the Delta, the Yolo Bypass, floods during approximately 60% of years (Harrell and Sommer 2003). The magnitude of peak flows from January through March, the period during which inflows have been greatest into the Delta historically, gives an indication of the potential for floodplain inundation relative to base conditions. Modeled peak Delta inflows under Option 1 during January through March are nearly identical to base conditions (see Appendix H). Therefore, relative to base conditions, Option 1 would not be expected to provide increased organic material and nutrients from floodplains and transported downstream into the Delta.

The SWP and CVP pumps and the over 2,200 in-Delta agricultural diversions (Herren and Kawasaki 2001) export zooplankton, nutrients, and organic material that would otherwise support the base of the food web in the Delta, thus affecting food availability for the delta smelt (Jassby et al. 2002, POD Action Plan 2007). Based on PTM modeling results for exported particles, the removal of food organisms, nutrients, and organics by diversions is lower relative to base conditions (see Appendices D and H). However, the benefit to delta smelt is expected to be very low because the magnitude of the reduction is relatively low.

The co-occurrence of suitable food supplies (zooplankton) and various life stages of delta smelt (e.g., larval and juvenile life stages) has been identified as an important factor affecting delta smelt survival and abundance (Feyrer et al. 2007, Miller 2007). Reduced hydrologic residence time is thought to reduce productivity in the Delta because nutrients and organics are transported downstream and out of the Delta before stimulating phytoplankton or zooplankton production (Jassby et al. 2002, Kimmerer 2002a,b, POD Action Plan 2007). Increased hydrologic residence time allows more time for bacterial activity to use nutrients and organic carbon and for the production of phytoplankton and zooplankton that provide food for delta smelt and other aquatic species. Based on PTM modeling results, the hydrologic residence time within the Delta varies with both the insertion location and the amount of water entering the system (i.e., exceedance percentage). Overall, residence time within the central Delta under Option 1 would be highly variable but on average would be similar to base conditions (see Appendices D and H). Consequently, the effect of Option 1 on food production is expected to be similar to base conditions. In addition to hydraulic residence time within the Central Delta, results of the PTM showed a similar pattern of particle movement downstream into Suisun Bay where phytoplankton and zooplankton production co-occurs with delta smelt.

It has been hypothesized that exposure of phytoplankton and zooplankton to toxics (e.g., pesticides, herbicides) that enter the Delta from point and non-point sources may also contribute to ongoing low abundance of delta smelt zooplankton prey species (Weston et al. 2004, Luoma 2007). Though this relationship is uncertain, Option 1 would be unlikely to reduce the exposure of primary and secondary producers to these toxics because dilution flows would remain similar to base conditions.

Reduced Food Quality

Low food quality for delta smelt can result from the displacement of native zooplankton species by less nutritious non-native species (see Figure 2-1 and Appendix C). The measurement used to assess the likely effects of Option 1 on food quality was the proportion of the Delta expected to be suitable for restoration of aquatic and intertidal habitat.

The zooplankton community inhabiting the Delta has been affected by a number of factors including the introduction of a number on non-native zooplankton species. These changes in the zooplankton species composition have affected the quality of food resources available to delta smelt since many of the introduced zooplankton species do not appear to be as suitable a food resource as the native species (POD Action Plan 2007). For example, *Limnoithona tetraspina* is a non-native copepod that is smaller and faster than native forage species of zooplankton and is protected by spines (Orsi and Ohtsuka 1999). In the presence of *Limnoithona tetraspina* foraging efficiency of delta smelt has decreased (POD Action Plan 2007; B. Herbold pers comm.).

Restoration of shallow water tidal and subtidal habitats under Option 1 could improve nutrient production and production of suitable zooplankton species (e.g., native calanoid copepods) as forage for delta smelt. Under Option 1, habitat could be restored within Suisun Bay and Marsh and approximately 28% of the Delta to provide high quality aquatic habitat under this Option

(Figure 1-2), which encompasses a smaller proportion of the delta smelt's range than restoration that could be implemented under the other Options. Consequently, relative to the other Options, Option 1 would be expected to provide a low level of benefit for food quality (see Appendix H).

3.1.1.5 Criterion #5. Relative degree to which the Option would reduce the abundance of non-native competitors and predators to increase native species production (reproduction, growth, survival), abundance and distribution for each of the covered fish species.

Non-native competitors and predators are an impact mechanism for the following important delta smelt stressors (see Appendix C):

- Reduced food availability,
- Reduced turbidity,
- Reduced food quality, and
- Predation.

Option 1 is expected to provide low benefits for the delta smelt relative to the abundance of non-native competitors and predators. For reasons described under Criterion #4, Option 1 would be expected to provide a very low beneficial effect by reducing the impacts of populations of non-native food competitors and predators relative to base conditions. For reasons described under Criteria #1 and #2, Option 1 could provide a low beneficial effect by reducing the risk of delta smelt predation relative to base conditions.

3.1.1.6 Criterion #6. Relative degree to which the Option improves ecosystem processes in the BDCP planning area to support aquatic and associated habitats.

Measurements used to assess the potential for Option 1 to improve ecosystem processes included (1) PTM modeling results for hydraulic residence time in the central Delta and (2) the proportion of the Delta expected to be suitable for restoration of aquatic and intertidal habitat. Based on the proportion of the planning area suitable for restoration under Option 1 relative to the other Options and modeling results for hydraulic residence time (see Appendix H), Option 1 would be expected to provide a very low beneficial improvement in ecosystem function relative to base conditions because habitat restoration under Option 1 would improve ecosystem processes, hydraulic residence time would be similar to base conditions. Under Option 1, Delta channels would continue to serve as the water conveyance facilities for freshwater supplies moving from the Sacramento River across the Delta to the export facilities in the south Delta. Movement of large volumes of water through these channels would adversely affect hydraulic conditions within the Delta (e.g., reverse flows), affect salinity levels and distribution, require riprapped levees to reduce erosion and levee scour, and limit the opportunities for habitat enhancement. The hydraulic conditions within the Delta under these operations would continue to reduce hydraulic residence times and export nutrients, organic carbon, phytoplankton, and zooplankton from the Delta resulting in adverse effects on aquatic food production and availability.

3.1.1.7 Criterion #7. Relative degree to which the Option can be implemented within a timeframe to meet the near-term needs of each covered fish species (post BDCP authorization).

Habitat restoration under Option 1 can be initiated immediately following authorization of the BDCP and thus could be implemented in a manner that would meet the near term needs of delta smelt. The expected period for initiating implementation of Option 1 is the same as the other Options.

3.1.2 Longfin Smelt

Based on the evaluation presented below of the expected performance of Option 1 for addressing important longfin smelt stressors, Option 1 would be expected to have a very low beneficial effect on longfin smelt production, distribution, and abundance relative to base conditions when operated to meet water supply objectives (Scenario A). If water supply exports are reduced (Scenario B), Option 1 would be expected to provide a low beneficial effect on longfin smelt production, distribution, and abundance relative to base conditions. Option 1 would be expected to provide the lowest benefits for longfin smelt compared to the other Options.

Stressors that affect longfin smelt are presented in Figures 2-2 and are described in Appendix C. The effect of these stressors on the longfin smelt population vary among years in response to environmental conditions (e.g., seasonal hydrology) and may also interact with each other in additive or synergistic ways. The effects of these stressors include both the incremental contribution of a stressor to the population as well as the cumulative effects of multiple stressors over time. The assessment of Option 1 evaluates the degree to which Option 1 would be expected to address these stressors.

Table 3-2 summarizes the expected effects of implementing Option 1 under Scenarios A and B on important longfin smelt stressors relative to base conditions.

Table 3-2. Summary of Expected Effects of Option 1 on Highly and Moderately Important Longfin Smelt Stressors

Stressors[1]	Applicable Criteria	Option Effects on Important Species Stressors Relative to Base Conditions	
		Scenario A	Scenario A
Highly Important Stressors			
Reduced access to spawning habitat	2	No net effect	Moderate benefit
Reduced access to rearing habitat	2	No net effect	Moderate benefit
Reduced food	1,4,5	Very low benefit	Moderate benefit
Predation	1,5	Low benefit	Low benefit
Reduced turbidity	1,2, 3,5	Very low benefit	Low benefit
Reduced spawning habitat	3	Very low benefit	Very low benefit
Reduced food quality	1,4,5	Very low benefit	Very low benefit

Table 3-2. Summary of Expected Effects of Option 1 on Highly and Moderately Important Longfin Smelt Stressors (continued)

Stressors[1]	Applicable Criteria	Option Effects on Important Species Stressors Relative to Base Conditions	
		Scenario A	Scenario A
Moderately Important Stressors			
CVP/SWP entrainment[2]	1	No net effect	Moderate benefit
Reduced rearing habitat	2	No net effect	Moderate benefit
Exposure to toxics	2	No net effect	Low adverse effect

Notes:

1. See Appendix C for descriptions of stressors, stressor impact mechanisms, and stressor effects.
2. It is recognized that the risk of entrainment at the SWP and CVP export facilities may be a high level stressor to longfin smelt in some years and a very low level stressor to longfin smelt in other years. For purposes of this analysis, the risk of delta smelt entrainment has been characterized, on average, as a moderate level stressor to the population.

3.1.2.1 Criterion #1. Relative degree to which the Option would reduce species mortality attributable to non-natural mortality sources, in order to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species.

Important stressors that cause non-natural mortality of longfin smelt (see Appendix C) are:

- Reduced food availability,
- Predation,
- Entrainment by CVP/SWP facilities,
- Reduced turbidity,
- Reduced food quality,
- Predation, and
- Exposure to toxics.

Based on the following evaluation of Option 1 effects on applicable longfin smelt stressors, Option 1 is expected to provide very low benefits relative to base conditions by reducing the effects of non-natural sources of mortality on longfin smelt.

Reduced Food Availability and Quality

Reduced food availability and quality can result in non-natural levels of mortality. The effects of Option 1 on longfin smelt food availability and quality are evaluated under Criterion #4 below.

As described in the Criterion #4 evaluation, Option 1 would be expected to provide a very low beneficial effect on food availability and quality for longfin smelt relative to base conditions.

Reduced Turbidity

Reduced turbidity may increase the vulnerability of longfin smelt to predation and reduce foraging efficiency. The effects of Option 1 on turbidity are evaluated under Criterion #2 below. As described in the Criterion #2 evaluation, Option 1 would be expected to provide very low beneficial increases in turbidity conditions relative to base conditions.

Predation

The primary impact mechanism for predation by non-native species (e.g., sunfish, largemouth bass) on longfin smelt are non-native submerged aquatic plants throughout the planning area that provide habitat for non-native predators and reduced turbidity which can increase the vulnerability of longfin smelt to predation. Although there is a high degree of uncertainty, restoration of high quality aquatic habitat under Option 1 could reduce the vulnerability of longfin smelt to predation. Under Option 1, habitat could be restored within Suisun Bay and Marsh and approximately 28% of the Delta to provide high quality aquatic habitat under this option (Figure 1-2). Benefits associated with this habitat restoration relative to predation vulnerability, however, would be expected to be tempered because hydrodynamic conditions (e.g., flow rates at multiple Delta locations; see Appendix D) would not change substantially from base conditions, which currently benefit non-native predators. Consequently, the potential to reduce the impact of non-native predators on longfin smelt is expected to low under Option 1.

Entrainment by CVP/SWP facilities

Operation of the SWP and CVP export facilities results in the entrainment and salvage of longfin smelt. Longfin smelt entrained into the export facilities are expected to experience increased risk of predation mortality, entrainment through the louvers, direct loss from the Delta, and increased levels of stress and mortality during collection, handling, transport, and release from the fish salvage operations.

The vulnerability of longfin smelt to export-related losses varies in response to a number of factors including the geographic distribution of smelt within the estuary, hydrodynamic conditions occurring within the central and southern regions of the Delta (e.g., the magnitude of reverse flows within Old and Middle rivers), and the export rate. Measurements used to assess entrainment risk by the SWP/CVP pumps included (1) hydrodynamic model results of the magnitude of reverse flows in Middle and Old rivers under each Option, (2) PTM results of CVP/SWP export fate, and (3) index of vulnerability for longfin smelt to salvage at the export facilities.

Results of these measurements indicate that the hydrodynamics of the Delta would remain similar to base conditions and that the risk for entrainment of longfin smelt would remain similar to base conditions (see Appendix D and H).

Exposure to Toxics

Exposure of longfin smelt to toxic substances can result in mortality of longfin smelt. The effects of Option 1 on exposure to toxics are evaluated under Criterion #2 below. As described in the Criterion #2 evaluation, Option 1 would be expected to have a similar risk for exposure to toxics relative to base conditions.

3.1.2.2 Criterion #2. Relative degree to which the Option would provide water quality and flow conditions necessary to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species.

Important stressors that affect water quality and flow conditions for longfin smelt (see Appendix C) are:

- Reduced access to spawning habitat
- Reduced access to rearing habitat,
- Reduced turbidity, and
- Exposure to toxics.

Based on the following evaluation of Option 1 effects on applicable longfin smelt stressors, Option 1 is expected to provide very low benefits for water quality and flow conditions that support longfin smelt relative to base conditions.

Reduced Access to Spawning Habitat

Higher Delta outflows tend to locate X_2 further downstream within Suisun Bay, which is thought to increase the quantity and quality of estuarine rearing habitat (defined as open water) for longfin smelt and makes them less vulnerable to reverse flows on Old and Middle rivers and, therefore, entrainment. Conversely, lower Delta outflows tend to push X_2 farther upstream. Results of analyses of CDFG fishery survey data have shown a relationship between X_2 location and indices of longfin smelt abundance (Swanson et. Al. 2007). Modeling results for Option 1 show that the change in location of X_2 in April relative to base conditions is 0.5 km upstream (see Appendices D and H). The potential changes in access to spawning habitat for adult longfin smelt, based on winter and spring flows are expected to be similar under Option 1 as base conditions.

Reduced Access to Rearing Habitat

Reduced access to rearing habitat for longfin smelt can result from low net downstream flows that impede the transport of longfin smelt to rearing habitat (see Figures 2-2 and Appendix C). Measurements used to assess effects of Option 1 on access to rearing habitat included (1) PTM modeling results for particle fate past Chipps Island and particle residence time in the central Delta, (2) Sacramento River flows at Rio Vista and (3) Delta outflow during March and April, when larval longfin smelt are transported downstream.

Net downstream flows are important for transporting planktonic larval longfin smelt downstream towards suitable rearing habitat in the western Delta and Suisun Bay. PTM modeling results indicate that the percentage of particles that moved past Chipps Island or into Suisun Bay would generally be equal to or marginally greater under Option 1 relative to base conditions, indicating Option 1 would be unlikely to affect downstream movement of larval longfin smelt (see Appendices D and H).

Modeling results for Sacramento River flows and total Delta outflow indicate that in all water year types larval fish from the Cache Slough/Yolo Bypass area, which is thought to be high quality longfin smelt spawning habitat, will be transported downstream to the low salinity zone similarly to base conditions. Once these fish are in the Delta, flow rates (i.e., Delta Outflow and the influence of tidal flows) greatly increase and fish are transported towards the low salinity zone rearing habitats much more effectively than under base conditions (see Appendices D and H) which is expected to benefit larval and early juvenile longfin smelt by improved rearing conditions.

Reduced Turbidity

Reduced turbidity can result from at least four impact mechanisms: reduction in hydraulic residence time, filtering of organic material from the water column by *Corbula* and other benthic and pelagic species, filtering of suspended sediments from the water column by non-native aquatic plants (e.g., *Egeria*), and reduction in upstream inputs of sediments resulting from upstream water management and reservoir storage that reduce sediment flow and attenuate peak flows into the Delta (Kimmerer and Orsi 1996, Jassby et al. 2002, Nestor et al. 2003, Kimmerer 2000a,b, 2004, Feyrer et al. 2007, POD Action Plan 2007). Levee construction and river channelization have also affected sediment scour and erosion within the watershed. Measurements used to assess performance of Option 1 for reducing turbidity included (1) hydrologic model results of peak Delta inflows from January through March, (2) PTM modeling results for hydraulic residence time for the central Delta, and (3) the proportion of the Delta expected to be potentially suitable for restoration of aquatic subtidal and intertidal habitat.

There is growing evidence that longfin smelt have specific turbidity requirements that may influence their ability to forage and avoid predation (Basker-Bridges et al. 2004, S. Foote unpubl. data, R. Baxter pers. comm.). Turbidity has decreased over the past several decades in the Delta as a result of a variety of factors. Increasing currently low turbidity levels in the Delta may reduce the vulnerability of longfin smelt to predation and increase longfin smelt foraging efficiency.

Model results indicate that peak Delta inflows during January through March under Option 1 were similar to base conditions on average (see Appendices D and H), indicating that peak flows will not be expected to change turbidity levels under Option 1 relative to base conditions.

Increasing hydraulic residence time increases turbidity by allowing primary producers (phytoplankton) and primary consumers (zooplankton) to bloom in the Delta when conditions are favorable (Feyrer et al. 2007). Generally, residence time under Option 1 would be expected to be highly variable, but on average similar to base conditions.

Non-native clams that filter phytoplankton and zooplankton from the water column (i.e., *Corbula*) and extensive submerged beds of non-native aquatic vegetation (e.g., *Egeria*, water hyacinth) can reduce water velocity and increase settling rates of sediments thereby reducing turbidity (Kimmerer and Orsi 1996, Jassby et al. 2002, Kimmerer 2002; Nestor et al. 2003, Hobbs et al. 2006). Restoration of aquatic subtidal and intertidal habitats could occur over approximately 28% of Delta (Figure 1-2), which provides the smallest proportion of the Delta within which habitat can be restored among the Options. Therefore, this Option has the lowest potential among the four Options to increase turbidity by reducing the potential effects of non-native species and would be expected to provide a very low beneficial improvement in turbidity conditions for longfin smelt.

Exposure to Toxics

Exposure of longfin smelt to toxic substances can result from point and non-point sources associated with agricultural, urban, and industrial land uses. Longfin smelt would potentially be exposed to these toxic materials during their period of residence within the Delta. As with delta smelt (see Section 3.1.1), there is little evidence that toxics impact longfin smelt directly (S. Footte unpubl. data, R. Baxter pers comm., POD Action Plan 2007). Further, there is inconsistent evidence that the invertebrate prey of longfin smelt is affected by toxics. However, this stressor is still identified as a concern for longfin smelt. Chronic exposure of longfin smelt to toxics may be more of a concern than for delta smelt because they are slightly longer-lived (2-3 years) and can, therefore, potentially bioaccumulate toxics to higher levels.

Dilution flows from the Sacramento River and other Delta tributaries are one way of reducing concentrations of toxics and their effect on longfin smelt. Measurements used to assess the dilution potential of Option 1 included (1) Sacramento River flows at Rio Vista and (2) Delta outflow during March and April, when larval longfin smelt are transported downstream. Modeling results indicate that the toxics dilution potential of Option 1 would be similar to base conditions (see Appendices D and H).

Reduced Rearing Habitat

Reduced rearing habitat for longfin smelt can result from compression of the estuarine salinity field (X_2), which is measured using the hydrodynamic modeling results for the position of X_2 in April.

Rearing habitat of longfin smelt is thought to be located in and downstream of the low salinity zone in open waters (Baxter 1999, Moyle 2002). When the low salinity zone is located upstream during periods of low Delta outflow, particularly upstream of the confluence between the Sacramento and San Joaquin rivers, the quantity and quality of rearing habitat may be reduced. Modeling results indicate that in April X_2 would be located 0.5 km farther upstream relative to base conditions. As described below, Option 2 would be expected to provide no improvement in turbidity conditions relative to base conditions and therefore would not be expected to improve the foraging efficiency of longfin smelt or reduce their vulnerability to predation. Consequently, overall Option 1 would be expected to have no benefits to rearing habitat conditions relative to base conditions.

3.1.2.3 Criterion# 3. Relative degree to which the Option would increase habitat quality, quantity, accessibility, and diversity in order to enhance and sustain production (reproduction, growth, survival), abundance, and distribution; and to improve the resiliency of each of the covered species' populations to environmental change and variable hydrology.

Important stressors that affect longfin smelt habitat quality, quantity, accessibility, and diversity (see Figure 2-2 and Appendix C) are:

- Reduced access to spawning habitat,
- Reduced access to rearing habitat,
- Reduced food availability
- Reduced turbidity,
- Reduced spawning habitat
- Reduced rearing habitat.

Within the planning area, longfin smelt habitat conditions are governed by hydrodynamic conditions and the extent and quality of habitat within the planning area. Under Option 1, these conditions relative to base conditions would be affected by the conveyance configuration of Option 1 and the opportunities for restoration of physical habitat that could be sited within Suisun Bay and Marsh and within the planning area in the north and west Delta, which represents approximately 28% of the planning area.

Based on the following evaluation of Option 1 effects on applicable longfin smelt stressors, Option 1 is expected to provide very low benefits relative to habitat conditions for the longfin smelt.

Reduced Accessibility to Spawning and Rearing Habitats

The effects of Option 1 on the accessibility of spawning and rearing habitats are evaluated under Criterion #2 above. As described in the Criterion #2 evaluation, Option 1 would not be expected to affect longfin smelt access to spawning and rearing habitats relative to base conditions.

Reduced Food Availability and Quality

Reduced food availability and quality can result in non-natural levels of mortality. The effects of Option 1 on longfin smelt food availability and quality are evaluated under Criterion #4 below. As described in the Criterion #4 evaluation, Option 1 would be expected to provide a very low beneficial effect on food availability and quality for longfin smelt relative to base conditions.

Reduced Turbidity

Habitat conditions that support non-native filter feeders and aquatic plants can reduce turbidity. The effects on turbidity associated with these impact mechanisms are evaluated under Criterion #2 above. As described in the Criterion #2 evaluation, restoring habitat under Option 1 would be expected to have a very low beneficial effect on turbidity conditions for longfin smelt relative to base conditions.

Reduced Spawning Habitat

Spawning habitat for longfin smelt is believed to be located in the main river channels upstream of the low salinity zone. The primary impact mechanism believed to affect spawning habitat is the reclamation and channelization of historical intertidal wetlands that has presumably reduced the amount of habitat available for spawning by longfin smelt. Under Option 1 approximately 28% of the planning area would be available for restoration/enhancement of aquatic subtidal and intertidal habitats (Figure 1-2), which encompasses most of the geographic range of longfin smelt within the Delta (Rosenfield and Baxter, in press). Because turbidity conditions would remain similar to base conditions (which affects predation vulnerability and foraging efficiency), habitat restoration under Option 1 would likely provide a very low benefit to longfin smelt.

Reduced Rearing Habitat

The effects on rearing habitat associated with Option 1 are evaluated under Criterion #2 above. Option 1 is expected to have no net effect on the transport of longfin smelt larvae to downstream rearing habitats relative to base conditions.

3.1.2.4 Criterion #4. Relative degree to which the Option would increase food quality, quantity, and accessibility (e.g., phytoplankton, zooplankton, macro-invertebrates, forage fish) to enhance production (reproduction, growth, survival) and abundance for each of the covered fish species.

Important stressors that affect longfin smelt food quality, quantity, and accessibility (see Figure 2-2 and Appendix C) are:

- Reduced food availability and
- Reduced food quality.

Based on the following evaluation of Option 1 effects on applicable longfin smelt stressors, Option 1 is expected to provide very low benefits relative to food quality, quantity, and accessibility for the longfin smelt.

Reduced Food Availability

Reduced food availability for longfin smelt can result from at least five impact mechanisms: competition with non-native species, reduced frequency of floodplain inundation, nutrient and food exports from CVP/SWP pumps and in-Delta agricultural diversions, hydraulic residence time, and effects of toxics (e.g., pesticides/herbicides) on phytoplankton and zooplankton abundance (see Figure 2-2 and Appendix C). Measurements used to assess effects on food availability included (1) PTM modeling results for CVP/SWP for particle fate, (2) change in peak total Delta inflows from January through March, and (3) the proportion of the Delta expected to be suitable for restoration of aquatic subtidal and intertidal habitat.

Restoration of subtidal and intertidal habitats could create conditions that disfavor non-native species that indirectly or directly affect food abundance, thereby improving food availability for longfin smelt. For example, the highly efficient filter-feeding clam, *Corbula amurensis*, consumes zooplankton that would otherwise be available to longfin smelt (Kimmerer and Orsi 1996, Sweetnam 1999, Jassby et al. 2002, Kimmerer et al. 2002a, Hobbs et al. 2006). Approximately 28% of the Delta could potentially be enhanced to provide high quality aquatic habitat under this option (Figure 1-2), which would primarily be located within the northern region of the Delta and the Suisun Bay and Marsh. The brackish water area within Suisun Bay (Figure 1-2) is the area of the estuary most likely to be inhabited by the overbite clam, *Corbula*. Habitat restoration and enhancement also has the potential to increase production of nutrients, organic carbon, phytoplankton, and zooplankton, however, the biological response of native and non-native species to large-scale habitat improvement within the Delta remains uncertain. However, because the overall hydrologic conditions (e.g., flow rates at multiple locations; see Appendix D) do not differ substantially from base conditions in most water years (conditions which are believed to favor competitor species), the effect of restoring habitat on reducing food competition may be limited. Consequently, the potential benefits for reducing competition to increase food availability for longfin smelt under Option 1 are considered very low.

Floodplains are highly productive and are thought to be a source of high amounts of allochthonous nutrients and organic carbon production from the terrestrial community that inhabit the floodplain and upland areas during the remainder of the year (Sommer et al. 2001, Harrell and Sommer 2003). The magnitude of peak flows from January through March, the period during which inflows have been greatest into the Delta historically, gives an indication of the potential for floodplain inundation relative to base conditions. Modeled peak Delta inflows under Option 1 during January through March are similar to base conditions (see Appendix H). Therefore, relative to base conditions, Option 1 would not be expected to provide increased mobilization of organic material and nutrients from floodplains that would then be transported downstream into the Delta.

In addition to removing water from the Delta, SWP/CVP pumps and the over 2,200 in-Delta agricultural diversions (Herren & Kawasaki 2001) can export phytoplankton, zooplankton, nutrients, and organic material (Jassby et al. 2002, POD Action Plan 2007) that would otherwise support the base of the food web from the Delta, and thus could affect food availability for the longfin smelt. Based on PTM modeling results for exported particles, the removal of food organisms, nutrients, and organics by diversions is lower relative to base conditions (see Appendices D and H). However, the benefit to longfin smelt is expected to be very low because the magnitude of the reduction is relatively low.

Reduced hydrologic residence time is thought to reduce productivity in the Delta because nutrients and organics are transported downstream and out of the Delta before stimulating phytoplankton or zooplankton production (Jassby et al. 2002, Kimmerer 2002a,b, POD Action Plan 2007). Increased hydrologic residence time allows more time for bacterial activity to use nutrients and organic carbon and for the production of phytoplankton and zooplankton that provide food for longfin smelt and other aquatic species. Based on PTM modeling results, the hydrologic residence time within the Delta varies with both the insertion location and the amount of water entering the system (i.e., exceedance percentage). Overall, residence time within the central Delta under Option 1 was highly variable but on average similar to base conditions (sees Appendices D and H). Consequently, the effect of Option 1 on food production is expected to be similar to base conditions. In addition to hydraulic residence time within the central Delta, results of the PTM showed a similar pattern of particle movement downstream into Suisun Bay where phytoplankton and zooplankton production co-occurs with longfin smelt.

It has been hypothesized that exposure of phytoplankton and zooplankton to toxics (e.g., pesticides, herbicides) that enter the Delta from point and non-point sources may also contribute to ongoing low abundance of longfin smelt zooplankton prey species (Weston et al. 2004, Luoma 2007). Though this relationship is uncertain, Option 1 would be unlikely to reduce the exposure of primary and secondary producers to these toxics because dilution flows would remain similar to base conditions.

Reduced Food Quality

Reduced food quality for longfin smelt can result from the displacement of native species of zooplankton species with less nutritious non-native species (see Figure 2-2 and Appendix C). The measurement used to assess likely effects of Option 1 on food quality was the proportion of the Delta expected to be suitable for restoration of aquatic subtidal and intertidal habitat.

The zooplankton community inhabiting the Delta has been affected by a number of factors including the introduction of a number on non-native zooplankton species. These changes in the zooplankton species composition have affected the quality of food resources available to longfin smelt since many of the introduced zooplankton species do not appear to be as suitable a food resource as the native species (POD Action Plan 2007). For example, the non-native copepod *Limnoithona tetraspina* (Orsi and Ohtsuka 1999) is described as lower quality prey for longfin smelt because they are small, spiny and have sufficient swimming ability to avoid capture (POD Action Plan 2007, Orsi and Ohtsuka 1999, B. Herbold pers. comm.). As a result, foraging efficiency of longfin smelt has decreased (POD Action Plan 2007).

Restoration of shallow water subtidal and intertidal habitats under Option 1 could improve nutrient production and production of suitable zooplankton species (e.g., native calanoid copepods) as forage for longfin smelt. Under Option 1, habitat could be restored within Suisun Bay and Marsh and approximately 28% of the Delta to provide high quality aquatic habitat under this option (Figure 1-2), which encompasses a smaller proportion of the longfin smelt's range than the proportion of the Delta within which habitat could be restored under the other Options. Consequently, relative to the other Options, Option 1 would be expected to provide a low level of benefit for longfin smelt food quality (see Appendix H).

3.1.2.5 Criterion #5. Relative degree to which the Option would reduce the abundance of non-native competitors and predators to increase native species production (reproduction, growth, survival), abundance and distribution for each of the covered fish species.

Non-native competitors and predators are an impact mechanism for the following important longfin smelt stressors (see Appendix C):

- Reduced food availability
- Reduced turbidity,
- Reduced food quality, and
- Increased predation.

Based on the following evaluation of Option 1 effects on applicable longfin smelt stressors, Option 1 is expected to provide low benefits for the longfin smelt relative to the abundance of non-native competitors and predators.

For reasons described under Criterion #4, Option 1 would be expected to provide a very low beneficial effect by reducing the adverse impacts of populations of non-native food competitors and predators relative to base conditions.

3.1.2.6 Criterion #6. Relative degree to which the Option improves ecosystem processes in the BDCP planning area to support aquatic and associated habitats.

Based on the proportion of the planning area suitable for potential restoration under Option 1 relative to the other Options and modeling results for hydraulic residence time (see Appendix H), Option 1 would be expected to provide a very low beneficial improvement in ecosystem function relative to base conditions.

Measurements used to assess the potential for Option 1 to improve ecosystem processes included (1) PTM modeling results for hydraulic residence time in the central Delta and (2) the proportion of the Delta expected to be suitable for restoration of aquatic and intertidal habitat. Based on the proportion of the planning area suitable for restoration under Option 1 relative to the other Options and modeling results for hydraulic residence time (see Appendix H), Option 1 would be expected to provide a very low beneficial improvement in ecosystem function relative to base conditions because habitat restoration under Option 1 would improve ecosystem processes, hydraulic residence time would be similar to base conditions. Under Option 1, Delta channels would continue to serve as the water conveyance facilities for freshwater supplies moving from the Sacramento River across the Delta to the export facilities in the south Delta. Movement of large volumes of water through these channels would adversely affect hydraulic conditions within the Delta (e.g., reverse flows), affect salinity levels and distribution, require riprapped levees to reduce erosion and levee scour, and limit the opportunities for habitat enhancement. The hydraulic conditions within the Delta under these operations would continue to reduce hydraulic residence times and export nutrients, organic carbon, phytoplankton, and zooplankton from the Delta resulting in adverse effects on aquatic food production and availability.

3.1.2.7 Criterion #7. Relative degree to which the Option can be implemented within a timeframe to meet the near-term needs of each covered fish species (post BDCP authorization).

Habitat restoration under Option 1 can be initiated immediately following authorization of the BDCP and thus could be implemented in a manner that would meet the near-term needs of longfin smelt.

3.1.3 Sacramento River Salmonids[1]

This analysis focuses only on stressors affecting juvenile and adult life stages of Sacramento River salmonids during their migration through the Delta (Figure XX, Appendix C). The Sacramento River supports populations of winter-run, spring-run, fall-run, and late fall-run Chinook salmon, as well as Central Valley steelhead. The majority of juvenile salmonid rearing occurs either within the coastal ocean waters or in tributaries upstream of the Delta (Williams 2006). Juvenile salmonids (fry) may migrate downstream and rear within the Delta for multiple months (Williams 2006), with the greatest numbers typically occurring within the Delta during high-flow years. Juvenile salmonids that rear within upstream river habitats migrate downstream through the Delta as larger juvenile smolts and are thought to inhabit the Delta for a relatively short period of time (weeks, VAMP 2006). Neither Chinook salmon nor steelhead spawn within the Delta, but rather inhabit upstream river habitat for spawning, egg incubation, and juvenile rearing (Williams 2006). Although spawning and most juvenile rearing occurs upstream of the Delta, hydrologic conditions and SWP and CVP facilities operations can potentially affect upstream migration and cold water pool storage in upstream reservoirs. The early life stages of both salmon and steelhead (e.g., incubating eggs and rearing juveniles) are particularly sensitive to exposure to elevated water temperatures (Sullivan et al. 2000). Therefore, the potential for depletion of cold-water storage within SWP and CVP reservoirs located within the Sacramento River watershed compared to base conditions was included as an evaluation metric for this analysis.

It was assumed for purposes of these analyses that the effects of the Options on adult harvest by recreational anglers, such as changes in regulations or enforcement, would apply equally to all Options and, therefore, are not included in this assessment.

Overall, Option 1 will provide low benefit to Sacramento River salmon and steelhead compared to base conditions. The potential opportunities for habitat restoration/enhancement under Option 1 were the lowest among the four Options evaluated.

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[1] Because life history characteristics of steelhead are not well understood and are broadly similar (based on what is known) to Chinook salmon life history characteristics, this analysis treats steelhead and Chinook similarly. Important differences are distinguished in the text. Because there are four runs of Chinook salmon that spawn in the Sacramento River (fall-/late fall-, spring, and winter-runs), differences among runs are noted as relevant to the evaluation.

Based on the evaluation of each biological criterion presented below, Table 3-X and Table 3-X summarize the expected degree to which Option 1 would be expected to affect Sacramento salmonids relative to base conditions.

Table 3-3. Summary of Expected Effects of Option 1 on Highly and Moderately Important Sacramento River Chinook Salmon Stressors

Stressors[1]	Applicable Criteria	Option Effects on Important Species Stressors Relative to Base Conditions	
		Scenario A	Scenario B
Highly Important Stressors			
Reduced staging and spawning habitat	2,3	No net effect	No net effect
Reduced rearing and outmigration habitat	2,3	Low benefit	Moderate benefit
Predation by non-native species	1,5	Low benefit	Low benefit
Moderately Important Stressors			
Harvest	1	No net effect	No net effect
Reduced genetic diversity/ integrity	1	No net effect	No net effect
SWP/CVP entrainment	1,4	No net effect	Moderate benefit
Exposure to toxics	1,2	No net effect	No net effect
Increased water temperature	2,3	No net effect	No net effect

Notes:
1. See Appendix C for descriptions of stressors, stressor impact mechanisms, and stressor effects.

Table 3-4. Summary of Expected Effects of Option 1 on Highly and Moderately Important Sacramento River Steelhead Stressors

Stressor[1]	Applicable Criteria	Option Effects on Important Species Stressors Relative to Base Conditions	
		Scenario A	Scenario B
Highly Important Stressors			
Reduced staging and spawning habitat	2,3	No net effect	No net effect
SWP/CVP entrainment	1,4	No net effect	No net effect
Reduced rearing and outmigration habitat	2,3	Low benefit	Moderate benefit
Predation by non-natives	1,5	Low benefit	Low benefit
Moderately Important Stressors			
Exposure to toxics	1,2	No net effect	No net effect
Reduced genetic diversity/ integrity	1	No net effect	No net effect

Table 3-4. Summary of Expected Effects of Option 1 on Highly and Moderately Important Sacramento River Steelhead Stressors (continued)

Stressor[1]	Applicable Criteria	Option Effects on Important Species Stressors Relative to Base Conditions	
		Scenario A	Scenario B
Harvest	1	No net effect	No net effect
Increased water temperature	2,3	No net effect	No net effect

Notes:
1. See Appendix C for descriptions of stressors, stressor impact mechanisms, and stressor effects.

3.1.3.1 Criterion #1. Relative degree to which the Option would reduce species mortality attributable to non-natural mortality sources, in order to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species.

Based on the best available scientific information, the primary stressors that contribute to non-natural mortality of Sacramento River salmonids and that can be differentially influenced by the four Options include:

Chinook salmon	**Steelhead**
Predation by non-native fish	Entrainment/salvage
Entrainment/salvage	Predation by non-native fish
Exposure to toxics	Exposure to toxics
Exposure to elevated water temperatures	Exposure to elevated water temperatures

It is thought that predation by non-native species is a lower stressor contributing to non-natural mortality of steelhead than Chinook salmon. Juvenile steelhead are typically larger when migrating through the Delta and are, therefore, expected to have a lower vulnerability to predation mortality when compared to juvenile Chinook salmon. Conclusions below incorporate this difference between steelhead and Chinook salmon. The assessment of Option 1 evaluated, in part, the degree to which the Option addressed these stressors.

Overall, Option 1 is expected to provide a very low reduction in non-natural mortality for Sacramento River salmonids.

Predation by non-native species

A variety of non-native predatory fish species have established sustainable populations within the Delta, including striped bass and largemouth bass (Moyle 2002). Three primary mechanisms influence the degree to which non-native predation affects juvenile salmonids.

First, colonies of non-native aquatic vegetation, such as *Egeria densa* and water hyacinth, grow in dense stands that prohibit access to and reduce quality of shallow water channel margins on which salmonids rear, forcing salmonids into deeper water and exposing them to higher predation risk (Grimaldo et al. 2000). Second, the gravel pits and in-stream flooded ponds, in addition to the operation of water control gates and weirs, can attract non-native predators and expose juvenile salmonids to higher predation risk from the lack of cover. Because this mechanism occurs upstream of the Delta, it is not expected to be affected by the Options, and will not be discussed further. Third, it has been hypothesized that changes in habitat quality and characteristics within the Delta (e.g., construction of riprap protected levees, construction of a number of structures, and the reduction of natural cover) have increased the vulnerability of juvenile salmonids to predation (NOAA 2005). Although the control of these non-native predators is difficult, one approach to addressing the issue of increased vulnerability to predation by non-natives is to enhance the quality and availability of habitat, including cover habitat, for native species (Lund et al. 2007). Although there is a high degree of uncertainty concerning the effectiveness of reducing versus enhancing non-native predator populations under this action, it is assumed for purposes of this assessment that increasing habitat quantity and quality will benefit salmonids and reduce the impacts of predation mortality by non-native fish species. Approximately 28% of the Delta is potentially available for restoration/ enhancement under this Option (Figure 1-2), but much of the range of Sacramento River salmonids within the Delta would be within this area (e.g., northern and western regions of the Delta located along the migration corridor for Sacramento River salmonids). Improvements in the hydraulics and flows entering several channels on the Sacramento River (e.g., Sutter and Steamboat sloughs, Yolo Bypass, etc.) that would be available under this Option would provide alternative migration routes for juvenile salmonids that would potentially reduce their exposure to sources of mortality within the Delta. Risk to predation mortality can decrease with increased turbidity. Overall, Option 1 would provide a low reduction in mortality by non-native predation.

Entrainment

Operation of the SWP and CVP export facilities results in the entrainment and salvage of juvenile Chinook salmon and steelhead. The vulnerability of salmon and steelhead to export related losses varies in response to a number of factors including distribution of salmonids within the Delta, operation of Delta Cross-Channel gates, hydrodynamic conditions occurring within the central and southern regions of the Delta (e.g., Old and Middle rivers), and export rates (USBR and DWR, unpubl. data). The risk of entrainment by the SWP/CVP export facilities can be estimated as the magnitude of reverse flows in Middle and Old rivers and an index of vulnerability for salmon and steelhead to salvage at the export facilities. When combined reverse flows in Old and Middle rivers are negative (reverse flow direction) the vulnerability of juvenile Chinook salmon and steelhead to SWP and CVP exports is expected to increase. Hydrologic model results indicate that operations under Option 1would potentially result in a similar level of entrainment risk as under the base conditions. The vulnerability index indicates that Option 1 would provide a minimal reduction in entrainment risk (<8% of base conditions). Overall, entrainment would be similar to base conditions under Option 1.

Exposure to toxics

There is evidence that toxics can impact juvenile salmonids (DFG 1996, USBR 2004, Klnick et al. 2005). As indicated in the delta smelt section above, flows into the Delta to dilute toxics are not expected to be different under Option 1 than under base conditions. The potential significance of exposure by juvenile salmonids to toxics may be reduced, in part, by their relatively short period of residency in the Delta relative to delta smelt. However, the fact that the majority of juvenile salmonids migrate through the Delta during the late winter and spring, in contrast, may result in an increased vulnerability to toxic exposure resulting from stormwater runoff and other point and non-point sources.

3.1.3.2 Criterion #2. Relative degree to which the Option would provide water quality and flow conditions necessary to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species.

Water quality changes that impact Sacramento River salmonids can be measured as differences in exposure to toxics and water temperature[2] relative to base conditions. Flow conditions can affect the quality, quantity, and accessibility of habitat.

Overall, Option 1 would be expected to provide no benefits to habitat conditions for salmonids based on water quality and flow conditions compared to base conditions.

Exposure to toxics

Dilution flows that decrease concentrations of toxics would be similar under Option 1 to those under base conditions. Therefore, Option 1 would not change exposure of Sacramento River salmonids to toxics.

Rearing habitat

The location of X_2 affects the location of the low salinity zone, and potentially habitat quality and availability for juvenile rearing salmonids within Suisun Bay and the western Delta. Higher outflows tend to locate X_2 further downstream, which would potentially provide improved habitat for juvenile salmonid rearing during the late winter and spring. Results of the hydrologic modeling for Option 1 show that the change in location of X_2 in April relative to base conditions under Option 1 is 0.5 km upstream, which would result in a negligible adverse effect to rearing habitat for juvenile salmon during the late winter and spring. Dilution flows to reduce the concentrations of toxics will not change appreciably under Option 1 in rearing habitat of juvenile salmonids.

Net downstream flows are important to the migration of salmonids to downstream rearing habitat. Positive relationships have been identified between Sacramento River flow and juvenile salmon survival during migration (P. Brandes, unpubl. data). Model output indicates

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[2] Under the current Delta configuration and that of Option 1, dissolved oxygen is limiting in specific areas of the Delta (i.e., the Stockton Ship Channel, adjacent to discharges in Suisun Marsh from managed wetlands) during times of year, however these typically occur in areas where Sacramento River Chinook salmon and steelhead would not be expected to occur. Therefore, dissolved oxygen is not expected to be a major stressor to juvenile salmon or steelhead migrating from the Sacramento River downstream through the Delta.

that both Rio Vista flows and total Delta outflow under Option 1 would be approximately equal to base conditions for all water year types in both months (Table ____), indicating that Option 1 would provide no benefit to downstream flows for Sacramento River salmonids.

Access to staging and spawning habitat

Although staging and spawning habitat occurs upstream of the Delta, actions in the Delta are influenced differentially by the four Options. Changes in Sacramento River flows are likely to affect attraction and migratory cues for adults to reach upstream spawning habitat (Hasler and Cooper 1976). Sacramento River inflows at Rio Vista indicate that Option 1 would not change inflows and, therefore, not alter migratory cues.

3.1.3.3 Criterion #3. Relative degree to which the Option would increase habitat quality, quantity, accessibility, and diversity in order to enhance and sustain production (reproduction, growth, survival), abundance, and distribution; and to improve the resiliency of each of the covered species' populations to environmental change and variable hydrology.

The two important parameters that affect habitat quality, quantity, accessibility, and diversity of Sacramento River salmonids include (Appendix C): reduced access to adult staging and spawning habitat and reduced quality, quantity, accessibility, and diversity of juvenile rearing habitat.

Overall, Option 1 would support a low increase in habitat quality and availability for Sacramento River salmonids.

Staging and spawning habitat

Low seasonal flows can influence the attraction and accessibility of upstream adult salmonid staging and spawning habitat because salmonids may be unable to sense migratory cues from upstream or stray because of false cues from flows that pass through intermediate waterways (i.e., the central Delta) before reaching downstream. Flow conditions under Option 1, as reported in Criterion 2 above, would be negligibly different from base conditions. As a result, access to spawning habitat would not be affected by Option 1. Reservoir releases under Option 1 would be similar to base conditions, indicating that water temperatures would be similar in upstream spawning grounds to base conditions. Overall, these results indicate that the effect of Option 1 on upstream spawning habitat conditions would be minimal.

Rearing habitat

The location of X_2 is expected to be farther upstream by 0.5 km. This small change in rearing habitat would have a negligible effect to salmonids. The quantity, quality, accessibility, and diversity of juvenile salmonid rearing habitat within the Delta has been affected by a number of factors including changes in hydrodynamic conditions, reductions in tidal and shallow subtidal habitat, and construction of riprap protected levees. Under Option 1 approximately 28% of the habitat in the Delta would potentially be available for restoration/enhancement (Figure 1-2). Much of this habitat is located in the northern region of the Delta along the migration pathway for Sacramento River salmonids. Habitat improvement in this region of the Delta would be expected to provide a low benefit for salmonids migrating from the Sacramento River. As described in Criterion #2, downstream flows under Option 1, which affect access of migrating salmonids to their rearing habitat, would not be expected to change relative to base conditions.

3.1.3.4 Criterion #4. Relative degree to which the Option would increase food quality, quantity, and accessibility (e.g., phytoplankton, zooplankton, macro-invertebrates, forage fish) to enhance production (reproduction, growth, survival) and abundance for each of the covered fish species.

Juvenile Chinook salmon and steelhead forage on a variety of macroinvertebrates (e.g., copepods, amphipods) and small fish during their residency within the Delta. The abundance of these prey species varies in response to a number of factors that include availability of nutrients, organic carbon, phytoplankton and zooplankton production. Reduced food availability or quality, however, are not identified as important stressors for Sacramento River salmonids. Consequently, benefits of increasing food quantity and quality under the Options would not be expected to result in a population level response relative to base conditions.

3.1.3.5 Criterion #5. Relative degree to which the Option would reduce the abundance of non-native competitors and predators to increase native species production (reproduction, growth, survival), abundance and distribution for each of the covered fish species.

One method for reducing population impacts to, and promoting populations of, juvenile salmonids by non-native species is to restore Delta habitat to mimic historical habitat conditions (Lund et al. 2007). Under Option 1, approximately 28% of the Delta would potentially be available for effective restoration/enhancement, the lowest of all the Options evaluated in this assessment. This restoration is located primarily in the northern and western regions of the Delta and overlaps habitat that is thought to be important for juvenile Chinook salmon and steelhead emigrating from the Sacramento River. Therefore, this Option would provide low benefit to Sacramento River salmonids.

3.1.3.6 Criterion #6. Relative degree to which the Option improves ecosystem processes in the BDCP planning area to support aquatic and associated habitats.

Measurements used to assess the potential for Option 1 to improve ecosystem processes included (1) PTM modeling results for hydraulic residence time in the central Delta and (2) the proportion of the Delta expected to be suitable for restoration of aquatic and intertidal habitat. Based on the proportion of the planning area suitable for restoration under Option 1 relative to the other Options and modeling results for hydraulic residence time (see Appendix H), Option 1 would be expected to provide a very low beneficial improvement in ecosystem function relative to base conditions because habitat restoration under Option 1 would improve ecosystem processes, hydraulic residence time would be similar to base conditions. Under Option 1, Delta channels would continue to serve as the water conveyance facilities for freshwater supplies moving from the Sacramento River across the Delta to the export facilities in the south Delta. Movement of large volumes of water through these channels would adversely affect hydraulic conditions within the Delta (e.g., reverse flows), affect salinity levels and distribution, require riprapped levees to reduce erosion and levee scour, and limit the opportunities for habitat enhancement. The hydraulic conditions within the Delta under these operations would continue to reduce hydraulic residence times and export nutrients, organic carbon, phytoplankton, and zooplankton from the Delta resulting in adverse effects on aquatic food production and availability.

3.1.3.7 Criterion #7. Relative degree to which the Option can be implemented within a timeframe to meet the near-term needs of each covered fish species (post BDCP authorization).

Habitat restoration under Option 1 can be initiated immediately following authorization of the BDCP and thus could be implemented in a manner that would meet the near term needs of Sacramento River salmonids. The implementation period for Option 1 is the same as the other Options.

3.1.4 San Joaquin River Salmonids[3]

The San Joaquin River tributaries produce fall-run Chinook salmon and provide habitat for what appears to be a small population of steelhead. Recent monitoring has detected small self-sustaining populations of steelhead in the Stanislaus, Mokelumne, and Calaveras rivers, and other streams previously thought to be devoid of steelhead (McEwan 2001). As part of the assumptions used to compare the potential performance of various Options on fishery habitat a decision was made to maintain San Joaquin River flows as outlined in either the VAMP agreement or D-1641. The purpose of this analysis is therefore not intended to assess changes in upstream habitat conditions or factors affecting salmonid survival but rather to focus only on potential changes in conditions within the Delta that may affect San Joaquin River salmonids. Because many of the factors that affect Sacramento River salmonids discussed in the previous section also affect San Joaquin River salmonids, those similarities have been noted but not repeated in their entirety in this section.

Overall, Option 1 will provide very low benefit to San Joaquin River salmon and steelhead compared to base conditions. The potential opportunities for habitat restoration/enhancement under Option 1 were the lowest among the four Options evaluated and a portion of this area would likely not be utilized by salmonids originating in the San Joaquin River and tributaries.

Based on the evaluation of each biological criterion presented below, Table 3-X and Table 3-X summarize the degree to which Option 1 would be expected to affect San Joaquin River origin salmonids relative to base conditions.

[3] Because life history characteristics of steelhead are not well understood and are broadly similar (based on what is known) to Chinook salmon life history characteristics, this analysis treats steelhead and Chinook similarly. Important differences are distinguished in the text.

Table 3-5. Summary of Expected Effects of Option 1 on Highly and Moderately Important San Joaquin River Chinook Salmon Stressors

Stressor[1]	Applicable Criteria	Option Effects on Important Species Stressors Relative to Base Conditions	
		Scenario A	Scenario B
Highly Important Stressors			
Reduced staging and spawning habitat	2,3	No net effect	No net effect
Reduced rearing and outmigration habitat	2,3	Low benefit	Low benefit
Exposure to toxics	1,2	No net effect	No effect
Predation by non-natives	1,5	Very low benefit	Very low benefit
Moderately Important Stressors			
Reduced genetic diversity/ integrity	1	No net effect	No net effect
Harvest	1	No net effect	No net effect
SWP/CVP entrainment	1,4	No net effect	Moderate benefit
Increased water temperature	2,3	No net effect	No net effect

Notes:
1. See Appendix C for descriptions of stressors, stressor impact mechanisms, and stressor effects.

Table 3-6. Summary of Expected Effects of Option 1 on Highly and Moderately Important San Joaquin River Steelhead Stressors

Stressor[1]	Applicable Criteria	Option Effects on Important Species Stressors Relative to Base Conditions	
		Scenario A	Scenario B
Highly Important Stressors			
Reduced staging and spawning habitat	2,3	No net effect	No net effect
Reduced rearing and outmigration habitat	2,3	Very low benefit	Low benefit
Exposure to toxics	1,2	No net effect	No net effect
Reduced genetic diversity/ integrity	1	No net effect	No net effect
Predation by non-natives	1,5	Very low benefit	Very low benefit
Moderately Important Stressors			
SWP/CVP entrainment	1,4	Very low benefit	Moderate benefit
Harvest	1	No net effect	No net effect
Increased water temperature	2,3	No net effect	No net effect

Notes:
1. See Appendix C for descriptions of stressors, stressor impact mechanisms, and stressor effects.

3.1.4.1 Criterion #1. Relative degree to which the Option would reduce species mortality attributable to non-natural mortality sources, in order to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species.

The relative degree to which Option 1 would reduce sources of mortality for San Joaquin River Chinook salmon and steelhead and other identified stressors is summarized in Tables 3-5 and 3-6. Overall, the range of operations reflected in Option 1 would have a low benefit on reducing stressors on salmonids during their migration through the Delta.

Based on the best available scientific information, the primary stressors that contribute to non-natural mortality of San Joaquin River salmonids and that can be differentially influenced by the four Options include (see Figures 2-5, 2-6 and Appendix C):

Chinook salmon	Steelhead
Exposure to toxics	Exposure to toxics
Predation by non-native fish	Predation by non-native fish
Entrainment/salvage	Entrainment/salvage
Exposure to elevated water temperatures	Exposure to elevated water temperatures

The effect of these stressors on the salmon and steelhead populations vary among years in response to environmental conditions (e.g., seasonal hydrology) and may also interact with each other in additive or synergistic ways. No single stressor has been identified, with confidence, as the primary factor affecting the current status of Chinook salmon or steelhead. The effects of these stressors include both the incremental contribution of a stressor to the population as well as the cumulative effects of multiple stressors over time. The assessment of Option 1 evaluated, in part, the degree to which the Option addressed these stressors.

The ability of Option 1 to address the stressors affecting San Joaquin River origin salmonids is very limited. As a result of the continued use of Old and Middle rivers as primary water conveyance facilities through the Delta reverse flow conditions would be expected to continue and limit habitat enhancement opportunities in the central and southern Delta and the vulnerability of juveniles to entrainment and salvage at the SWP and CVP export facilities. Under Option 1 the potential for habitat enhancement to provide direct benefits to salmonids (cover and foraging habitat) as well as contribute to increased food availability are located in the northern and western regions of the Delta (Figure 1-2). These habitat enhancement features would be expected to provide little or no benefit to San Joaquin River salmonids during their downstream migration through the Delta. Habitat conditions along the lower San Joaquin River would be expected to be similar under Option 1 as current base conditions.

Exposure to toxics

The preferred method of reducing the risk of toxicity to salmonids within the Delta is through source control that could be applied across all of the Options included in this assessment. Dilution flows from the Sacramento River are another way of reducing concentrations of toxics and their effect on salmonids. For purposes of this assessment, the effects of dilution flows from the Sacramento River discussed in Sacramento River salmonids section are expected to be applicable to San Joaquin River salmonids. Because water quality conditions within the San Joaquin River are poorer and potential pollutant loading is greater, changes in dilution flows from the Sacramento River may have a lower effect on reducing the exposure and potential adverse effects within the southern and central Delta on San Joaquin River salmonids. Therefore, Option 1 is not expected to reduce exposure to toxics of San Joaquin River salmonids.

Predation by non-native fish

Under Option 1, the potential for restoration with the goal of reducing habitat conditions for non-native fish, thereby reducing predation risk of San Joaquin River Chinook salmon, is low. Steelhead are typically larger when migrating through the Delta and, therefore, are expected to have a lower vulnerability to predation mortality when compared to juvenile Chinook salmon.

Entrainment

The index of entrainment of San Joaquin River salmonids is expected to be marginally lower under Option 1 relative to base conditions. Model output indicates that the magnitude of reverse flows under Option 1 is also expected to be marginally lower. Therefore, overall, Option 1 will provide a very low benefit to entrainment risk relative to base conditions.

3.1.41.2 Criterion #2. Relative degree to which the Option would provide water quality and flow conditions necessary to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species.

Overall, water quality and flow conditions Option 1 would be expected to be similar to base conditions.

Exposure to toxics

As discussed under the previous criterion, Option 1 is not expected to change the exposure to toxics of San Joaquin River salmonids.

Rearing habitat

The location of X_2 will be 0.5 km upstream under Option 1, indicating that the Option will cause a negligible adverse effect to rearing habitat for juvenile salmon during the late winter and spring. As previously stated, the assumption was made to maintain San Joaquin River flows for modeling efforts to meet VAMP agreement or D-1641 flow standards. Therefore, the differences among Options in Vernalis flow, a metric for downstream movement of salmonids towards Delta rearing and emigration habitat, would be minimal among the Options.

Combined, this indicates that Option 1 will do little to improve water quality and flow conditions to increase the quality and availability of San Joaquin River salmonid rearing habitat.

Dissolved oxygen is limiting in specific areas of the Delta (i.e., the Stockton Ship Channel) during seasonal period when San Joaquin River salmonids are migrating upstream or downstream. The actions included in Option 1 would not be expected to change localized dissolved oxygen levels when compared to current base conditions.

Access to staging and spawning habitat

Changes in hydrodynamic conditions within central and south Delta channels under Option 1 are not expected to affect migration cues for adult and juvenile salmonids relative to base conditions. There are no major changes to the pathways or flow rates under this Option

3.1.4.3 Criterion #3. Relative degree to which the Option would increase habitat quality, quantity, accessibility, and diversity in order to enhance and sustain production (reproduction, growth, survival), abundance, and distribution; and to improve the resiliency of each of the covered species' populations to environmental change and variable hydrology.

Overall, Option 1 is expected to have a very low beneficial effect on the habitat quality, quantity, accessibility, and diversity for San Joaquin River salmonids.

Staging and spawning habitat

As indicated under Criterion 1, migratory cues are not expected to change under Option 1 relative to base conditions.

Rearing habitat

The small change in X_2 under Option 1 will have no effect on rearing habitat of salmonids. Approximately 28% of the habitat in the Delta would potentially be available for restoration/enhancement (Figure 1-2). A large portion of this habitat is located in the northern region of the Delta away from the migration pathway for San Joaquin River salmonids. Therefore, the opportunities available for restoration/enhancement under Option 1 would provide low benefit to San Joaquin River salmonids. As described in Criterion 2, Vernalis flows will not change among the Options.

3.1.4.4 Criterion #4 Relative degree to which the Option would increase food quality, quantity, and accessibility (e.g., phytoplankton, zooplankton, macro-invertebrates, forage fish) to enhance production (reproduction, growth, survival) and abundance for each of the covered fish species.

Juvenile Chinook salmon and steelhead forage on a variety of macroinvertebrates (e.g., copepods, amphipods) and small fish during their residency within the Delta. The abundance of these prey species varies in response to a number of factors that include availability of nutrients, organic carbon, phytoplankton and zooplankton production. Reduced food availability or quality, however, are not identified as important stressors for San Joaquin River salmonids. Consequently, benefits of increasing food quantity and quality under the Options would not be expected to result in a population level response relative to base conditions.

3.1.4.5 Criterion #5. Relative degree to which the Option would reduce the abundance of non-native competitors and predators to increase native species production (reproduction, growth, survival), abundance and distribution for each of the covered fish species.

Under Option 1, the southern and central Delta channels and aquatic habitat would be similar to current conditions (Figure 1-2). Opportunities under Option 1 to affect the abundance on non-native species of competitors and predators that would benefit San Joaquin River salmonids are expected to be very low.

3.1.4.6 Criterion #6. Relative degree to which the Option improves ecosystem processes in the BDCP planning area to support aquatic and associated habitats.

Measurements used to assess the potential for Option 1 to improve ecosystem processes included (1) PTM modeling results for hydraulic residence time in the central Delta and (2) the proportion of the Delta expected to be suitable for restoration of aquatic and intertidal habitat. Based on the proportion of the planning area suitable for restoration under Option 1 relative to the other Options and modeling results for hydraulic residence time (see Appendix H), Option 1 would be expected to provide a very low beneficial improvement in ecosystem function relative to base conditions because habitat restoration under Option 1 would improve ecosystem processes, hydraulic residence time would be similar to base conditions. Under Option 1, Delta channels would continue to serve as the water conveyance facilities for freshwater supplies moving from the Sacramento River across the Delta to the export facilities in the south Delta. Movement of large volumes of water through these channels would adversely affect hydraulic conditions within the Delta (e.g., reverse flows), affect salinity levels and distribution, require riprapped levees to reduce erosion and levee scour, and limit the opportunities for habitat enhancement. The hydraulic conditions within the Delta under these operations would continue to reduce hydraulic residence times and export nutrients, organic carbon, phytoplankton, and zooplankton from the Delta resulting in adverse effects on aquatic food production and availability.

3.1.4.7 Criterion #7. Relative degree to which the Option can be implemented within a timeframe to meet the near-term needs of each covered fish species (post BDCP authorization).

Habitat restoration under Option 1 can be initiated immediately following authorization of the BDCP and thus could be implemented in a manner that would meet the near term needs of San Joaquin River salmonids. The implementation period for Option 1 is the same as the other Options.

3.1.5 Green and White Sturgeon

Based on the evaluation presented below of the expected performance of Option 1 for addressing important green sturgeon and white sturgeon stressors, Option 1 would be expected to have a low beneficial effect on green sturgeon production, distribution, and abundance and a very low effect on white sturgeon relative to base conditions when operated to meet water supply objectives (Scenario A). If water supply exports were reduced (Scenario B), Option 1 would be expected to provide a similar level of benefit for sturgeon production, distribution, and abundance relative to base conditions. Option 1 would be expected to provide the lowest benefits for sturgeon compared to the other Options.

Stressors that affect sturgeon are presented in Figures 2-7 and 2-8 and are described in Appendix C. The effect of these stressors on the green and white sturgeon populations vary among years in response to environmental conditions (e.g., seasonal hydrology) and may also interact with each other in additive or synergistic ways. The effects of these stressors include both the incremental contribution of a stressor to the population as well as the cumulative effects of multiple stressors over time. The assessment of Option 1 evaluates the degree to which Option 1 would be expected to address these stressors.

Tables 3-7 and 3-8, respectively, summarize the expected effects of implementing Option 1 under Scenarios A and B on important sturgeon stressors relative to base conditions.

Table 3-7. Summary of Expected Effects of Option 1 on Highly and Moderately Important Green Sturgeon Stressors

Stressors[1]	Applicable Criteria	Option Effects on Important Species Stressors Relative to Base Conditions	
		Scenario A	**Scenario B**
Highly Important Stressors			
Reduced spawning habitat	3	No net effect	No net effect
Exposure to toxics	1,2,3	No net effect	No net effect
Harvest	1	No net effect	No net effect
Moderately Important Stressors			
Reduced rearing habitat	1,2,3	Low benefit	Low benefit
Increased water temperature (upstream)	1,2,3	No net effect	No net effect
Predation	1,3	No net effect	No net effect
Reduced turbidity	1,2,3	No net effect	No net effect
Notes: 1. See Appendix C for descriptions of stressors, stressor impact mechanisms, and stressor effects.			

Table 3-8. Summary of Expected Effects of Option 1 on Highly and Moderately Important White Sturgeon Stressors

Stressors[1]	Applicable Criteria	Option Effects on Important Species Stressors Relative to Base Conditions	
		Scenario A	**Scenario B**
Highly Important Stressors			
Harvest	1	No net effect	No net effect
Reduced spawning habitat	3	No net effect	No net effect

Table 3-8. Summary of Expected Effects of Option 1 on Highly and Moderately Important White Sturgeon Stressors (continued)

Stressors[1]	Applicable Criteria	Option Effects on Important Species Stressors Relative to Base Conditions	
		Scenario A	Scenario B
Exposure to toxics	1,2,3	No net effect	No net effect
Moderately Important Stressors			
Reduced rearing habitat	1,2,3	Very low benefit	Very low benefit
Increased water temperature (upstream)	1,2,3	No net effect	No net effect
Predation	1,3	No net effect	No net effect
Reduced turbidity	1,2,3	No net effect	No net effect

Notes:
1. See Appendix C for descriptions of stressors, stressor impact mechanisms, and stressor effects.

Harvest, reduced spawning habitat, predation, reduced turbidity, and increased water temperatures are not important stressors that would be affected by or affected differently (i.e., harvest, reduced spawning habitat) under the Options and, therefore, are not described in the criteria evaluations below (see Table 2-3 and Appendix C). These stressors could only be addressed through changes in regulation and law enforcement (for harvest) or through conservation actions implemented outside of the planning area. Any effects within the planning area of the Options on the non-harvest stressors described above would not be expected to have any benefits to sturgeon at the population level. As described in Table 2-3, the ability to address harvest and reduced spawning habitat within the planning area would be the same among the Options. Consequently, these stressors are initially identified under the applicable criteria below, but are not evaluated under the criteria.

3.1.5.1 Criterion #1. Relative degree to which the Option would reduce species mortality attributable to non-natural mortality sources, in order to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species.

Important stressors that cause non-natural mortality of green and white sturgeon (see Appendix C) are:

- Harvest,
- Exposure to toxics,
- Reduced rearing habitat,
- Increased water temperature (upstream),
- Predation, and
- Reduced turbidity.

Based on the following evaluation of Option 1 effects on applicable green and white sturgeon stressors, the risk for sturgeon mortality from non-natural causes under Option 1 is expected to be similar to base conditions.

Exposure to Toxics

Exposure of green and white sturgeon to toxic substances can result in mortality of sturgeon. The effects of Option 1 on exposure to toxics are evaluated under Criteria #2 and #4 below. As described in the Criteria #2 and #4 evaluations, the risk for exposure to toxics under Option 1 would be expected to be similar to base conditions.

3.1.5.2 Criterion #2. Relative degree to which the Option would provide water quality and flow conditions necessary to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species.

Important stressors that affect water quality and flow conditions for green and white sturgeon (see Appendix C) are:

- Exposure to toxics,
- Reduced rearing habitat,
- Increased water temperature (upstream), and
- Reduced turbidity.

Based on the following evaluation of Option 1 effects on applicable green and white sturgeon stressors, Option 1 is expected to provide no benefits for water quality and flow conditions that support green and white sturgeon relative to base conditions.

Exposure to toxics

Exposure of sturgeon to toxic substances can result from point and non-point sources associated with agricultural, urban, and industrial land uses. No specific causal link has been established between sturgeon exposure to toxic events on a large-scale within the Delta and subsequent growth or survival. There is inconsistent evidence that the invertebrate prey of green and white sturgeon is affected by toxics. Green and white sturgeon are long-lived species that forage primarily on benthic organisms and therefore are affected by chronic exposure to pollutants through bioaccumulation of toxics such as selenium. Bioaccumulation of selenium has been demonstrated to be a factor affecting green and white sturgeon production and survival. *Corbula* and *Corbicula*, which are filter-feeding clams that capture selenium, are a non-native food source that has become established in the western Delta and Suisun Bay. Consumption of these clams by sturgeon has resulted in the bioaccumulation of selenium in the sturgeon (EPIC et al 2001, Moyle 2002, Doroshov 2006). Reductions in selenium loads within the Delta would not be affected by any of the Options. Currently, the most likely effective method for reducing selenium loads within the Delta would be source reduction in areas located upstream of the Delta.

Two factors affecting the degree of potential exposure of sturgeon to toxics include hydraulic residence time in habitat, which effects the period of exposure to toxics, and flows from the Sacramento River and other Delta tributaries, which can dilute concentrations of toxics. Measurements used to assess the potential effects of Option 1 on exposure to toxics included (1) PTM modeling results for CVP/SWP for particle fate in the central Delta, (2) Sacramento River flows at Rio Vista, and (3) Delta outflow during March and April. Overall, residence time within the central Delta under Option 1 was highly variable but on average similar to base conditions (sees Appendices D and H). Modeling results indicate that the toxics dilution potential of Option 1 would be similar to base conditions (see Appendices D and H).

Reduced Rearing Habitat

Results of fishery sampling conducted by CDFG suggest that the abundance of juvenile sturgeon within the Delta increases with increasing flow in the Sacramento River and Delta Inflows. The location of X_2 affects the location of the low salinity zone, and can be used as an indicator of habitat quality and availability for green and white sturgeon. Higher outflows tend to locate X_2 further downstream, which would potentially provide improved habitat for green and white sturgeon rearing during the late winter and spring. Hydrologic modeling results for Option 1 show that the change in location of X_2 in April relative to base conditions was 0.5 km upstream. This indicates that the low salinity zone would be similar to base conditions under Option 1.

3.1.5.3 Criterion #3. Relative degree to which the Option would increase habitat quality, quantity, accessibility, and diversity in order to enhance and sustain production (reproduction, growth, survival), abundance, and distribution; and to improve the resiliency of each of the covered species' populations to environmental change and variable hydrology.

Important stressors that cause non-natural mortality of green and white sturgeon (see Appendix C) are:

- Reduced spawning habitat
- Exposure to toxics,
- Reduced rearing habitat,
- Increased water temperature (upstream),
- Predation, and
- Reduced turbidity.

Within the planning area, green and white sturgeon habitat conditions are governed by hydrodynamic conditions and the extent and quality of habitat within the planning area. Under Option 1, these conditions relative to base conditions would be affected by the conveyance configuration of Option 1 and restoration of physical habitat that could be sited within Suisun

Bay and Marsh and within the planning area in the north and west Delta, which represents approximately 28% of the planning area.

Based on the following evaluation of Option 1 effects on applicable green and white sturgeon stressors, Option 1 is expected to provide low habitat benefits for green sturgeon and very low habitat benefits for white relative to base conditions.

Exposure to Toxics

As described under Criterion #2 above, the risk for exposure of sturgeon to toxics is similar to base conditions. A major source for bioaccumulation of selenium in sturgeon is consumption of non-native *Corbula* and *Corbicula* which capture selenium from Delta waters. Restoration of aquatic shallow subtidal and intertidal habitats could create conditions that favor the production of alternative prey (e.g., bay shrimp) that reduce the risk of bioaccumulation of materials such as selenium for juvenile and adult sturgeon. The potential success of reducing the risk of toxics on sturgeon through habitat improvements and increased production of alternative prey resources is uncertain. Under Option 1, habitat could potentially be restored within Suisun Bay and Marsh and approximately 28% of the Delta to provide high quality aquatic habitat under this option (Figure 1-2). Because habitat could be restored within a more limited geographic range than under the other Options, Option 1 would be expected to provide very low benefit to white sturgeon by reducing their exposure to selenium. Because green sturgeon are not known to inhabit the San Joaquin River watershed, restoration under Option 1 would provide a low level of benefit to green sturgeon, which would be the same as under Options 2 and 3, but less than under Option 4 which provides the ability to restore habitat in additional portions of the planning area occupied by green sturgeon.

Reduced Rearing Habitat

The primary impact mechanism believed to affect the extent of rearing habitat and rearing habitat conditions is the reclamation of historical aquatic subtidal and intertidal habitats and channelization of river channels. Under Option 1, habitat could potentially be restored within Suisun Bay and Marsh and approximately 28% of the Delta to provide high quality aquatic habitat under this Option (Figure 1-2), which encompasses a smaller proportion of white sturgeon rearing habitat than restoration that could be implemented under the other Options. Because the green sturgeon is not known to occupy the San Joaquin River watershed, restoration opportunities would be the same under Option 1 as under Options 2 and 3, but less than under Option 4, which includes restoration opportunities in the east Delta north of the San Joaquin River. Consequently, relative to base conditions and the other Options, Option 1 would be expected to provide a very low benefit for white sturgeon rearing habitat and a low benefit for green sturgeon rearing habitat.

3.1.5.4 Criterion #4. Relative degree to which the Option would increase food quality, quantity, and accessibility (e.g., phytoplankton, zooplankton, macro-invertebrates, forage fish) to enhance production (reproduction, growth, survival) and abundance for each of the covered fish species.

Reduced food availability or quality are not identified as important stressors for green and white sturgeon. Consequently, benefits of increasing food quantity and quality under the

Options would not be expected to result in a population level response relative to base conditions.

3.1.5.5 Criterion #5. Relative degree to which the Option would reduce the abundance of non-native competitors and predators to increase native species production (reproduction, growth, survival), abundance and distribution for each of the covered fish species.

Predation in the form of illegal and legal harvest would not be changed under any of the Options from base conditions.

3.1.5.6 Criterion #6. Relative degree to which the Option improves ecosystem processes in the BDCP planning area to support aquatic and associated habitats.

Measurements used to assess the potential for Option 1 to improve ecosystem processes included (1) PTM modeling results for hydraulic residence time in the central Delta and (2) the proportion of the Delta expected to be potentially available for restoration of aquatic subtidal and intertidal habitat. Based on the proportion of the planning area suitable for restoration under Option 1 relative to the other Options and modeling results for hydraulic residence time (see Appendix H), Option 1 would be expected to provide a very low beneficial improvement in ecosystem function relative to base conditions because although habitat restoration under Option 1 would improve ecosystem processes, hydraulic residence time and flow patterns within the Delta would be similar to base conditions. Under Option 1, Delta channels would continue to serve as the water conveyance facilities for freshwater supplies moving from the Sacramento River across the Delta to the export facilities located in the southern Delta. Movement of large volumes of water through these channels would adversely affect hydraulic conditions within the Delta (e.g., reverse flows), salinity levels and distribution, the need for riprapped levees to reduce erosion and levee scour, and limit the opportunities for habitat enhancement. The hydraulic conditions within the Delta under these operations would also continue to result in reduced hydraulic residence times and the export of nutrients, organic carbon, phytoplankton, and zooplankton from the Delta and thereby affect aquatic food production and availability.

3.1.5.7 Criterion #7. Relative degree to which the Option can be implemented within a timeframe to meet the near-term needs of each covered fish species (post BDCP authorization).

Habitat restoration under Option 1 can be initiated immediately following authorization of the BDCP and thus could be implemented in a manner that would meet the near term needs of green and white sturgeon. The implementation period for implementation of Option 1 is the same as the other Options.

3.1.6 Splittail

Based on the evaluation presented below of the expected performance of Option 1 for addressing important Sacramento splittail stressors, Option 1 would be expected to have a very low beneficial effect on Sacramento splittail production, distribution, and abundance relative to base conditions when operated to meet water supply objectives (Scenario A). If water supply exports are reduced (Scenario B), Option 1 would be expected to provide a low beneficial effect on splittail production, distribution, and abundance relative to base conditions. Option 1 would be expected to provide the lowest benefits for splittail compared to the other Options.

Stressors that affect Sacramento splittail are presented in Figure 2-9 and are described in Appendix C. The effect of these stressors on the splittail population vary among years in response to environmental conditions (e.g., seasonal hydrology) and may also interact with each other in additive or synergistic ways. The effects of these stressors include both the incremental contribution of a stressor to the population as well as the cumulative effects of multiple stressors over time. The assessment of Option 1 evaluates the degree to which Option 1 would be expected to address these stressors.

Table 3-9 summarizes the expected effects of implementing Option 1 under Scenarios A and B on important delta smelt stressors relative to base conditions.

Table 3-9. Summary of Expected Effects of Option 1 on Highly and Moderately Important Splittail Stressors

Applicable Criteria	Stressor[1]	Option Effects on Important Species Stressors Relative to Base Conditions	
		Scenario A	Scenario B
Highly Important Stressors			
2,3	Reduced juvenile rearing/adult habitat	Low benefit	Low benefit
2,3	Reduced spawning/larval rearing habitat	Low benefit	Moderate benefit
1,4	Reduced food	Very low benefit	Low benefit
1,2	Exposure to toxics	No net effect	Low benefit
Moderately Important Stressors			
1,5	Predation	Low benefit	Low benefit
1,4	SWP/CVP entrainment[2]	Very low benefit	Low benefit
1	Harvest	No net effect	No net effect

Notes:

1. See Appendix C for descriptions of stressors, stressor impact mechanisms, and stressor effects.
2. It is recognized that the risk of entrainment at the SWP and CVP export facilities may be a high level stressor to splittail in some years and a very low level stressor to splittail in other years. For purposes of this analysis, the risk of delta smelt entrainment has been characterized, on average, as a moderate level stressor to the population.

The Delta provides habitat for larval, juvenile, and adult Sacramento splittail. Splittail spawn primarily in seasonally inundated vegetation along channel margins and floodplain habitat located upstream within the Sacramento and San Joaquin river watersheds.

Harvest is not an important stressor that would be affected by or affected differently under the Options and, therefore, is not described in the criteria evaluations below (see Table 2-3 and Appendix C). Harvest is initially identified under the applicable criteria below, but is not evaluated under the criteria.

3.1.6.1 Criterion 1. Relative degree to which the Option would reduce species mortality attributable to non-natural mortality sources, in order to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species.

Important stressors that cause non-natural mortality of Sacramento splittail (see Appendix C) are:

- Reduced food availability,
- Exposure to toxics,
- Predation,
- Entrainment by CVP/SWP facilities, and
- Harvest.

Based on the following evaluation of Option 1 effects on applicable splittail stressors, Option 1 is expected to provide very low benefits relative to base conditions by reducing the effects of non-natural sources of mortality on splittail.

The stressors that have been identified that contribute to non-natural mortality of Sacramento splittail include starvation as a result in reductions in the quantity and/or quality of available prey, exposure to toxics, predation by non-native species, risk of SWP/CVP entrainment, and harvest (Appendix C). The affect of these stressors on the splittail population vary among years in response to environmental conditions (e.g., seasonal hydrology) and may also interact with each other in additive or synergistic ways. No single stressor has been identified, with confidence, as the primary factor affecting the current status of splittail, although there is a strong relationship between the frequency and duration of seasonally inundated floodplains and the abundance of juvenile (young-of-the-year [YOY]) splittail within the Delta (Sommer et al. 1997, 2001). The effects of these stressors include both the incremental contribution of a stressor to the population as well as the cumulative effects of multiple stressors over time. The assessment of Option 1 evaluated the degree to which the option addressed these stressors.

Reduced Food Availability

Habitat conditions can affect the availability and quality of splittail food. The effects of Option 1 on splittail food availability are evaluated under Criterion #4 below. As described in the Criterion #4 evaluation, Option 1 would be expected to provide a very low beneficial effect on food supply for the splittail relative to base conditions.

Exposure to Toxics

The effect of Option 1 on exposure to toxics is addressed below under Criterion 2. Overall, toxic exposure would not be expected to change under Option 1, providing no benefits to splittail.

Predation

Under Option 1, approximately 28% of the Delta would potentially be available for restoration/enhancement (Figure 1-2), which, if designed properly, would reduce predation risk and adverse impacts of by non-native species. This entire area would be located within the geographic range of splittail within the northern and western regions of the Delta. Relative to the proportion of the splittail range within which habitat could be restored in the planning area, restoration under Option 1 would be expected to provide a low benefit for potentially reducing predation relative to base conditions and the other Options. However, there is a high degree of uncertainty regarding the biological response of splittail, other native fish and macroinvertebrate species, and non-native species to large-scale habitat restoration/ enhancement within the Delta.

Entrainment by CVP/SWP Facilities

Hydrologic model output indicates that the magnitude of reverse flows in Middle and Old rivers under Option 1 is expected to be marginally lower relative to base conditions (see Appendices D and H). The actual numbers of juveniles expected to be entrained at the SWP and CVP export facilities is expected to increase in proportion to the abundance (year class strength) of splittail in a given year (Sommer et al. 1997, Moyle et al. 2004). Therefore, few splittail are expected to be entrained when the overall population of juvenile splittail in a year is low, but large numbers may be expected to be entrained when the juvenile population is high. As a result, the risk of entrainment at the export facilities is not expected to be a significant factor in the relative reduction of population abundance in most years. During periods of extended drought during which little or no splittail production occurs and the adult population is reduced, however, a reduction in the entrainment of adults could measurably increase the reproductive potential of the population to recover following the drought period.

3.1.6.2 Criterion #2. Relative degree to which the Option would provide water quality and flow conditions necessary to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species.

Factors that influence water quality conditions include dissolved oxygen, salinity, water temperature, and turbidity. Changes in these conditions are not expected to be major stressors to splittail (Appendix C) because they are well adapted to living in a highly variable tidally influenced estuarine environment (Sommer et al. 1997, Moyle et al. 2004).

Important stressors of splittail that are affected by water quality and flow conditions include (see Appendix C):

- Exposure to toxics
- Reduced juvenile rearing/adult habitat, and
- Reduced spawning/larval rearing habitat.

Based on the following evaluation of Option 1 effects on applicable splittail stressors, Option 1 is expected to no overall effect water quality and flow conditions that support splittail relative to base conditions.

Exposure to Toxics

Although there is strong support from laboratory studies that toxics can be lethal to splittail (Teh et al. 2002, 2004a,b, 2005), there is little information about the toxicity within the Delta (but see Greenfield et al. in review). Although reductions in the potential exposure of splittail and other species to toxics is expected to be most effective through source control, the risk of mortality from exposure to toxics would be expected to be reduced under conditions when higher Sacramento River flows and Delta inflows increased dilution of toxics within the Delta. For purposes of this analysis two metrics were used from the hydrologic modeling of Option 1 to assess potential changes from base conditions: flow in the Sacramento River at Rio Vista and Delta inflow during March and April. Under Option 1, flows at Rio Vista and total Delta inflow were generally equal to base conditions during March and April, (splittail spawning and YOY rearing season). This indicates that operating the Delta according to Option 1 would be expected to have no effects on the exposure of splittail to toxics.

Reduced Rearing Habitat

Reduced spring flows can reduce the rate of downstream transport of early juvenile splittail to high quality rearing habitat in the western Delta and Suisun Bay. Lower flows are expected to increase the residence time of young splittail in areas of lower productivity and food supplies within the upstream rivers and central Delta, and may lead to an increased risk of entrainment at the SWP/CVP export facilities, exposure to lower environmental conditions that could reduce growth and survival, and increased probability of exposure to contaminants toxics derived from upstream areas and within the Delta (Moyle et al. 2004). Hydrologic model output for Sacramento River flows at Rio Vista and total Delta outflow during March and April were used in the analysis of potential differences in downstream transport flows relative to base conditions. Particle tracking results were not used in this part of the analysis because, unlike larval delta and longfin smelt, juvenile splittail do not behave as neutrally buoyant particles and can actively swim downstream (Moyle et al. 2004). Results of hydrologic model simulations for Option 1 indicated that Rio Vista flows and total Delta outflows were generally similar to base conditions. These results indicate that transport of YOY splittail into the Delta from the upstream under Option 1 is expected to be similar to base conditions.

Reduced Spawning Habitat

Splittail primarily spawn in seasonally inundated floodplain habitat. Changes in hydrologic conditions within the watersheds (e.g., operation of reservoirs for flood control) and construction of levees have reduced the availability and access of floodplains for splittail spawning. Peak Delta inflows under Option 1 were nearly identical to base conditions between January and March, resulting in no expected change in the frequency or duration of floodplain inundation under this Option.

3.1.6.3 Criterion #3. Relative degree to which the Option would increase habitat quality, quantity, accessibility, and diversity in order to enhance and sustain production (reproduction, growth, survival), abundance, and distribution; and to improve the resiliency of each of the covered species' populations to environmental change and variable hydrology.

Important stressors that affect splittail habitat quality, quantity, accessibility, and diversity (see Appendix C) are:

- Reduced juvenile rearing/adult habitat,
- Reduced spawning/larval rearing habitat, and
- Reduced food availability.

Within the planning area, splittail habitat conditions are governed by hydrodynamic conditions and the extent and quality of habitat within the planning area. Under Option 1, these conditions relative to base conditions would be affected by the conveyance configuration of Option 1 and restoration of physical habitat that could potentially be sited within Suisun Bay and Marsh and within 28% of the planning area in the north and west Delta.

The quality, quantity, diversity, and accessibility of both spawning and rearing habitat for splittail within the Delta has been reduced substantially as a result of reclamation and channelization of Delta waterways and changes in flows resulting from flood control operations. Increasing the quantity, quality, and accessibility of rearing and spawning habitat would be expected to provide the single best opportunity to promote splittail population increases.

Based on the following evaluation of Option 1 effects on applicable splittail stressors, Option 1 is expected to provide low benefits relative to habitat conditions for the splittail.

Reduced Rearing Habitat

One way to estimate the ability of Option 1 to increase the availability of splittail rearing habitat is by comparing the percentage of habitat potentially available for restoration under this Option. Approximately 28% of the Delta would be potentially available for restoration/enhancement under Option 1, which is the lowest among the four Options evaluated. However, a large proportion of the potential area would be accessible and suitable rearing habitat for splittail. Therefore, this Option would be expected to provide a low benefit to splittail in terms of increased rearing habitat. Improved access to rearing habitat can be accomplished, in part, by increasing net downstream transport. As shown above, downstream transport under Option 1 was expected to be similar to base conditions.

Reduced Spawning Habitat

High quality splittail spawning habitat occurs on floodplains and other flow-dependent habitat (Sommer et al. 1997, 2001, 2003, Harrell and Sommer 2003, Moyle et al. 2004, 2007). Access to this habitat is only available in higher flow years. In drier years, spawning occurs, but is limited to river edges and backwaters created by slightly increased flows (Moyle et al. 2004). As discussed under Criterion 2 above, peak inflows during January through March were approximately equal to base conditions, resulting in no expected change in floodplain availability under Option 1. Further, a portion of the area potentially available for restoration under Option 1 is within spawning range of splittail. Therefore, it is expected that the Option would provide low benefit to spawning habitat.

Reduced Food Availability

Habitat conditions can affect the availability and quality of splittail food. The effects of Option 1 on splittail food availability are evaluated under Criterion #4 below. As described in the Criterion #4 evaluation, Option 1 would be expected to provide a very low beneficial effect on food supply for the splittail relative to base conditions.

3.1.6.4 Criterion #4. Relative degree to which the Option would increase food quality, quantity, and accessibility (e.g., phytoplankton, zooplankton, macro-invertebrates, forage fish) to enhance production (reproduction, growth, survival) and abundance for each of the covered fish species.

The important stressor for splittail that affects food quality, quantity, and accessibility is reduced food availability (see Appendix C).

Based on the following evaluation of Option 1 effects on applicable splittail stressors, Option 1 is expected to provide very low benefits relative to food supply for the splittail. In low flow years, Option 1 would be expected to provide very low benefit for food availability to splittail and, therefore, would marginally reduce starvation mortality. In higher flow years when floodplains are inundated sufficiently, food supplies are not expected to be a major factor limiting splittail.

Reduced Food Availability

Reduced food availability can result from at least four mechanisms:

- frequency and extent of floodplain inundation,
- competition with non-native species,
- nutrient and food exports from CVP/SWP pumps and in-Delta agricultural diversions, and
- hydraulic residence time.

The degree to which food is limiting to splittail remains poorly understood (Moyle et al. 2004). It is thought that year class strength of splittail is primarily a function of frequency and duration of floodplain inundation (Sommer et al. 1997). In addition to providing spawning habitat, floodplain inundation provides larval rearing and foraging habitat. Floodplains are highly productive and beneficial seasonal habitat for juvenile splittail, salmonids and other fish (Sommer et al. 2001, Harrell and Sommer 2003) and are a source of allochthonous nutrients and organic carbon production from the terrestrial community Therefore, year-class strength may be limited to some degree by the availability of food to YOY splittail from seasonally inundated floodplains. Reduced frequency of floodplain inundation has resulted from water storage and flood protection practices by reducing the magnitude of peak flows, as well as construction of levees designed to protect floodplains from inundation. As presented above, peak Delta inflow under Option 1 would be similar to base conditions during this period (see Appendices D and H). Therefore, relative to base conditions, Option 1 would not be expected to change food availability from floodplain inundation.

With respect to the effects of non-native species on food quantity, quality, and availability to splittail, one of the major mechanisms contributing to a recent reduction in phytoplankton, zooplankton, and macroinvertebrates within the Delta has been the introduction of the overbite clam, *Corbula amurensis*. However, Kimmerer (2002) found no reduction in overall splittail population abundance after the *Corbula* invasion, unlike reductions in delta and longfin smelt. Individual growth rates of splittail have declined since the 1980s, suggesting that food supplies may have become increasingly limited (Moyle et al. 2004). *Neomysis mercedis*, a mysid shrimp known to be the primary prey species of splittail, collapsed concurrently with the invasions of a variety of lower quality non-native zooplankton species (Feyrer et al. 2003). Due to the high rate of non-native species invasions into the Delta, it is reasonable to assume that there is a causal link between these invasions, changes in the quantity and quality of prey available to splittail, and splittail abundance and year-class strength. Although the ability to manage or control non-native species within the Delta is extremely limited, one method for mitigating the adverse effects of these non-native species is through restoration and enhancement of habitat and hydrologic conditions for native species. Under Option 1, approximately 28% of the Delta would potentially be available for restoration/enhancement (Figure 1-2). This area is primarily located in the northern (e.g., Cache Slough region) and western Delta (e.g., Suisun Marsh). Both regions appear to have high habitat value for splittail and would, therefore, directly increase potential habitat for splittail rearing and foraging (Sommer et al. 1997, 2001, Moyle et al. 2004). As a result, Option 1 would be expected to have a low benefit to increasing habitat and potentially reducing the impact of non-native species on the quantity and quality of prey available to splittail. Restoration of shallow subtidal and intertidal habitats under Option 1 would also be expected to improve food supply.

In addition to exporting water, SWP/CVP diversions and over 2200 agricultural diversions throughout the Delta (Herren and Kawasaki 2001) potentially export nutrients, organic material, phytoplankton, and zooplankton that can support the base of the food web of the Delta, providing food to support the multi-aged population of splittail inhabiting the Delta (Jassby et al. 2002, POD Action Plan 2007). Because food supplies may only be limiting under drier, lower flow conditions when floodplains are not inundated, it is reasonable to assume that increasing exports of food would be important to splittail food production primarily during these periods. Particle tracking model output under the lowest water supply scenario (50% exceedance) indicates that exports of food organisms, nutrients, and organics under Option 1 are marginally lower relative to base conditions (see Appendices D and H). As a result, Option 1 provides a very low benefit to splittail by reducing exports of food during drier hydrologic conditions.

Increased residence time is expected to increase the conversion of nutrients and organics more effectively and stimulate production of phytoplankton and zooplankton. Because food supplies may only be limiting under drier, lower flow conditions when floodplains are not inundated, it is reasonable to assume that increasing residence time would be important to splittail food production primarily during these periods. Particle tracking model results indicates that there would be no difference under Option 1 relative to base conditions, indicating that this Option would not be expected to change residence time and, therefore, productivity in the Delta under drier conditions.

3.1.6.5 Criterion #5. Relative degree to which the Option would reduce the abundance of non-native competitors and predators to increase native species production (reproduction, growth, survival), abundance and distribution for each of the covered fish species.

Non-native competitors and predators are an impact mechanism for splittail predation and harvest stressors (see Appendix C).

Based on the following evaluation of Option 1 effects on applicable splittail stressors, Option 1 is expected to provide low benefits for the splittail relative to the abundance of non-native competitors and predators.

Despite the large number of non-native species that have been introduced into the Delta and Estuary, splittail have persisted (Moyle et al. 2004). Major predators of splittail are non-native species such as striped bass and centrarchids (e.g., largemouth bass and sunfish). Further, food quantity and quality may be influenced by non-native species (see above). Restoration and enhancement of habitat and natural hydrologic conditions could be implemented to decrease habitat conditions for non-native species and to the benefit of native species. Under Option 1, habitat could potentially be restored within 28% of the Delta (Figure 1-2). This entire area would be within the range of splittail and could, therefore, potentially be expected to provide a low benefit to splittail populations. There is, however, a high degree of uncertainty regarding the biological response of native species such as splittail and their prey, and non-native species of competitors and predators, to large-scale habitat modification within the Delta.

3.1.6.6 Criterion #6. Relative degree to which the Option improves ecosystem processes in the BDCP planning area to support aquatic and associated habitats.

Measurements used to assess the potential for Option 1 to improve ecosystem processes included (1) PTM modeling results for hydraulic residence time in the central Delta and (2) the proportion of the Delta expected to be suitable for restoration of aquatic subtidal and intertidal habitat. Based on the proportion of the planning area available for potential restoration under Option 1 relative to the other Options and modeling results for hydraulic residence time (see Appendix H), Option 1 would be expected to provide a very low beneficial improvement in ecosystem function relative to base conditions because although habitat restoration under Option 1 would improve ecosystem processes, hydraulic residence time would be similar to base conditions. Under Option 1, Delta channels would continue to serve as the water conveyance facilities for freshwater supplies moving from the Sacramento River across the Delta to the export facilities located in the southern Delta. Movement of large volumes of water through these channels would adversely affect hydraulic conditions within the Delta (e.g., reverse flows), salinity levels and distribution, the need for riprapped levees to reduce erosion and levee scour, and limit the opportunities for habitat enhancement. The hydraulic conditions within the Delta under these operations would also continue to result in reduced hydraulic residence times and the export of nutrients, organic carbon, phytoplankton, and zooplankton from the Delta and thereby affect aquatic food production and availability.

3.1.1.39 Criterion #7. Relative degree to which the Option can be implemented within a timeframe to meet the near-term needs of each covered fish species (post BDCP authorization).

Habitat restoration under Option 1 can be initiated immediately following authorization of the BDCP and thus could be implemented in a manner that would meet the near term needs of splittail. The implementation period for implementation of Option 1 is the same as the other Options.

3.2 PLANNING CRITERIA

3.2.1.1 Criterion #8: Relative degree to which the Option allows covered activities to be implemented in a way that meets the goals and purposes of those activities

Option 1 is anticipated to have the least ability to meet CVP/SWP water supply goals of all the Options.

Option 1 was modeled for water operations less restrictive of exports (Scenario A) and water operations more restrictive of exports (Scenario B). The ability of Option 1 to achieve the water delivery reliability and facility operation goals of the CVP/SWP is highly dependent on regulatory constraints to operations imposed by regulatory or judicial requirements (e.g., timing and quantity of water pumping to meet endangered species and water quality regulations). Although future regulatory restrictions are not known, recent court decisions applicable to Delta water management suggest that Option 1 would likely be implemented only with continued or increased operational restrictions to meet regulatory requirements (e.g., Natural Resources Defense Council versus Kempthorne). Therefore, water supply reliability under Option 1 is anticipated to be closer to the model outputs for Scenario B. Based on this assumption, Option 1 would have the least ability of the 4 Options to meet CVP/SWP water delivery goals.

Under operations and restrictions similar to existing conditions, Option 1 is expected to provide equivalent water delivery reliability as compared to current conditions (Figure 3-1). Hydrodynamic modeling results under Scenario A indicate the potential for increased long-term average CVP/SWP exports of up to 110 TAF/YR (thousand acre-feet/year), but since operations under this scenario are not likely to be authorized by current or projected regulatory restrictions, these export gains would not likely be realized. The operation of CVP/SWP Delta water project facilities under Scenario A exhibited greater flexibility primarily due to the removal the export-inflow ratio constraints as a model input. Export water quality is also expected to be similar to that under current conditions (Figure 3-2).

Under Option 1, as modeled under Scenario B, water delivery reliability and operational flexibility would be substantially reduced. Under Option 1, as modeled under Scenario B, long-term export water deliveries could be reduced by approximately 3.8 MAF/YR (million acre-feet/year). The primary cause of the reduced water delivery reliability is the restrictions on the

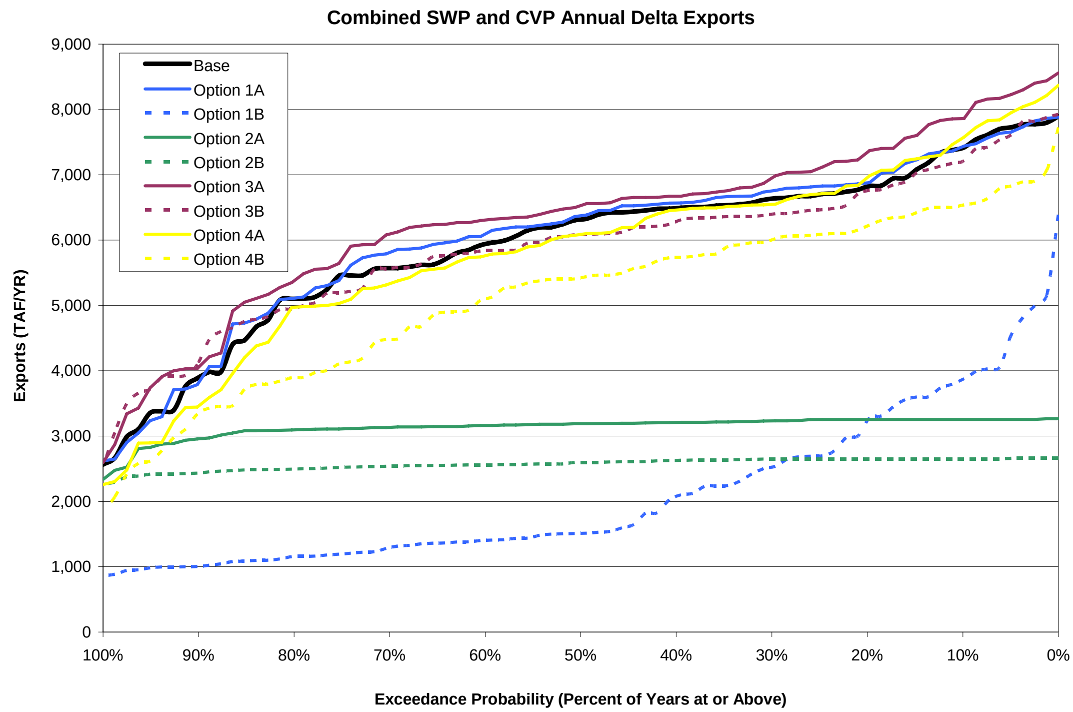

Figure 3-1. Export reliability (exceedance probability) curves for base conditions and the four Options.

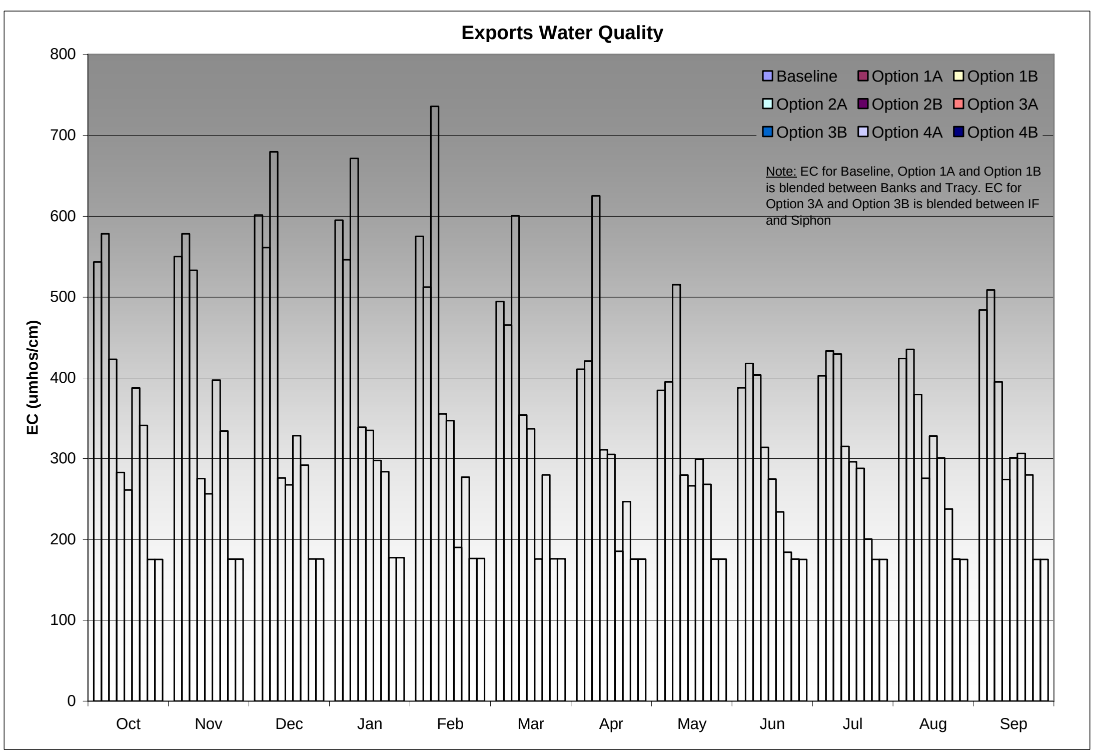

Figure 3-2. Export water quality under base conditions and the four Options.

magnitude of reverse flows in Old and Middle Rivers assumed in the model inputs. To a lesser extent, the model restrictions on reverse flows in the lower San Joaquin River (QWEST) limit the ability to export water from the south Delta. Under these conditions, deliveries to senior water right holders (CVP Water Rights and Exchange contractors) as well as CVP Refuge deliveries are not likely to be fulfilled, while deliveries to other CVP/SWP contractors (Agricultural and Municipal & Industrial) would be reduced to near zero amounts. Water quality in the south Delta is also expected to become degraded in the winter and spring as compared to current conditions as lower export rates limit the amount of Sacramento River water that is circulated in this region.

Option 1, as modeled with reduced restrictions on exports (Scenario A), would provide similar water delivery reliability to the CVP/SWP pumps as Option 3, slightly better than Option 4, and significantly better than Option 2. However, Option 1, under the more restrictive operations (Scenario B), would have the lowest CVP/SWP water delivery reliability of all Options. As described above, it is anticipated that operations under Option 1 would need to be more restricted due to regulatory constraints and, therefore, Option 1 performance would be the poorest of the 4 Options.

3.2.1.2 Criterion #9: The relative feasibility and practicability of the Option, including the ability to fund, engineer, and implement

While Option 1 may appear to be highly feasible and practicable based on its low construction cost and lack of new infrastructure, this Option has several challenges to its feasibility most importantly its questionable ability to meet planning and conservation goals within substantial ongoing input of resources.

Option 1 would use the existing Delta configuration and infrastructure to continue the long effort to achieve both species and habitat conservation and CVP/SWP water supply goals. These dual goals have not been accomplished after many years of effort under various other programs. With its relatively limited range of proactive actions, successful regulatory authorizations of Option 1 are less likely than other Options and make Option 1 less feasible as a solution for habitat conservation and water supply reliability. The more narrowly focused geographic area for habitat restoration under Option 1 limits the flexibility in choosing restoration sites; therefore, selection of the most cost-effective habitat restoration sites under Option 1 is less practicable than under the other options. The extensive permitting, engineering, and costs associated with construction of new facilities under the other Options adversely affect the feasibility and practicability compared to Option 1. Cost practicability of Option 1 is addressed in Criterion #10, below. Option 1 is estimated to be the most costly Option over the long term. For these reason, Option 1 is considered the least feasible and practicable of the four Options.

3.2.1.3 Criterion #10: Relative costs (including infrastructure, operations, and management) associated with implementing the Option

Delta Infrastructure Costs

Option 1 is expected to have the lowest infrastructure costs of the four Options. Option 1 would use existing export facilities (Jones and Banks Delta Pumping Plants) in the South Delta. No new Delta facilities are described under Option 1 in the report *Descriptions of Potential BDCP Conservation Strategy Options* (BDCP May 2007). However, there are several conceivable Delta infrastructure improvements that could be relevant to implementation of Option 1, including levee strengthening and improvements in CVP and SWP fish screens and salvage facilities.

Because levee improvements are not included as part of Option 1, it has the lowest construction costs of the four Options, but also is expected to have the highest catastrophic event impact costs, as discussed below. Possible improvements to screening and fish salvage facilities at CVP and SWP intakes are described in the DRMS Phase II report (DRMS Phase II 2007).[4] The cost of potential screening and fish salvage improvements at the Jones Pumping Plant are on the order of $290 million (2007 dollars).[5] A new fish facility at the head of Clifton Court Forebay could cost in excess of $1 billion (DRMS Phase II 2007).[6] The total construction cost to improve CVP and SWP screening and salvage facilities could be on the order of $1.3 billion.

Delta Conveyance Disruption Costs

While Option 1 entails the lowest construction cost because no new facilities are currently proposed, it would also be the most vulnerable to flood and seismic events, which have a high probability of causing significant damage to levee infrastructure and disruption of water exports. Given existing Delta conveyance facilities, seismic events pose the greatest risk to Delta water exports.[7] Analysis done for DRMS Phase 1 (DRMS Phase I Report June 2007) indicated that a seismic event resulting in the simultaneous flooding to ten or more islands could shut down water exports for up to 10 months. The probability of such an event occurring in the next 25 years was estimated to be between 50% and 60%. Flooding of 20 or more islands could shut down water exports for up to 2 years. The probability of such an event occurring in the next 25 years was estimated to be between 30% and 40%. DRMS estimated the ten-island scenario would reduce Delta water exports during the repair and recovery period by 0.7 to 2.5 MAF/YR. For the case of 20 or more flooded islands, DRMS estimated that exports from the Delta would fall by between 6.3 and 9.3 MAF/YR during the repair and recovery period. State-wide economic impacts from such events were estimated to range between $10 and $50 billion.

Export Water Quality Costs

Based on BDCP hydrodynamic modeling results, Option 1 would provide only a negligible improvement in export water quality relative to existing conditions.[8] Option 1, therefore, would not provide the large savings in municipal water treatment costs expected under Options 2, 3,

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[4] Fish screen improvements and costs are discussed in Section 15 of the DRMS Phase II report.

[5] The estimate is based on improvements described in a 1998 report prepared by the United States Bureau of Reclamation's (USBR's) Tracy Fish Facility Team (USBR November 1998). USBR, *A Proposed Technology Facility to Support Improvement and/or Replacement of Fish Salvage Facilities at Tracy and Other Large Fish Screening Sites in the Sacramento-San Joaquin Delta, California*, prepared by the Tracy Fish Facility Team, November 18, 1998.

[6] The DRMS Phase II report is the source of this estimate. Costs for Clifton Court Forebay improvements are very preliminary and DRMS noted that technically feasible facilities have yet to be determined. DWR investigations cited by DRMS found high unit costs, ranging between $50,000 and $90,000/cfs, due to extensive changes to the fish collection system, scale of construction, and geotechnical challenges posed by south Delta soils.

[7] Flood events had much lesser impacts on Delta exports because high water flows prevented significant saltwater intrusion from occurring in the southern part of the Delta.

[8] This finding is based on CALSIM modeling result summarized in BDCP-ModelingResults_082707.ppt.

and 4. Under the other Options, these savings could be between $1.0 and $2.5 billion over the next 25 years. Relative to the other three Options, Option 1 is, therefore, expected to result in the highest export water quality costs.

Habitat Restoration Costs

The evaluation assumes that the overall amount of habitat restoration would be roughly the same across the four Options although the locations could differ. Therefore, cost estimates for habitat restoration that were developed with currently available information do not distinguish Option 1 from the other three Options. While the unit costs of restoration may vary to some degree according to the range and location of the restoration activity, sufficient information on unit restoration cost differentials is not available at this time to distinguish among the four Options. Thus, habitat restoration costs are not treated as a significant distinguishing feature among the four Options.

3.3 FLEXIBILITY/DURABILITY/SUSTAINABILITY CRITERIA

3.3.1.1 Criterion #11: Relative degree to which the Option will be able to withstand the effects of climate change (e.g., sea level rise and changes in runoff), variable hydrology, seismic events, subsidence of Delta islands, and other large-scale changes to the Delta

Among the four Options, Option 1 is expected to have the least ability to withstand large-scale changes to the Delta that would adversely affect species conservation and covered activities. The extent of levees supporting Option 1 conveyance that are subject to breaching or overtopping during flood events is greater than under the other Options because all (Option 4) or portions (Options 2 and 3) of conveyance infrastructure would be engineered to withstand floods. The probability of flood-induced levee failures is expected to increase in the future based on climate change-induced sea level rise and river hydrology change (DRMS Draft Stage I Report 2007). Option 1 would have to incorporate substantial financial investments in levee improvements to approach the durability levels that could be achieved by other Options.

Risk to Habitat Restoration Actions

Under Option 1, habitat restoration would be focused in the north Delta and Suisun Marsh and is expected to have the narrowest geographic distribution among the Options. A levee failure at or near restoration sites may have a disproportionate adverse effect under Option 1 because restoration sites are geographically more concentrated than in other Options. Similarly, Option 1 would provide less flexibility to adjust flow operations in restored habitat in the event of levee failure(s) caused by flooding or seismic events than would be provided by the other Options because of the more localized habitat restoration sites. All Options, however, include restoration outside the planning area at Suisun Marsh, an area that likely is less subject to habitat loss from seismic or flood events than much of the planning area.

Protecting physical habitat restoration against the effects of sea level rise requires that restoration sites be located at higher elevations (sites in the Delta with less subsidence) and along elevation gradients that include an ecotone between tidal and upland habitat. Restoration sites in such locations would allow the gradual upward elevation shift of all tidal habitats in response to sea level rise over time. The limited geographic focus of habitat restoration under

Option 1 relative to other Options reduces the number and extent of sites with such elevation characteristics available for habitat restoration in the Delta and, therefore, restoration would be less durable.

Risk to Water Supply Infrastructure

Option 1 would provide the least protection of the four Options to water supply facilities from seismic or flood events and from the ongoing effects of sea level rise. Levee failure from a seismic event during low Delta inflow/outflow periods (seasonally in all years and most of year in dry and critical dry years) poses the greatest risk to water export facilities in the south Delta; Option 1 provides no new protection to these facilities from levee failure and the subsequent expected intrusion of saline water up to the pumping facilities (DRMS Draft Stage I Report 2007). The other Options provide new protections to water conveyance facilities through operable gates, improved levees, and a peripheral aqueduct. These protections are not provided by Option 1 and, therefore, make Option 1 less durable and less sustainable for water supply than the other options.

3.3.1.2 Criterion #12: Relative degree to which the Option could improve ecosystem processes that support the long-term needs of each of the covered species and their habitats with minimal future input of resources

Of the 4 Options, Option 1 appears to be the least sustainable without an ongoing input of resources for the following reasons:

1. Depending on location, existing and restored habitat that supports covered species may be influenced by Delta pumping to a greater extent than under the other three Options. Therefore, Option 1 would likely face continued seasonal pumping restrictions and would require continued funding of water acquisitions for environmental purposes.

2. Habitat management and restoration under Option 1 would be more limited than under the other three Options and thus could prevent or slow the recovery of covered species that are dependent on improved in-Delta habitat conditions.

3. Option 1 likely would continue to entrain fish, including covered species, at a higher rate than under all other Options and, therefore, would require continual funding for trucking, hauling, and release of fish.

4. Option 1 would have greater ongoing costs associated with managing for harmful invasive species than Options 2, 3, or 4. This is because Option 1 provides the least opportunity to use variable salinity regimes in the Delta as a tool to control invasive species. The more stable hydrological conditions under Option 1 limit the ability to adaptively manage the hydrologic regime for the control of invasive species and, therefore, require that repeated and likely more costly on-site measures be taken to achieve similar control.

3.3.1.3 Criterion #13: Relative degree to which the Option can be adapted to address needs of covered fish species over time

Option 1 is expected to be the least flexible and adaptable among the Options to address possible future conservation of the covered fish species.

Relative to the other Options, a substantially smaller percentage of land area within the Delta is available for restoring high function habitat under Option 1. Therefore, the ability to increase the extent of restored habitat for covered species in the future would be constrained to fewer possible sites. Because of the geographic limitations for habitat restoration to the west and north Delta and Suisun Marsh under Option 1, there is less adaptability than other Options to restore habitat in other geographic portions of the Delta that may be identified in the future as important to the conservation of covered species.

The flexibility to adjust Delta hydrology is substantially constrained by the need to maintain through-Delta flow conveyance to the south Delta pumping facilities. Consequently, additional infrastructure would be required to manage flow patterns to adaptively improve ecological process and benefit covered species while maintaining conveyance through the Delta to the water export facilities.

3.3.1.4 Criterion #14: Relative degree of reversibility of the Option once implemented

Option 1 is the most reversible among the Options because no new conveyance infrastructure would be constructed. Consequently, no removal or demolition of facilities would be required. Public acceptance would likely be high because there would be no physical effects on infrastructure. Costs to reverse the Option are expected to be minimal.

3.4 OTHER RESOURCES IMPACTS CRITERIA

3.4.1.1 Criterion #15: Relative degree to which the Option avoids impacts on the distribution and abundance of other native species in the BDCP planning area

If Option 1 were implemented with flow requirements similar to current conditions, then the probability of adverse impacts on other native aquatic species within the Delta under Option 1 is expected to be similar to existing conditions and greater than under the other Options.

Implementation of Option 1 is not expected to result in changes to the distribution and abundance of other native aquatic species within the Delta relative to changes occurring under existing Delta conditions. Because other native fishes are entrained at the SWP/CVP export facilities (DFG file data), reduced exports compared to current conditions that could be provided for within the range of possible operations could be beneficial for native aquatic species as a result of reducing the risk for their entrainment. Minor adverse impacts on native aquatic species could result from increased entrainment potential and reduced food production (see evaluation of biological criteria) during periods that exports exceed current conditions. These impacts are expected to be minor because the proportionate potential increase in exports from current conditions is small (see Figure 3-1).

Under Options 2, 3, and 4, the volumes of water exported from the south Delta are substantially less than under Option 1 and current conditions. Consequently, the likelihood for entrainment of other native aquatic species in the south Delta would be greater under Option 1 than under the other Options. Option 1, however, would result in less entrainment of fish from the central Delta than Options 2 and 3 where Options 2 and 3 result in increased reverse flows in Middle River.

The level of adverse impacts on terrestrial native species within the Delta are expected to be the lowest under Option 1 relative to the other options because Option 1 does not include new facility construction that could remove existing habitat or disturb wildlife.

3.4.1.2 Criterion #16: Relative degree to which the Option avoids impacts on the human environment

The types of adverse impacts as defined under the California Environmental Quality Action (CEQA) and the National Environmental Protection Agency (NEPA) on the human environment that could be associated with Option 1 are described in this section.[9] Potential impacts described here for Option 1 would not necessarily be significant or could be reduced to less-than-significant levels through CEQA/NEPA mitigation measures.

As defined for this evaluation, Option 1 would not require the construction of new facilities or any other type of ground-disturbing activities. Consequently, Option 1 is expected to incur no or minimal impacts on the following CEQA/NEPA impact categories:

- Geology/soils,
- Cultural resources,
- Air quality,
- Noise,
- Aesthetics,
- Hazards/hazardous materials,
- Transportation/traffic,
- Land use/planning,
- Recreation,
- Utilities and public services,

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[9] The evaluation of Criterion #16 focuses on the likely range of adverse direct and indirect impacts of the Options in the planning area and not the indirect impacts to water quality and water supply reliability and in the service areas. These issues in the service areas are addressed in Criteria #8 and #11. Although Option 1 would have the fewest direct impacts, it is expected to result in the lowest export water quality with attendant adverse effects on treatment costs, agricultural production, and human health. Option 1 is also the most vulnerable among the Options to future disruption of water supply to service areas as a result of catastrophic events.

- Energy usage, and
- Environmental justice.

Because Options 2 through 4 would involve construction of new facilities and ground-disturbing activities, Option 1 would have the lowest impact in the planning area of the four Options on the resources listed above.

Water Quality/Hydrology

The quality of water, as measured by electrical conductivity (EC), that would be exported from the SWP/CVP facilities under Option 1 would generally be expected, within the range of modeled operations, to be similar to current conditions. Option 1 would provide the lowest quality of exported water among the Options (see Figure 3-2). Opportunistic operations under Option 1 that export more water during peak flow periods and less during low flow periods to achieve water supply goals, however, could improve the quality of exported water. Relative to the other Options, lower quality water that is exported under Option 1 would be expected to incur higher water treatment costs to meet water quality standards and needs for municipal, agricultural, and residential uses in service areas (see discussion under Criteria #10).

Within the range of Option 1 operations that would likely meet water supply objectives, water quality within the Delta is expected to be similar to current conditions (see Figures 3-3 and 3-4). Within the Sacramento River Delta (as measured at Emmaton on Sherman Island) and the range of modeled operations, water quality under Option 1 would generally be expected to be lower than Option 2 during fall and winter months but higher than Option 2 during late spring and summer; generally higher than Option 3 in all months; and generally higher than Option 4 from February through August and lower than Option 4 from September through January. Water quality would be expected to be somewhat lower in the east Delta under Option 1 than under Options 2 and 3 because those Options will prevent or reduce the flow of lower quality San Joaquin River water entering the east Delta.

Within the San Joaquin River Delta (as measured on Old River at State Highway 4) and the range of modeled operations, water quality under Option 1 would generally be expected to be higher than the other Options in all but the fall months. Water quality would be higher during these periods because lower quality San Joaquin River water would not be exported under those Options and would be allowed to discharge into the south central Delta.

Because no new construction would occur, Option 1, unlike the other Options, would not result in any temporary localized erosion and runoff of sediments into Delta waters that could temporarily degrade water quality.

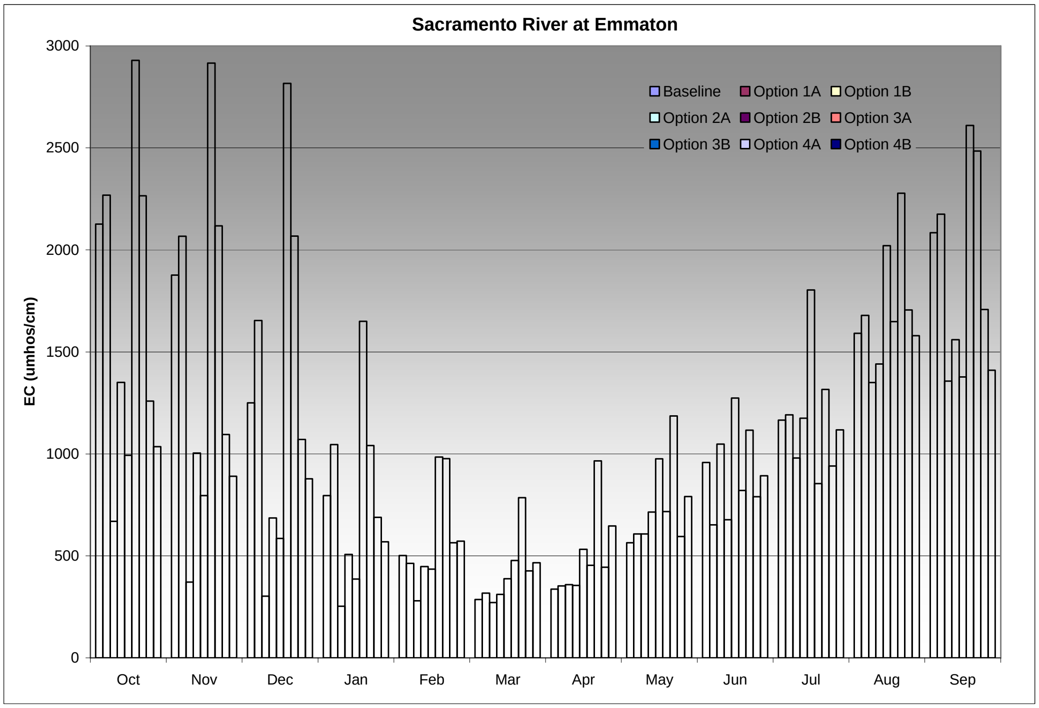

Figure 3-3. Predicted Sacramento River water quality at Emmaton (Sherman Island) expressed as electrical conductivity (EC) for each of the Options and current conditions.

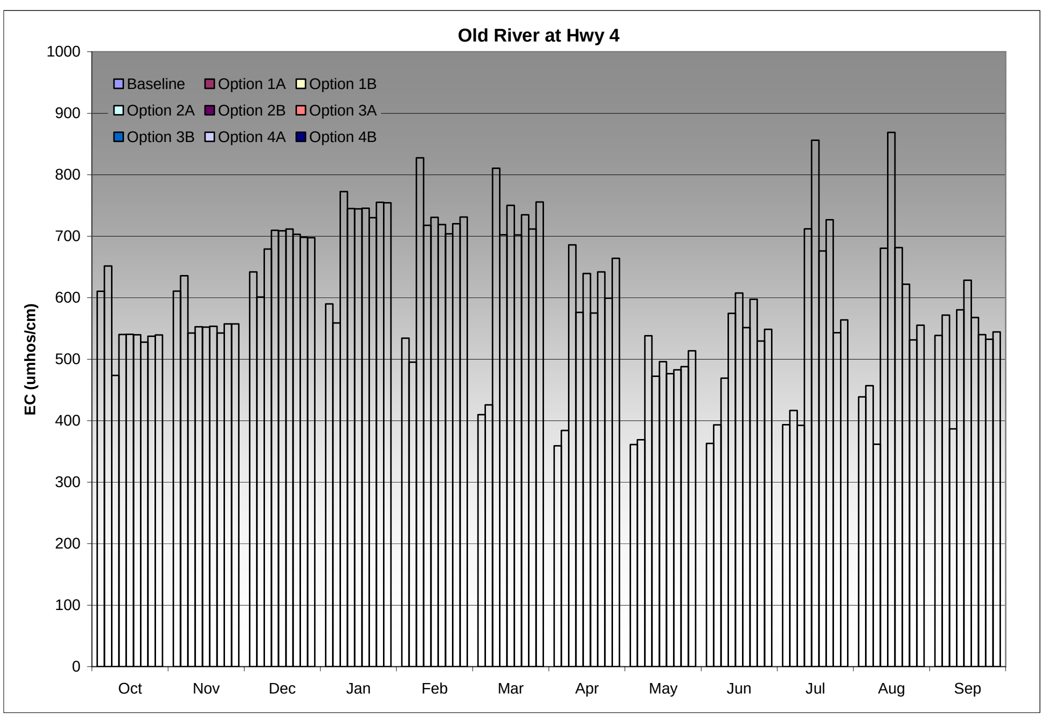

Figure 3-4. Predicted San Joaquin River water quality at the State Highway 4 crossing of Old River expressed as electrical conductivity (EC) for each of the Options and current conditions.

Agricultural Resources

Option 1 is expected to have the least impact among the Options on agricultural lands in the Delta for the following reasons:

- Existing farmed lands would not be removed from production for facility construction as would occur under Options 3 and 4.
- Water quality would remain similar to current conditions and water quality under the other Options would be lower in the south central Delta. Farming practices or production could be affected.

3.4.1.3 Criterion #17: Relative degree of risk of the Option causing impacts on sensitive species and habitats in areas outside of the BDCP planning area

Adverse or beneficial effects on native species and habitats outside the planning area downstream in Suisun Bay and Marsh and upstream in the Sacramento River and its major tributaries could result from changes in flow regimes downstream of the Delta. The potential for adverse effects downstream of the Delta are indicated by differences in Delta outflow among the Options, and the potential for adverse effects in the Sacramento River and its tributaries are indicated by differences in end-of-September reservoir storage volumes, which is a measure of the capacity of reservoirs to provide for cold water releases to sustain water temperatures within ranges favored by native aquatic species.

Based on model outputs, average annual outflow for Options and base conditions are estimated to be:

- Base conditions – 14,991 cfs
- Option 1 – 14,890 cfs
- Option 2 – similar to Option 1 (14,799 cfs – preliminary model output with pump facility)
- Option 3 – 20,289 cfs
- Option 4 – 20,996 cfs

Based on preliminary analyses, the potential for beneficial effects on aquatic species and habitats downstream of the planning area appear to be less under Option 1 than under Options 3 and 4 because the potential average annual Delta outflows supported under Option 1 are anticipated to be lower than the potential outflows under Options 3 and 4 under a range of hydrodynamic model scenarios (see Appendices D-G). Option 1 would generally provide for Delta outflows similar to current conditions. Option 1 outflows would be similar to Option 2. Opportunistic operations under Option 1 that export more water during peak flow periods and less during low flow periods to achieve water supply goals could allow for greater Delta outflow during low-flow months that could result in benefits to native aquatic species. Modeled Delta outflows, however, under Option 1 in different water-year types, with CVP/SWP exports similar to current conditions, do not appreciably differ from current conditions and would not be expected to have a measurable effect on sensitive species and habitats outside of the Delta. In the biologically important months of March and April, Option 1 provides greater Delta outflow (2%-6% less than base in below normal years) than Options 3 and 4 (3%-12% less than base in below normal years) because Options 3 and 4 would distribute outflows more evenly through the year.

Under the range of modeled operations, Option 1 is not expected to affect upstream river water temperature conditions relative to current conditions and could provide for cooler releases from Oroville Reservoir compared to current conditions during critical water years. Based on reservoir storage volumes at the end of September, the ability to provide for cold water releases downstream of Shasta, Folsom, and Oroville Reservoirs under Option 1 would be expected to be similar to Options 2, 3, and 4 in most water-year types. During critical water years, Shasta Reservoir storage volume would be similar to Option 2, but greater than under Options 3 and 4; Folsom Reservoir storage volume would be similar to Options 2 and 3, but greater than Option 4; Oroville Reservoir storage volume would be similar to Options 2 and 3 and greater than Option 4 during dry years; and during critical years, Oroville Reservoir storage volume would be lower than under Options 2 and 3, but higher than under Option 4.

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4.0 CONSERVATION STRATEGY OPTION 2 EVALUATION

This section presents the evaluation of Option 2 relative to each of the criteria using the methods described in Section 2. As described in Section 2.2, Option 2 as originally configured could not meet water supply objectives because the ability to gravity siphon the volume of water necessary to meet water supply objectives is hydraulically constrained. Consequently, for applicable criteria (see below), this section evaluates the likely performance of Option 2 reconfigured to include components that would increase the siphon flow sufficiently to achieve water supply objectives. Increasing siphon flow is considered to be technically feasible by using low-head pumps to increase flow.

The criteria for which the evaluation results for Option 2 with a pump facility would be expected to differ from Option 2 with a gravity siphon are:

- biological criteria 1 through 6,
- planning criteria 8 and 10, and
- other resource impacts criteria 15 through 17.

4.1 BIOLOGICAL CRITERIA

Option 2 includes construction and operation of a series of barriers designed to isolate the effects of SWP and CVP export operations on hydraulic conditions to the Middle River and east Delta and protect habitat areas for delta smelt and other species in Old River and the west-central part of the Delta (Figure 1-3). Middle River would continue to be used for water conveyance across the Delta to the existing export facilities through the use of operable barriers. A siphon and pump facility would be constructed to deliver water from Middle River and Victoria Canal to the export facilities and, thus, reduce the amount of water diverted from the San Joaquin River. This separation of flows should improve passage of salmon and other fish into and out of the San Joaquin River system. Option 2 also includes operational modifications to the existing SWP and CVP export facilities located in the south Delta. The structural modifications included in Option 2 are intended to improve hydraulic residence time, food production, and habitat in the central Delta and to the west of Old River to benefit covered fish species and aquatic resources. To accommodate through-Delta water conveyance under Option 2 the primary locations of potential physical habitat restoration and enhancement measures are expected to be in the northern reaches of the Delta (e.g., Cache Slough area, Yolo Bypass, Sutter and Steamboat Sloughs), Suisun Marsh, and the central region of the Delta (Figure 1-3). Results of the assessment of biological criteria and potential benefits to the covered fish species under Option 2 are described in this section.

The evaluation of biological criteria for Option 2 is based on the hydrodynamic parameter values modeled for operational Scenarios A and B. The evaluation discussions presented below for each species and criterion, however, focus on Scenario A because:

- the type of effects of Scenario B on stressors and stressor impact mechanisms for each of the covered fish species are the same as described for Scenario A and a description of the performance of Scenario B would be repetitious;
- Scenario A would be more likely to achieve water supply objectives than Scenario B and, therefore, comparison of hydrodynamic outputs for scenario A across the Options puts each Option on an equivalent basis; and
- The magnitude of the effects of the Option on covered fish species differs between Scenarios A and B and, consequently, CALSIM II and DSM2 modeling results for Scenario B provided information useful in determining the range of flexibility within the Option to improve performance of the Option relative to achieving each of the biological criteria.

Though not described in the criteria evaluation text, the expected performance of Scenario B on each of the important stressors for each of the covered fish species relative to the performance of Scenario A is presented in summary tables at the beginning of each species evaluation section below.

Descriptions of the stressors and impact mechanisms addressed by the Options relative to each of the biological criteria and the tools used to measure changes in stressor effects are described in Section 3, "Conservation Strategy Option 1 Evaluation", and are not repeated in this section.

4.1.1 Delta Smelt

Based on the evaluation presented below of the expected performance of Option 2 for addressing important delta smelt stressors, Option 2 would be expected to have a low beneficial effect on delta smelt production, distribution, and abundance relative to base conditions when operated to meet water supply objectives (Scenario A). If water supply exports are reduced (Scenario B), Option 2 would be expected to provide a moderate beneficial effect on delta smelt production, distribution, and abundance relative to base conditions. Option 2 would be expected to provide a greater level of benefit for delta smelt than Option 1, but a lower level of benefit compared to Options 3 and 4.

Table 4-1 summarizes the expected effects of implementing Option 2 under Scenarios A and B on important delta smelt stressors relative to base conditions.

Table 4-1. Summary of Expected Effects of Option 2 on Highly and Moderately Important Delta Smelt Stressors

Stressors[1]	Applicable Criteria	Option Effects Relative to Important Species Stressors	
		Scenario A	**Scenario B**
Highly Important Stressors			
Reduced food availability	1,3,4,5	Low benefit	Moderate benefit
Reduced rearing habitat	2,3	Low benefit	Moderate benefit
Reduced turbidity	1,2,3	Low benefit	Low benefit
Reduced spawning habitat	3	Moderate benefit	Moderate benefit
Reduced food quality	1,4,5	Moderate benefit	Moderate benefit
Moderately Important Stressors			
Predation	1,5	Moderate benefit	Moderate benefit
CVP/SWP entrainment[2]	1,3	Low benefit	Moderate benefit
Exposure to toxics	1,2	Low adverse effect	No effect

Notes:

1. See Appendix C for descriptions of stressors, stressor impact mechanisms, and stressor effects.
2. It is recognized that the risk of entrainment at the SWP and CVP export facilities may be a high level stressor to delta smelt in some years and a very low level stressor to delta smelt in other years. For purposes of this analysis, the risk of delta smelt entrainment has been characterized, on average, as a moderate level stressor to the population.

4.1.1.1 Criterion #1. Relative degree to which the Option would reduce species mortality attributable to non-natural mortality sources, in order to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species.

Based on the following evaluation of Option 2 effects on applicable delta smelt stressors, Option 2 is expected to provide low benefits for delta smelt by reducing the effects of non-natural sources of mortality relative to base conditions.

Reduced Food Availability and Quality

The effects of Option 2 on delta smelt food availability and quality are evaluated under Criterion #4 below. As described in the Criterion #4 evaluation, Option 2 would be expected to provide a low beneficial effect on food availability and a moderate beneficial effect on food quality for the delta smelt relative to base conditions.

Reduced Turbidity

The effects of Option 2 on turbidity are evaluated under Criterion #2 below. As described in the Criterion #2 evaluation, Option 2 would be expected to provide low beneficial increase in turbidity conditions for delta smelt.

Predation

As described below under Criterion #2, Option 2 would be expected to provide a moderate beneficial effect in turbidity conditions relative to base conditions and, therefore, would be expected to reduce the vulnerability of delta smelt to predation. The proportion of the Delta (35%) within which habitat could potentially be implemented is greater than under Option 1, the same as under Option 3, but less than under Option 4 (see Figure 1-3). Based on the potential for low improvement in turbidity conditions and the proportion of the Delta available for restoration, Option 2 would be expected to provide a low benefit by reducing the predation vulnerability of delta smelt relative to base conditions.

Entrainment by CVP/SWP Facilities[1]

Based on how Option 2 would be expected to affect hydrodynamic conditions relative to the PTM model results for export fate for base conditions and the other Options, Option 2 would be expected to provide a low benefit for delta smelt by reducing the likelihood for entrainment of delta smelt relative to base conditions (see Table 2-1 and Appendix A).

In Middle River, which is designated as the conveyance corridor to move water through the Delta to the export facilities, PTM modeling results indicated that entrainment was greater relative to base conditions. Other than from the Middle River insertion location, there was a reduction in entrainment of particles by the SWP/CVP exports. In Middle River, which is designated as the conveyance corridor to move water through the Delta to the export facilities, entrainment was greater than base conditions. It is unlikely, however, that there would be many larval or juvenile delta smelt in Middle River relative to base conditions and Option 1 because they would be blocked from entering the corridor from the west by the structural barriers. Risk for entrainment into Middle River, however, would be increased during periods of reverse flow in the San Joaquin River and would be expected to higher than under Option 3, which does not provide for pumping water from Middle River through the siphon.

Exposure to Toxics

The effects of Option 2 on exposure to toxics are evaluated under Criterion #2 below. As described in the Criterion #2 evaluation, Option 2 would be expected to continue to provide dilution flows similar to base conditions and could increase exposure to toxics discharged from the San Joaquin River into the central Delta, which could have a low adverse effect on delta smelt. It is uncertain, however, if the potential increase in concentrations of toxics in the central Delta would adversely affect delta smelt.

[1]Modeling results for reverse flows in Old and Middle River are not used in the assessment of this stressor under Option 2 because Old River flows are isolated from the CVP/SWP pumping facilities and modeled reverse flow results for Old River cannot be disaggregated from results for Middle River.

4.1.1.2 Criterion #2. Relative degree to which the Option would provide water quality and flow conditions necessary to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species.

Option 2 is expected to provide low benefits for delta smelt by improving flow and water quality conditions relative to base conditions.

Reduced Rearing Habitat

Option 2 is expected to provide rearing habitat flow conditions for delta smelt that would be similar to base conditions.

Based on how Option 2 would be expected to affect the X_2 location in April relative to X_2 modeling results for base conditions and the Options, X_2 position would remain similar to base conditions (see Table 2-1 and Appendix A). Based on how Option 2 would be expected to affect hydrodynamic conditions relative to the PTM model results for base conditions and the other Options, the percentage of particles moving downstream past Chipps Island and into Suisun Bay indicate that Option 2 would be unlikely to affect the downstream movement of delta smelt relative to base conditions. (see Table 2-1 and Appendix A). Sacramento River inflows during March and April under Option 2 that support the transport of larval fish from the Cache Slough/Yolo Bypass area would continue to be transported downstream similar to base conditions. As described below, Option 2 would be expected to provide a low improvement in turbidity conditions relative to base conditions, thus possibly improving the foraging efficiency of delta smelt and reducing their vulnerability to predation. The potential restoration of rearing habitats as described under Criterion #3, however, would also be expected to improve rearing habitat conditions. Consequently, overall Option 2 would be expected to have low beneficial effects on rearing habitat accessibility and conditions relative to base conditions.

Reduced Turbidity

Under Option 2, habitat restoration sites could be located within approximately 35% of the planning area and could improve turbidity conditions for delta smelt by reducing the abundance of non-native species that remove particles from Delta waters. A portion of the populations of filtering benthic macroinvertebrates, including *Corbula* and *Corbicula*, inhabiting the central Delta, however, would continue to reduce phytoplankton and zooplankton densities by filter feeding. Based on how Option 2 would be expected to affect hydrodynamic conditions relative to the PTM model results for base conditions and the Options, hydraulic residence time in the central Delta would be expected to create conditions beneficial to phytoplankton and zooplankton production that could improve turbidity conditions relative to base conditions (see Table 2-1 and Appendix A). These potential effects of Option 2 on turbidity would be expected to have low benefits for improving turbidity conditions for delta smelt relative to base conditions.

Exposure to Toxics

Option 2 is expected to have a low adverse effect by increasing the exposure of delta smelt to toxics as a result of redirecting the discharge of the San Joaquin River into the central Delta. The level of effect of this increased exposure on delta smelt, however, is uncertain.

Based on how Option 2 would be expected to affect Sacramento River inflow and total Delta inflows relative to modeling results for base conditions and the Options, dilution flows under Option 2 would be expected to be similar to base conditions (see Table 2-1 and Appendix A). There is the potential for the physical configuration of Option 2 to cause an increase in toxic loading in the area of the central Delta that is available for habitat restoration (Figure 1-3). The configuration of barriers and the siphon to pass San Joaquin River water into the central Delta would potentially increase toxic loads, increase residence time of and potential exposure to toxics, and reduce dilution of higher concentrations of toxics and salinity originating within the San Joaquin River watershed. The central Delta is one of the primary areas where habitat restoration may occur under Option 2, and is closer to the low salinity zone where delta smelt rear. San Joaquin River water will not be diluted with Delta water before it enters the central Delta. If water quality conditions under Option 2 in the central Delta were to adversely affect delta smelt, the relocation of San Joaquin River flows could have adverse effects of sufficient magnitude on delta smelt that could offset the benefits of isolating the central Delta from the effects of SWP and CVP export operations. It is uncertain, however, if the potential increase in concentrations of toxics in the central Delta would adversely affect delta smelt and San Joaquin River toxic loads would be expected to decline with implementation of water quality standards and improvement programs under development.

4.1.1.3 Criterion #3 Relative degree to which the Option would increase habitat quality, quantity, accessibility, and diversity in order to enhance and sustain production (reproduction, growth, survival), abundance, and distribution; and to improve the resiliency of each of the covered species' populations to environmental change and variable hydrology.

Based on the following evaluation of Option 2 effects on applicable delta smelt stressors, Option 2 is expected to provide low benefits relative to habitat conditions for the delta smelt.

Within the planning area, delta smelt habitat conditions are governed by hydrodynamic conditions and the extent and quality of habitat within the planning area. Under Option 2, these conditions relative to base conditions would be affected by the conveyance configuration of Option 2 and the opportunities for restoration of physical habitat that could be sited within Suisun Bay and Marsh and within 35% of the planning area in the north and west Delta.

Reduced Food Availability

The effects of Option 2 on delta smelt food availability are evaluated under Criterion #4 below. As described in the Criterion #4 evaluation, Option 2 would be expected to provide a low beneficial effect on food supply for the delta smelt relative to current conditions.

Reduced Rearing Habitat

Under Option 2, habitat could be restored within Suisun Bay and Marsh and approximately 35% of the Delta to provide high quality shallow aquatic subtidal and intertidal habitat (Figure 1-4). This encompasses a larger proportion of the delta smelts rearing range than restoration that could be implemented under Option 1, the same proportion as under Option 3, and a smaller proportion than under Option 4. Consequently, relative to base conditions and the other Options, Option 2 would be expected to provide a low benefit for delta smelt rearing habitat.

Reduced Turbidity

The effects of Option 2 on turbidity are evaluated under Criterion #2 above. As described in the Criterion #2 evaluation, Option 2 would be expected to provide low beneficial increases in turbidity conditions.

Reduced Spawning Habitat

The primary impact mechanism believed to affect spawning habitat is the reclamation and channelization of historical intertidal and shallow subtidal wetlands that has presumably reduced the amount of habitat available for spawning by delta smelt. Under Option 2, habitat could potentially be restored within Suisun Bay and Marsh and approximately 35% of the Delta to provide high quality aquatic habitat under this Option (Figure 1-3), which encompasses a slightly larger proportion of the likely spawning range of delta smelt than restoration that could be implemented under Option 1, the same proportion as Option 3, and smaller proportion than Option 4. Consequently, relative to the other Options and to the extent that functioning delta smelt spawning habitat can be successfully restored based on current understanding of its habitat requirements, restoration under Option 2 would be expected to provide a moderate level of benefit (see Appendix H) relative to base conditions.

4.1.1.4 Criterion #4. Relative degree to which the Option would increase food quality, quantity, and accessibility (e.g., phytoplankton, zooplankton, macro-invertebrates, forage fish) to enhance production (reproduction, growth, survival) and abundance for each of the covered fish species.

Overall, Option 2 would be expected to provide low benefits for improving food availability and quality for delta smelt.

Reduced Food Availability

The habitat restoration that would be implemented under Option 2 would all be located within the geographic range of delta smelt and could create conditions that disfavor non-native species that indirectly or directly affect food abundance (e.g., overbite clam (*Corbula*), threadfin shad), thereby improving food availability for delta smelt relative to base conditions (Figure 1-3). The potential opportunity for restoration of habitat and natural hydrology is expected to improve food availability relative to Option 1, would be the same relative to Option 3, and less than under Option 4.

Based on how Option 2 would be expected to affect the magnitude of peak Delta inflows (Jan-Mar), which contributes to floodplain inundation and increased transport and production of nutrients and organic carbon downstream into the Delta, relative to modeling results for base conditions and the Options, peak Delta inflows under Option 2 would be expected to be similar to base conditions (see Table 2-1 and Appendix A).

Based on how Option 2 would be expected to affect hydrodynamic conditions relative to the PTM model results for export fate for base conditions and the Options, Option 2 would be expected to provide a low beneficial increase in food availability by reducing the export of nutrients and organic material that support primary and secondary production by agricultural diversions and SWP/CVP exports. Under this option, Middle River flow was directed towards the export facilities, whereas Old River flow was directed towards the western Delta. Therefore, a high proportion of Middle River particles were immediately entrained, some particles released at San Joaquin River at Head of Old River were also entrained as a results of particles moving downstream on the San Joaquin River to Middle River, where they were entrained by the SWP/CVP exports, and very few particles from Old River, Sacramento River at Cache Slough and San Joaquin River at Dutch Slough location were entrained. In addition, under Option 2, water with high nutrient loads from the San Joaquin River would no longer be subject to the same level of exports as under base conditions and these waters would be conveyed downstream into the central region of the Delta where increased nutrient loads, in combination with increased residence times, would be expected to stimulate phytoplankton and zooplankton production.

Overall, the percentage of particles that remain in the central Delta under Option 2, an indicator of hydraulic residence time, relative to PTM modeling results for base conditions and the Options (see Table 2-1 and Appendix A) would be expected to provide for a low beneficial increase in food production.

Reduced Food Quality

Restoration of shallow water intertidal and subtidal habitats under Option 2 could improve nutrient production and production of suitable zooplankton species (e.g., native calanoid copepods) as forage for delta smelt. Under Option 2, habitat could potentially be restored within Suisun Bay and Marsh and approximately 35% of the Delta to provide high quality aquatic habitat under this Option (Figure 1-3), which encompasses a larger proportion of the delta smelt's range than restoration that could be implemented under Option 1 and the same proportion as under Option 3,, but less than under Option 4. Consequently, relative to the other Options, Option 2 would be expected to provide a moderate level of benefit for food quality (see Appendix H).

4.1.1.5 Criterion #5. Relative degree to which the Option would reduce the abundance of non-native competitors and predators to increase native species production (reproduction, growth, survival), abundance and distribution for each of the covered fish species.

Based on the following evaluation of Option 2 effects on applicable delta smelt stressors, Option 2 is expected to provide moderate benefits for the delta smelt relative to the abundance of non-native competitors and predators.

Option 2 could reduce the effects of non-native competitors and predators on delta smelt primarily through restoration of intertidal and shallow subtidal aquatic habitats in the north and central Delta. For reasons described in Section 3.1.2.4, Option 2 would be expected to provide a moderate beneficial effect by reducing the impacts of populations of non-native food competitors relative to base conditions. For reasons described under Criteria #1 and #2, Option 2 could provide a low beneficial effect by reducing the risk of delta smelt predation relative to base conditions. Additionally, the operable barriers along Middle River provide some opportunity under Option 2 to adaptively manage Delta hydrodynamics to create hydrodynamic conditions that favor the delta smelt and disfavor predators and competitors to improve conditions for the delta smelt. Although the ability to control non-native species by varying hydrodynamic conditions in the Delta is uncertain, Option 2 provides a greater opportunity for doing so than under Option 1, but much less opportunity for doing so compared to Options 3 and 4.

4.1.1.6 Criterion #6. Relative degree to which the Option improves ecosystem processes in the BDCP planning area to support aquatic and associated habitats.

Based on the proportion of the planning area suitable for potential restoration under Option 2 relative to the other Options and modeling results for hydraulic residence time (see Appendix H), Option 2 would be expected to provide a low beneficial improvement in ecosystem function relative to base conditions.

Under Option 2, Middle River would continue to serve as the water conveyance facility for freshwater supplies moving from the Sacramento River across the Delta to the export facilities located in the southern Delta. Movement of large volumes of water through Middle River would adversely affect hydraulic conditions, require dredging to increase conveyance capacity, and may require additional riprap to reduce levee scour and erosion. These conditions would degrade the quality of fishery habitat within Middle River. In contrast, the area adjacent to Old River and the central and western portion of the Delta would be improved by isolating these areas from the effects of export operations and by increasing residence times within the central Delta thereby reducing the export of nutrients, organic carbon, phytoplankton, and zooplankton from the Delta and increasing aquatic food production and availability. These changes would be expected to improve ecosystem processes within the central and western regions of the Delta when compared to base conditions and Option 1, but not to the degree expected under Options 3 and 4. It is uncertain, however, if the discharge of low quality San Joaquin River water into the central Delta would impair ecosystem processes.

4.1.1.7 Criterion #7. Relative degree to which the Option can be implemented within a timeframe to meet the near-term needs of each covered fish species (post BDCP authorization).

In the near-term, until construction of Option 2 conveyance features and facilities is completed, Option 2 would use the existing conveyance facilities to meet water supply objectives. As for Option 1, implementation of physical habitat restoration under Option 2 in the north and west Delta can be initiated immediately following authorization of the BDCP and thus could be implemented in a manner that would meet the near-term needs of delta smelt.

4.1.2 Longfin Smelt

Option 2: Improved Through-Delta Conveyance

Based on the evaluation presented below of the expected performance of Option 2 for addressing important longfin smelt stressors, Option 2 would be expected to have a low beneficial effect on longfin smelt production, distribution, and abundance relative to base conditions when operated to meet water supply objectives (Scenario A). If water supply exports are reduced (Scenario B), Option 2 would be expected to provide a moderately beneficial effect on longfin smelt production, distribution, and abundance relative to base conditions. Option 2 would be expected to provide a greater level of benefit for longfin smelt than Option 1, but a lower level of benefit compared to Options 3 and 4.

Stressors that affect longfin smelt are presented in Figure 2-2 and are described in Appendix C. The effect of these stressors on the longfin smelt population vary among years in response to environmental conditions (e.g., seasonal hydrology) and may also interact with each other in additive or synergistic ways. The effects of these stressors include both the incremental contribution of a stressor to the population as well as the cumulative effects of multiple stressors over time. The assessment of Option 2 evaluates the degree to which Option 2 would be expected to address these stressors.

Table 4-2 summarizes the expected effects of implementing Option 2 under Scenarios A and B on important longfin smelt stressors relative to base conditions.

Table 4-2. Summary of Expected Effects of Option 1 on Highly and Moderately Important Longfin Smelt Stressors

Stressors[1]	Applicable Criteria	Option Effects Relative to Important Species Stressors	
		Scenario A	Scenario B
Highly Important Stressors			
Reduced access to spawning habitat	2	No net effect	Moderate benefit
Reduced access to rearing habitat	2	No net effect	Low benefit
Reduced food	1,4,5	Low benefit	Moderate benefit
Predation	1,5	Moderate benefit	Moderate benefit
Reduced turbidity	1,2, 3,5	Low benefit	Low benefit
Reduced spawning habitat	3	Low benefit	Moderate benefit
Reduced food quality	1,4,5	Moderate	Moderate benefit
Moderately Important Stressors			
CVP/SWP entrainment[2]	1	Low benefit	Moderate benefit
Reduced rearing habitat	2	No net effect	Low benefit
Exposure to toxics	2	Low adverse effect	No net effect

Notes:

1. See Appendix C for descriptions of stressors, stressor impact mechanisms, and stressor effects.
2. Although it is recognized that the risk of entrainment at the SWP and CVP export facilities may, in some years, be a high level stressor to longfin smelt, and in some years represents a very low level stressor to longfin smelt, for purposes of the analysis the risk of longfin smelt entrainment under each of the Options has been characterized, on average, as a moderate level stressor to the population.

4.1.2.1 Criterion #1. Relative degree to which the Option would reduce species mortality attributable to non-natural mortality sources, in order to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species.

Based on the following evaluation of Option 2 effects on applicable longfin smelt stressors, Option 2 is expected to provide low benefits for longfin smelt by reducing the effects of non-natural sources of mortality relative to base conditions.

Reduced Food Availability and Quality

Reduced food availability and quality can result in non-natural levels of mortality. The effects of Option 2 on longfin smelt food availability and quality are evaluated under Criterion #4 below. As described in the Criterion #4 evaluation, Option 2 would be expected to provide a low beneficial effect on food availability and a moderately beneficial effect on food quality for longfin smelt relative to base conditions.

Reduced Turbidity

Reduced turbidity may increase the vulnerability of longfin smelt to predation and reduce foraging efficiency. The effects of Option 2 on turbidity are evaluated under Criterion #2 below. As described in the Criterion #2 evaluation, Option 2 would be expected to provide low beneficial increases in turbidity conditions relative to base conditions.

Predation

As described below under Criterion #2, Option 2 would be expected to provide a low improvement in turbidity conditions relative to base conditions and, therefore, would be expected to reduce the vulnerability of longfin smelt to predation. The proportion of the Delta (35%) within which habitat enhancement could potentially be implemented is greater than under Option 1, the same the same as under Option 3, but less than under Option 4 (see Figure 1-3). Based on the potential for low improvement in turbidity conditions and the proportion of the Delta available for restoration, Option 2 would be expected to provide a moderate benefit by reducing the predation vulnerability of longfin smelt relative to base conditions.

Entrainment by CVP/SWP Facilities[2]

Based on how Option 2 would be expected to affect hydrodynamic conditions relative to the PTM model results for export fate for base conditions and the Options, Option 2 would be expected to provide a low benefit for longfin smelt by reducing the likelihood for entrainment of longfin smelt relative to base conditions (see Table 2-1 and Appendix A). Other than from the Middle River insertion location, there was a substantial reduction in entrainment of particles

[2]Modeling results for reverse flows in Old and Middle River are not used in the assessment of this stressor under Option 2 because Old River flows are isolated from the CVP/SWP pumping facilities and modeled reverse flow results for Old River cannot be disaggregated from results for Middle River.

by the SWP/CVP exports. The isolation of Old River and adjacent areas from the hydraulic effects of SWP and CVP export operations (e.g., reducing and avoiding reverse flows within Old River) is expected to benefit longfin smelt under Option 2. In Middle River, which is designated as the conveyance corridor to move water through the Delta to the export facilities, entrainment was greater than base conditions. In reality, however, there should be fewer larval or juvenile longfin smelt in Middle River relative to base conditions and Option 1 because they would be blocked from entering the corridor from the west by the structural barriers. Risk for entrainment into Middle River, however, would be increased during periods of reverse flow in the lower San Joaquin River.

Exposure to Toxics

The effects of Option 2 on exposure to toxics are evaluated under Criterion #2 below. As described in the Criterion #2 evaluation, Option 2 would be expected to continue to provide dilution flows similar to base conditions and could increase exposure to toxics discharged from the San Joaquin River into the central Delta, which could have a low adverse effect on longfin smelt. It is uncertain, however, if the potential increase in concentrations of toxics in the central Delta would adversely affect longfin smelt.

4.1.2.2 Criterion #2. Relative degree to which the Option would provide water quality and flow conditions necessary to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species.

Option 2 is expected to provide very low benefits for delta smelt by improving flow and water quality conditions relative to base conditions.

Reduced Access to Spawning Habitat

Access of adult longfin smelt to spawning habitat is thought to be a function of river flows and availability and quality of habitat. Under Option 2 flows within the Sacramento River during the late winter and early spring longfin smelt spawning period are expected to be similar to base conditions. Flows on the San Joaquin River have been assumed, for purposes of these analyses, to be similar under base conditions and Option 2. Option 2 includes the opportunity to potentially enhance intertidal and subtidal habitat in the lower Sacramento River and northern Delta that would be expected to benefit longfin smelt when compared to base conditions.

Reduced Access to Rearing Habitat

Based on how Option 2 would be expected to affect hydrodynamic conditions relative to the PTM model results for base conditions and the Options, the percentage of particles moving downstream past Chipps Island and into Suisun Bay indicate that Option 2 would be unlikely to affect the downstream movement of longfin smelt relative to base conditions (see Table 2-1 and Appendix A). Sacramento River inflows during March and April under Option 2 that transport larval fish from the Cache Slough/Yolo Bypass area would be similar to base conditions.

Reduced Turbidity

Under Option 2, habitat restoration sites could be located within approximately 35% of the planning area and could improve turbidity conditions for longfin smelt by reducing the abundance or impacts of non-native species that remove particles from Delta waters. A portion of the populations of filtering benthic macroinvertebrates, including *Corbula* and *Corbicula*, inhabiting the central Delta, however, would continue to reduce phytoplankton and zooplankton densities by filter feeding. Based on how Option 2 would be expected to affect total peak Delta inflows, peak Delta inflows during January through March under Option 2 would be expected to be similar to base conditions on average (see Table 2-1 and Appendix A), indicating that peak flows would not be expected to change turbidity levels under Option 2 relative to base conditions. Based on how Option 2 would be expected to affect hydrodynamic conditions relative to the PTM model results for base conditions and the Options, hydraulic residence time in the central Delta would be expected to create conditions beneficial to phytoplankton and zooplankton production that could improve turbidity conditions relative to base conditions (see Table 2-1 and Appendix A). These potential effects of Option 2 on turbidity would be expected to have low benefits for improving turbidity conditions for longfin smelt relative to base conditions.

Exposure to Toxics

Option 2 is expected to have a low adverse effect by increasing the exposure of longfin smelt to toxics as a result of redirecting the discharge of the San Joaquin River into the central Delta. The level of effect of this increased exposure on longfin smelt, however, is uncertain.

Based on how Option 2 would be expected to affect Sacramento River inflow and total Delta inflows relative to modeling results for base conditions and the Options, dilution flows under Option 2 would be expected to be similar to base conditions (see Table 2-1 and Appendix A). There is the potential for the physical configuration of Option 2 to cause an increase in the concentration of toxics in the area of the central Delta that is available for habitat restoration (Figure 1-3). The configuration of barriers and the passage of San Joaquin River water into the central Delta would potentially increase concentrations of toxics, increase residence time of and potential exposure to toxics, and reduce dilution of higher concentrations of toxics and salinity originating within the San Joaquin River watershed. The central Delta is one of the primary areas where habitat restoration may occur under Option 2, and is closer to where longfin smelt rear. San Joaquin River water will not be diluted with Delta water before it enters the central Delta. If water quality conditions under Option 2 in the central Delta were to adversely affect longfin smelt, the relocation of San Joaquin River flows could have adverse effects of sufficient magnitude on longfin smelt that could offset the benefits of isolating the central Delta from the effects of SWP and CVP export operations. It is uncertain, however, if the potential increase in concentrations of toxics in the central Delta would adversely affect longfin smelt and San Joaquin River toxic loads would be expected to decline with implementation of water quality standards and improvement programs under development.

Reduced Rearing Habitat

Based on how Option 2 would be expected to affect X_2 location in April relative to X_2 modeling results for base conditions and the Options, X_2 position would be expected to remain similar to base conditions (see Table 2-1 and Appendix A). River flows that are important to the downstream transport of larval longfin smelt would also be expected to be similar under Option as base conditions. As described below, Option 2 would be expected to provide a low improvement in turbidity conditions relative to base conditions, thus possibly improving the foraging efficiency of longfin smelt and reducing their vulnerability to predation. Consequently, overall Option 2 would be expected to have no to marginal beneficial effects on rearing habitat conditions relative to base conditions.

4.1.2.3 Criterion 3. Relative degree to which the Option would increase habitat quality, quantity, accessibility, and diversity in order to enhance and sustain production (reproduction, growth, survival), abundance, and distribution; and to improve the resiliency of each of the covered species' populations to environmental change and variable hydrology.

Based on the following evaluation of Option 2 effects on applicable longfin smelt stressors, Option 2 is expected to provide moderate benefits relative to habitat conditions for the longfin smelt.

Within the planning area, longfin smelt habitat conditions are governed by hydrodynamic conditions and the extent and quality of habitat within the planning area. Under Option 2, these conditions relative to base conditions would be affected by the conveyance configuration of Option 2 and the opportunities for restoration of physical habitat that could be sited within Suisun Bay and Marsh and within the planning area in the north and west Delta, which represents approximately 35% of the planning area.

Reduced Accessibility to Spawning and Rearing Habitats

Changes in X_2 location and downstream transport flows can impede longfin smelt access to spawning and rearing habitats, respectively. The effects of Option 2 on the accessibility of spawning and rearing habitats are evaluated under Criterion #2 above. As described in the Criterion #2 evaluation, Option 2 would not be expected to affect longfin smelt access to spawning and rearing habitats relative to base conditions.

Reduced Food Availability and Quality

Reduced food availability and quality can result in non-natural levels of mortality. The effects of Option 2 on longfin smelt food availability and quality are evaluated under Criterion #4 below. As described in the Criterion #4 evaluation, Option 2 would be expected to provide a low beneficial effect on food availability and moderate beneficial effect on food quality for longfin smelt relative to base conditions.

Reduced Turbidity

Habitat conditions that support non-native filter feeders and aquatic plants can reduce turbidity. The effects on turbidity associated with these impact mechanisms are evaluated under Criterion #2 above. As described in the Criterion #2 evaluation, restoring habitat under Option 2 would be expected to have a low beneficial effect on turbidity conditions for longfin smelt relative to base conditions.

Reduced Spawning Habitat

Under Option 2 approximately 35% of the planning area would potentially be available for restoration/enhancement of aquatic subtidal and intertidal habitats (Figure 1-3), which encompasses much of the geographic range of longfin smelt within the Delta (Rosenfield and Baxter, in press). Spawning habitat for longfin smelt would be expected to increase in response to habitat restoration/enhancement actions in the upstream regions of the Delta (e.g., mainstem Sacramento River, Cache Slough, etc.) and the central Delta. Because turbidity conditions, which affect predation vulnerability and foraging efficiency, would remain similar to base conditions, habitat restoration under Option 2 would likely provide a low benefit to longfin smelt.

Reduced Rearing Habitat

The effects on rearing habitat associated with Option 2 are evaluated under Criterion #2 above. Option 2 is expected to have no to marginal beneficial effects on rearing habitat conditions relative to base conditions.

4.1.2.4 Criterion 4. Relative degree to which the Option would increase food quality, quantity, and accessibility (e.g., phytoplankton, zooplankton, macro-invertebrates, forage fish) to enhance production (reproduction, growth, survival) and abundance for each of the covered fish species.

Overall, Option 2 would be expected to provide low benefits for improving food availability and quality for longfin smelt.

Reduced Food Availability

The habitat restoration that would be implemented under Option 2 would all be located within the geographic range of longfin smelt and could create conditions that disfavor non-native species that indirectly or directly affect food abundance (e.g., overbite clam (*Corbula*), threadfin shad), thereby improving food availability for longfin smelt relative to base conditions (Figure 1-3). The potential opportunity for habitat restoration is expected to improve food availability relative to Option 1, would be the same relative to Option 3, and less than under Option 4.

Based on how Option 2 would be expected to affect the magnitude of peak Delta inflows (Jan-Mar), which contributes to floodplain inundation and increased transport and production of nutrients and organic carbon downstream into the Delta, relative to modeling results for base conditions and the Options, peak Delta inflows under Option 2 would be expected to be similar to base conditions (see Table 2-1 and Appendix A).

Based on how Option 2 would be expected to affect hydrodynamic conditions relative to the PTM model results for export fate for base conditions and the Options, Option 2 would be expected to provide a low beneficial increase in food availability by reducing the export of nutrients and organic material that support primary and secondary production by agricultural diversions and SWP/CVP exports. Under this option, Middle River flow was directed towards the export facilities, whereas Old River flow was directed towards the western Delta. Therefore, a high proportion of Middle River particles were immediately entrained, some particles released at SJR at HOR were also entrained as a results of particles moving downstream on the San Joaquin River to Middle River, where they were entrained by the SWP/CVP exports, and very few particles from Old River, Sacramento River at Cache Slough and SJR at Dutch Slough locations were entrained. In addition, under Option 2, water with high nutrient loads from the San Joaquin River would no longer be subject to the same level of exports as under base conditions and these waters would be conveyed downstream into the central region of the Delta where increased nutrient loads, in combination with increased residence times, would be expected to stimulate phytoplankton and zooplankton production.

Exposure of phytoplankton and zooplankton to toxics (e.g., pesticides, herbicides) that enter the Delta from point and non-point sources may also contribute to ongoing low abundance of longfin smelt zooplankton prey species (Weston et al. 2004, Luoma 2007). Though this relationship is uncertain, Option 2 would be unlikely to reduce the exposure of primary and secondary producers to these toxics because dilution flows would remain similar to base conditions.

Overall, the percentage of particles that remain in the central Delta, an indicator of hydrologic residence time, relative to PTM modeling results for base conditions and the Options (see Table 2-1 and Appendix A) would be expected to provide for a low beneficial increase in food production.

Reduced Food Quality

Restoration of shallow water intertidal and subtidal habitats under Option 2 could improve nutrient production and production of suitable zooplankton species (e.g., native calanoid copepods) as forage for longfin smelt. Under Option 2, habitat could potentially be restored within Suisun Bay and Marsh and approximately 35% of the Delta to provide high quality aquatic habitat under this option (Figure 1-3), which encompasses a larger proportion of the longfin smelt's range than restoration that could potentially be implemented under Option 1 and the same proportion as under Option 3, but less than under Option 4. Consequently, relative to the other Options, Option 2 would be expected to provide a moderate level of benefit for food quality (see Appendix H).

The degree to which Option 2 influences the quality, quantity, and accessibility of food to longfin smelt was discussed in detail in Criterion 1. Overall, Option 2 would likely provide moderate benefit to food quality for longfin smelt. This benefit could be enhanced by reducing water exports (under Option 2B) with lower reductions in water supply relative to Option 1.

4.1.2.5 Criterion 5. Relative degree to which the Option would reduce the abundance of non-native competitors and predators to increase native species production (reproduction, growth, survival), abundance and distribution for each of the covered fish species.

Option 2 could reduce the effects of non-native competitors and predators on longfin smelt primarily through restoration of intertidal and shallow subtidal aquatic habitats in the north and central Delta. For reasons described in Section 3.1.2.4, Option 2 would be expected to provide a moderate beneficial effect by reducing the impacts of populations of non-native food competitors relative to base conditions. For reasons described under Criteria #1 and #2, Option 2 could provide a low beneficial effect by reducing the risk of longfin smelt predation relative to base conditions. Additionally, the operable barriers along Middle River provide some opportunity under Option 2 to adaptively manage Delta hydrodynamics to create hydrodynamic conditions that favor the longfin smelt and disfavor predators and competitors to improve conditions for the longfin smelt. Although the ability to control non-native species by varying hydrodynamic conditions in the Delta is uncertain, Option 2 provides a greater opportunity for doing so than under Option 1, but much less opportunity for doing so compared to Options 3 and 4.

4.1.2.6 Criterion 6. Relative degree to which the Option improves ecosystem processes in the BDCP planning area to support aquatic and associated habitats.

Based on the proportion of the planning area suitable for potential restoration under Option 2 relative to the other Options and modeling results for hydraulic residence time (see Appendix H), Option 2 would be expected to provide a low beneficial improvement in ecosystem function relative to base conditions.

Under Option 2, Middle River would continue to serve as the water conveyance facility for freshwater supplies moving from the Sacramento River across the Delta to the export facilities located in the southern Delta. Movement of large volumes of water through Middle River would adversely affect hydraulic conditions, require dredging to increase conveyance capacity, and may require additional riprap to reduce levee scour and erosion. These conditions would degrade the quality of fishery habitat within Middle River. In contrast, the area adjacent to Old River and the central and western portion of the Delta would be improved by isolating these areas from the effects of export operations and the potential risk of longfin smelt entrainment at the SWP and CVP export facilities and by increasing residence times within the central Delta thereby reducing the export of nutrients, organic carbon, phytoplankton, and zooplankton from the Delta and increasing aquatic food production and availability. These changes would be expected to improve ecosystem processes within the central and western regions of the Delta when compared to base conditions and Option 1, but not to the degree expected under Options 3 and 4. It is uncertain, however, if the discharge of low quality San Joaquin River water into the central Delta would impair ecosystem processes.

4.1.2.7 Criterion 7. Relative degree to which the Option can be implemented within a timeframe to meet the near-term needs of each covered fish species (post BDCP authorization).

In the near-term, until construction of conveyance features and facilities is completed, Option 2 would use the existing conveyance facilities to meet water supply objectives. As for Option 1, implementation of physical habitat restoration under Option 2 in the north and west Delta can be initiated immediately following authorization of the BDCP and thus could be implemented in a manner that would meet the near-term needs of longfin smelt.

4.1.3 Sacramento River Salmonids

Option 2: Improved Through-Delta Conveyance

Based on the evaluation presented below of the expected performance of Option 2 for addressing important Sacramento River salmonid stressors, Option 2 would be expected to have a low beneficial effect on Sacramento River salmonid production, distribution, and abundance relative to base conditions when operated to meet water supply objectives (Scenario A). If water supply exports are reduced (Scenario B), Option 2 would be expected to provide a moderate beneficial effect on Sacramento River salmonid production, distribution, and abundance relative to base conditions. Option 2 would be expected to provide a greater level of benefit for Sacramento River salmonids than Option 1, but a lower level of benefit compared to Options 3 and 4.

Table 4-3 and 4-4 summarizes the expected effects of implementing Option 2 under Scenarios A and B on important delta smelt stressors relative to base conditions.

Table 4-3. Summary of Expected Effects of Option 2 on Highly and Moderately Important Sacramento River Chinook Salmon Stressors

Applicable Criteria	Stressor[1]	Option Effects Relative to Important Species Stressors	
		Scenario A	Scenario B
Highly Important Stressors			
2,3	Reduced staging and spawning habitat	No net effect	Very low benefit
2,3	Reduced rearing and outmigration habitat	Low benefit	No net effect
1,5	Predation by non-natives	Low benefit	Low benefit
Moderately Important Stressors			
1	Harvest	No net effect	No net effect
1	Reduced genetic diversity/ integrity	No net effect	No net effect
1,4	SWP/CVP entrainment	No net effect	Very low benefit
1,2	Exposure to toxics	No net effect	No net effect
2,3	Increased water temperature	No net effect	No net effect

Notes:
1. See Appendix C for descriptions of stressors, stressor impact mechanisms, and stressor effects.

Table 4-4. Summary of Expected Effects of Option 2 on Highly and Moderately Important Sacramento River Steelhead Stressors

Applicable Criteria	Stressor[1]	Option Effects Relative to Important Species Stressors	
		Scenario A	Scenario A
Highly Important Stressors			
2,3	Reduced staging and spawning spawning habitat	No net effect	Very low benefit
1,4	SWP/CVP entrainment	No net effect	Very low benefit
2,3	Reduced rearing and outmigration habitat	Low benefit	Low benefit
1,5	Predation by non-natives	Low benefit	Low benefit

Table 4-4. Summary of Expected Effects of Option 2 on Highly and Moderately Important Sacramento River Steelhead Stressors (continued)

Applicable Criteria	Stressor[1]	Option Effects Relative to Important Species Stressors	
		Scenario A	Scenario A
Moderately Important Stressors			
1	Exposure to toxics	No net effect	No net effect
1	Reduced genetic diversity/ integrity	No net effect	No net effect
1	Harvest	No net effect	No net effect
2,3	Increased water temperature	No net effect	No net effect

Notes:
1. See Appendix C for descriptions of stressors, stressor impact mechanisms, and stressor effects.

4.1.3.1 Criterion 1. Relative degree to which the Option would reduce species mortality attributable to non-natural mortality sources, in order to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species.

Overall, this Option provides low benefits for reducing effects of non-natural mortality of Sacramento River salmonids.

Predation by non-natives

The potential affect of non-native predators on juvenile salmonids may be reduced through improvements in the quality and available of habitat within the Delta. The effectiveness of habitat restoration/enhancement in mitigating the adverse effects of non-native species on juvenile salmonids, however, is uncertain. Approximately 35% of the Delta is potentially available for restoration/enhancement under this Option (Figure 1-3). Under Option 2, the hydrodynamic conditions occurring within Old River and the central Delta would be modified substantially when compared to base conditions. Although it is expected that these changes in residence time and hydrodynamics would benefit habitat conditions for salmon and enhance food production, the response of predatory species to these changed habitat conditions is uncertain. For example, the central Delta currently supports a population of largemouth bass. Increased habitat and reduced water velocities within the central Delta potentially could contribute to a further increase in the abundance of these non-native predators. In addition, the barriers and siphon included in Option 2 may act as cover for these predators. Therefore, modifications to habitat to reduce impacts of non-native predators are considered low under Option 2.

Entrainment

The index of entrainment risk at the SWP and CVP export facilities indicates that the level of risk under Option 2 would be moderately lower (on average) than base conditions. This value would be greater if the siphon were operating at a higher capacity resulting in a greater flow of water through Middle River from the Sacramento River and an increased vulnerability of salmonids to entrainment and salvage. Further, although not included in the assumptions for Option 2 used in this analysis, if fish screens were installed at the Delta Cross Channel and the mouth of Georgiana Slough, there would be a very low probability of Sacramento River salmonids entering the central Delta and entrainment would likely be substantially reduced.

Exposure to toxics

As discussed in Criterion 2 below, exposure of Sacramento River salmonids to toxics and, therefore, mortality due to toxic exposure, is not expected to change from base conditions under Option 2.

4.1.3.2 Criterion 2. Relative degree to which the Option would provide water quality and flow conditions necessary to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species.

Flow conditions can affect the quality, quantity, and accessibility of rearing and spawning habitat.

Overall, this Option provides no net benefits to flow and water quality conditions for Sacramento River salmonids.

Exposure to toxics

Based on how Option 2 would be expected to affect Sacramento River inflows and total Delta inflows relative to modeling results for base conditions and the Options, dilution flows under Option 2 would be expected to be similar to base conditions (see Table 2-1 and Appendix E). This indicates that exposure to toxics would be not change under Option 2 than under base conditions. There is the potential for the physical configuration of Option 2 to cause an increase in toxic concentrations in the area of the central Delta that is available for restoration (Figure 1-3). The configuration of barriers and the siphon to transport San Joaquin River water into the central Delta would potentially increase toxic concentrations to the central Delta by reducing the dilution of higher concentrations of toxics and salinity originating within the San Joaquin River watershed. The potential effects of higher toxic concentrations in this area would be lower on Sacramento River salmonids than on fish that inhabit the central Delta year-round, particularly if the Delta Cross Channel and Georgiana Slough were screened. Therefore, overall, this Option would likely cause no change in toxic exposure to Sacramento River salmonids in the Delta. Toxic exposure would likely increase farther downstream (e.g., downstream of the confluence with the San Joaquin River) when Sacramento salmonids are exposed to San Joaquin River water.

Rearing habitat

Based on how Option 2 would be expected to affect the location of X_2 in April relative to modeling results for base conditions and the Options (see Table 2-1 and Appendix E), X_2 will not change substantially under Option 2. Therefore, there will be no change under this Option to spring rearing habitat for juvenile salmonids.

Model output for how Option 2 would be expected to affect flows relative to modeling results for base conditions and the Options (see Table 2-1 and Appendix E) indicates that flows occurring during late winter and spring (juvenile salmon and steelhead migration) would be negligibly different under Option 2 than under base conditions. This suggests that there would be no effect of Option 2 on downstream migration of Sacramento River salmonids towards their rearing habitat.

SWP and CVP operations and the associated hydrologic conditions expected to occur within the Delta under Option 2 are not expected to result in dissolved oxygen depression greater than base conditions. One exception may be the region just downstream of the head of Old River. Although particle tracking models indicate net downstream flows, the rate of water flow is greatly reduced until particles reach Turner Cut (Fig. 1-3). This indicates that the Stockton Deep Water Ship Channel may experience even more extensive dissolved oxygen sags than it currently does. Second, there is potential for the accumulation of high algal concentrations within the area of Old River and the western Delta resulting from increased nutrient concentrations, increased residence times, and reduced flushing during late summer low flows from the San Joaquin River. The barriers used to isolate Old River from Middle River (Figure 1-3) would be equipped with operable gates that, in the event of a dissolved oxygen depletion, could be opened to increase flushing and increase dissolved oxygen concentrations.

Access to staging and spawning habitat

Flow patterns would likely not change on the Sacramento River under Option 2, but patterns and rates would likely change in the Delta. Because all water from the San Joaquin River would be routed westward via Old River rather than into the Delta, water from the Sacramento River would need to be routed directly to the pumps at higher rates and would not exit the Delta through other waterways (e.g., San Joaquin River) as readily as it could under base conditions. As a result, migration cues from upstream may be marginally better under Option 2 because the potential for false cues resulting from water exiting the central Delta would be reduced. Therefore, access to staging and spawning habitat would likely be marginally better under this Option.

4.1.3.3 Criterion 3. Relative degree to which the Option would increase habitat quality, quantity, accessibility, and diversity in order to enhance and sustain production (reproduction, growth, survival), abundance, and distribution; and to improve the resiliency of each of the covered species' populations to environmental change and variable hydrology.

Overall, Option 2 is expected to provide very low increases in quality, quantity, diversity, and accessibility of habitat for Sacramento River salmonids.

Staging and spawning habitat

Staging and spawning habitat could be affected by migration cues that influence access and water temperature of staging and spawning habitat. As described in Criterion 2, migration cues would likely be negligibly better under this Option.

Rearing habitat

Approximately 35% of the statutory Delta is potentially available for habitat restoration under Option 2 that could serve as foraging and rearing habitat for juvenile salmonids (Figure 1-3). The additional area under Option 2 relative to Option 1, however, would be largely inaccessible to outmigrating Sacramento River salmonids. As a result, the benefit of the additional area is low to Sacramento River salmonids.

As reported under Criterion 2, there would be no net change in X_2 or net downstream flows under Option 3.

4.1.3.4 Criterion 4. Relative degree to which the Option would increase food quality, quantity, and accessibility (e.g., phytoplankton, zooplankton, macro-invertebrates, forage fish) to enhance production (reproduction, growth, survival) and abundance for each of the covered fish species.

Juvenile Chinook salmon and steelhead forage on a variety of macroinvertebrates (e.g., copepods, amphipods) and small fish during their residency within the Delta. The abundance of these prey species varies in response to a number of factors that include availability of nutrients, organic carbon, phytoplankton and zooplankton production. Reduced food availability or quality, however, are not identified as important stressors for Sacramento River salmonids. Consequently, benefits of increasing food quantity and quality under the Options would not be expected to result in a population level response relative to base conditions.

4.1.3.5 Criterion 5. Relative degree to which the Option would reduce the abundance of non-native competitors and predators to increase native species production (reproduction, growth, survival), abundance and distribution for each of the covered fish species.

Option 2 could reduce the effects of non-native competitors and predators on juvenile salmonids rearing and migrating through the Delta primarily through restoration of intertidal and shallow water subtidal aquatic habitats in the north and central Delta, representing approximately 35% of the planning area. For reasons described under Criterion #4, Option 2 would be expected to provide a low beneficial effect by improving food availability and quality relative to current conditions. For reasons described under Criteria #1 and #2, Option 2 would provide a low beneficial effect by reducing the risk of predation relative to base conditions.

4.1.3.6 Criterion 6. Relative degree to which the Option improves ecosystem processes in the BDCP planning area to support aquatic and associated habitats.

Based on the proportion of the planning area suitable for restoration under Option 2 relative to the other Options and modeling results for hydraulic residence time (see Appendix H), Option 2 would be expected to provide a moderate beneficial improvement in ecosystem function relative to base conditions.

Under Option 2, Middle River would continue to serve as the water conveyance facility for freshwater supplies moving from the Sacramento River across the Delta to the export facilities located in the southern Delta. Movement of large volumes of water through Middle River would adversely affect hydraulic conditions, require dredging to increase conveyance capacity, and may require additional riprap to reduce levee scour and erosion. These conditions would degrade the quality of fishery habitat within Middle River. In contrast, the area adjacent to Old River and the central and western portion of the Delta would be improved by isolating these areas from the effects of export operations and by increasing residence times within the central Delta thereby reducing the export of nutrients, organic carbon, phytoplankton, and zooplankton from the Delta and increasing aquatic food production and availability. These changes would be expected to improve ecosystem processes within the central and western regions of the Delta when compared to base conditions.

4.1.3.7 Criterion 7. Relative degree to which the Option can be implemented within a timeframe to meet the near-term needs of each covered fish species (post BDCP authorization).

Habitat restoration under Option 2 can be initiated immediately following authorization of the BDCP and thus could be implemented in a manner that would meet the near term needs of Sacramento River salmonids. The implementation period for Option 2 is the same as the other Options.

4.1.4 San Joaquin River Salmonids

Based on the evaluation presented below of the expected performance of Option 2 for addressing important San Joaquin River salmonid stressors, Option 2 would be expected to have a low beneficial effect on San Joaquin River salmonid production, distribution, and abundance relative to base conditions when operated to meet water supply objectives (Scenario A). If water supply exports are reduced (Scenario B), Option 2 would be expected to provide a moderate beneficial effect on San Joaquin River salmonid production, distribution, and abundance relative to base conditions.

Table 4-5 and 4-6 summarizes the expected effects of implementing Option 2 under Scenarios A and B on important San Joaquin River salmonid stressors relative to base conditions.

Table 4-5. Summary of Expected Effects of Option 2 on Highly and Moderately Important San Joaquin River Chinook Salmon Stressors

Applicable Criteria	Stressor[1]	Option Effects Relative to Important Species Stressors	
		Scenario A	Scenario B
Highly Important Stressors			
2,3	Reduced staging and spawning habitat	No net effect	No net effect
2,3	Reduced rearing and outmigration habitat	Low benefit	Low benefit
1,2	Exposure to toxics	Low adverse effect	Low adverse effect
1,5	Predation by non-natives	Low benefit	Low benefit
Moderately Important Stressors			
1	Reduced genetic diversity/ integrity	No net effect	No net effect
1	Harvest	No net effect	No net effect

Table 4-5. Summary of Expected Effects of Option 2 on Highly and Moderately Important San Joaquin River Chinook Salmon Stressors (continued)

Applicable Criteria	Stressor[1]	Option Effects Relative to Important Species Stressors	
		Scenario A	Scenario B
1,4	SWP/CVP entrainment	Very low benefit	Low benefit
2,3	Increased water temperature	No net effect	No net effect

Notes:
1. See Figure 2-5 and Appendix C for descriptions of stressors, stressor impact mechanisms, and stressor effects.

Table 4-6. Summary of Expected Effects of Option 2 on Highly and Moderately Important San Joaquin River Steelhead Stressors

Applicable Criteria	Stressor[1]	Option Effects Relative to Important Species Stressors	
		Scenario A	Scenario B
Highly Important Stressors			
2,3	Reduced staging and spawning habitat	No effect	No effect
2,3	Reduced rearing and outmigration habitat	Low benefit	Low benefit
1,2	Exposure to toxics	Low adverse effect	Low adverse effect
1	Reduced genetic diversity/ integrity	No effect	No effect
1,5	Predation by non-natives	Low benefit	Low benefit
Moderately Important Stressors			
1,4	SWP/CVP entrainment	Very low benefit	Low benefit
1	Harvest	No effect	No effect
2,3	Increased water temperature	No effect	No effect

Notes:
1. See Figure 2-6 and Appendix C for descriptions of stressors, stressor impact mechanisms, and stressor effects.

4.1.4.1 Criterion 1. Relative degree to which the Option would reduce species mortality attributable to non-natural mortality sources, in order to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species.

The primary stressors identified that can contribute to non-natural mortality for salmon and steelhead migrating through the Delta are listed in the analysis of Option 1 and discussed individually here (see Figure 2-6 and Appendix C).

Overall, Option 2 is expected to provide a low beneficial effect on sources of non-natural mortality to San Joaquin River salmonids.

Exposure to toxics

As discussed under Criterion 2 below, Option 2 would likely have low adverse effects on exposure of San Joaquin River salmonids to toxics relative to base conditions.

Predation by non-native fish

Approximately 35% of the Delta is potentially available for habitat restoration and enhancement under this Option (Figure 1-3). Therefore, modifications to habitat and flow conditions to reduce impacts of non-native predators are considered to be low under Option 2. This effect will be slightly lower for steelhead, which typically outmigrate at a larger size than Chinook salmon.

Entrainment

Under operations of Option 2 all juvenile salmon and steelhead emigrating from the San Joaquin River would be transported downstream into the Old River and the central Delta. As a result, San Joaquin River salmonids would no longer be vulnerable to entrainment or salvage at the SWP or CVP export facilities. The change in migration pathways that would occur under Option 2 would be expected to substantially reduce export related mortality on juvenile salmonids. The configuration of barriers and increased flows in Middle River under Option 2 would, however, be expected to contribute to a substantial increase in mortality of juvenile salmonids emigrating from the Mokelumne and Cosumnes rivers. These juvenile salmonids would be expected to migrate downstream within Middle River and be substantially more vulnerable to entrainment and salvage at the SWP and CVP export facilities. Because a large percentage of San Joaquin River Chinook salmon originate from the Cosumnes and Mokelumne rivers (over 41% annual average since 1999; GrandTab 2007), this will likely have a substantial negative impact on San Joaquin River salmonids. As a result, Option 2 is expected to provide a very low net reduction in overall entrainment.

4.1.4.2 Criterion 2. Relative degree to which the Option would provide water quality and flow conditions necessary to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species.

In general, this Option would be expected to provide no net benefits to flow and water quality conditions for San Joaquin River Chinook salmon and steelhead.

Exposure to toxics

Based on how Option would be expected to affect Sacramento River inflow and total Delta inflows relative to modeling results for base conditions and the Options (see Table 2-1 and Appendix E), Sacramento River flows at Rio Vista and total Delta inflow under Option 2 would be similar to base conditions. However, the configuration of barriers and the siphon to pass San Joaquin River water into the central Delta (Figure 1-3) would potentially increase concentrations, residence time, exposure to elevated toxic concentrations, and reduce dilution of higher concentrations of toxics and salinity originating within the San Joaquin River watershed. The central Delta is one of the primary areas where habitat restoration may occur under Option 2. The San Joaquin River water would not be diluted with Delta water before it enters the central Delta. As a result, this relocation would likely have low adverse effects on exposure of San Joaquin River salmonids to toxics.

Rearing habitat

Based on how Option 2 would be expected to affect the location of X_2 in April relative to modeling results for base conditions and the other Options (See Table 2-1 and Appendix E), X_2 under Option 2 is not expected to be substantially different from base conditions. This would provide no improvement to spring rearing habitat for juvenile salmonids.

As reported in Option 1, model output for Vernalis flows is not expected to change from base conditions under any Option.

SWP and CVP operations and the associated hydrologic conditions expected to occur within the Delta under Option 2 are expected to cause an increase in localized dissolved oxygen depressions relative to baseline conditions. By diverting the San Joaquin River at Old River, flushing flows in the Stockton ship channel would likely be reduced, causing a greater extent of localized depressions of dissolved oxygen levels than currently exist. Further, the accumulation of high algal concentrations within the area of Old River and the western Delta resulting from increased nutrient loading, increased residence times, and reduced flushing. The barriers used to isolate Old River from Middle River (Figure 1-3) would be equipped with operable gates that, in the event of a dissolved oxygen depletion, could be opened to increase flushing and increase dissolved oxygen concentrations. The extent to which dissolved oxygen sags will occur under this Option is largely uncertain.

Access to staging and spawning habitat

The passage of San Joaquin River flow downstream into the central Delta would be expected to provide a net positive downstream flow and may improve migration cues for juvenile movement and improved attraction flows for adult upstream migration when compared to base conditions. Option 2 would reduce migratory cues for the large portion of San Joaquin River salmonids that originate from the Cosumnes and Mokelumne rivers. Overall, there would likely be a very low positive effect on migratory cues for San Joaquin River salmonids.

4.1.4.3 Criterion 3. Relative degree to which the Option would increase habitat quality, quantity, accessibility, and diversity in order to enhance and sustain production (reproduction, growth, survival), abundance, and distribution; and to improve the resiliency of each of the covered species' populations to environmental change and variable hydrology.

Overall, the range of operations and potential habitat enhancement under Option 2 would be expected to provide a low increase in the quality, quantity, accessibility, and diversity of salmonid rearing and foraging habitat within the Delta.

Staging and spawning habitat

As discussed in Criterion #2, there is expected to be no net change in migratory cues that guide adults to upstream spawning habitat. Further, upstream reservoirs will not affect water temperatures under Option 2.

Rearing habitat

There is expected to be a low benefit to San Joaquin River salmonids from the 35% of the Delta available for physical habitat restoration and natural flow conditions (see Criterion 1). Salmonids emigrating from the San Joaquin River would be expected to benefit from improved habitat within the central Delta, however those salmonids emigrating from the Mokelumne or Cosumnes Rivers would not. San Joaquin River flows, which carry substantially higher salinity and toxic concentrations, would discharge into the restoration area and may reduce the positive effects of the restoration. The location of X_2 would not change substantially under Option 2 relative to base conditions. Downstream transport of San Joaquin River salmonids would not differ from base conditions because flow standards were assumed to be similar to standards currently in place.

4.1.4.4 Criterion 4. Relative degree to which the Option would increase food quality, quantity, and accessibility (e.g., phytoplankton, zooplankton, macro-invertebrates, forage fish) to enhance production (reproduction, growth, survival) and abundance for each of the covered fish species.

Juvenile Chinook salmon and steelhead forage on a variety of macroinvertebrates (e.g., copepods, amphipods) and small fish during their residency within the Delta. The abundance of these prey species varies in response to a number of factors that include availability of nutrients, organic carbon, phytoplankton and zooplankton production. Reduced food availability or quality, however, are not identified as important stressors for San Joaquin River salmonids. Consequently, benefits of increasing food quantity and quality under the Options would not be expected to result in a population level response relative to base conditions.

4.1.4.5 Criterion 5. Relative degree to which the Option would reduce the abundance of non-native competitors and predators to increase native species production (reproduction, growth, survival), abundance and distribution for each of the covered fish species.

The degree to which Option 2 can reduce the adverse effects of non-native competitors and predators on juvenile salmonids would be moderate. The 35% of the Delta what would potentially be available for restoration of physical habitat and natural flow conditions would occur throughout a large portion of the Delta that is occupied by San Joaquin River salmonids.

4.1.4.6 Criterion 6. Relative degree to which the Option improves ecosystem processes in the BDCP planning area to support aquatic and associated habitats.

Based on the proportion of the planning area available for potential restoration under Option 2 relative to the other Options and modeling results for hydraulic residence time (see Appendix H), Option 2 would be expected to provide a low beneficial improvement in ecosystem function relative to base conditions.

Under Option 2, Middle River would continue to serve as the water conveyance facility for freshwater supplies moving from the Sacramento River across the Delta to the export facilities located in the southern Delta. Movement of large volumes of water through Middle River would adversely affect hydraulic conditions, require dredging to increase conveyance capacity, and may require additional riprap to reduce levee scour and erosion. These conditions would degrade the quality of fishery habitat within Middle River. In contrast, the area adjacent to Old River and the central and western portion of the Delta would be improved by isolating these areas from the effects of export operations and by increasing residence times within the central Delta thereby reducing the export of nutrients, organic carbon, phytoplankton, and zooplankton from the Delta and increasing aquatic food production and availability. These changes would be expected to improve ecosystem processes within the central and western regions of the Delta when compared to base conditions and Option 1, but not to the degree expected under Options 3 and 4. It is uncertain, however, if the discharge of low quality San Joaquin River water into the central Delta would impair ecosystem processes.

4.1.4.7 Criterion 7. Relative degree to which the Option can be implemented within a timeframe to meet the near-term needs of each covered fish species (post BDCP authorization).

In the near-term, until construction of Option 2 conveyance features and facilities is completed, Option would use the existing conveyance facilities to meet water supply objectives. As for Option 1, implementation of physical habitat restoration under Option 2 in the north and west Delta can be initiated immediately following authorization of the BDCP and thus could be implemented in a manner that would meet the near-term needs of San Joaquin River salmonids.

4.1.5 Green and White Sturgeon

Based on the evaluation presented below of the expected performance of Option 2 for addressing important green sturgeon and white sturgeon stressors, Option 2 would be expected to have a low beneficial effect on green and white sturgeon production, distribution, and abundance relative to base conditions when operated to meet water supply objectives (Scenario A). If water supply exports were reduced (Scenario B), Option 2 would be expected to provide a similar level of benefit for sturgeon production, distribution, and abundance relative to base conditions. For green sturgeon, Option 2 would be expected to provide the same level of benefits as Option 3, and lower benefits than under Option 1. For white sturgeon, Option 2 would be expected to provide higher benefits than under Option 1, the same benefits as under Option 3, and lower benefits than under Option 4.

Stressors that affect sturgeon are presented in Figures 2-7 and 2-8 and are described in Appendix C. The effect of these stressors on the green and white sturgeon populations vary among years in response to environmental conditions (e.g., seasonal hydrology) and may also interact with each other in additive or synergistic ways. The effects of these stressors include both the incremental contribution of a stressor to the population as well as the cumulative effects of multiple stressors over time. The assessment of Option 2 evaluates the degree to which Option 2 would be expected to address these stressors.

Tables 4-7 and 4-8, respectively, summarize the expected effects of implementing Option 2 under Scenarios A and B on important sturgeon stressors relative to base conditions.

Table 4-7. Summary of Expected Effects of Option 2 on Highly and Moderately Important Green Sturgeon Stressors

Stressors[1]	Applicable Criteria	Option Effects Relative to Important Species Stressors	
		Scenario A	Scenario B
Highly Important Stressors			
Reduced spawning habitat	3	No net effect	No net effect
Exposure to toxics	1,2,3	No net effect	No net effect
Harvest	1	No net effect	No net effect
Moderately Important Stressors			
Reduced rearing habitat	1,2,3	Low benefit	Low benefit
Increased water temperature (upstream)	1,2,3	No net effect	No net effect
Predation	1,3	No net effect	No net effect
Reduced turbidity	1,2,3	No net effect	No net effect

Notes:
1. See Appendix C for descriptions of stressors, stressor impact mechanisms, and stressor effects.

Table 4-8. Summary of Expected Effects of Option 2 on Highly and Moderately Important White Sturgeon Stressors

Stressors[1]	Applicable Criteria	Option Effects Relative to Important Species Stressors	
		Scenario A	Scenario B
Highly Important Stressors			
Harvest	1	No net effect	No net effect
Reduced spawning habitat	3	No net effect	No net effect
Exposure to toxics	1,2,3	Very low adverse effect	Low adverse effect
Moderately Important Stressors			
Reduced rearing habitat	1,2,3	Low benefit	Low benefit
Increased water temperature (upstream)	1,2,3	No effect	No effect
Predation	1,3	No effect	No effect
Reduced turbidity	1,2,3	No effect	No effect

Notes:
1. See Appendix C for descriptions of stressors, stressor impact mechanisms, and stressor effects.

Harvest, reduced spawning habitat, predation, reduced turbidity, and increased water temperatures are not important stressors that would be affected by or affected differently (i.e., harvest, reduced spawning habitat) under the Options and, therefore, are not described in the criteria evaluations below (see Table 2-3 and Appendix C). These stressors could only be addressed through changes in regulation and law enforcement (for harvest) or through conservation actions implemented outside of the planning area. Any effects within the planning area of the Options on the non-harvest stressors described above would not be expected to have any benefits to sturgeon at the population level. As described in Table 2-3, the ability to address harvest and reduced spawning habitat within the planning area would be the same among the Options. Consequently, these stressors are initially identified under the applicable criteria below, but are not evaluated under the criteria.

4.1.5.1 Criterion 1. Relative degree to which the Option would reduce species mortality attributable to non-natural mortality sources, in order to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species.

Based on the following evaluation of Option 2 effects on applicable green and white sturgeon stressors, Option 2 is expected to provide very low benefits for green and white sturgeon relative to base conditions by reducing the effects of non-natural sources of mortality on sturgeon.

Exposure to Toxics

Exposure of green and white sturgeon to toxic substances can result in mortality of sturgeon. The effects of Option 2 on exposure to toxics are evaluated under Criteria #2 and #4 below. As described in the Criteria #2 and #4 evaluations, Option 2 would be expected to provide very low benefits for reducing the exposure of green and white sturgeon to toxics.

4.1.5.2 Criterion 2. Relative degree to which the Option would provide water quality and flow conditions necessary to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species.

Based on the following evaluation of Option 2 effects on applicable green and white sturgeon stressors, Option 2 is expected to provide no benefits for water quality and flow conditions that support green sturgeon and very low adverse effects white sturgeon relative to base conditions.

Exposure to toxics

Two factors affecting the degree of potential exposure of sturgeon to toxics include hydraulic residence time in habitat, which effects the period of exposure to toxics, and flows from the Sacramento River and other Delta tributaries, which can dilute concentrations of toxics. Measurements used to assess the potential effects of Option 2 on exposure to toxics included (1) PTM modeling results for CVP/SWP for particle fate in the central Delta, (2) Sacramento River flows at Rio Vista, and (3) Delta outflow during March and April. Overall, the percentage of particles that remain in the central Delta under Option 2, an indicator of hydraulic residence time, relative to PTM modeling results for base conditions and the Options (see Table 2-1 and Appendix E) would be expected to provide for a very low adverse increase in exposure to toxics for white sturgeon. Based on how Option 2 would be expected to affect Sacramento River inflow and total Delta inflows relative to modeling results for base conditions and the Options, dilution flows under Option 2 would be expected to be similar to base conditions (see Table 2-1 and Appendix E).

There is the potential for the physical configuration of Option 2 to cause an increase in toxic loading in the area of the central Delta that is available for habitat restoration (Figure 1-3). The configuration of barriers and the siphon to pass San Joaquin River water into the central Delta would potentially increase toxic loads, increase residence time of and potential exposure to toxics, and reduce dilution of higher concentrations of toxics and salinity originating within the San Joaquin River watershed. The central Delta is one of the primary areas where habitat restoration may occur under Option 2. San Joaquin River water will not be diluted with Delta water before it enters the central Delta. It is uncertain, however, if the potential increase in concentrations of toxics in the central Delta would adversely affect sturgeon and San Joaquin River toxic loads would be expected to decline with implementation of water quality standards and improvement programs under development.

Water quality conditions affecting habitat for green and white sturgeon also included consideration of changes in local dissolved oxygen concentrations. The potential accumulation of high algal concentrations within the area of Old River and the western Delta resulting from increased nutrient loading, increased residence times, and reduced flushing may contribute to locally reduced dissolved oxygen concentrations. The barriers used to isolate Old River from Middle River (Figure 1-3) would be equipped with operable gates that, in the event of a dissolved oxygen depletion, could be opened to increase flushing and increase dissolved oxygen concentrations.

Reduced Rearing Habitat

Based on how Option 2 would be expected to affect the X_2 location in April relative to X_2 modeling results for base conditions and the Options, X_2 position would remain similar to base conditions (see Table 2-1 and Appendix E), indicating that the extent of available rearing habitat would be similar to base conditions. In addition, Option 2 would be expected to improve westerly flows through the central Delta as a migration cue for both juvenile and adult sturgeon migration. The changes in hydrologic conditions expected to occur under Option 2 on Middle River would be expected to degrade habitat conditions and hydraulic migration cues for adult and juvenile sturgeon inhabiting the eastern region of the Delta. The effect of these changed hydraulic conditions is unknown, because the frequency of occurrence of green or white sturgeon juveniles and adults within the eastern region of the Delta.

4.1.5.3 Criterion 3 Relative degree to which the Option would increase habitat quality, quantity, accessibility, and diversity in order to enhance and sustain production (reproduction, growth, survival), abundance, and distribution; and to improve the resiliency of each of the covered species' populations to environmental change and variable hydrology.

Within the planning area, green and white sturgeon habitat conditions are governed by hydrodynamic conditions and the extent and quality of habitat within the planning area. Under Option 2, these conditions relative to base conditions would be affected by the conveyance configuration of Option 2 and the opportunities for restoration of physical habitat that could be sited within Suisun Bay and Marsh and within the planning area in the north, central, and west Delta, which represents approximately 35% of the planning area.

Based on the following evaluation of Option 2 effects on applicable green and white sturgeon stressors, Option 2 is expected to provide low habitat benefits for green sturgeon relative to base conditions.

Exposure to Toxics

As described under Criterion #2 above, the risk for exposure of sturgeon to toxics is similar to base conditions. A major source for bioaccumulation of selenium in sturgeon is consumption of non-native *Corbula* and *Corbicula*, which capture selenium from Delta waters. Restoration of aquatic shallow subtidal and intertidal habitats could create conditions that favor the production of alternative prey (e.g., bay shrimp) that reduce the risk of bioaccumulation of materials such as selenium for juvenile and adult sturgeon. The potential success of reducing the risk of toxics on sturgeon through habitat improvements and increased production of alternative prey resources is uncertain. Under Option 2, habitat could potentially be restored within Suisun Bay and Marsh and approximately 35% of the Delta to provide high quality aquatic habitat under this Option (Figure 1-3), which encompasses a larger proportion of the white sturgeon's rearing range than restoration that could be implemented under Option 1, the same proportion as under Option 3, and a smaller proportion than under Option 4. Because the green sturgeon is not known to occupy the San Joaquin River watershed but may occur within the central Delta, restoration opportunities would be the same under Option 2 as under Option 3, but less than under Option 4, which includes restoration opportunities in the east Delta north of the San Joaquin River. Consequently, relative to base conditions and the other Options, Option 2 would be expected to provide a low benefit for improving green and white sturgeon rearing habitat.

Reduced Rearing Habitat

The primary impact mechanism believed to affect the extent of rearing habitat and rearing habitat conditions is the reclamation of historical aquatic subtidal and intertidal habitats and channelization of river channels. Under Option 2, habitat could be restored within Suisun Bay and Marsh and approximately 35% of the Delta to provide high quality aquatic habitat under this Option (Figure 1-3), which encompasses a larger proportion of the white sturgeon's rearing range than restoration that could be implemented under Option 1, the same proportion as under Option 3, and a smaller proportion than under Option 4. Because the green sturgeon is not known to occupy the San Joaquin River watershed but may occur within the central Delta, restoration opportunities would be the same under Option 2 as under Option 3, but less than under Option 4, which includes restoration opportunities in the east Delta north of the San Joaquin River. Consequently, relative to base conditions and the other Options, Option 2 would be expected to provide a low benefit for green and white sturgeon rearing habitat.

4.1.5.4 Criterion 4. Relative degree to which the Option would increase food quality, quantity, and accessibility (e.g., phytoplankton, zooplankton, macro-invertebrates, forage fish) to enhance production (reproduction, growth, survival) and abundance for each of the covered fish species.

Overall, Option 2 would be expected to marginally increase food availability for juvenile and adult sturgeon within the Delta.

Based on the following evaluation of Option 2 effects on applicable green and white stressors, Option 2 is expected to provide low food supply benefits for green and white sturgeon relative to base conditions.

Exposure to Toxics

As described under Criterion #3 above, restoration of rearing habitat could reduce the relative importance of non-native *Corbula* and *Corbicula* thus improving the quality of food for sturgeon by reducing their exposure to selenium. Relative to base conditions and the other Options, Option 2 would be expected to provide low benefits for green and white sturgeon rearing habitat.

4.1.5.5 Criterion 5. Relative degree to which the Option would reduce the abundance of non-native competitors and predators to increase native species production (reproduction, growth, survival), abundance and distribution for each of the covered fish species.

Predation in the form of illegal and legal harvest would not be changed under any of the Options from base conditions.

4.1.5.6 Criterion 6. Relative degree to which the Option improves ecosystem processes in the BDCP planning area to support aquatic and associated habitats.

Based on the proportion of the planning area available for potential restoration under Option 2 relative to the other Options and modeling results for hydraulic residence time (see Appendix H), Option 2 would be expected to provide a low beneficial improvement in ecosystem function relative to base conditions.

Under Option 2, Middle River would continue to serve as the water conveyance facility for freshwater supplies moving from the Sacramento River across the Delta to the export facilities located in the southern Delta. Movement of large volumes of water through Middle River would adversely affect hydraulic conditions, require dredging to increase conveyance capacity, and may require additional riprap to reduce levee scour and erosion. These conditions would degrade the quality of fishery habitat within Middle River. In contrast, the area adjacent to Old River and the central and western portion of the Delta would be improved by isolating these areas from the effects of export operations and by increasing residence times within the central Delta thereby reducing the export of nutrients, organic carbon, phytoplankton, and zooplankton from the Delta and increasing aquatic food production and availability. These changes would be expected to improve ecosystem processes within the central and western regions of the Delta when compared to base conditions and Option 1, but not to the degree expected under Options 3 and 4. It is uncertain, however, if the discharge of low quality San Joaquin River water into the central Delta would impair ecosystem processes.

4.1.5.7 Criterion 7. Relative degree to which the Option can be implemented within a timeframe to meet the near-term needs of each covered fish species (post BDCP authorization).

In the near-term, until construction of Option 2 conveyance features and facilities is completed, Option would use the existing conveyance facilities to meet water supply objectives. As for

Option 1, implementation of physical habitat restoration under Option 2 in the north and west Delta can be initiated immediately following authorization of the BDCP and thus could be implemented in a manner that would meet the near-term needs of green and white sturgeon.

4.1.6 Splittail

Based on the evaluation presented below of the expected performance of Option 2 for addressing important splittail stressors, Option 2 would be expected to have a moderate beneficial effect on splittail production, distribution, and abundance relative to base conditions when operated to meet water supply objectives (Scenario A). If water supply exports were reduced (Scenario B), Option 2 would also be expected to provide a moderate beneficial effect on splittail production, distribution, and abundance relative to base conditions. Option 2 would be expected to provide a greater level of benefit for splittail than Option 1, a similar level of benefit as Option 3, but a lower level of benefit compared to Option 4.

Table 4-9 summarizes the expected effects of implementing Option 2 under Scenarios A and B on important splittail stressors relative to base conditions.

Table 4-9. Summary of Expected Effects of Option 2 on Highly and Moderately Important Splittail Stressors

Applicable Criteria	Stressor[1]	Option Effects Relative to Important Species Stressors	
		Scenario A	Scenario B
Highly Important Stressors			
2,3	Reduced juvenile rearing/adult habitat	Moderate benefit	Moderate benefit
2,3	Reduced spawning/larval rearing habitat	Moderate benefit	Moderate benefit
1,4	Reduced food	Low benefit	High benefit
1,2	Exposure to toxics	Low adverse effect	Low adverse effect
Moderately Important Stressors			
1,5	Predation	Moderate benefit	Moderate benefit
1,4	SWP/CVP entrainment[2]	Low benefit	Moderate benefit
1	Harvest	No net effect	No net effect

Notes:
1. See Appendix C for descriptions of stressors, stressor impact mechanisms, and stressor effects.
2. Although it is recognized that the risk of entrainment at the SWP and CVP export facilities may, in some years, be a high level stressor to splittail, and in some years represents a very low level stressor to splittail, for purposes of the analysis the risk of delta smelt entrainment under each of the Options has been characterized, on average, as a moderate level stressor to the population.

4.1.6.1 Criterion 1. Relative degree to which the Option would reduce species mortality attributable to non-natural mortality sources, in order to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species.

Based on the following evaluation of Option 2 effects on applicable splittail stressors, Option 2 is expected to provide low benefits for splittail by reducing the effects of non-natural sources of mortality relative to base conditions.

Reduced Food Availability

Habitat conditions can affect the availability and quality of splittail food. The effects of Option 2 on splittail food availability are evaluated under Criterion #4 below. As described in the Criterion #4 evaluation, Option 2 would be expected to provide a low beneficial effect on food supply for the splittail relative to base conditions.

Exposure to Toxics

The effects of Option 2 on exposure to toxics are evaluated under Criterion #2 below. As described in the Criterion #2 evaluation, Option 2 would be expected to continue to provide dilution flows similar to base conditions and could increase exposure to toxics discharged from the San Joaquin River into the central Delta, which could have a low adverse effect on splittail. It is uncertain, however, if the potential increase in concentrations of toxics in the central Delta would adversely affect splittail.

Predation

Under Option 2, approximately 35% of the Delta would potentially be available for restoration/enhancement (Figure 1-3), which, if designed properly, could potentially reduce the adverse impacts of predation risk by non-natives. This entire area would be located within the geographic range of splittail within the northern, western, and central regions of the Delta. The proportion of the planning area within which habitat could potentially be implemented is greater than under Option 1, the same as under Option 3, but less than under Option 4. Habitat restoration under Option 2 would be expected to provide a moderate benefit for potentially reducing predation impacts relative to base conditions and the other Options. However, there is a high degree of uncertainty regarding the biological response of splittail, other native fish and macroinvertebrate species, and non-native species to large-scale habitat restoration/ enhancement within the Delta.

Entrainment by CVP/SWP Facilities

Under operations of Option 2 juvenile splittail emigrating from the San Joaquin River would be transported downstream into Old River and the central Delta. As a result, the vulnerability of San Joaquin River juvenile splittail to entrainment or salvage at the SWP or CVP export facilities would be greatly reduced. San Joaquin River splittail could be exposed to an increased risk for entrainment during periods of reverse flow in Middle River and resulting reverse flows within the lower San Joaquin River (QWEST). The configuration of barriers and increased flows in Middle River under Option 2 would, however, be expected to contribute to a substantial increase in mortality of juvenile splittail emigrating from other east side tributaries such as the Mokelumne and Cosumnes rivers. These juvenile splittail would be expected to migrate downstream within Middle River and have increased vulnerability to entrainment and salvage at the SWP and CVP export facilities. Splittail that spawn in the Sacramento River would continue to be at risk of entrainment as a result of flows passing through the Delta Cross-Channel, Georgiana Slough, and Three Mile Slough that would result in movement of juvenile splittail into the central Delta. Option 2 would be expected to provide a low benefit for splittail by reducing the likelihood for entrainment of splittail relative to base conditions (see Table 2-1 and Appendix C).

4.1.6.2 Criterion 2. Relative degree to which the Option would provide water quality and flow conditions necessary to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species.

Overall, Option 2 is expected to provide very low benefits for splittail by improving flow and water quality conditions relative to current conditions.

Exposure to Toxics

Option 2 is expected to have a low adverse effect by increasing the exposure of splittail to toxics as a result of redirecting the discharge of the San Joaquin River into the central Delta. The level of effect of this increased exposure on juvenile and adult splittail, however, is uncertain.

Based on how Option 2 would be expected to affect Sacramento River inflow and total Delta inflows relative to modeling results for base conditions and the Options, dilution flows under Option 2 would be expected to be similar to base conditions (see Table 2-1 and Appendix E). There is the potential for the physical configuration of Option 2 to cause an increase in toxic loading in the area of the central Delta that is available for habitat restoration (Figure 1-3). The configuration of barriers and the siphon to pass San Joaquin River water into the central Delta would potentially increase toxic loads, increase residence time of and potential exposure to toxics, and reduce dilution of higher concentrations of toxics and salinity originating within the San Joaquin River watershed. The central Delta is one of the primary areas where habitat restoration may occur under Option 2. San Joaquin River water will not be diluted with Delta water before it enters the central Delta. Splittail are a long-lived species that primarily forage on benthic macroinvertebrates. Given their diet and longevity there is a relatively high potential that splittail could bioaccumulate toxic materials (e.g., selenium, mercury, etc.) at chronic exposure concentrations that could reach levels in the body that adversely impact growth, reproduction, and survival. If water quality conditions under Option 2 in the central Delta were to adversely affect splittail, the relocation of San Joaquin River flows could have adverse effects of sufficient magnitude on splittail that could offset the benefits of isolating the central Delta from the effects of SWP and CVP export operations. It is uncertain, however, if the potential increase in concentrations of toxics in the central Delta would adversely affect splittail and San Joaquin River toxic loads would be expected to decline with implementation of water quality standards and improvement programs under development.

Reduced Rearing Habitat

Sacramento River inflows during March and April under Option 2 that facilitate the downstream movement of juvenile splittail are expected to remain similar to base conditions. Expected changes in peak Delta inflows during January through March indicate that Option 2 would have a marginally higher probability of floodplain inundation during wetter years relative to base conditions (see Table 2-1 and Appendix E). The potential restoration of rearing habitats as described under Criterion #3, however, would be expected to improve rearing habitat conditions. Consequently, overall Option 2 would be expected to have moderate beneficial effects on rearing habitat conditions relative to base conditions.

Reduced Spawning/Larval Rearing Habitat

Expected changes in peak Delta inflows during January through March indicate that, under Option 2, there would be a marginally higher probability of floodplain inundation during wetter years relative to base conditions (see Table 2-1 and Appendix E). The potential restoration of spawning/larval rearing habitats as described under Criterion #3, however, would be expected to improve spawning/larval rearing habitat conditions. Consequently, overall Option 2 would be expected to have moderate beneficial effects on spawning/larval rearing habitat conditions relative to base conditions.

4.1.6.3 Criterion 3. Relative degree to which the Option would increase habitat quality, quantity, accessibility, and diversity in order to enhance and sustain production (reproduction, growth, survival), abundance, and distribution; and to improve the resiliency of each of the covered species' populations to environmental change and variable hydrology.

Based on the following evaluation of Option 2 effects on applicable splittail stressors, Option 2 is expected to provide moderate benefits relative to habitat conditions for the splittail.

Within the planning area, splittail habitat conditions are governed by hydrodynamic conditions and the extent and quality of habitat within the planning area. Under Option 2, these conditions relative to base conditions would be affected by the conveyance configuration of Option 2 and the opportunities for restoration of physical habitat that could potentially be sited within Suisun Bay and Marsh and within 35% of the planning area in the north, central, and west Delta.

Reduced Rearing and Spawning Habitat

Under Option 2, habitat could potentially be restored within Suisun Bay and Marsh and approximately 35% of the Delta to provide high quality shallow aquatic subtidal and intertidal habitat (Figure 1-3), which encompasses a larger proportion of the splittail spawning and rearing range than restoration that could be implemented under Option 1, the same proportion as under Option 3, and a smaller proportion than under Option 4. In addition, increases in hydraulic residence time under Option 2 also provide for lower velocity habitats that are expected to be more suitable for splittail relative to base conditions. Consequently, relative to base conditions and the other Options, Option 2 would be expected to provide a moderate benefit for splittail rearing and spawning habitat.

Reduced Food Availability

Habitat conditions can affect the availability and quality of splittail food. The effects of Option 2 on splittail food availability are evaluated under Criterion #4 below. As described in the Criterion #4 evaluation, Option 2 would be expected to provide a moderate beneficial effect on food supply for the splittail relative to base conditions.

4.1.6.4 Criterion 4. Relative degree to which the Option would increase food quality, quantity, and accessibility (e.g., phytoplankton, zooplankton, macro-invertebrates, forage fish) to enhance production (reproduction, growth, survival) and abundance for each of the covered fish species.

Overall, Option 2 would be expected to provide low benefits for improving food supply for splittail.

Reduced Food Availability

Option 2 would not be expected to substantively increase the frequency or duration of seasonally inundated floodplain habitat within the Sacramento or San Joaquin Rivers, other than opportunities for physical modification within the Delta. Hydraulic residence would be substantially increased in the central Delta and would be expected to increase phytoplankton, zooplankton, and macroinvertebrate production within the central Delta. Restoration of shallow subtidal and intertidal habitats under Option 2 would also be expected to improve food supply. Consequently, Option 2 would be expected to provide a low benefit for splittail food supply.

The habitat restoration that would be implemented under Option 2 would all be located within the geographic range of splittail and could create conditions that disfavor non-native species that indirectly or directly affect food abundance (e.g., overbite clam (*Corbula*), threadfin shad), thereby improving food availability for splittail relative to base conditions (Figure 1-3). The potential opportunity for habitat restoration is expected to improve food availability relative to Option 1, would be the same relative to Option 3, and less than under Option 4. In addition, under Option 2, water with high nutrient loads from the San Joaquin River would no longer be subject to the same level of exports as under base conditions and these waters would be conveyed downstream into the central region of the Delta where increased nutrient loads, in combination with increased residence times, would be expected to stimulate phytoplankton and zooplankton production.

4.1.6.5 Criterion 5. Relative degree to which the Option would reduce the abundance of non-native competitors and predators to increase native species production (reproduction, growth, survival), abundance and distribution for each of the covered fish species.

Based on the following evaluation of Option 2 effects on applicable splittail stressors, Option 2 is expected to provide moderate benefits for splittail relative to the abundance of non-native competitors and predators.

Option 2 could reduce the effects of non-native competitors and predators on splittail primarily through restoration of intertidal and shallow subtidal aquatic habitats in the north, west, and central Delta. For reasons described above, Option 2 would be expected to provide a moderate beneficial effect by reducing the impacts of populations of non-native food competitors relative to base conditions. Additionally, the operable barriers along Middle River provide some opportunity under Option 2 to adaptively manage Delta hydrodynamics to create hydrodynamic conditions that favor the splittail and disfavor predators and competitors to improve conditions for the splittail. Although the ability to control non-native species by varying hydrodynamic conditions in the Delta is uncertain, Option 2 provides a greater opportunity for doing so than under Option 1, but much less opportunity for doing so compared to Option 3.

4.1.6.6 Criterion 6. Relative degree to which the Option improves ecosystem processes in the BDCP planning area to support aquatic and associated habitats.

Based on the proportion of the planning area available for potential restoration under Option 2 relative to the other Options and modeling results for hydraulic residence time (see Appendix H), Option 2 would be expected to provide a low beneficial improvement in ecosystem function relative to base conditions.

Under Option 2, Middle River would continue to serve as the water conveyance facility for freshwater supplies moving from the Sacramento River across the Delta to the export facilities located in the southern Delta. Movement of large volumes of water through Middle River would adversely affect hydraulic conditions, require dredging to increase conveyance capacity, and may require additional riprap to reduce levee scour and erosion. These conditions would degrade the quality of fishery habitat within Middle River. In contrast, the area adjacent to Old River and the central and western portion of the Delta would be improved by isolating these areas from the effects of export operations and by increasing residence times within the central Delta thereby reducing the export of nutrients, organic carbon, phytoplankton, and zooplankton from the Delta and increasing aquatic food production and availability. These changes would be expected to improve ecosystem processes within the central and western regions of the Delta when compared to base conditions and Option 1, but not to the degree expected under Options 3 and 4. It is uncertain, however, if the discharge of low quality San Joaquin River water into the central Delta would impair ecosystem processes.

4.1.6.7 Criterion 7. Relative degree to which the Option can be implemented within a timeframe to meet the near-term needs of each covered fish species (post BDCP authorization).

In the near-term, until construction of Option 2 conveyance features and facilities is completed, the Option would use the existing conveyance facilities to meet water supply objectives. As for Option 1, implementation of physical habitat restoration under Option 2 in the north and west Delta can be initiated immediately following authorization of the BDCP and thus could be implemented in a manner that would meet the near-term needs of splittail.

4.2 PLANNING CRITERIA

4.2.1.1 Criterion #8: Relative degree to which the Option allows covered activities to be implemented in a way that meets the goals and purposes of those activities

Under Option 2 as modeled under flow Scenarios 2A and 2B, the ability to achieve the water delivery reliability and facility operation goals of the CVP/SWP is lower than current conditions and Option 1 (Scenario A), Option 3, and Option 4 (Figure 3-1). Option 2 model results indicate greater water delivery reliability than the more restrictive range of Option 1 (Scenario B).

The ability to meet water supply goals is low under Option 2 primarily due to limitations in the hydraulic ability to convey water from Victoria Canal to Clifton Court Forebay through the gravity siphon. Hydraulic calculations and hydrodynamic model simulations indicate that use of a gravity siphon at this location would limit conveyance to approximately 4,500 cfs. As described in Section 2.2, the limitation of increased conveyance through the siphon is primarily controlled by the tidal stage in Victoria Canal and the permissible operating range of water levels in Clifton Court Forebay.

With the upper range of water delivery reliability under Option 2 constrained by the siphon conveyance capacity, the CALSIM II model simulations indicate that CVP/SWP exports may be reduced by 2.8 to 3.4 MAF/YR as compared to the current conditions and depending on the range of Middle River flow restrictions applied. Operational flexibility would be expected to be significantly reduced as the diversion of water from the Delta would be fully dependent on the tidal range in Middle River and Victoria Canal. CVP/SWP operations would “respond” to the availability of stage-dependent supply as opposed to being able to draw the supply as required. Option 2 would need to be revised to improve its ability to meet this criterion. The inclusion of a low-head pump facility at the siphon under Option 2 (described in Section 2) would increase siphon flow. In addition, lowering of Clifton Court Forebay elevations (through dredging) could be conducted to increase hydraulic head. To achieve water export objectives, the pump facility would need a capacity of about 13,000 cfs to deliver sufficient water to the Banks (about 8,500 cfs) and Jones (about 4,600 cfs) facilities.

A pump facility of such size would reduce surface elevation and produce high velocity flows in Victoria Canal and Middle River. To support these flows, Victoria canal would need to be expanded, Middle River levees would need reinforcement to protect against scour, and agricultural diversion facilities in these channels would need to be improved (to address lowered surface) or moved.

With these improvements Option 2, export reliability would exceed base conditions and be similar to Option 1. Option 2 could be more reliable than Option 1 if pumping restrictions for regulatory compliance were reduced through operations of the barriers to minimize entrainment of protected species. Export reliability under Option 2 is expected to be less than Option 4 because Option 4 is projected to avoid most of the regulatory constraints imposed on in-Delta pumping facilities. Export reliability of Option 2 would be lower than Option 3 because Option 3 includes all of the Option 2 conveyance facilities and a peripheral aqueduct resulting in greater capacity and flexibility.

With the development of the Middle River corridor under Option 2, better quality Sacramento River water would be conveyed more directly and efficiently to the CVP/SWP export facilities and export water quality would be expected to improve as compared to current conditions and Option 1. Water quality is not expected to improve as substantially as under Options 3 and 4, however (Figure 3-2).

4.2.1.1 Criterion #9: The relative feasibility and practicability of the Option, including the ability to fund, engineer, and implement

A number of uncertainties affect the feasibility and practicability of Option 2. Hydrodynamic modeling results indicate that a gravity siphon under Old River would not support sufficient flows (<4,500 cfs) to meet water export goals. A low-head pump would remove this limitation, but would result in other impacts and costs that affect feasibility including lower water levels and high velocities in Middle River and Victoria Canal and would require additional channel engineering to resolve at an unknown (but likely substantial) cost. The pump facility would need to support approximately 13,000 cfs and therefore could be a substantial cost (estimated at $224 million). Cost practicability of this Option is addressed in Criterion #10, below.

Technical uncertainties are associated with habitat restoration along Old River that effect the feasibility of habitat conservation actions in this area. These uncertainties include the unknown effects of possible reduced water quality (e.g., higher salt and selenium content) associated with concentrating San Joaquin River discharge into the habitat restoration area and how best to manage flow conditions (e.g., fluctuating salinity) in the central Delta west of the proposed Option 2 barriers to provide ecological benefits. The technologies for constructing operable barriers and strengthening levees are proven (DWR SDIP EIR/EIS 2005), but methods and timing for operating barriers to achieve species conservation and water supply goals are untested.

The geographic area for habitat restoration under Option 2 is smaller than under Option 4, and, consequently, would provide limited flexibility in choosing the most cost and ecologically effective and sustainable restoration sites. Options 2 and 3 include the same geographic area for habitat restoration and are, therefore, comparable regarding the feasibility of physical habitat restoration actions.

4.2.1.3 Criterion #10: Relative costs (including infrastructure, operations, and management) associated with implementing the Option

Delta Infrastructure Costs

Option 2 is expected to have higher infrastructure costs than Option 1 but lower costs than Options 3 and 4. Expected costs for Option 2 vary considerably according to the amount and degree of levee strengthening assumed and whether Option 2 is assumed to require relocation of Contra Costa Water District (CCWD) intakes, screening of the Delta Cross Channel and Georgiana Slough, and addition of a pump station to ensure proper functioning of the siphon. As described here, Option 2 infrastructure costs could be as low as $0.5 billion or as high as $2.8 billion. With the additional intake, screen structures, and pump station included in Option 2, its infrastructure costs could be as low as $1.5 billion or as high as $3.8 billion.

As described and evaluated in this report, Option 2 entails construction of:

- Operable physical channel barriers on Woodward Canal, Railroad Cut, Connection Slough near their confluences with Middle River, and on Old River north of Franks Tract near its mouth (confluence with the San Joaquin River).

- A large box-culvert siphon to hydraulically connect Victoria Canal with Clifton Court Forebay.

- Strengthening approximately 34 miles of levees along Middle River from Medford Island to the Old River siphon.

- An operable physical barrier on the San Joaquin River near the head of Old River.

- Hydraulic intertie between Clifton Court Forebay and CVP intake channel.

- Although not included in Option 2, other proposals of similar approaches to through-Delta conveyance have included additional infrastructure features such as:

- Fish screens for the Delta Cross Channel and Georgiana Slough.

- Relocation of CCWD intakes.

- A pump station to increase siphon performance.

The fish screen and CCWD intake elements were included as part of BDCP's conservation elements Bundle #8 "San Joaquin Corridor Isolated from Through-Delta Conveyance and SWP/CVP Intakes" in the Conservation Strategy Short-Listing Analysis Report (BDCP May 2007). The pump station was identified as a possible reconfiguration of Option 2 after initial hydrodynamic modeling results indicated a gravity siphon might be incapable of meeting flow requirements. Costs estimates are presented here both with and without these additional three elements. The cost of these additional elements is not included in the overall comparison of the Options presented in Section 7. Note that while their inclusion or exclusion changes the magnitude of infrastructure costs for Option 2, it does not alter the cost ranking of the four Options.

Tables 4-1 and 4-2 present low, medium, and high infrastructure cost estimates for Option 2. Table 4-1 includes only those facilities included in Option 2 in the Descriptions of Conservation Strategy Options (BDCP May 2007). Table 4-2 includes Option 2 facilities plus fish screens for the Delta Cross Channel and Georgiana Slough, relocation of CCWD intakes, and a pump facility at the siphon.

The assumptions regarding costs of levees along Middle River from Medford Island to the Old River siphon are as follows:

Low levee estimate assumes levees are upgraded to the PL84-99 standard. This level of improvement would reduce flood risk from high water events, but would provide minimal seismic risk reduction. It does address increased vulnerability due to future sea level rise. Per mile levee improvement costs are $5.4 million/mile.

Medium levee estimate assumes levees are upgraded to the urban standard of protection.[3] This level of improvement would significantly reduce flood risk from high water events and would provide some improvement in seismic protection relative to the PL84-99 standard. Per mile levee improvement costs are $21 million/mile.

High levee estimate assumes levees are upgraded to resist 1-in-300 year seismic events. This level of improvement would significantly reduce both flood and seismic risks. Per mile levee improvement costs are $71 million/mile.

Unit costs for levee improvements are taken from the *DRMS Phase II Building Blocks Evaluation* (DRMS Phase II 2007).[4]

Other costs listed in Tables 4-1 and 4-2 are from the following sources:

Siphon Cost: the estimate is the average of estimated siphon costs developed by Washington Group International (WGI) and URS Corporation for their cost evaluations of a peripheral aqueduct. The estimate includes construction contingency and engineering, construction management, and administration costs. For WGI, we use the siphon cost for the San Joaquin River as the proxy cost for the Option 2 siphon. The URS Corporation estimate only provides total cost for eleven siphons. We, therefore, use the average cost for the eleven siphons. The two resulting estimates differ by less than 5%. Table 4-1 uses the midpoint of the two estimates.

Operable Barriers: costs for operable barriers are taken from previous CALFED cost evaluations for SDIP (DWR 2006). SDIP estimated four operable gates and related actions would cost approximately $110 million (updated to 2007 dollars). We increase this cost by a factor of 1.25 to estimate the cost of five operable gates.

Clifton Court Forebay-Jones Pumping Plant Intertie: The cost for this intertie is unknown at this time. According to USBR, the project has not moved beyond the conceptual stage and cost estimates have not been developed for it. USBR expects the intertie to be more expensive than the proposed intertie between the California Aqueduct and the Delta Mendota Canal, which currently is expected to cost about $30 million (USBR personal communication). For this evaluation, we have adopted the Delta Mendota Canal intertie cost as a proxy but emphasize that this estimate is likely to understate the actual cost of the project.

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[3] The urban standard used in the DRMS Phase II evaluation is based on the following levee design: Maximum waterside and landside slopes 3H:1V; Minimum crest width 20 feet; Minimum 3.0 feet of freeboard above 100-year flood stage.

[4] Per mile levee improvement costs from DRMS Phase II were as follows: (1) $5.4 million/mile to upgrade to PL 84-99 standards, (2) $21 million/mile to upgrade to urban standards, and (3) $71 million/mile to upgrade to the seismic resistance level of protection. In cases (1) and (3), DRMS developed costs for two improvement options. In each case, we use the mid-point cost for the two options.

Table 4-1. Option 2 Capital Cost Range for Infrastructure Improvements (Millions of 2007 Dollars)

Infrastructure Elements	Low	Medium	High
Levee Strengthening (34 miles)	$184	$714	$2,499
Old River Siphon (1)	$182	$182	$182
Operable Barriers (5)	$138	$138	$138
Hydraulic Intertie	$30	$30	$30
Total	**$534**	**$1,064**	**$2,849**

Table 4-2. Option 2 Capital Cost Range for Infrastructure Improvements, Including Delta Cross Channel/Georgiana Slough Fish Screens and Relocation of CCWD Intakes (Millions of 2007 Dollars)

Infrastructure Elements	Low	Medium	High
Levee Strengthening (34 miles)	$184	$714	$2,499
Old River Siphon (1)	$182	$182	$182
Operable Barriers (5)	$138	$138	$138
Hydraulic Intertie	$30	$30	$30
Possible Additional Elements			
Fish Screens (2)	$500	$500	$500
CCWD Intake Relocation (2)	$200	$200	$200
Siphon Pump Station (1)	$224	$224	$224
Total	**$1,458**	**$1,988**	**$3,773**

CCWD Intakes: The cost estimate is based on estimated planning and construction costs for CCWD's Alternative Intake Project. This project has an estimated planning and construction cost of $100 million (CCWD 2006). Relocation of both CCWD intakes may, therefore, cost on the order of $200 million.

Delta Cross Channel and Georgiana Slough Screens: The cost estimate is based on the Glenn-Colusa Irrigation District fish screen construction costs. The Glenn-Colusa Irrigation District fish screen project had a $76 million capital cost (Glenn-Colusa Irrigation District, Undated). The project constructed a 620-feet extension to the existing interim Glenn-Colusa Irrigation District fish screen, an average cost of about $12.3 million per 100-feet of screen. Applying this average unit cost to the two proposed fish screens suggests that screening costs for Option 2 may be on the order of $500 million.

Siphon Booster Pump Station: The cost estimate is based on pump station costs proposed for the peripheral aqueduct. Cost estimates developed by URS Corporation and WGI range between $217 and $230 million. We use the mid-point of these two estimates as a proxy for the siphon booster pump station.

An additional construction costs under Option 2 that would need evaluation is the dredging of Victoria Canal and reinforcing of levees on Middle River to support anticipated higher velocity flows to the siphon/pump facility. Such costs could be substantial. Because of the low water conditions expected in Middle River, agricultural diversion facilities drawing from the river would either need to be improved or moved to a new location. The extent and cost of such an action has not been estimated at this time, but could be substantial.

Delta Conveyance Disruption Costs

Risks to water exports from major flood or seismic events would be lower under Option 2 than Option 1, but higher than under Options 3 or 4. The amount of risk reduction under Option 2 depends on the type and extent of levee improvements to protect the through-Delta conveyance pathway. DRMS Phase I results indicate that seismic events pose the primary risks to Delta water exports because such events have the highest likelihood of drawing large amounts of salt water into the south Delta and shutting down water exports for periods lasting from months to years. DRMS Phase I estimated that over the next 25 years, the likelihood of a flood or seismic event shutting down CVP and SWP exports for at least ten months was between 50% and 60%, while the likelihood of an event shutting down exports for up to two years was between 30% and 40%. Under the latter scenario, water exports would decrease by 6 to 9 MAF during the repair and recovery period and economic impacts were estimated to range between $10 and $50 billion. DRMS Phase II concluded that a seismically engineered conveyance pathway through the Delta combined with operable barriers in the south Delta could reduce these risks by a factor of ten.[5] The through-Delta conveyance pathway evaluated by DRMS Phase II would move water from the Sacramento River near Hood down to the CVP and SWP export pumps. This is a much more extensive pathway than contemplated for Option 2 and, therefore, Option 2 is not expected to provide the same level of risk reduction.[6] However, assuming Option 2 included a seismically engineered conveyance corridor from Medford Island to the Old River siphon, Option 2 is expected to be less vulnerable to significant export disruptions than Option 1.

Export Water Quality Costs

Option 2 is expected to have lower costs in terms of export water quality than Option 1, but higher costs than Options 3 or 4. Hydrodynamic modeling results indicate this Option could reduce total dissolved solids in export water by 100 to 125 mg/L. A reduction of this magnitude would provide a significant water quality benefit to urban water users in Southern California. San Joaquin Valley agricultural users may benefit to some extent from slower salt buildup in soils and less need for flushing salts from the root zone.[7] Salt loading is of particular concern in Southern California urban areas. A 1999 study of the problem (USBR 1999) estimated a $95 million annual benefit for each 100 mg/L reduction in the total dissolved solids of the region's imported water. Updating population estimates and accounting for the share of water imported from the SWP and Colorado River, the annual benefit was estimated to be on the order of $100 million (2007 dollars) per 100-mg/L reduction in SWP total dissolved solids. The present value

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[5] Through-Delta conveyance is discussed in Section 8 of the DRMS Phase II report.

[6] The "armored" through-Delta conveyance pathway evaluated by DRMS Phase II had an estimated construction cost of $10.1 billion compared to the cost of Option 2 with seismically engineered levee improvements of $3.8 billion.

[7] Improved agricultural export water quality benefits would probably be negligible for south-of-Delta farmland. For impaired lands on the west side of the San Joaquin Valley, the binding constraint is drainage. Without improvements to drainage, improvements in the quality of delivered irrigation water would not be expected to significantly improve productivity on impaired lands. For non-impaired lands, improvements to water quality would provide only negligible production benefits, if any. Over the long-run, better water quality could slow salt buildup and reduce the need for flushing salts from the soil. (Mark Roberson, *pers comm.*).

of avoided salinity damages in Southern California over the next 25 years under Option 2 could, therefore, be on the order of $1.0 to $1.5 billion.[8]

Habitat Restoration Costs

Because it is assumed the overall amount of habitat restoration would be roughly the same across the four Options (though the locations could differ), restoration cost estimates developed with currently available information would not distinguish Option 2 from the other three Options. While it is recognized that unit costs of restoration may vary to some degree according to the range and location of restoration activity, sufficient information on unit restoration cost differentials is not available at this time to distinguish among the four Options. Thus, habitat restoration costs are not treated as a significant distinguishing feature among the four Options.

4.3 FLEXIBILITY/ DURABILITY/SUSTAINABILITY CRITERIA

4.3.1.1 Criterion #11: Relative degree to which the Option will be able to withstand the effects of climate change (e.g., sea level rise and changes in runoff), variable hydrology, seismic events, subsidence of Delta islands, and other large-scale changes to the Delta

Option 2 is expected to have a greater ability than Option 1, but less ability than Options 3 and 4, to withstand large-scale changes to the Delta that would adversely affect species conservation and covered activities. The extent of levees supporting Option 2 conveyance that are subject to breaching or overtopping during flood events is somewhat less than under Options 1 and 3, but Option 3 provides for alternate conveyance through a peripheral aqueduct should levees fail, and Option 4 is not dependent on Delta levees for conveyance. The probability for flood-induced levee failures is expected to increase in the future based on predicted future changes in sea level and in river hydrology as a result of climate change (DRMS Draft Stage I 2007).

Risk to Habitat Restoration Actions

Physical and operational habitat restoration actions under Option 2 are at less risk from seismic or flood events and from the ongoing effects of sea level rise relative to Option 1, at greater risk than Option 4, and at the same risk as Option 3. Under Option 2, habitat restoration would be focused in the north and central Delta and is expected to be more narrowly distributed than under Option 4. A levee failure at or near restoration sites would have a disproportionate adverse effect under Option 2 where restoration sites are more concentrated than under Option 4 where restoration sites are expected to be distributed over a wider area of the Delta. Similarly, with more localized restoration sites, Option 2 would provide less flexibility than under Option 4 to adjust flow operations at these concentrated sites in the event of levee failure(s).

Protecting physical habitat restoration against the effects of sea level rise requires restoration sites at higher elevations (sites in the Delta with less subsidence) and with elevation gradients that include an ecotone between tidal and upland habitat (allowing, over decades, the gradual upward elevation shift of all tidal habitats in response to sea level rise). The more limited geographic focus of habitat restoration under Option 2 relative to Option 4 reduces the number

[8] The present value calculation of avoided damages uses a real discount rate of 6.0%, per DWR guidance.

and extent of sites with such elevation characteristics available for habitat restoration in the Delta and hence provides less durability of restored habitat.

Risk to Water Supply Infrastructure

Option 2 would provide somewhat more protection to water supply facilities from seismic or flood events and from the ongoing effects of sea level rise than Option 1, but less than Options 3 and 4. Levees that direct conveyance through the north Delta (e.g., Tyler Island) are at greater risk of failure from seismic and flood events than the peripheral aqueduct included in Options 3 and 4 (the aqueduct would be expected to be engineered to withstand probable seismic and flood events). Because the levees along Middle River are expected to be strengthened to meet future seismic and flood protection standards, conveyance under Option 2 is considered to be more reliable than conveyance along Old and Middle Rivers that would be provided under Option 1 (DRMS Draft Stage I 2007).

4.3.1.2 Criterion #12: Relative degree to which the Option could improve ecosystem processes that support the long term needs of each of the covered species and their habitats with minimal future input of resources

Option 2 may be able to sustain improvements in ecosystem processes through time better than Option 1, but may be less able to sustain ecosystem processes than Options 3 and 4 for the following reasons:

1. Option 2 may provide more habitat than Option 1 that would be less influenced by hydrological effects of water supply pumping from the Delta. Although this Option likely would not eliminate pumping constraints for protection of fish or other environmental reasons, it likely would be less constrained and, therefore, would have greater water reliability than Option 1.

2. Option 2 may be less sustainable than Option 1 if the operable barriers are determined to present barriers to movement of covered species within the Delta (e.g., sturgeon). If operable barriers are found to be adequately responsive to fishery conditions, then Option 2 may be more sustainable than Option 1 once operating rules are devised that benefit all covered species.

3. Option 2 would be more sustainable through time than Option 1 because it provides for greater flexibility in managing for a more variable Delta hydrology.

4. Option 2 would be less sustainable through time than Options 3 and 4 as these Options should increase the ability to adaptively manage Delta flows to improve conditions for covered species.

5. Option 2 may require greater input of future resources than Options 3 or 4 to implement a new approach if it is determined that the use of operable barriers is not compatible with the recovery of some covered species (e.g., sturgeon).

6. Option 2 likely would entrain fewer fish than Option 1, but more fish than under Options 3 and 4. Option 2 would require continued funding for trucking and hauling of salvaged fish; however, the needed resources should be less than for Option 1.

4.3.1.3 Criterion #13: Relative degree to which the Option can be adapted to address the needs of covered fish species over time

Option 2 is expected to be more adaptable than Option 1, but less adaptable than Options 3 and 4 to address possible future conservation of the covered fish species for the following reasons:

1. A larger percentage of land area compared to Option 1, but substantially smaller percentage compared to Option 4, within the Delta for restoring high function habitat is available under Option 2 should it be necessary to increase the extent of restored habitat for covered species in the future.

2. The geographic extent of land area that is suitable for habitat restoration is greater than under Option 1, but less than under Option 4; therefore, Option 2 is less adaptable than Option 4 to opportunities to restore habitat in other portions of the Delta that may be required to meet conservation needs of covered species in the future.

3. The flexibility to adjust Delta hydrology is less constrained than under Option 1 because the operable barriers along Middle River provide an opportunity to manage the hydrology west of Middle River and south of the San Joaquin River if needed to improve flow and water quality conditions for the benefit of covered fish species. Opportunities for adjusting hydrology in other portions of the Delta to address future conservation needs of covered fish species is less than under Options 3 and 4, which include the flexibility to restore a more natural hydrology throughout the Delta if needed.

4.3.1.4 Criterion #14: Relative degree of reversibility of the Option once implemented

Option 2 is expected to be less practicable to reverse than Option 1, but more practicable to reverse than Options 3 and 4.

Under Option 2, upgrading levees to standards that will withstand the risk of failure from seismic, flood, and subsidence hazards along Middle River and construction of new facilities (i.e., operable barriers, siphon, and intertie) would entail substantial investment of capital (see Criterion #10) that would be lost if their use were abandoned. Additional costs would be incurred if structures needed to be removed or demolished. Compared to Options 3 and 4, reversing Option 2 would be more likely to be acceptable to the public because costs and the land area subject to disturbances (e.g., noise and road closures) would be less.

4.4 OTHER RESOURCES IMPACTS CRITERIA

4.4.1.1 Criterion #15: Relative degree to which the Option avoids impacts on the distribution and abundance of other native species in the BDCP planning area

Under Option 2, the probability of adverse impacts on other native aquatic species within the Delta is expected to less than under Option 1 and current conditions, but greater than Options 3 and 4 for the following reasons:

1. Relative to Option 1 and current conditions, Option 2 would result in reduced entrainment of aquatic organisms in the south Delta with the separation of Old River flows from the export facilities and the operation of barriers along Middle River. Option 2 could result in more entrainment of fish from the central Delta than Option 1 where Options 2 increases reverse flows in Middle River and pulls in aquatic organisms from channels near Medford Island. Option 2 would have greater aquatic organism entrainment at the SWP/CVP facilities than Options 3 and 4 because of the reduced entrainment anticipated at the state-of-the-art fish screening facility at the Sacramento River intake.

2. Under Option 2, the placement and operation of the barriers along Middle River could impede the movement of one or more covered native fish and aquatic organisms to and from the east and central Delta. This would also be a potential impact under Option 3, which includes barriers, but not under Options 1 and 4, which do not include barriers along Middle River. The degree of adverse impact is not known at this time but would be expected to be greatest for species that require such movements to fulfill their lifecycle. Because the barriers are expected to be operable, there is the opportunity to adjust operation of barriers to avoid and minimize this potential impact should it occur.

3. Potential intertidal and aquatic habitat restoration areas are expanded from Option 1 to include areas in the Delta west of the Option 2 barriers along Middle River, which could benefit other native aquatic species in that portion of the Delta. Technical uncertainties, however, are associated with habitat restoration along Old River that affect the feasibility of conservation actions in this area. These uncertainties include the unknown effects of reduced water quality (e.g., higher salt and selenium content) associated with concentrating San Joaquin River discharge into the habitat restoration area and how best to manage flow conditions (e.g., fluctuating salinity) in the central Delta west of the proposed Option 2 barriers to provide ecological benefits.

4. Construction of barriers, siphons, and strengthening of levees could result in temporary impacts on water quality associated with sediment discharge or mobilization of channel bed sediments and disturbance to or mortality of aquatic organisms associated with in-channel operation of equipment. These impacts are expected to be temporary and minor, but would be greater than under Option 1, which does not include any construction activities. Similar types and levels of impacts would be expected under Options 3 and 4 with construction of a peripheral aqueduct under both Options and barriers and siphon under Option 3.

The probability for adverse impacts on terrestrial native species within the Delta is expected to be substantially more than under Option 1, which does not include ground-disturbing activities that could affect wildlife and their habitats, but less than under Options 3 and 4. Impacts of Options 2 from construction activities to improve approximately 34 miles of levees along Middle River and Victoria Canal could have substantial effects on riparian, wetland, and upland (mainly agricultural land) habitats and the species that use these habitats. Assuming a construction zone of 200 feet in width, levee improvement could affect over 800 acres of terrestrial habitats.

Construction of the siphon and five barriers could result in temporary disturbances (i.e., visual and noise) to wildlife. Impacts on wildlife habitats are expected to be relatively minor because the construction footprint of barriers and the siphon would be relatively small and impacts would be limited to areas immediately adjacent to affected channels. For example, five gates proposed under the South Delta Improvements Program (SDIP) would result in removal of less than five acres of terrestrial habitat (Department of Water Resources and Reclamation 2005).

As shown in Figure 3-3, salinity intrusion in the west-central Delta could increase during the growing season compared to current conditions. This level of potential change in salinity, however, is not expected to affect crops yields sufficiently to reduce their value as foraging habitat for wildlife (Lund et al. 2007). For example, research conducted by Hoffman et al. (1982) indicated that yields of field corn in the Delta were not affected by salinities of less than 3.7 mS/cm.

4.4.1.2 Criterion #16: Relative degree to which the Option avoids impacts on the human environment

The types of adverse impacts as defined under CEQA and NEPA on the human environment that could be associated with Option 2 are described in this section.[9] Potential impacts described here for Option 2 would not necessarily be significant or could be expected to be reduced to a less than significant effect with CEQA/NEPA mitigation.

Option 2 would require the construction of barriers and a siphon and strengthening of levees along Middle River. Because these disturbances are highly localized and the construction footprint of these Option features is relatively small, Option 2 is expected to potentially incur only minimal impacts on the following CEQA/NEPA impact categories:

- Geology and soils—risk for erosion,
- Utilities and public services, and

[9] The evaluation of Criterion #16 focuses on the likely range of adverse direct and indirect impacts of the Options in the planning area and not the indirect impacts to water quality and water supply reliability and in the service areas. These issues in the service areas are addressed in Criteria #8 and #11. Option 2 is expected to provide higher water quality and be less vulnerable to supply disruption than Option 1, but portions of the conveyance system would still be vulnerable to future disruption and loss of water supply to service areas. Options 3 and 4 are expected to be substantially less vulnerable than Option 2 to future disruption of water supply. Export water quality improvements would be greater under Options 3 and 4 and the reduction in impacts to treatment costs, agricultural production, and human health would, therefore, be greater than Options 2.

- Environmental justice.

Option 2 would have a greater potential for greater impacts than Option 1 and fewer impacts than Options 3 and 4 on the following impact categories because the extent of construction-related activities that could result in impacts within these categories are greater than under Option 1 and less than under Options 3 and 4:

- Cultural resources—likelihood for encountering cultural resources.
- Air quality—PM10 emissions associated with ground disturbance and operation of equipment.
- Noise—operation of equipment.
- Transportation/traffic—likelihood that construction activities to improve levees along Middle River and Victoria Canal would disrupt transportation infrastructure and traffic patterns.
- Energy usage—fuel and electricity used in construction.

Water Quality/Hydrology. The quality of water, as measured by EC, that would be exported from the SWP/CVP facilities under Option 2 would generally be expected, within the range of modeled operations, to be substantially higher than under current conditions and Option 1; generally higher than or similar to Option 3 from August through December and lower from January through July; and substantially lower than Option 4 in all months (see Figure 3-1). Improvements in water quality exported from the Delta relative to current conditions and Option 1 would be expected to reduce water treatment costs to meet water quality standards and needs for municipal, agricultural, and residential uses in service areas. Water treatment costs would be expected to be similar to Option 3, but higher than Option 4.

Within the Sacramento River Delta (as measured at Emmaton on Sherman Island) and the range of modeled operations most likely to achieve water supply objectives, water quality under Option 2 would generally be expected to be higher than Option 1 and compared to current conditions from August through January and generally similar to Option 1 and current conditions from February through July; generally higher than Option 3 in all months; and generally higher than Option 4 from August through April and similar to or lower than Option 4 from May through July. Water quality would be expected to be somewhat higher in the east Delta under Option 2 than under Options 1 and 4 because Option 2 would prevent lower quality San Joaquin River water from entering the east Delta (see Figure 3-4). Changes in Sacramento River water quality are expected to have no or minimal impacts on farming practices or production.

Within the San Joaquin River Delta (as measured on Old River at State Highway 4) and the range of modeled operations most likely to achieve water supply objectives, water quality under Option 2 would generally be lower than Option 1 and current conditions from December through August and similar to or higher than Option 1 and current conditions from September through November; similar to Option 3 in all months; and similar to Option 4 from September through June, but lower than Option 4 during July and August(see Figure 3-4). Changes in water quality in the west central Delta under Option 2 potentially could affect farming practices or production. Because Option 2 includes operable barriers along Middle River, it provides for operational flexibility to adjust operation of the barriers to improve water quality conditions in the west central Delta, if needed.

Construction of five operable barriers and the siphon and strengthening of levees along Middle River could result in localized and temporary erosion and runoff of sediments into adjacent Delta waters that could temporarily degrade water quality. This impact would not occur under Option 1 and would likely be substantially less than Options 3 and 4 because those Options would require construction of a peripheral aqueduct that would include more extensive construction in Delta waters (e.g., siphons under the Mokelumne, San Joaquin, Middle, and Old Rivers).

Aesthetics. Construction of Option 2 facilities would temporarily and permanently affect the visual character of each facility site as viewed from public roads and/or boats more than for Option 1 and less than for Options 3 and 4 because no new facilities would be built in Option 1 and more facilities would be built in Options 3 and 4. The levee improvements in Option 2 could adversely affect views of Middle River and Victoria Canal from nearby locations, and the barriers would affect views from boats using these waters. Any lights associated with the new Option 2 facilities could increase night lighting and glare at those locations (DWR 2005) as compared to no new lighting for Option 1 and more lighting for Options 3 and 4.

Hazards/Hazardous Materials. Option 2 would have a greater potential for spills of fuel and lubricants as a result of equipment operation and maintenance during construction of new facilities than for Option 1 because no new facilities would be built for Option 1, while the potential would be less than for Options 3 and 4 because more facilities would be built in the latter two Options. Construction activities could also expose people to hazardous materials and waste uncovered during the work (DWR 2000), and the potential under Option 2 would be greater than for Option 1 and less than for Options 3 and 4 due to the relative amounts of ground disturbance during construction under each of these options. Operation of the barriers in Options 2 could pose a safety hazard to recreational boaters that would be the same as for Option 3 and greater than in the Options 1 and 4 that do not include such barriers.

Recreation. Option 2 would be more likely to affect recreation than Option 1 but less likely than Options 3 and 4. Construction of barriers and the siphon could result in temporary or permanent impacts on recreational patterns (e.g., restricting boat access to channels), so it would have more impacts than Option 1. Option 2 would likely have fewer impacts than Options 3 and 4 because construction of a peripheral aqueduct under these Options could impact access to lands used for recreational activities or reduce the quality of recreational experiences.

Agricultural Resources. Option 2 is expected to have greater potential for impacts on agricultural resources compared to Option 1 because irrigation water quality in the south-central Delta would be substantially lower than Option 1 and could affect farming practices and production. This impact, however, may be reduced if there is sufficient operational flexibility to manage the operable barriers along Middle River to improve water quality west of the barriers. Impacts on farmed lands associated with improvement of approximately 34 miles of levees along Middle River and Victoria Canal could result in removal of agricultural land from production. Option 2 would be expected to have fewer impacts on agricultural land than Options 3 and 4, which are estimated to remove a larger quantity of farmland from production with construction of a peripheral aqueduct. Option 2 potentially could have greater impacts than Option 4 on agriculture in the west-central Delta if water quality under Option 2 is sufficiently lower than Option 4 during July and August to affect crop production.

4.4.1.3 Criterion #17: Relative degree of risk of the Option causing impacts on sensitive species and habitats in areas outside of the BDCP planning area

Adverse or beneficial effects on native species and habitats outside the planning area could result from changes in flow regimes downstream of the Delta in Suisun Bay and Marsh and upstream in the Sacramento River and its major tributaries. The potential for adverse effects downstream of the Delta are indicated by differences in Delta outflow among the Options. The potential for adverse effects in the Sacramento River and its tributaries are indicated by differences in end-of-September reservoir storage volumes, which is a measure of the capacity of reservoirs to provide for cold water releases to sustain water temperatures within ranges favored by native aquatic species.

Hydrodynamic modeling outputs for Option 2 indicated potentially greater Delta outflows then other Options, but this result was based on the gravity siphon that produced exports below supply goals. Option 2 with the pump facility is anticipated to support similar Delta outflows to Option 1 and base conditions (see Section 2). Based on this assumption, the potential for beneficial effects on species and habitats downstream of the planning area is expected to be less under Option 2 than under Options 3 and 4 which could support substantially higher Delta outflows to Suisun Marsh and Bay.

Under the range of modeled operations, Option 2 is not expected to affect upstream river water temperature conditions relative to current conditions and could provide for cooler releases from Shasta and Oroville Reservoirs compared to current conditions during critical water years. Based on reservoir storage volumes at the end of September, the ability to provide for cold water releases downstream of Shasta, Folsom, and Oroville Reservoirs under Option 2 would be expected to be similar to Options 1, 3, and 4 in most water-year types. During critical water years, Shasta Reservoir storage volume would be similar to Option 1, but greater than under Options 3 and 4; Folsom Reservoir storage volume would be similar to Options 1 and 3, but greater than Option 4; Oroville Reservoir storage volume would be similar to Options 1 and 3 and greater than Option 4 during dry years; and during critical years, Oroville Reservoir storage volume would be similar to Option 3 and greater than Options 1 and 4.

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5.0 CONSERVATION STRATEGY OPTION 3 EVALUATION

Using the methods described in Section 2, this section presents an evaluation of Option 3. Option 3 is evaluated based on how it addresses each of the evaluation criteria and how it performs relative to the other Options and base conditions.

5.1 BIOLOGICAL CRITERIA

Option 3 includes construction and operation of a series of barriers designed to reduce the effects of SWP and CVP export operations on hydraulic conditions and habitat for covered species within Old River and the central region of the Delta (Figure 1-4). Option 3 also includes the construction and operation of an intake facility with a state-of-the-art- positive barrier fish screen located on the Sacramento River in the vicinity of Hood. Diversions would be made preferentially from the Hood facility, however, diversions would also be made from the south Delta. To accommodate through-Delta water conveyance under Option 3 the primary locations of potential physical habitat restoration and enhancement measures are expected to be in the northern reaches of the Delta (e.g., Cache Slough area, Yolo Bypass, Sutter and Steamboat Sloughs), in Suisun Marsh, and in the central region of the Delta (Figure 1-4). Results of the assessment of biological criteria and potential benefits to the covered fish species under Option 3 are described in this section.

The evaluation of biological criteria for Option 3 is based on the hydrodynamic parameter values modeled for operational Scenarios A and B. The evaluation discussions presented below for each species and criterion, however, focus on Scenario A because:

- the type of effects of Scenario B on stressors and stressor impact mechanisms for each of the covered fish species are the same as described for Scenario A and a description of the performance of Scenario B would be repetitious;

- Scenario A would be more likely to achieve water supply objectives than Scenario B and, therefore, comparison of hydrodynamic outputs for scenario A across the Options puts each Option on an equivalent basis; and

- The magnitude of the effects of the Option on covered fish species differs between Scenarios A and B and, consequently, CALSIM II and DSM2 modeling results for Scenario B provided information useful in determining the range of flexibility within the Option to improve performance of the Option relative to achieving each of the biological criteria.

Though not described in the criteria evaluation text, the expected performance of Scenario B on each of the important stressors for each of the covered fish species relative to the performance of Scenario A is presented in summary tables at the beginning of each species evaluation section below.

Descriptions of the stressors and impact mechanisms addressed by the Options relative to each of the biological criteria and the tools used to measure changes in stressor effects are described in Section 3, “Conservation Strategy Option 1 Evaluation”, and are not repeated in this section.

5.1.1 Delta Smelt

Based on the evaluation presented below of the expected performance of Option 3 for addressing important delta smelt stressors, Option 3 would be expected to have a moderate beneficial effect on delta smelt production, distribution, and abundance relative to base conditions when operated to meet water supply objectives (Scenario A). If water supply exports are reduced (Scenario B), Option 2 would also be expected to provide a moderate beneficial effect on delta smelt production, distribution, and abundance relative to base conditions. Option 3 would be expected to provide higher benefits for delta smelt compared to Options 1 and 2, but lower benefits compared to Option 4.

Table 5-1 summarizes the expected effects of implementing Option 3 under Scenarios A and B on important delta smelt stressors relative to base conditions.

Table 5-1. Summary of Expected Effects of Option 3 on Highly and Moderately Important Delta Smelt Stressors

Stressors[1]	Applicable Criteria	Option Effects on Important Species Stressors Relative to Base Conditions	
		Scenario A	Scenario B
Highly Important Stressors			
Reduced food availability	1,3,4,5	Moderate benefit	Moderate benefit
Reduced rearing habitat	2,3	Moderate benefit	Moderate benefit
Reduced turbidity	1,2,3,5	Moderate benefit	Moderate benefit
Reduced spawning habitat	3	Moderate benefit	Moderate benefit
Reduced food quality	1,4,5	Moderate benefit	Moderate benefit
Moderately Important Stressors			
Predation	1,5	Moderate benefit	Moderate benefit
CVP/SWP entrainment[2]	1	High benefit	High benefit
Exposure to toxics	1,2	Moderate adverse effect	Moderate adverse effect

Notes:

1. See Appendix C for descriptions of stressors, stressor impact mechanisms, and stressor effects.
2. Although it is recognized that the risk of entrainment at the SWP and CVP export facilities may, in some years, be a high level stressor to delta smelt, and in some years represents a very low level stressor to delta smelt, for purposes of the analysis the risk of delta smelt entrainment under each of the Options has been characterized, on average, as a moderate level stressor to the population.

5.1.1.1 Criterion #1. Relative degree to which the Option would reduce species mortality attributable to non-natural mortality sources, in order to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species.

Based on the following evaluation of Option 3 effects on applicable delta smelt stressors, Option 3 is expected to provide moderate benefits for delta smelt by reducing the effects of non-natural sources of mortality relative to base conditions.

Reduced Food Availability and Quality

The effects of Option 3 on delta smelt food availability and quality are evaluated under Criterion #4 below. As described in the Criterion #4 evaluation, Option 3 would be expected to provide a moderate beneficial effect on food availability and a moderate beneficial effect on food quality for the delta smelt relative to base conditions.

Reduced Turbidity

The effects of Option 3 on turbidity are evaluated under Criterion #2 below. As described in the Criterion #2 evaluation, Option 3 would be expected to provide moderate beneficial increase in turbidity conditions for delta smelt.

Predation

As described below under Criterion #2, Option 3 would be expected to improve turbidity conditions relative to base conditions and, therefore, would be expected to reduce the vulnerability of delta smelt to predation. The proportion of the Delta (35%) within which habitat restoration could potentially be implemented is greater than under Option 1, the same as under Option 2, but less than under Option 4 (see Figure 1-4). Based on the potential for improvement in turbidity conditions and the proportion of the Delta available for restoration, Option 3 would be expected to provide a moderate benefit by reducing the predation vulnerability of delta smelt relative to base conditions.

Entrainment by CVP/SWP Facilities[1]

In Middle River, which is designated as the conveyance corridor to move water through the Delta to the export facilities, PTM modeling results indicated that entrainment was greater relative to base conditions when SWP and CVP exports were being made from the south Delta. Other than from the Middle River insertion location, there was a substantial reduction in entrainment of particles by the SWP/CVP exports. In Middle River, which is designated as the conveyance corridor to move water through the Delta to the export facilities, entrainment was greater than base conditions. In reality, however, there should be very few or no larval or juvenile delta smelt in Middle River relative to base conditions and Option 1 because they would be blocked from entering the corridor from the west by the structural barriers. Risk for

[1]Modeling results for reverse flows in Old and Middle River are not used in the assessment of this stressor under Option 3 because Old River flows are isolated from the CVP/SWP pumping facilities and modeled reverse flow results for Old River cannot be disaggregated from results for Middle River.

entrainment into Middle River, however, would be increased during periods of reverse flow in the San Joaquin River, but would be expected to be lower than under Option 2 which would pump water from Middle River through the siphon.

Risk for entrainment of delta smelt at the Hood intake facility would be minimal because the intake would be equipped with a positive barrier fish screen that would be expected to be highly effective in reducing the vulnerability of all but the early larval stages of delta smelt to entrainment. Furthermore, most delta smelt are believed to spawn downstream of the proposed Hood intake location, thus reducing the proportion of the delta smelt population that is vulnerable to entrainment.[2] The proportion of the population, however, that could be vulnerable to entrainment could increase in future years as sea levels rise sufficiently to move spawning upstream from current locations. Under Option 3 delta smelt would continue to be vulnerable to entrainment and salvage at the south Delta export facilities to the extent that water is exported from the south Delta under this Option. PTM modeling results indicate that the percentage of particles entrained by SWP and CVP exports under Option 3 would be negligible from most insertion locations and flow conditions (see Appendices F and H). The only insertion location from which particles were entrained regularly was Middle River. The index of vulnerability to SWP and CVP salvage for delta smelt shows a substantial decrease in the risk of smelt salvage under Option 3 when compared to base conditions and Options 1 or 2 (see Appendices F and H). Consequently, Option 3 would be expected to provide a high benefit for delta smelt by substantially reducing the likelihood for entrainment of delta smelt relative to base conditions.

Exposure to Toxics

The effects of Option 3 on delta smelt exposure to toxics are evaluated under Criterion #2 below. As described in the Criterion #2 evaluation, Option 3 would be expected to have a moderate adverse increase in delta smelt exposure to toxics.

5.1.1.2 Criterion #2. Relative degree to which the Option would provide water quality and flow conditions necessary to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species.

Based on the following evaluation of Option 3 effects on applicable delta smelt stressors, Option 3 is expected to have a low beneficial effect on water quality and flow conditions that support delta smelt relative to base conditions.

Reduced Rearing Habitat

Results of hydrologic modeling indicate that the position of X_2 in April would be located upstream relative to base conditions and therefore could result in a slight reduction in the availability of rearing habitat. Net downstream flows and Sacramento River flows at Rio Vista during March and April, which serve to transport larval smelt to downstream rearing habitats, would be reduced relative to base conditions (see Appendices F and H). PTM modeling results,

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[2] Results of fishery surveys conducted by CDFG and USFWS have shown that the majority of delta smelt inhabit the Sacramento River downstream of Walnut Grove and Georgiana Slough although a small number of delta smelt have been collected upstream of Hood in some years.

however, indicate that more particles would move downstream of Chipps Island relative to base conditions. As described below, Option 3 would be expected to improve turbidity conditions, thus improving the foraging efficiency of delta smelt and reducing their vulnerability to predation. The potential restoration of rearing habitats as described under Criterion #3 would also be expected to improve rearing habitat conditions. Consequently, overall Option 3 would be expected to have a moderate beneficial effect on delta smelt rearing habitat conditions relative to base conditions.

Reduced Turbidity

Option 3 is expected to moderately improve turbidity conditions for delta smelt relative to base conditions. Peak total Delta inflows from January through March are reduced from base conditions, indicating that turbidity inputs from Delta tributaries could be reduced from base conditions in those months. PTM modeling results for the central Delta indicate, however, that residence time would be substantially higher, thus creating the potential for increases in turbidity associated with primary and secondary production (see Appendices F and H). Restoration of aquatic subtidal and intertidal habitats that could reduce the impacts of non-native aquatic pelagic and benthic organisms that filter sediment and organic materials from Delta waters could occur within approximately 35% of the Delta (Figure 1-4). Although peak Delta inflows could be reduced, improved turbidity conditions associated with increased hydraulic residence time and habitat restorations would be such that, overall, Option 3 would be expected to provide a moderate beneficial improvement in turbidity conditions for delta smelt relative to base conditions.

Exposure to Toxics

Dilution flows from the Sacramento River and other Delta tributaries are one way of reducing concentrations of toxics and their effect on delta smelt. Modeling results indicate that Option 3 would be expected to reduce dilution flows relative to base conditions, thus potentially increasing concentrations of toxics (see Appendices F and H). As described for Option 2, there is also the potential for the physical configuration of Option 3 to cause an increase in toxic loading in the area of the central Delta that is available for restoration (Figure 1-4). The configuration of barriers and the siphon to transport San Joaquin River water into the central Delta would potentially increase toxic loading to the central Delta by reducing the dilution of higher concentrations of toxics and salinity originating within the San Joaquin River watershed. Although the effects of toxics on delta smelt are uncertain, Option 3 has the potential for having a moderate adverse effect on delta smelt by increasing the exposure of delta smelt to higher concentrations of toxics.

5.1.1.3 Criterion #3. Relative degree to which the Option would increase habitat quality, quantity, accessibility, and diversity in order to enhance and sustain production (reproduction, growth, survival), abundance, and distribution; and to improve the resiliency of each of the covered species' populations to environmental change and variable hydrology.

Based on the following evaluation of Option 3 effects on applicable delta smelt stressors, Option 3 is expected to provide moderate benefits relative to habitat conditions for the delta smelt.

Within the planning area, delta smelt habitat conditions are governed by hydrodynamic conditions and the extent and quality of habitat within the planning area. Under Option 3, these conditions relative to base conditions would be affected by the conveyance configuration of Option 3 and restoration of physical habitat that could be sited within Suisun Bay and Marsh and within the planning area in the north and west Delta, which represents approximately 35% of the planning area.

Reduced Food Availability

The effects of Option 3 on delta smelt food availability are evaluated under Criterion #4 below. As described in the Criterion #4 evaluation, Option 3 would be expected to provide a moderate beneficial effect on food supply for the delta smelt relative to base conditions.

Reduced Rearing Habitat

Under Option 3, in addition to the flow benefits for rearing habitat conditions described above under Criterion #2, habitat could be restored within Suisun Bay and Marsh and approximately 35% of the Delta to provide high quality shallow aquatic subtidal and intertidal habitat (Figure 1-4), which encompasses a larger proportion of the delta smelts rearing range than restoration that could be implemented under Option 1, the same proportion as under Option 2, and a smaller proportion than under Option 4. Consequently, relative to base conditions and the other Options, Option 3 would be expected to provide a moderate benefit for delta smelt rearing habitat.

Reduced Turbidity

The effects of Option 3 on turbidity are evaluated under Criterion #2 above. As described in the Criterion #2 evaluation, Option 3 would be expected to provide moderate beneficial increases in turbidity conditions.

Reduced Spawning Habitat

The primary impact mechanism believed to affect spawning habitat is the reclamation and channelization of historical shallow subtidal and intertidal wetlands that has presumably reduced the amount of habitat available for spawning by delta smelt. Under Option 3, habitat could potentially be restored within Suisun Bay and Marsh and approximately 35% of the Delta to provide high quality aquatic habitat under this Option (Figure 1-4), which encompasses a slightly larger proportion of the likely spawning range of delta smelt than restoration that could be implemented under Option 1, the same proportion as Option 2, and smaller proportion than Option 4. Consequently, relative to the other Options and to the extent that functioning delta smelt spawning habitat can be successfully restored based on current understanding of its habitat requirements, restoration under Option 3 would be expected to provide a moderate benefit (see Appendix H) relative to base conditions.

5.1.1.4 Criterion #4. Relative degree to which the Option would increase food quality, quantity, and accessibility (e.g., phytoplankton, zooplankton, macro-invertebrates, forage fish) to enhance production (reproduction, growth, survival) and abundance for each of the covered fish species.

Overall, Option 3 would be expected to provide moderate benefits for improving food availability and quality for delta smelt.

Reduced Food Availability

The habitat restoration that would potentially be implemented under Option 3 would all be located within the geographic range of delta smelt and could create conditions that disfavor non-native species that indirectly or directly affect food abundance (e.g., overbite clam (*Corbula*), threadfin shad), thereby improving food availability for delta smelt relative to base conditions (Figure 1-4). The potential opportunity for habitat restoration is expected improve food availability relative to Option 1, would be the same relative to Option 2, and less than under Option 4.

Floodplains are highly productive and are thought to be a source of high amounts of allochthonous nutrient and organic carbon production from the terrestrial community that inhabits the floodplain and upland areas during the remainder of the year (Sommer et al. 2001, Harrell and Sommer 2003). The magnitude of peak flows from January through March, the period during which inflows have been greatest into the Delta historically, gives an indication of the potential for floodplain inundation relative to base conditions. Modeled peak Delta inflows under Option 3 during January through March are substantially lower relative to base conditions (see Appendices F and H). Therefore, relative to base conditions, Option 3 would be expected to have a low adverse effect on the transport of organic material and nutrients from floodplains into the Delta.

Based on PTM modeling results for exported particles, the removal of food organisms, nutrients, and organics by diversions would be appreciably lower relative to base conditions. PTM modeling results for particles released into the central Delta, an indicator of hydrologic residence time, indicated that hydraulic residence time within the central Delta was greater relative to base conditions. Based on these results, Option 3 would be expected to provide a moderate benefit for delta smelt associated with a reduction in exports of nutrients and organic material that support delta smelt food supplies.

Reduced Food Quality

Restoration of shallow water tidal and subtidal habitats under Option 3 could improve nutrient production and production of suitable zooplankton species (e.g., native calanoid copepods) as forage for delta smelt. Under Option 3, habitat could potentially be restored within Suisun Bay and Marsh and approximately 35% of the Delta to provide high quality aquatic habitat under this Option (Figure 1-3), which encompasses a larger proportion of the delta smelt's range than restoration that could be implemented under Option 1, the same proportion as under Option 2, but less than under Option 4. Consequently, relative to the other Options, Option 3 would be expected to provide a moderate benefit for food quality (see Appendix H).

5.1.1.5 Criterion #5. Relative degree to which the Option would reduce the abundance of non-native competitors and predators to increase native species production (reproduction, growth, survival), abundance and distribution for each of the covered fish species.

Option 3 could reduce the effects of non-native competitors and predators on delta smelt primarily through restoration of shallow water subtidal and intertidal and aquatic habitats in the north and central Delta. For reasons described above, Option 3 would be expected to provide a moderate beneficial effect by reducing the potential adverse effects of populations of non-native food competitors relative to base conditions. For reasons described under Criteria #1 and #2, Option 3 could provide a moderate beneficial effect by reducing the risk of delta smelt predation relative to base conditions. Additionally, the flexibility provided by dual conveyance facilities and operable barriers provides the opportunity under Option 3 to adaptively manage Delta hydrodynamics to create hydrodynamic conditions that favor the delta smelt and disfavor predators and competitors to improve conditions for the delta smelt. Although the ability to control non-native species by varying hydrodynamic conditions in the Delta is uncertain, Option 3 provides the greatest opportunity for doing so among the Options.

5.1.1.6 Criterion #6. Relative degree to which the Option improves ecosystem processes in the BDCP planning area to support aquatic and associated habitats.

Based on the proportion of the planning area potentially available and suitable for restoration under Option 3 relative to the other Options and modeling results for hydraulic residence time (see Appendix H), Option 3 would be expected to provide a moderate beneficial improvement in ecosystem function relative to base conditions.

Under the range of operations and the potential opportunities to restore/enhance high quality aquatic habitat within the Delta habitat, the effectiveness of Option 3 in improving ecosystem processes is considered to be moderate. Middle River would continue to serve as the water conveyance facility for freshwater supplies moving from the Sacramento River across the Delta to the export facilities located in the southern Delta. Movement of large volumes of water through Middle River would adversely affect hydraulic conditions, require dredging to increase conveyance capacity, and may require additional riprap to reduce levee scour and erosion. These conditions would degrade the quality of fishery habitat within Middle River. In contrast, the area adjacent to Old River and the central and western portion of the Delta would be improved by isolating these areas from the effects of export operations and by increasing residence times within the central Delta thereby reducing the export of nutrients, organic carbon, phytoplankton, and zooplankton from the Delta and increasing aquatic food production and availability. These changes would be expected to improve ecosystem processes within the central and western regions of the Delta when compared to base conditions. In addition, the ability to divert water directly from the Sacramento River at Hood while reducing the export operations within the south Delta would be expected to substantially improve the hydrodynamics of the Delta and improve the quality of habitat available for delta smelt. Under these operating conditions Option 3 offers the opportunity to improve the processes affecting habitat conditions within the Delta (e.g., providing net westerly flows, reducing or eliminating reverse flow conditions, etc.). These potential changes to the estuarine processes within the Delta are expected to benefit delta smelt and other species. It is uncertain, however, if the discharge of low quality San Joaquin River water into the central Delta would impair ecosystem processes.

5.1.1.7 Criterion #7. Relative degree to which the Option can be implemented within a timeframe to meet the near-term needs of each covered fish species (post BDCP authorization).

In the near-term, until construction of Option 3 conveyance features and facilities is completed, Option 3 would use the existing conveyance facilities to meet water supply objectives. As for Option 1, implementation of physical habitat restoration under Option 3 in the north and west Delta can be initiated immediately following authorization of the BDCP and thus could be implemented in a manner that would meet the near-term needs of delta smelt.

5.1.2 Longfin Smelt

Based on the evaluation presented below of the expected performance of Option 3 for addressing important longfin smelt stressors, Option 3 would be expected to have a moderate beneficial effect on longfin smelt production, distribution, and abundance relative to base conditions when operated to meet water supply objectives (Scenario A). If water supply exports are reduced (Scenario B), Option 3 would also be expected to provide a moderate beneficial effect on longfin smelt production, distribution, and abundance relative to base conditions. Option 3 would be expected to provide higher benefits for longfin smelt compared Options 1 and 2, but lower benefits compared to Option 4.

Stressors that affect longfin smelt are presented in Figure 2-2 and are described in Appendix C. The effect of these stressors on the longfin smelt population vary among years in response to environmental conditions (e.g., seasonal hydrology) and may also interact with each other in additive or synergistic ways. The effects of these stressors include both the incremental contribution of a stressor to the population as well as the cumulative effects of multiple stressors over time. The assessment of Option 3 evaluates the degree to which Option 3 would be expected to address these stressors.

Table 5-2 summarizes the expected effects of implementing Option 3 under Scenarios A and B on important longfin smelt stressors relative to base conditions.

Table 5-2. Summary of Expected Effects of Option 3 on Highly and Moderately Important Longfin Smelt Stressors

Stressors[1]	Applicable Criteria	Option Effects on Important Species Stressors Relative to Base Conditions	
		Scenario A	Scenario B
Highly Important Stressors			
Reduced access to spawning habitat	2	Very low adverse effect	Moderate benefit
Reduced access to rearing habitat	2	Low benefit	Moderate benefit
Reduced food	1,4,5	Moderate benefit	Moderate benefit
Predation	1,5	Moderate benefit	Very low benefit
Reduced turbidity	1,2, 3,5	Moderate benefit	Low benefit
Reduced spawning habitat	3	Low benefit	Very low benefit
Reduced food quality	1,4,5	Moderate benefit	Very low benefit

Table 5-2. Summary of Expected Effects of Option 3 on Highly and Moderately Important Longfin Smelt Stressors (continued)

Stressors[1]	Applicable Criteria	Option Effects on Important Species Stressors Relative to Base Conditions	
		Scenario A	Scenario B
Moderately Important Stressors			
CVP/SWP entrainment[2]	1	High benefit	Moderate benefit
Reduced rearing habitat	2	Low benefit	Moderate benefit
Exposure to toxics	2	Moderate adverse effect	Low adverse effect

Notes:
1. See Appendix C for descriptions of stressors, stressor impact mechanisms, and stressor effects.
2. Although it is recognized that the risk of entrainment at the SWP and CVP export facilities may, in some years, be a high level stressor to longfin smelt, and in some years represents a very low level stressor to longfin smelt, for purposes of the analysis the risk of longfin smelt entrainment under each of the Options has been characterized, on average, as a moderate level stressor to the population.

5.1.2.1 Criterion #1. Relative degree to which the Option would reduce species mortality attributable to non-natural mortality sources, in order to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species.

Based on the following evaluation of Option 3 effects on applicable longfin smelt stressors, Option 3 is expected to provide moderate benefits for longfin smelt by reducing the effects of non-natural sources of mortality relative to base conditions.

Reduced Food Availability and Quality

Reduced food availability and quality can result in non-natural levels of mortality. The effects of Option 3 on longfin smelt food availability and quality are evaluated under Criterion #4 below. As described in the Criterion #4 evaluation, Option 3 would be expected to provide a moderate beneficial effect on food availability and quality for longfin smelt relative to base conditions.

Reduced Turbidity

Reduced turbidity may increase the vulnerability of longfin smelt to predation and reduce foraging efficiency. The effects of Option 3 on turbidity are evaluated under Criterion #2 below. As described in the Criterion #2 evaluation, Option 3 would be expected to provide moderate beneficial increases in turbidity conditions relative to base conditions.

Predation

As described below under Criterion #2, Option 3 would be expected to provide a moderate improvement in turbidity conditions relative to base conditions and, therefore, would be expected to reduce the vulnerability of longfin smelt to predation. The proportion of the Delta (35%) within which habitat could potentially be implemented is greater than under Option 1, the same the same as under Option 2, but less than under Option 4 (see Figure 1-3). Based on the potential for improvements in turbidity conditions and the proportion of the Delta available for restoration, Option 3 would be expected to provide a moderate benefit by reducing the predation vulnerability of longfin smelt relative to base conditions.

Entrainment by CVP/SWP Facilities[3]

In Middle River, which is designated as the conveyance corridor to move water through the Delta to the export facilities, PTM modeling results indicated that entrainment under Option 3 is expected to be greater relative to base conditions. Other than from the Middle River insertion location, there would a substantial reduction in entrainment of particles by the SWP/CVP exports. The isolation of Old River and adjacent areas from the hydraulic effects of SWP and CVP export operations (e.g., reducing and avoiding reverse flows within Old River) are expected to benefit longfin smelt under Option 3 as would preferential diversion of water from the Sacramento River using a positive barrier fish screen when compared to base conditions. In Middle River, which is designated as the conveyance corridor to move water through the Delta to the export facilities, entrainment would be greater than base conditions. In reality, however, there should be very few or no larval or juvenile longfin smelt in Middle River relative to base conditions and Option 1 because they would be blocked from entering the corridor from the west by the structural barriers. Risk for entrainment into Middle River, however, would be increased during periods of reverse flow in the San Joaquin River, but would be expected to be lower than under Option 2 which would pump water from Middle River through the siphon. Reduction in the occurrence of reverse flows within Middle River under Option 3 through use of the Hood diversion would also benefit longfin smelt through both improved habitat conditions within the Delta as well as a reduction in the risk of entrainment and salvage losses.

Longfin smelt are primarily distributed downstream of the vicinity of Hood within the Sacramento River and, therefore, would not be at risk for entrainment at the Hood intake facility. In the event that longfin smelt do occur near the Hood diversion location, the risk for entrainment of adult longfin smelt would be minimal because the intake would be equipped with a positive barrier fish screen. Longfin smelt, however, could become vulnerable to entrainment in future years if sea levels rise sufficiently to move spawning upstream from current locations. The Hood intake facility would, however, be equipped with a positive barrier fish screen that would be expected to be highly effective in reducing the vulnerability of all but the early larval stages of longfin smelt to entrainment should their range extend upstream in future years. Under Option 3 longfin smelt would continue to be vulnerable to entrainment and salvage at the south Delta export facilities to the extent that water is exported from the south

[3]Modeling results for reverse flows in Old and Middle River are not used in the assessment of this stressor under Option 3 because Old River flows are isolated from the CVP/SWP pumping facilities and modeled reverse flow results for Old River cannot be disaggregated from results for Middle River.

Delta under this Option. PTM modeling results indicate that the percentage of particles entrained by SWP and CVP exports under Option 3 would be negligible from most insertion locations and flow conditions (see Appendices F and H). The only insertion location from which particles were entrained regularly was Middle River. The index of vulnerability to SWP and CVP salvage for longfin smelt shows a substantial decrease in the risk of smelt salvage under Option 3 when compared to base conditions and Options 1 and 2 (see Appendices F and H). Consequently, Option 3 would be expected to provide a high benefit by substantially reducing the likelihood for entrainment of longfin smelt relative to base conditions.

Exposure to Toxics

The effects of Option 3 on longfin smelt exposure to toxics are evaluated under Criterion #2 below. As described in the Criterion #2 evaluation, Option 3 would be expected to have a moderate adverse increase in longfin smelt exposure to toxics.

5.1.2.2 Criterion #2. Relative degree to which the Option would provide water quality and flow conditions necessary to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species.

Based on the following evaluation of Option 3 effects on applicable longfin smelt stressors, Option 3 is expected to provide very low benefits for water quality and flow conditions that support longfin smelt relative to base conditions.

Reduced Access to Spawning Habitat

Access of adult longfin smelt to spawning habitat is thought to be a function of river flows and availability and quality of habitat. Under Option 3 flows within the Sacramento River during the late winter and early spring longfin smelt spawning period are expected to be lower than base conditions. Lower winter and early spring flows may reduce upstream attraction and movement of adult longfin smelt and would also be expected to contribute to reduce downstream transport of larval and early juvenile smelt. Flows on the San Joaquin River have been assumed, for purposes of these analyses, to be similar under base conditions and Option 3. Option 3 includes the opportunity to potentially enhance intertidal and subtidal habitat in the lower Sacramento River and northern Delta that would be expected to benefit longfin smelt when compared to base conditions.

Reduced Access to Rearing Habitat

Net downstream flows are important for transporting planktonic larval longfin smelt downstream towards suitable rearing habitat in the western Delta and Suisun Bay. PTM modeling results indicate that the percentage of particles that moved past Chipps Island or into Suisun Bay during the early spring would be marginally lower under Option 3 relative to base conditions (see Appendices E and H).

Net downstream flows and Sacramento River flows at Rio Vista during March and April, which serve to transport larval smelt to downstream rearing habitats, would be reduced relative to base conditions (see Appendices F and H). As described below, Option 3 would be expected to improve turbidity conditions, thus improving the foraging efficiency of longfin smelt and reducing their vulnerability to predation. Consequently, overall Option 3 would be expected to have a low beneficial effect on longfin smelt accessibility to rearing habitats.

Reduced Turbidity

Option 3 is expected to moderately improve turbidity conditions for longfin smelt relative to base conditions. Peak total Delta inflows from January through March are reduced from base conditions, indicating that turbidity inputs from Delta tributaries could be reduced from base conditions in those months. PTM modeling results for the central Delta indicate, however, that residence time would be substantially higher, thus creating the potential for increases in turbidity associated with primary and secondary production (see Appendices F and H). Restoration of aquatic subtidal and intertidal habitats that could reduce the abundance and/or impacts of non-native aquatic pelagic and benthic organisms that filter sediment and organic materials from Delta waters could occur within approximately 35% of Delta (Figure 1-4). Although peak Delta inflows could be reduced, improved turbidity conditions associated with increased hydraulic residence time and habitat restorations would be such that, overall, Option 3 would be expected to provide a moderate beneficial improvement in turbidity conditions for longfin smelt relative to base conditions.

Reduced Rearing Habitat

Results of hydrologic modeling indicate that the position of X_2 in April would be located upstream relative to base conditions and, therefore, could result in a slight reduction in the availability of rearing habitat. As described below, Option 3 would be expected to improve turbidity conditions, thus improving the foraging efficiency of longfin smelt and reducing their vulnerability to predation. Consequently, overall Option 3 would be expected to have a low beneficial effect on longfin smelt rearing habitat conditions relative to base conditions.

Exposure to Toxics

Dilution flows from the Sacramento River and other Delta tributaries are one way of reducing concentrations of toxics and their effect on longfin smelt. Modeling results indicate that Option 3 would be expected to reduce dilution flows relative to base conditions, thus potentially increasing concentrations of toxics (see Appendices F and H). As described for Option 2, there is also the potential for the physical configuration of Option 3 to cause an increase in toxic loading in the area of the central Delta that is available for restoration (Figure 1-4). The configuration of barriers and the passage of San Joaquin River water into the central Delta would potentially increase toxic loading to the central Delta by reducing the dilution of higher concentrations of toxics and salinity originating within the San Joaquin River watershed. Although the effects of toxics on longfin smelt are uncertain, Option 3 has the potential for having a moderate adverse effect on longfin smelt by increasing the exposure of longfin smelt to higher concentrations of toxics.

5.1.2.3 Criterion #3. Relative degree to which the Option would increase habitat quality, quantity, accessibility, and diversity in order to enhance and sustain production (reproduction, growth, survival), abundance, and distribution; and to improve the resiliency of each of the covered species' populations to environmental change and variable hydrology.

Based on the following evaluation of Option 3 effects on applicable delta smelt stressors, Option 3 is expected to provide low benefits relative to habitat conditions for the delta smelt.

Within the planning area, longfin smelt habitat conditions are governed by hydrodynamic conditions and the extent and quality of habitat. Under Option 3, these conditions relative to base conditions would be affected by the conveyance configuration of Option 3 and the opportunities for restoration of physical habitat that could be sited within Suisun Bay and Marsh and within the planning area in the north, central, and west Delta, which represents approximately 35% of the planning area.

Reduced Access to Spawning and Rearing Habitats

The effects of Option 3 on the accessibility of spawning and rearing habitats are evaluated under Criterion #2 above. As described in the Criterion #2 evaluation, Option 3 would be expected to have a very low adverse effect on accessibility of spawning habitat and a low beneficial effect on accessibility of rearing habitat relative to base conditions.

Reduced Food Availability and Quality

Reduced food availability and quality can result in non-natural levels of mortality. The effects of Option 3 on longfin smelt food availability and quality are evaluated under Criterion #4 below. As described in the Criterion #4 evaluation, Option 3 would be expected to provide a moderate beneficial effect on food availability and quality for longfin smelt relative to base conditions.

Reduced Turbidity

Habitat conditions that support non-native filter feeders and aquatic plants can reduce turbidity. The effects on turbidity associated with these impact mechanisms are evaluated under Criterion #2 above. As described in the Criterion #2 evaluation, restoring habitat under Option 3 would be expected to have a moderate beneficial effect on turbidity conditions for longfin smelt relative to base conditions.

Reduced Spawning Habitat

Under Option 3 approximately 35% of the planning area would available for restoration/ enhancement of aquatic subtidal and intertidal habitats (Figure 1-3), which encompasses much of the geographic range of longfin smelt within the Delta (Rosenfield and Baxter, in press). Spawning habitat for longfin smelt would be expected to increase in response to habitat restoration/enhancement actions. Habitat restoration under Option 3, given the improved Delta hydrodynamic conditions that would be expected under Option 3, would likely provide a low benefit to longfin smelt.

Reduced Rearing Habitat

The effects on rearing habitat associated with Option 3 are evaluated under Criterion #2 above. Option 3 is expected to have a low beneficial effect on longfin smelt rearing conditions relative to base conditions.

5.1.2.4 Criterion #4. Relative degree to which the Option would increase food quality, quantity, and accessibility (e.g., phytoplankton, zooplankton, macro-invertebrates, forage fish) to enhance production (reproduction, growth, survival) and abundance for each of the covered fish species.

Overall, Option 3 would be expected to provide moderate benefits for improving food availability and quality for longfin smelt.

Reduced Food Availability

The habitat restoration that could potentially be implemented under Option 3 would all be located within the geographic range of longfin smelt and could create conditions that disfavor non-native species that indirectly or directly affect food abundance (e.g., overbite clam (*Corbula*), threadfin shad), thereby improving food availability for longfin smelt relative to base conditions (Figure 1-4). Habitat restoration is expected improve food availability relative to Option 1, would be the same relative to Option 2, and less than under Option 4.

Floodplains are highly productive and are thought to be a source of high amounts of allochthonous nutrients and organic carbon production from the terrestrial community that inhabits the floodplain and upland areas during the remainder of the year (Sommer et al. 2001, Harrell and Sommer 2003). The magnitude of peak flows from January through March, the period during which inflows have been greatest into the Delta historically, gives an indication of the potential for floodplain inundation relative to base conditions. Modeled peak Delta inflows under Option 3 during January through March are substantially lower relative to base conditions (see Appendices F and H). A reduction in peak flows would be expected to result in a reduction in the frequency and duration of seasonal floodplain inundation and a corresponding reduction in the mobilization and downstream transport of nutrients and organic material. Therefore, relative to base conditions, Option 3 would be expected to have a low adverse effect on the transport of organic material and nutrients from floodplains into the Delta.

Based on PTM modeling results for exported particles, the removal of food organisms, nutrients, and organics by diversions would be appreciably lower relative to base conditions. PTM modeling results for particles released into the central Delta, an indicator of hydrologic residence time, indicated that hydraulic residence time within the central Delta was greater relative to base conditions. Based on these results, Option 3 would be expected to provide a moderate benefit for longfin smelt associated with a reduction in exports of nutrients and organic material that support longfin smelt food supplies as well as an increase in residence time that would be expected to contribute to increased phytoplankton and zooplankton production within the Delta.

It has been hypothesized that exposure of phytoplankton and zooplankton to toxics (e.g., pesticides, herbicides) that enter the Delta from point and non-point sources may contribute to ongoing low abundance of longfin smelt zooplankton prey species (Weston et al. 2004, Luoma 2007). Though this relationship is uncertain, Option 3 would be unlikely to reduce the exposure of primary and secondary producers to these toxics because dilution flows would be lower than under base conditions.

Reduced Food Quality

Restoration of shallow water tidal and subtidal habitats under Option 3 could improve nutrient production and production of suitable zooplankton species (e.g., native calanoid copepods) as forage for longfin smelt. Under Option 3, habitat could potentially be restored within Suisun Bay and Marsh and approximately 35% of the Delta to provide high quality aquatic habitat under this option (Figure 1-3), which encompasses a larger proportion of the longfin smelt's range than restoration that could be implemented under Option 1 and the same proportion as under Option 2, but less than under Option 4. Consequently, relative to the other Options, Option 3 would be expected to provide a moderate benefit for food quality (see Appendix H).

5.1.2.5 Criterion #5. Relative degree to which the Option would reduce the abundance of non-native competitors and predators to increase native species production (reproduction, growth, survival), abundance and distribution for each of the covered fish species.

Option 3 could reduce the effects of non-native competitors and predators on longfin smelt primarily through restoration of intertidal and shallow subtidal aquatic habitats in the north, central, and western Delta. For reasons described above, Option 3 would be expected to provide a moderate beneficial effect by reducing the adverse impacts of populations of non-native food competitors relative to base conditions. For reasons described under Criteria #1 and #2, Option 3 could provide a low beneficial effect by reducing the risk of longfin smelt predation relative to base conditions. Additionally, the flexibility provided by dual conveyance facilities and operable barriers provides the opportunity under Option 3 to adaptively manage Delta hydrodynamics to create hydrodynamic conditions that favor the longfin smelt and disfavor predators and competitors to improve conditions for the longfin smelt. Although the ability to control non-native species by varying hydrodynamic conditions in the Delta is uncertain, Option 3 provides the greatest opportunity for doing so among the Options.

5.1.2.6 Criterion #6. Relative degree to which the Option improves ecosystem processes in the BDCP planning area to support aquatic and associated habitats.

Based on the proportion of the planning area suitable for restoration under Option 3 relative to the other Options and modeling results for hydraulic residence time (see Appendix H), Option 3 would be expected to provide a moderate beneficial improvement in ecosystem function relative to base conditions.

Under the range of operations and the potential opportunities to restore/enhance high quality aquatic habitat within the Delta habitat, the effectiveness of Option 3 in improving ecosystem processes is considered to be moderate. Middle River would continue to serve as the water conveyance facility for freshwater supplies moving from the Sacramento River across the Delta to the export facilities located in the southern Delta. Movement of large volumes of water through Middle River would adversely affect hydraulic conditions, require dredging to increase conveyance capacity, and may require additional riprap to reduce levee scour and erosion. These conditions would degrade the quality of fishery habitat within Middle River. In contrast, the area adjacent to Old River and the central and western portion of the Delta would be improved by isolating these areas from the effects of export operations and by increasing residence times within the central Delta thereby reducing the export of nutrients, organic carbon, phytoplankton, and zooplankton from the Delta and increasing aquatic food production and availability. These changes would be expected to improve ecosystem processes within the central and western regions of the Delta when compared to base conditions. In addition, the ability to divert water directly from the Sacramento River at Hood while reducing the export operations within the south Delta would be expected to substantially improve the hydrodynamics of the Delta and improve the quality of habitat available for longfin smelt. Under these operating conditions Option 3 offers the opportunity to improve the processes affecting habitat conditions within the Delta (e.g., providing net westerly flows, reducing or eliminating reverse flow conditions, etc.). These potential changes to the estuarine processes within the Delta are expected to benefit longfin smelt and other species. It is uncertain, however, if the discharge of low quality San Joaquin River water into the central Delta would impair ecosystem processes.

5.1.2.7 Criterion #7. Relative degree to which the Option can be implemented within a timeframe to meet the near-term needs of each covered fish species (post BDCP authorization).

In the near-term, until construction of Option 3 conveyance features and facilities is completed, Option would use the existing conveyance facilities to meet water supply objectives. As for Option 1, implementation of physical habitat restoration under Option 3 in the north and west Delta can be initiated immediately following authorization of the BDCP and thus could be implemented in a manner that would meet the near-term needs of longfin smelt.

5.1.3 Sacramento River Salmonids

Overall, this Option will provide low benefit to Sacramento River Chinook salmon and steelhead compared to base conditions. Operations under Option 3 would result in reducing the risk of juvenile salmonid entrainment at the SWP and CVP export facilities and improve hydrodynamic conditions affecting habitat and migration cues for both upstream migrating adults and downstream migrating juvenile salmonids within the Delta. Option 3 is considered to be better for salmonids than either Option 1 or Option 2. There would be 7% more of the Delta available for potential habitat restoration/ enhancement under Option 3. The habitat opportunities under Option 3 would be the same as those under Option 2 but were not as great as those under Option 4.

Table 5-3 and 5-4 summarize the expected effects of implementing Option 3 under Scenarios A and B on important delta smelt stressors relative to base conditions.

Table 5-3. Summary of Expected Effects of Option 3 on Highly and Moderately Important Sacramento River Chinook Salmon Stressors

Applicable Criteria	Stressor[1]	Option Effects on Important Species Stressors Relative to Base Conditions	
		Scenario A	Scenario B
Highly Important Stressors			
2,3	Reduced staging and spawning habitat	Very low adverse effect	Very low adverse effect
2,3	Reduced rearing and outmigration habitat	Very low benefit	Very low benefit
1	Predation by non-natives	Low benefit	Low benefit
Moderately Important Stressors			
1	Harvest	No net effect	No net effect
1	Reduced genetic diversity/integrity	No net effect	No net effect
1,4	SWP/CVP entrainment	Moderate benefit	Moderate benefit
1,2	Exposure to toxics	Moderate adverse effect	Low adverse effect
2,3	Increased water temperature	No net effect	No net effect

Notes:
1. See Appendix C for descriptions of stressors, stressor impact mechanisms, and stressor effects.

Table 5-4. Summary of Expected Effects of Option 3 on Highly and Moderately Important Sacramento River Steelhead Stressors

Applicable Criteria	Stressor[1]	Option Effects on Important Species Stressors Relative to Base Conditions	
		Scenario A	Scenario B
Highly Important Stressors			
2,3	Reduced staging and spawning habitat	Very low adverse effect	Very low adverse effect
1,4	SWP/CVP entrainment	Moderate benefit	Moderate benefit
2,3	Reduced rearing and outmigration habitat	Very low benefit	Very low benefit
1	Predation by non-natives	Low benefit	Low benefit
Moderately Important Stressors			
1	Exposure to toxics	Moderate adverse effect	Low adverse effect
1	Reduced genetic diversity/ integrity	No net effect	No net effect
1	Harvest	No net effect	No net effect
2,3	Increased water temperature	No net effect	No net effect

Notes:
1. See Appendix C for descriptions of stressors, stressor impact mechanisms, and stressor effects.

5.1.3.1 Criterion #1. Relative degree to which the Option would reduce species mortality attributable to non-natural mortality sources, in order to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species.

Overall, Option 3 would be expected to have a low benefit to Sacramento River salmonids by reducing sources of non-natural mortality.

Predation by Non-native Species

The ability to reduce the adverse impacts of populations of non-native predatory species under Option 3 is similar to that of Option 2 (see Option 2 for description). As with Option 2, there is a low increase in the ability to reduce the risk predation by non-natives under Option 3.

Entrainment

Juvenile Chinook salmon and steelhead would continue to be vulnerable to entrainment and salvage at the south delta export facilities to the extent that exports are made. The index of vulnerability to SWP and CVP salvage for juvenile salmon and steelhead indicates that the risk of salmonid salvage would substantial decrease under Option 3 relative to base conditions as a result of the reduction in exports from the south Delta and the ability to divert water from the Sacramento River through a fish screen. The diversion from the Sacramento River at Hood would be equipped with a state-of-the-art positive barrier fish screen that is expected to reduce the vulnerability of adult and juvenile salmon and steelhead to entrainment. The fish screen is expected to be designed in accordance to CDFG and NMFS design criteria for the protection of juvenile salmon and steelhead. The potential losses of juvenile salmonids to SWP and CVP exports are expected to be substantially lower than losses under either Options 1 or 2 and greater than predicted losses under Option 4.

Exposure to Toxics

Dilution of toxics was measured as flow at Rio Vista and total Delta inflow in March and April. Sacramento River flows at Rio Vista and total Delta inflows were generally moderately lower (20-30%) compared to base conditions under Option 3 during March and April for all water year types. These results suggest that Options 3 would reduce dilution flows of toxics in the Delta, resulting in a potential moderate increase the concentrations of toxics. Further, similar to Option 2, when San Joaquin River flow is conveyed directly to the central Delta, all toxics in the San Joaquin River would be transported directly to the central and western Delta, which is important juvenile salmon and steelhead foraging and rearing habitat and within the range of potential habitat restoration under Option 3 (Figure 1-4). Overall, Option 3 is expected to moderately increase exposure of salmonids to toxics.

5.1.3.2 Criterion #2. Relative degree to which the Option would provide water quality and flow conditions necessary to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species.

Water quality changes that impact Sacramento River salmonids can be measured as differences in exposure to toxics, water temperature, and dissolved oxygen relative to base conditions.

Overall, a low adverse effect would be expected on flow and water quality conditions for Sacramento River salmonids under Option 3.

Exposure to Toxics

As discussed under Criterion #1, Option 3 is expected to moderately increase exposure of salmonids to toxics.

Rearing Habitat

The location of X_2 under Option 3 is expected to be 0.9 km upstream of the location of X_2 under base conditions. This would have a very low adverse effect on habitat quality of salmonids relative to base conditions. As discussed in the delta smelt section above, downstream flows are expected to be moderately lower under Option 3, thus reducing access to rearing habitat downstream.

SWP and CVP operations and the associated hydrologic conditions expected to occur within the Delta under Option 3 are not expected to result in dissolved oxygen depression greater than base conditions. The possible exception, would be the accumulation of high algal concentrations within the area of Old River and the western Delta resulting from increased nutrient concentrations, increased residence times, and reduced flushing. However, the barriers used to isolate Old River from Middle River (Figure 1-4) would be equipped with operable gates that, in the event of a dissolved oxygen depletion, could be opened to increase flushing and increase dissolved oxygen concentrations.

Access to Staging and Spawning Habitat

The effect of Option 3 on migration cues to Sacramento River salmonids would be similar to that of Option 2 when the Delta would be operated like Option 2. When the Delta would be operated like Option 4, migration cues would likely be reduced relative to base conditions due to water exports at Hood. Migration cues would likely be reduced in direct proportion to the export to inflow ratio. In general, attraction flows and migration cues would be expected to decline under Option 3.

5.1.3.3 Criterion #3. Relative degree to which the Option would increase habitat quality, quantity, accessibility, and diversity in order to enhance and sustain production (reproduction, growth, survival), abundance, and distribution; and to improve the resiliency of each of the covered species' populations to environmental change and variable hydrology.

Overall, Option 3 is expected to provide very low increases in quality, quantity, diversity, and accessibility of habitat for Sacramento River salmonids.

Rearing Habitat

The location of X_2 under Option 3 is expected to be 0.9 km upstream. This small change in rearing habitat would likely have a negligible effect on salmonids. Downstream transport to rearing habitat under Option 3 is expected to be lower, resulting in a low adverse effect to Sacramento River salmonids. The area of the Delta potentially available for restoration falls primarily in rearing habitat for juvenile Sacramento River salmonids, such that there will be a moderate benefit to salmonids relative to base conditions. The potential opportunities to restore and enhance habitat for salmonids under Option 3 are the same as those describe for Option 2, are greater than those opportunities under Option 1, and are less than those opportunities under Option 4. Overall, Option 3 is expected to have a very low benefit on the quality, quantity, diversity, and accessibility of rearing and foraging habitat of juvenile Sacramento River Chinook salmon and steelhead.

Access to Staging and Spawning Habitat

As described in Criterion #2, there would be a low adverse effect of Option 3 on attraction flows and migration cues for Sacramento River salmonids. Overall, Option 3 is expected to cause a very low adverse effect on access of Sacramento River salmonids to staging and spawning habitat.

5.1.3.4 Criterion #4. Relative degree to which the Option would increase food quality, quantity, and accessibility (e.g., phytoplankton, zooplankton, macro-invertebrates, forage fish) to enhance production (reproduction, growth, survival) and abundance for each of the covered fish species.

Juvenile Chinook salmon and steelhead forage on a variety of macroinvertebrates (e.g., copepods, amphipods) and small fish during their residency within the Delta. The abundance of these prey species varies in response to a number of factors that include availability of nutrients, organic carbon, phytoplankton and zooplankton production. Reduced food availability or quality, however, are not identified as important stressors for Sacramento River salmonids. Consequently, benefits of increasing food quantity and quality under the Options would not be expected to result in a population level response relative to base conditions.

5.1.3.5 Criterion # 5. Relative degree to which the Option would reduce the abundance of non-native competitors and predators to increase native species production (reproduction, growth, survival), abundance and distribution for each of the covered fish species.

The potential for reducing non-native competitors and predators through restoration of aquatic habitat within the Delta under Option 3 is similar to Option 2 (see Option 2 for details). There are approximately 260,000 acres potentially available in the northern, central, and western Delta, or 35% of the entire statutory Delta, that could potentially support successful habitat restoration/enhancement. Therefore, Option 3 would be expected to provide a low benefit to Sacramento River salmonids by reducing the adverse impacts of non-native competitors and predators.

5.1.3.6 Criterion #6. Relative degree to which the Option improves ecosystem processes in the BDCP planning area to support aquatic and associated habitats.

Based on the proportion of the planning area suitable for restoration under Option 3 relative to the other Options and modeling results for hydraulic residence time (see Appendix H), Option 3 would be expected to provide a moderate beneficial improvement in ecosystem function relative to base conditions.

Under Option 3, Middle River would continue to serve as the water conveyance facility for freshwater supplies moving from the Sacramento River across the Delta to the export facilities located in the southern Delta. Movement of large volumes of water through Middle River would adversely affect hydraulic conditions, require dredging to increase conveyance capacity, and may require additional riprap to reduce levee scour and erosion. These conditions would degrade the quality of fishery habitat within Middle River. In contrast, the area adjacent to Old River and the central and western portion of the Delta would be improved by isolating these areas from the effects of export operations and by increasing residence times within the central Delta thereby reducing the export of nutrients, organic carbon, phytoplankton, and zooplankton from the Delta and increasing aquatic food production and availability. These changes would be expected to improve ecosystem processes within the central and western regions of the Delta when compared to base conditions.

5.1.3.7 Criterion #7. Relative degree to which the Option can be implemented within a timeframe to meet the near-term needs of each covered fish species (post BDCP authorization).

Habitat restoration under Option 3 can be initiated immediately following authorization of the BDCP and thus could be implemented in a manner that would meet the near term needs of Sacramento River salmonids. The implementation period for implementation of Option 3 is the same as the other Options.

5.1.4 San Joaquin River Salmonids

Overall, this Option will provide low benefit to San Joaquin River Chinook salmon and steelhead compared to base conditions. The potential opportunities for habitat restoration/enhancement under Option 3 would be possible in approximately 7% more of the Delta than under Option 1. The habitat opportunities under Option 3 were the same as those under Option 2 but were not as great as those under Option 4.

Tables 5-5 and 5-6 summarize the expected effects of implementing Option 3 under Scenarios A and B on important San Joaquin River salmonid stressors relative to base conditions.

Table 5-5. Summary of Expected Effects of Option 3 on Highly and Moderately Important San Joaquin River Chinook Salmon Stressors

Applicable Criteria	Stressor[1]	Option Effects on Important Species Stressors Relative to Base Conditions	
		Scenario A	Scenario B
Highly Important Stressors			
2,3	Reduced staging and spawning habitat	Very low benefit	Very low benefit
2,3	Reduced rearing and outmigration habitat	Low benefit	Low benefit
1,2	Exposure to toxics	Moderate adverse effect	Low adverse effect
1,5	Predation by non-natives	Low benefit	Low benefit

Table 5-5. Summary of Expected Effects of Option 3 on Highly and Moderately Important San Joaquin River Chinook Salmon Stressors (continued)

Applicable Criteria	Stressor[1]	Option Effects on Important Species Stressors Relative to Base Conditions	
		Scenario A	Scenario B
Moderately Important Stressors			
1	Reduced genetic diversity/ integrity	No net effect	No net effect
1	Harvest	No net effect	No net effect
1,4	SWP/CVP entrainment	Moderate benefit	Moderate benefit
2,3	Increased water temperature	No net effect	No net effect

Notes:
1. See Appendix C for descriptions of stressors, stressor impact mechanisms, and stressor effects.

Table 5-6. Summary of Expected Effects of Option 3 on Highly and Moderately Important San Joaquin River Steelhead Stressors

Applicable Criteria	Stressor[1]	Option Effects on Important Species Stressors Relative to Base Conditions	
		Scenario A	Scenario B
Highly Important Stressors			
2,3	Reduced staging and spawning habitat	Very low benefit	Very low benefit
2,3	Reduced rearing and outmigration habitat	Low benefit	Low benefit
1,2	Exposure to toxics	Moderate adverse effect	Low adverse effect
1	Reduced genetic diversity/ integrity	No net effect	No net effect
1,5	Predation by non-natives	Low benefit	Low benefit
Moderately Important Stressors			
1,4	SWP/CVP entrainment	Moderate benefit	Moderate benefit
1	Harvest	No net effect	No net effect
2,3	Increased water temperature	No net effect	No net effect

Notes:
1. See Appendix C for descriptions of stressors, stressor impact mechanisms, and stressor effects.

5.1.4.1 Criterion #1. Relative degree to which the Option would reduce species mortality attributable to non-natural mortality sources, in order to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species.

Overall, Option 3 would be expected to have moderate benefit to San Joaquin River salmonids by reducing sources of non-natural mortality.

Predation by Non-native Species

The potential reducing predation risk by non-native species under Option 3 would be similar to Option 2 describe above. Overall, the potential for reduced predation risk is expected to be moderate.

Entrainment

Entrainment risk would be eliminated for San Joaquin River salmonids under Option 3 relative to base conditions for San Joaquin River salmonids when water is exported according to the Option 4 configuration. Under this condition water would be diverted from the Sacramento River through a positive barrier fish screen. San Joaquin River salmonids would not be present in the vicinity of the diversion location. When water is exported according to the Option 2 configuration, San Joaquin River fish from the Mokelumne and Cosumnes rivers would experience substantially increased entrainment relative to base conditions, whereas those from other San Joaquin tributaries would be less vulnerable to entrainment than under base conditions. Overall, the vulnerability index indicates that Option 3 is expected to cause a moderate reduction in entrainment of San Joaquin River.

Exposure to Toxics

As discussed below under Criterion #2, Option 3 would cause a moderate increase in exposure of San Joaquin River salmonids to toxics.

5.1.4.2 Criterion #2. Relative degree to which the Option would provide water quality and flow conditions necessary to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species.

Overall, it is expected that Option 3 would provide a very low adverse effect to water quality and flow conditions for San Joaquin River salmonids. However, this finding is based, in part, on model output that assumes diversions would occur preferentially at Hood. By having two diversion locations, there would be potential to modify the effects of this Option on water quality and flow conditions.

Exposure to Toxics

Sacramento River flows at Rio Vista and total Delta inflow under Option 3 would be lower than base conditions in both months and in all water year types (see Appendices F and H). In addition, the configuration of barriers and the siphon to pass San Joaquin River water into the central Delta (Figure 1-3) would potentially increase concentrations, residence time, exposure to elevated toxic concentrations, and reduce dilution of higher concentrations of toxics and salinity originating within the San Joaquin River watershed. The San Joaquin River water would not be diluted with Delta water before it enters the central Delta. As a result, this relocation would likely have moderate adverse effects on exposure of San Joaquin River salmonids to toxics.

Rearing Habitat

The location of X_2 under Option 3 is expected to be 0.9 km upstream of the location of X_2 under base conditions. This would have a very low adverse effect on habitat quality of salmonids relative to base conditions. As discussed above, downstream flows are expected to be moderately lower under Option 3, thus reducing access to rearing habitat downstream. A reduction in flows passing through the Delta under Option 3 has the potential to contribute to reduced juvenile salmonid survival, however, the magnitude of potential change is unknown.

SWP and CVP operations and the associated hydrologic conditions expected to occur within the Delta under Option 3 are expected to cause an increase in localized dissolved oxygen depressions relative to baseline conditions. By diverting the San Joaquin River at Old River, flushing flows in the Stockton ship channel would likely be reduced, causing a greater extent of localized depressions of dissolved oxygen levels than currently exist. Further, the accumulation of high algal concentrations within the area of Old River and the western Delta resulting from increased nutrient loading, increased residence times, and reduced flushing. The barriers used to isolate Old River from Middle River (Figure 1-3) would be equipped with operable gates that, in the event of a dissolved oxygen depletion, could be opened to increase flushing and increase dissolved oxygen concentrations. The extent to which dissolved oxygen sags will occur under this Option is largely uncertain.

Access to Staging and Spawning Habitat

The passage of San Joaquin River flow downstream into the central Delta would be expected to provide a net positive downstream flow and may improve migration cues for juvenile movement and improved attraction flows for adult upstream migration when compared to base conditions. However, Option 3 would potentially reduce migratory cues for the large portion of San Joaquin River salmonids that originate from the Cosumnes and Mokelumne rivers in the event that Middle river is used to convey large flows across the Delta to the south Delta export facilities. To the extent that water diversions occur under Option 3 from the Sacramento River at Hood operations under Option 3 would be expected to result in substantially improve hydrodynamic conditions affecting adult and juvenile attraction and migration when compared to base conditions. Overall, because exports would likely be diverted preferentially from Hood, there would likely be a low positive effect on migratory cues for San Joaquin River salmonids under Option 3.

5.1.4.3 Criterion #3. Relative degree to which the Option would increase habitat quality, quantity, accessibility, and diversity in order to enhance and sustain production (reproduction, growth, survival), abundance, and distribution; and to improve the resiliency of each of the covered species' populations to environmental change and variable hydrology.

Overall, Option 3 is expected to provide a low increase in habitat availability and quality.

Rearing Habitat

The small change in X_2 under Option 3 would likely have a negligible effect on rearing habitat conditions for salmonids. Downstream transport to rearing habitat under Option 3 is not expected to change under Option 3 because San Joaquin flow standards (D-1641 and VAMP) were set as assumptions in the hydrologic model. The area of the Delta potentially available for restoration falls primarily in rearing habitat for juvenile San Joaquin River salmonids, such that there will be a moderate benefit to salmonids relative to base conditions. However, San Joaquin River flows, which carry substantially higher salinity and toxic concentrations, would discharge into this restoration area. Therefore, the effectiveness of the restoration may be limited. Overall, Option 3 is expected to have a low benefit on the quality, quantity, diversity, and accessibility of rearing and foraging habitat of juvenile River Chinook salmon and steelhead.

Access to Staging and Spawning Habitat

As discussed in Criterion #2, Option 3 would likely have a very low positive effect on migratory cues for San Joaquin River salmonids.

Overall, Option 3 is expected to provide a low increase in habitat availability and quality.

5.1.4.4 Criterion #4. Relative degree to which the Option would increase food quality, quantity, and accessibility (e.g., phytoplankton, zooplankton, macro-invertebrates, forage fish) to enhance production (reproduction, growth, survival) and abundance for each of the covered fish species.

Juvenile Chinook salmon and steelhead forage on a variety of macroinvertebrates (e.g., copepods, amphipods) and small fish during their residency within the Delta. The abundance of these prey species varies in response to a number of factors that include availability of nutrients, organic carbon, phytoplankton and zooplankton production. Reduced food availability or quality, however, are not identified as important stressors for Sacramento River salmonids. Consequently, benefits of increasing food quantity and quality under the Options would not be expected to result in a population level response relative to base conditions.

5.1.4.5 Criterion #5. Relative degree to which the Option would reduce the abundance of non-native competitors and predators to increase native species production (reproduction, growth, survival), abundance and distribution for each of the covered fish species.

The potential for reducing the adverse impacts of non-native competitors and predators through restoration of aquatic habitat within the Delta under Option 3 is similar to Option 2 (see Option 2 for details). Habitat restoration could potentially occur within approximately 35% of the planning area in the northern, central, and western Delta. Therefore, Option 3 would be expected to provide a moderate benefit to San Joaquin River salmonids by reducing non-native competitors and predators.

5.1.4.6 Criterion #6. Relative degree to which the Option improves ecosystem processes in the BDCP planning area to support aquatic and associated habitats.

Based on the proportion of the planning area suitable for restoration under Option 3 relative to the other Options and modeling results for hydraulic residence time (see Appendix H), Option 3 would be expected to provide a moderate beneficial improvement in ecosystem function relative to base conditions.

Under Option 3, Middle River would continue to serve as the water conveyance facility for freshwater supplies moving from the Sacramento River across the Delta to the export facilities located in the southern Delta. Movement of large volumes of water through Middle River would adversely affect hydraulic conditions, require dredging to increase conveyance capacity, and may require additional riprap to reduce levee scour and erosion. These conditions would degrade the quality of fishery habitat within Middle River. In contrast, the area adjacent to Old River and the central and western portion of the Delta would be improved by isolating these areas from the effects of export operations and by increasing residence times within the central Delta thereby reducing the export of nutrients, organic carbon, phytoplankton, and zooplankton from the Delta and increasing aquatic food production and availability. These changes would be expected to improve ecosystem processes within the central and western regions of the Delta when compared to base conditions.

5.1.4.7 Criterion #7. Relative degree to which the Option can be implemented within a timeframe to meet the near-term needs of each covered fish species (post BDCP authorization).

Habitat restoration under Option 3 can be initiated immediately following authorization of the BDCP and thus could be implemented in a manner that would meet the near term needs of San Joaquin River salmonids. The implementation period for implementation of Option 3 is the same as the other Options.

5.1.5 Green and White Sturgeon

Based on the evaluation presented below of the expected performance of Option 3 for addressing important green and white sturgeon stressors, Option 3 would be expected to have a low beneficial effect on green and white sturgeon production, distribution, and abundance relative to base conditions when operated to meet water supply objectives (Scenario A). If water supply exports were reduced (Scenario B), Option 3 would be expected to provide a similar level of benefit for sturgeon production, distribution, and abundance relative to base conditions. For green sturgeon, Option 3 would be expected to provide the same level of benefits as Option 2, and lower benefits than under Option 1, and lower benefits than under Option 4. For white sturgeon, Option 3 would be expected to provide higher benefits than under Option 1, the same benefits as under Option 2, and lower benefits than under Option 4.

Stressors that affect sturgeon are presented in Figures 2-7 and 2-8 and are described in Appendix C. The effect of these stressors on the green and white sturgeon populations vary among years in response to environmental conditions (e.g., seasonal hydrology) and may also interact with each other in additive or synergistic ways. The effects of these stressors include both the incremental contribution of a stressor to the population as well as the cumulative effects of multiple stressors over time. The assessment of Option 3 evaluates the degree to which Option 3 would be expected to address these stressors.

Tables 5-7 and 5-8, respectively, summarize the expected effects of implementing Option 1 under Scenarios A and B on important sturgeon stressors relative to base conditions.

Table 5-7. Summary of Expected Effects of Option 1 on Highly and Moderately Important Green Sturgeon Stressors

Stressors[1]	Applicable Criteria	Option Effects on Important Species Stressors Relative to Base Conditions	
		Scenario A	Scenario B
Highly Important Stressors			
Reduced spawning habitat	3	No net effect	No net effect
Exposure to toxics	1,2,3	Moderate adverse effect	Moderate adverse effect
Harvest	1	No net effect	No net effect
Moderately Important Stressors			
Reduced rearing habitat	1,2,3	Low benefit	Low benefit
Increased water temperature (upstream)	1,2,3	No net effect	No net effect
Predation	1,3	No net effect	No net effect
Reduced turbidity	1,2,3	No net effect	No net effect

Notes:
1. See Appendix C for descriptions of stressors, stressor impact mechanisms, and stressor effects.

Table 5-8. Summary of Expected Effects of Option 1 on Highly and Moderately Important White Sturgeon Stressors

Stressors[1]	Applicable Criteria	Option Effects on Important Species Stressors Relative to Base Conditions	
		Scenario A	Scenario B
Highly Important Stressors			
Harvest	1	No net effect	No net effect
Reduced spawning habitat	3	No net effect	No net effect
Exposure to toxics	1,2,3	Moderate adverse effect	Moderate adverse effect
Moderately Important Stressors			
Reduced rearing habitat	1,2,3	Low benefit	Low benefit
Increased water temperature (upstream)	1,2,3	No net effect	No net effect
Predation	1,3	No net effect	No net effect
Reduced turbidity	1,2,3	No net effect	No net effect

Notes:
1. See Appendix C for descriptions of stressors, stressor impact mechanisms, and stressor effects.

Harvest, reduced spawning habitat, predation, reduced turbidity, and increased water temperatures are not important stressors that would be affected by or affected differently (i.e., harvest, reduced spawning habitat) under the Options and, therefore, are not described in the criteria evaluations below (see Table 2-3 and Appendix C). These stressors could only be addressed through changes in regulation and law enforcement (for harvest) or through conservation actions implemented outside of the planning area. Any effects within the planning area of the Options on the non-harvest stressors described above would not be expected to have any benefits to sturgeon at the population level. As described in Table 2-3, the ability to address harvest and reduced spawning habitat within the planning area would be the same among the Options. Consequently, these stressors are initially identified under the applicable criteria below, but are not evaluated under the criteria.

5.1.5.1 Criterion #1. Relative degree to which the Option would reduce species mortality attributable to non-natural mortality sources, in order to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species.

Based on the following evaluation of Option 3 effects on applicable green and white sturgeon stressors, Option 3 is expected to provide no change from base conditions in the risk of non-natural mortality of sturgeon.

Exposure to Toxics

Exposure of green and white sturgeon to toxic substances can result in mortality of sturgeon. The effects of Option 3 on exposure to toxics are evaluated under Criteria #2 and #4 below. As described in the Criteria #2 and #4 evaluations, Option 3 would be expected to provide a moderate adverse increase for exposure of green and white sturgeon to toxics.

5.1.5.2 Criterion #2. Relative degree to which the Option would provide water quality and flow conditions necessary to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species.

Based on the following evaluation of Option 3 effects on applicable green and white sturgeon stressors, Option 3 is expected to provide a very low adverse effect for water quality and flow conditions that support green and white sturgeon relative to base conditions.

Exposure to Toxics

Based on how Option 3 would be expected to affect Sacramento River inflow and total Delta inflows relative to modeling results for base conditions and the Options, dilution flows under Option 3 would be lower than under base conditions and could have a moderate adverse affect by increasing the exposure of sturgeon to toxics (see Appendices F and H).

Reduced Rearing Habitat

Based on how Option 3 would be expected to affect the X_2 location in April relative to X_2 modeling results for base conditions and the Options, X_2 position would move upstream relative to base conditions (see Appendices F and H), indicating that the extent of available rearing habitat could be reduced relative to base conditions. In addition, Option 3 would be expected to improve westerly flows through the central Delta as a migration cue for both juvenile and adult sturgeon migration. The changes in hydrologic conditions expected to occur under Option 3 on Middle River would be expected to degrade habitat conditions and hydraulic migration cues for adult and juvenile sturgeon inhabiting the eastern region of the Delta to the extent that exports are made from the south Delta under Option 3. The effect of these changed hydraulic conditions is unknown, because the frequency of occurrence of green or white sturgeon juveniles and adults within the eastern region of the Delta is unknown. To the extent that exports are made from the Sacramento River under Option 3 flow patterns in Delta channels would be expected to improve for juvenile and adult sturgeon.

5.1.5.3 Criterion #3 Relative degree to which the Option would increase habitat quality, quantity, accessibility, and diversity in order to enhance and sustain production (reproduction, growth, survival), abundance, and distribution; and to improve the resiliency of each of the covered species' populations to environmental change and variable hydrology.

Within the planning area, green and white sturgeon habitat conditions are governed by hydrodynamic conditions and the extent and quality of habitat within the planning area. Under Option 3, these conditions relative to base conditions would be affected by the conveyance configuration of Option 3 and the opportunities for restoration of physical habitat that could be sited within Suisun Bay and Marsh and within the planning area in the north, central, and west Delta, which represents approximately 35% of the planning area. A reduction in the magnitude and frequency of water diversions from the south Delta under Option 3 would improve channel flows and habitat conditions within the Delta for sturgeon.

Based on the following evaluation of Option 3 effects on applicable green and white sturgeon stressors, Option 3 is expected to provide low habitat benefits for sturgeon relative to base conditions.

Exposure to Toxics

As described under Criterion #2 above, Option 3 could have a low adverse effect on the risk for exposure of sturgeon to toxics relative to base conditions. A major source for bioaccumulation of selenium in sturgeon is consumption of non-native *Corbula* and *Corbicula*, which capture selenium from Delta waters. Restoration of aquatic shallow subtidal and intertidal habitats could create conditions that favor the production of alternative prey (e.g., bay shrimp) that reduce the risk of bioaccumulation of materials such as selenium for juvenile and adult sturgeon. The potential success of reducing the risk of toxics on sturgeon through habitat improvements and increased production of alternative prey resources is uncertain. Under Option 3, habitat could potentially be restored within Suisun Bay and Marsh and approximately 35% of the Delta to provide high quality aquatic habitat under this Option (Figure 1-4), which encompasses a larger proportion of the white sturgeon's rearing range than restoration that could be implemented under Option 1, the same proportion as under Option 2, and a smaller proportion than under Option 4. Because the green sturgeon is not known to occupy the San Joaquin River watershed but do occur within the central Delta, restoration opportunities would be the same under Option 3 as under Option 2, but less than under Option 4, which includes restoration opportunities in the east Delta north of the San Joaquin River. Consequently, relative to base conditions and the other Options, Option 3 would be expected to provide a low benefit for improving green and white sturgeon rearing habitat.

Reduced Rearing Habitat

The primary impact mechanism believed to affect the extent of rearing habitat and rearing habitat conditions is the reclamation of historical aquatic subtidal and intertidal habitats and channelization of river channels. Under Option 3, habitat could potentially be restored within Suisun Bay and Marsh and approximately 35% of the Delta to provide high quality aquatic habitat under this Option (Figure 1-4), which encompasses a larger proportion of the white sturgeon's rearing range than restoration that could be implemented under Option 1, the same proportion as under Option 2, and a smaller proportion than under Option 4. Because the green sturgeon is not known to occupy the San Joaquin River watershed but do occur within the central Delta, restoration opportunities would be the same under Option 3 as under Option 2, but less than under Option 4, which includes restoration opportunities in the east Delta north of the San Joaquin River. Consequently, relative to base conditions and the other Options, Option 3 would be expected to provide a low benefit for green and white sturgeon rearing habitat.

5.1.5.4 Criterion #4. Relative degree to which the Option would increase food quality, quantity, and accessibility (e.g., phytoplankton, zooplankton, macro-invertebrates, forage fish) to enhance production (reproduction, growth, survival) and abundance for each of the covered fish species.

Based on the following evaluation of Option 3 effects on applicable green and white stressors, Option 3 is expected to provide low food supply benefits for green and white sturgeon relative to base conditions.

Exposure to Toxics

As described under Criterion #3 above, restoration of rearing habitat could reduce the relative importance of non-native *Corbula* and *Corbicula* thus improving the quality of food for sturgeon by reducing their exposure to selenium. Relative to base conditions and the other Options, Option 3 would be expected to provide low benefits for green and white sturgeon rearing habitat.

5.1.5.5 Criterion #5. Relative degree to which the Option would reduce the abundance of non-native competitors and predators to increase native species production (reproduction, growth, survival), abundance and distribution for each of the covered fish species.

Predation in the form of illegal and legal harvest would not be changed under any of the Options from base conditions.

5.1.5.6 Criterion #6. Relative degree to which the Option improves ecosystem processes in the BDCP planning area to support aquatic and associated habitats.

Based on the proportion of the planning area potentially available for restoration under Option 3 relative to the other Options and modeling results for hydraulic residence time (see Appendix H), Option 3 would be expected to provide a moderate beneficial improvement in ecosystem function relative to base conditions. These benefits to ecosystem processes under Option 3 are also linked to the ability to divert water from the Sacramento River and improve hydrodynamic flow patterns within the Delta.

Under the range of operations and the potential opportunities to restore/enhance high quality aquatic habitat within the Delta habitat, the effectiveness of Option 3 in improving ecosystem processes is considered to be moderate. Middle River would continue to serve as the water conveyance facility for freshwater supplies moving from the Sacramento River across the Delta to the export facilities located in the southern Delta. Movement of large volumes of water through Middle River would adversely affect hydraulic conditions, require dredging to increase conveyance capacity, and may require additional riprap to reduce levee scour and erosion. These conditions would degrade the quality of fishery habitat within Middle River. In contrast, the area adjacent to Old River and the central and western portion of the Delta would be improved by isolating these areas from the effects of export operations and by increasing residence times within the central Delta thereby reducing the export of nutrients, organic carbon, phytoplankton, and zooplankton from the Delta and increasing aquatic food production and availability. These changes would be expected to improve ecosystem processes within the central and western regions of the Delta when compared to base conditions. In addition, the ability to divert water directly from the Sacramento River at Hood while reducing the export operations within the south Delta would be expected to substantially improve the hydrodynamics of the Delta and improve the quality of habitat available for juvenile and adult sturgeon. Under these operating conditions Option 3 offers the opportunity to improve the processes affecting habitat conditions within the Delta (e.g., providing net westerly flows, reducing or eliminating reverse flow conditions, etc.). These potential changes to the estuarine processes within the Delta are expected to benefit sturgeon and other species. It is uncertain, however, if the discharge of low quality San Joaquin River water into the central Delta would impair ecosystem processes.

5.1.5.7 Criterion #7. Relative degree to which the Option can be implemented within a timeframe to meet the near-term needs of each covered fish species (post BDCP authorization).

In the near-term, until construction of Option 3 conveyance features and facilities is completed, Option would use the existing conveyance facilities to meet water supply objectives. As for Option 1, implementation of physical habitat restoration under Option 3 in the north and west Delta can be initiated immediately following authorization of the BDCP and thus could be implemented in a manner that would meet the near-term needs of green and white sturgeon.

5.1.6 Splittail

Based on the evaluation presented below of the expected performance of Option 3 for addressing important splittail stressors, Option 3 would be expected to have a moderate beneficial effect on splittail production, distribution, and abundance relative to base conditions when operated to meet water supply objectives (Scenario A). If water supply exports were reduced (Scenario B), Option 3 would also be expected to provide a moderate beneficial effect on splittail production, distribution, and abundance relative to base conditions. Option 3 would be expected to provide a greater level of benefit for splittail than Options 1 and 2, but a lower level of benefit compared to Option 4.

Table 5-9 summarizes the expected effects of implementing Option 3 under Scenarios A and B on important splittail stressors relative to base conditions.

Table 5-9. Summary of Expected Effects of Option 3 on Highly and Moderately Important Splittail Stressors

Applicable Criteria	Stressor[1]	Option Effects on Important Species Stressors Relative to Base Conditions	
		Scenario A	Scenario B
Highly Important Stressors			
2,3	Reduced juvenile rearing/adult habitat	Moderate benefit	Moderate benefit
2,3	Reduced spawning/larval rearing habitat	Moderate benefit	Moderate benefit
1,4	Reduced food	Moderate benefit	High benefit
1,2	Exposure to toxics	Moderate adverse effect	Low adverse effect
Moderately Important Stressors			
1,5	Predation	Moderate benefit	Moderate benefit
1,4	SWP/CVP entrainment	High benefit	High benefit
1	Harvest	No net effect	No net effect

Notes:

1. See Appendix C for descriptions of stressors, stressor impact mechanisms, and stressor effects.
2. Although it is recognized that the risk of entrainment at the SWP and CVP export facilities may, in some years, be a high level stressor to splittail, and in some years represents a very low level stressor to splittail, for purposes of the analysis the risk of delta smelt entrainment under each of the Options has been characterized, on average, as a moderate level stressor to the population.

5.1.6.1 *Criterion #1. Relative degree to which the Option would reduce species mortality attributable to non-natural mortality sources, in order to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species.*

Based on the following evaluation of Option 3 effects on applicable splittail stressors, Option 3 is expected to provide moderate benefits for splittail by reducing the effects of non-natural sources of mortality relative to base conditions.

Reduced Food Availability

Habitat conditions can affect the availability and quality of splittail food. The effects of Option 3 on splittail food availability are evaluated under Criterion #4 below. As described in the Criterion #4 evaluation, Option 3 would be expected to provide a moderate beneficial effect on food supply for the splittail relative to base conditions.

Exposure to Toxics

The effects of Option 3 on exposure to toxics are evaluated under Criterion #2 below. As described in the Criterion #2 evaluation, Option 3 would be expected to continue to provide lower dilution flows relative base conditions and could increase exposure to toxics discharged from the San Joaquin River into the central Delta, which could have a moderate adverse effect on splittail. It is uncertain, however, if the potential increase in concentrations of toxics in the central Delta would adversely affect splittail.

Predation

Under Option 3, approximately 35% of the Delta would potentially be available for restoration/enhancement (Figure 1-4), which, if designed properly, would reduce predation risk by non-natives. This entire area would be located within the geographic range of splittail within the northern, western, and central regions of the Delta. The proportion of the planning area within which habitat could potentially be implemented is greater than under Option 1, the same as under Option 2, but less than under Option 4. Habitat restoration under Option 3 would be expected to provide a moderate benefit for potentially reducing the adverse impacts of predation relative to base conditions and the other Options. However, there is a high degree of uncertainty regarding the biological response of splittail, other native fish and macroinvertebrate species, and non-native species to large-scale habitat restoration/ enhancement within the Delta.

Entrainment by CVP/SWP Facilities

Under operations of Option 3, juvenile splittail emigrating from the San Joaquin River would be transported downstream into Old River and the central Delta. As a result, the vulnerability of San Joaquin River juvenile splittail to entrainment or salvage at the SWP or CVP export facilities would be greatly reduced. San Joaquin River splittail could be exposed to a risk for entrainment during periods of high reverse flow in Middle River and the lower San Joaquin River during periods when diversions from the south Delta export facilities are high. The configuration of barriers and increased flows in Middle River under Option 3 would, however, be expected to contribute to a substantial increase in mortality of juvenile splittail emigrating from other east side tributaries such as the Mokelumne and Cosumnes rivers. These juvenile splittail would be expected to migrate downstream within Middle River and have increased vulnerability to entrainment and salvage at the SWP and CVP export facilities. Risk for entrainment into Middle River, however, would be increased during periods of reverse flow in the San Joaquin River, but would be expected to be lower than under Option 2 which would pump water from Middle River through the siphon. Risk for entrainment of splittail at the Hood intake facility would be minimal because the intake would be equipped with a positive barrier fish screen that would be expected to be highly effective in reducing the vulnerability of juvenile and adult splittail to entrainment. The relative magnitude of potential benefits under Option 3 to reducing splittail entrainment would vary depending on the balance of exports that would be made from the Sacramento River at Hood relative to the exports from the south Delta. Option 3 would be expected to provide a high benefit for splittail by reducing the likelihood for entrainment of splittail relative to base conditions because:

- a gravity fed siphon would be employed,
- the amount of water pumped from the south Delta would be substantially reduced,
- there is flexibility to only export water from the south Delta when splittail would be least vulnerable to entrainment, and
- there is minimal risk for entrainment of splittail at the Hood intake facility.

5.1.6.2 Criterion #2. Relative degree to which the Option would provide water quality and flow conditions necessary to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species.

Based on the following evaluation of Option 3 effects on applicable splittail stressors, Option 3 is expected to have a low adverse effect on water quality and flow conditions that support splittail relative to base conditions.

Exposure to Toxics

Dilution flows from the Sacramento River and other Delta tributaries are one way of reducing concentrations of toxics and their effect on juvenile and adult splittail. Modeling results indicate that Option 3 would be expected to reduce dilution flows relative to base conditions, thus potentially increasing concentrations of toxics (see Appendices F and H). As described for Option 2, there is also the potential for the physical configuration of Option 3 to cause an increase in toxic loading in the area of the central Delta that is available for restoration (Figure 1-4). The configuration of barriers and the siphon to transport San Joaquin River water into the central Delta would potentially increase toxic loading to the central Delta by reducing the dilution of higher concentrations of toxics and salinity originating within the San Joaquin River watershed. Although the effects of toxics on splittail are uncertain, Option 3 has the potential for having a moderate adverse effect on splittail by increasing the exposure of rearing and foraging splittail to higher concentrations of toxics.

Reduced Rearing Habitat

Sacramento River inflows during March and April under Option 3 that facilitate the downstream movement of juvenile splittail are expected to be lower relative to base conditions. Expected changes in peak Delta inflows during January through March indicate that Option 3 would have a lower probability of floodplain inundation relative to base conditions in wetter years (see Appendices F and H). The potential restoration of rearing habitats as described under Criterion #3, however, would be expected to improve rearing habitat conditions. Consequently, overall Option 3 would be expected to have moderate beneficial effects on rearing habitat conditions relative to base conditions.

Reduced Spawning/Larval Rearing Habitat

Expected changes in peak Delta inflows during January through March indicate that, under Option 3, there would be a lower probability of floodplain inundation during wetter years relative to base conditions but a similar probability under drier water years (see Appendices F and H). The potential restoration of spawning/larval rearing habitats as described under Criterion #3, however, would be expected to improve spawning/larval rearing habitat conditions. Consequently, overall Option 3 would be expected to have moderate beneficial effects on rearing habitat conditions relative to base conditions.

5.1.6.3 Criterion #3. Relative degree to which the Option would increase habitat quality, quantity, accessibility, and diversity in order to enhance and sustain production (reproduction, growth, survival), abundance, and distribution; and to improve the resiliency of each of the covered species' populations to environmental change and variable hydrology.

Based on the following evaluation of Option 3 effects on applicable splittail stressors, Option 3 is expected to provide moderate benefits relative to habitat conditions for the splittail.

Within the planning area, splittail habitat conditions are governed by hydrodynamic conditions and the extent and quality of habitat. Under Option 3, these conditions relative to base conditions would be affected by the conveyance configuration of Option 3 and the opportunities for restoration of physical habitat that could be sited within Suisun Bay and Marsh and within 35% of the planning area in the north, central, and west Delta.

Reduced Rearing and Spawning Habitat

Under Option 3, habitat could be restored within Suisun Bay and Marsh and approximately 35% of the Delta to provide high quality shallow aquatic subtidal and intertidal habitat (Figure 1-4), which encompasses a larger proportion of the splittail spawning and rearing range than restoration that could be implemented under Option 1, the same proportion as under Option 2, and a smaller proportion than under Option 4. In addition, substantial increases in hydraulic residence time under Option 3 also provide for lower velocity habitats that are expected to be more suitable for splittail relative to base conditions. Consequently, relative to base conditions and the other Options, Option 3 would be expected to provide a moderate benefit for splittail rearing and spawning habitat.

Reduced Food Availability

Habitat conditions can affect the availability and quality of splittail food. The effects of Option 3 on splittail food availability are evaluated under Criterion #4 below. As described in the Criterion #4 evaluation, Option 3 would be expected to provide a moderate beneficial effect on food supply for the splittail relative to base conditions.

5.1.6.4 Criterion #4. Relative degree to which the Option would increase food quality, quantity, and accessibility (e.g., phytoplankton, zooplankton, macro-invertebrates, forage fish) to enhance production (reproduction, growth, survival) and abundance for each of the covered fish species.

Overall, Option 3 would be expected to provide moderate benefits for improving food supply for splittail.

Reduced Food Availability

Option 3 could decrease the frequency, duration, and extent of seasonally inundated floodplain habitat within the Sacramento or San Joaquin Rivers, which could reduce food availability in those areas in some years. Hydraulic residence would be substantially increased in the central Delta and would be expected to substantially increase phytoplankton, zooplankton, and macroinvertebrate production within the central Delta relative to base conditions. Restoration of shallow subtidal and intertidal habitats under Option 3 would also be expected to improve food supply. Consequently, Option 3 would be expected to provide a moderate benefit for splittail food supply.

The habitat restoration that would be implemented under Option 3 would all be located within the geographic range of splittail and could create conditions that disfavor non-native species that indirectly or directly affect food abundance (e.g., overbite clam (*Corbula*), threadfin shad), thereby improving food availability for splittail relative to base conditions (Figure 1-4). The potential opportunity for habitat restoration is expected to improve food availability relative to Option 1, would be the same relative to Option 2, and less than under Option 4.

Option 3 would be expected to provide a moderate beneficial increase in food availability by reducing the export of nutrients and organic material that support primary and secondary production by reducing SWP/CVP exports from the south Delta. In addition, under Option 3, water with high nutrient loads from the San Joaquin River would no longer be subject to the same level of exports as under base conditions and these waters would be conveyed downstream into the central region of the Delta where increased nutrient loads, in combination with increased residence times, would be expected to stimulate phytoplankton and zooplankton production.

5.1.6.5 Criterion #5. Relative degree to which the Option would reduce the abundance of non-native competitors and predators to increase native species production (reproduction, growth, survival), abundance and distribution for each of the covered fish species.

Based on the following evaluation of Option 3 effects on applicable splittail stressors, Option 3 is expected to provide moderate benefits for splittail relative to the abundance of non-native competitors and predators.

Option 3 could reduce the effects of non-native competitors and predators on splittail primarily through restoration of intertidal and shallow subtidal aquatic habitats in the north, west, and central Delta. For reasons described above, Option 3 would be expected to provide a moderate beneficial effect by reducing the impacts of populations of non-native food competitors relative to base conditions. Additionally, the operable barriers along Middle River provide some opportunity under Option 3 to adaptively manage Delta hydrodynamics to create hydrodynamic conditions that favor the splittail and disfavor predators and competitors to improve conditions for the splittail. Although the ability to control non-native species by varying hydrodynamic conditions in the Delta is uncertain, Option 3 provides the greatest opportunity for doing so among the Options.

5.1.6.6 Criterion #6. Relative degree to which the Option improves ecosystem processes in the BDCP planning area to support aquatic and associated habitats.

Based on the proportion of the planning area potentially available and suitable for restoration under Option 3 relative to the other Options and modeling results for hydraulic residence time (see Appendix H), Option 3 would be expected to provide a moderate beneficial improvement in ecosystem function relative to base conditions.

Under the range of operations and the potential opportunities to restore/enhance high quality aquatic habitat within the Delta habitat, the effectiveness of Option 3 in improving ecosystem processes is considered to be moderate. Middle River would continue to serve as the water conveyance facility for freshwater supplies moving from the Sacramento River across the Delta to the export facilities located in the southern Delta. Movement of large volumes of water through Middle River would adversely affect hydraulic conditions, require dredging to increase conveyance capacity, and may require additional riprap to reduce levee scour and erosion. These conditions would degrade the quality of fishery habitat within Middle River. In contrast, the area adjacent to Old River and the central and western portion of the Delta would be improved by isolating these areas from the effects of export operations and by increasing residence times within the central Delta thereby reducing the export of nutrients, organic carbon, phytoplankton, and zooplankton from the Delta and increasing aquatic food production and availability. These changes would be expected to improve ecosystem processes within the central and western regions of the Delta when compared to base conditions. In addition, the ability to divert water directly from the Sacramento River at Hood while reducing the export operations within the south Delta would be expected to substantially improve the hydrodynamics of the Delta and improve the quality of habitat available for juvenile and adult splittail. Under these operating conditions Option 3 offers the opportunity to improve the processes affecting habitat conditions within the Delta (e.g., providing net westerly flows, reducing or eliminating reverse flow conditions, etc.). These potential changes to the estuarine processes within the Delta are expected to benefit splittail and other species. It is uncertain, however, if the discharge of low quality San Joaquin River water into the central Delta would impair ecosystem processes.

5.1.6.7 Criterion #7. Relative degree to which the Option can be implemented within a timeframe to meet the near-term needs of each covered fish species (post BDCP authorization).

In the near-term, until construction of Option 3 conveyance features and facilities is completed, Option 3 would use the existing conveyance facilities to meet water supply objectives. As for Option 1, implementation of physical habitat restoration under Option 3 in the north and west Delta can be initiated immediately following authorization of the BDCP and thus could be implemented in a manner that would meet the near-term needs of splittail.

5.2 PLANNING CRITERIA

5.2.1.1 Criterion #8: Relative degree to which the Option allows covered activities to be implemented in a way that meets the goals and purposes of those activities

Under Option 3, the ability to achieve the water delivery reliability and facility operation goals of the CVP/SWP is expected to exceed current conditions and all other Options (Figure 3-1).

Model simulations undertaken for this evaluation indicate the potential for increased CVP/SWP exports in the range of 70 to 500 TAF/YR depending on the level of Rio Vista flow requirements, X2 objectives, salinity requirements, and Middle River and QWEST flow restrictions. The ability to meet the goals of this criterion is significantly enhanced by the use of a dual diversion facility for the CVP/SWP under this Option. Water delivery reliability and facility operations are afforded greater flexibility by the ability to opportunistically draw water from either the facility at Hood or the Victoria Canal siphon. The flexibility of Option 3 is greatly improved over Option 4 due to the ability of CVP/SWP facilities to capture a portion of flows, specifically Rio Vista-required flows, San Joaquin River flows, and Mokelumne River flows, at the south Delta diversion. Modeling simulations of Option 3 indicate that approximately 20% of total CVP/SWP exports are derived through the south Delta diversion, despite operating the Hood facility preferentially.

Export water quality would be improved as compared to current conditions, Option 1, and Option 2, but less than Option 4 (Figure 3-2). The improvements in water quality are expected through the direct diversion of better quality Sacramento River water at Hood as compared to the sole south Delta diversion under current conditions, Option 1, and Option 2. The water quality improvements are directly dependent on the mix of Hood and south Delta diversions. Water quality improvements are somewhat less than that indicated under Option 4 because Option 4 exports only high-quality Sacramento River water diverted at Hood.

5.2.1.2 Criterion #9. The relative feasibility and practicability of the Option, including the ability to fund, engineer, and implement

Option 3 has the highest implementation costs and greatest direct effects on the human environment (likely requiring substantial regulatory authorizations), but provides a more flexible approach to addressing the combined goals of species conservation and habitat restoration using practicable technologies.

The technologies for constructing the siphons and aqueducts are proven. There may be, however, some level of technical uncertainty under Options 3 and 2 regarding the design, construction, and operation of the operable barriers. A technical uncertainty common to Options 3 and 4 will be the ability to construct a state-of-the-art fish screen that will successfully reduce entrainment at the intake of the peripheral aqueduct to negligible levels. Cost practicability of this Option is addressed in Criterion #10, below.

The potential habitat restoration area under Option 3 is expanded over Option 1, specifically in areas along Old River. However, technical uncertainties are associated with habitat restoration along Old River that affect the feasibility of conservation actions in this location. These uncertainties include the unknown effects of reduced water quality (e.g., higher salt and selenium content) associated with concentrating San Joaquin River discharge into the habitat restoration area, and how best to manage flow conditions (e.g., residence time and fluctuating salinity) in the central Delta west of the proposed Option 3 barriers to provide ecological benefits. The geographic area for habitat restoration under Option 3 is more narrowly focused than under Option 4, limiting the flexibility in choosing the most cost effective and ecologically effective restoration sites. Options 2 and 3 include the same geographic area for habitat restoration and are, therefore, comparable regarding the feasibility of physical habitat restoration actions.

5.2.1.3 *Criterion #10. Relative costs (including infrastructure, operations, and management) associated with implementing the Option*

Delta Infrastructure Costs

Option 3 is expected to have the highest infrastructure costs among the four Options, though under certain configurations its costs could be less than Option 4.[4] Under Option 3, conveyance would be via: (1) a peripheral aqueduct with an intake on the Sacramento River; and (2) an improved through-Delta conveyance with operable barriers along Middle River and separated water supply flows from San Joaquin River flows by a siphon. Thus, Option 3 combines the conveyance approaches of Options 2 and 4.

The key issues in assessing infrastructure costs for Option 3 are:

1. The sizing of the peripheral aqueduct;
2. The extent and degree of levee strengthening assumed for improved through-Delta conveyance;
3. Whether through-Delta conveyance would involve screening the Delta Cross Channel and Georgiana Slough; and
4. The relocating the CCWD intakes.

The evaluation of criterion #10 for Option 2 in Section 4 provides a discussion of the costs of the latter two potential additions.

Tables 5-1 and 5-2 show a range of possible configurations and associated costs for Option 3. The configurations differ by peripheral aqueduct size, degree of levee strengthening, and presence or absence of Delta Cross Channel and Georgiana Slough screening and CCWD intake costs. Table 5-1 excludes costs for Delta Cross Channel and Georgiana Slough screening and CCWD intake costs, while Table 5-2 includes them. Option 3 costs shown in these tables are constructed as follows:

- Peripheral Aqueduct Sizing: Costs are provided for three aqueduct sizes: 5,000, 10,000, and 15,000 cfs.
- Low Cost Estimate: The low cost estimate assumes levee strengthening is limited to bringing Middle River levees between Medford Island and the siphon up to the PL 84-99 standard and uses the <u>lower</u> end of the cost range for the peripheral aqueduct.
- Medium Cost Estimate: The medium cost estimate assumes levees along Middle River between Medford Island and the siphon are brought up to the urban standard and uses the <u>mid-point</u> of the cost range for the peripheral aqueduct.[5]

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[4] For example, Option 4 costs could exceed Option 3 costs if (1) Option 4 sized the peripheral aqueduct at 15,000 cfs while Option 3 sized it at 5,000 cfs and (2) Option 3 levee strengthening costs were kept to a minimum.

[5] The urban standard used in the DRMS Phase II evaluation is based on the following levee design: Maximum waterside and landside slopes 3H:1V; Minimum crest width 20 feet; Minimum 3.0 feet of freeboard above 100-year flood stage.

- High Cost Estimate: The high cost estimate assumes levees along Middle River between Medford Island and the siphon are seismically upgraded and uses the upper end of the cost range for the peripheral aqueduct.

Tables 5-1 and 5-2 do not exhaust the universe of Option 3 configurations, but provide a representative range of possible Option 3 configurations and costs. They show costs for this Option ranging between $2.8 and $8.7 billion, with a mid-range cost of about $5.4 billion.

Table 5-1. Expected Infrastructure Costs for Various Configurations of Option 3 (Millions 2007 dollars)

Peripheral Aqueduct Capacity (cfs)	Low	Medium	High
5,000	2,830	3,760	5,945
10,000	3,530	4,660	7,045
15,000	4,130	5,460	8,045

Table 5-2. Expected Infrastructure Costs for Various Configurations of Option 3, with Delta Cross Channel/Georgiana Slough Screening and CCWD Intake Costs (Millions 2007 dollars)

Peripheral Aqueduct Capacity (cfs)	Low	Medium	High
5,000	3,530	4,460	6,645
10,000	4,230	5,360	7,745
15,000	4,830	6,160	8,745

Delta Conveyance Disruption Costs

Risks to water exports from major flood or seismic events are expected to be lowest under Option 3. Option 3's dual conveyance approach would provide a redundancy in the conveyance system, which is lacking in the other three Options. The peripheral aqueduct would reduce the vulnerability of Delta exports to seismic and flood events pulling large amounts of salt water into the south Delta. DRMS Phase I estimated a greater than 50-50 chance in the next 25 years of such an event resulting in disruption of Delta exports for ten months or more given existing Delta conveyance (Option 1). It estimated a 30 to 40% chance of a disruption to Delta exports lasting up to two years. The through-Delta conveyance component of Option 3 would significantly reduce these risks by providing conveyance redundancy. In essence, the two conveyance approaches would serve as backup systems to one another. Additionally, the DRMS Phase II report noted that a peripheral aqueduct, if designed with turnouts to the south Delta, could also facilitate recovery efforts by providing additional fresh water to the south Delta for flushing out brackish floodwater. Option 3 is, therefore, expected to have the lowest conveyance disruption costs of the four Options.

Export Water Quality Costs

It is assumed that the peripheral aqueduct would convey most water for export under Option 3 and that through-Delta conveyance would be used more opportunistically. Hydrodynamic modeling results for Option 3 based on an 80/20 export split between aqueduct and through-

Delta conveyance facilities indicate that Option 3 could lower total dissolved solids in export water by approximately 125 to 150 mg/L.[6] Modeling results indicate export water quality under Option 3 would improve relative to Options 1 and 2, but would be somewhat worse relative to Option 4.

Water quality improvements under Option 3 would benefit agricultural and urban users of exported Delta water. Urban users would benefit from reduced treatment costs and avoided equipment damage and reduced human health costs. South of Delta agricultural users would benefit to some extent from slower salt buildup in soils and less need for flushing salts from the root zone.[7] Salt loading is of particular concern in Southern California urban areas. A 1999 study of the problem (USBR 1999) estimated a $95 million annual benefit for each 100-mg/L reduction in the total dissolved solids of the region's imported water. Updating regional population estimates and accounting for the share of water imported into the region from the SWP and Colorado River, the annual benefit was estimated to be on the order of $100 million (2007 dollars) per 100-mg/L reduction in SWP total dissolved solids. The present value of avoided salinity damages in Southern California over the next 25 years under Option 3 could, therefore, be on the order of $1.5 to $2.0 billion.[8]

DRMS Phase II noted that a peripheral aqueduct (as in Option 4) could result in some degradation in Delta water quality, particularly in the south Delta. It further noted that a functional dual conveyance arrangement would probably be capable of mitigating these impacts. Thus, Option 3 is expected to result in improved south Delta water quality relative to Option 4.

Habitat Restoration Costs

Because it is assumed the overall amount of habitat restoration would be roughly the same across the four Options (though the locations could differ), restoration cost estimates developed with currently available information would not distinguish Option 3 from the other three Options. While it is recognized that unit costs of restoration may vary to some degree according to the range and location of restoration activity, sufficient information on unit restoration cost differentials is not available at this time to distinguish among the four Options. Thus, habitat restoration costs are not treated as a significant distinguishing feature among the four Options.

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[6] This estimate is based on converting EC results for export water quality presented in BDCP-ModelingResults_082707.ppt to total dissolved solids using EC to total dissolved solids conversion equations from http://www.iep.ca.gov/suisun/facts/salin/index.html.

[7] Improved agricultural export water quality benefits would probably be negligible for south-of-Delta farmland. For impaired lands on the west side of the San Joaquin Valley, the binding constraint is drainage. Without improvements to drainage, improvements in the quality of delivered irrigation water would not be expected to significantly improve productivity on impaired lands. For non-impaired lands, improvements to water quality would provide only negligible production benefits, if any. Over the long-run, better water quality could slow salt buildup and reduce the need for flushing salts from the soil. (Mark Roberson, *pers comm.*).

[8] The present value calculation of avoided damages uses a real discount rate of 6.0%, per DWR guidance.

5.3 FLEXIBILITY/DURABILITY/SUSTAINABILITY CRITERIA

5.3.1.1 Criterion #11. Relative degree to which the Option will be able to withstand the effects of climate change (e.g., sea level rise and changes in runoff), variable hydrology, seismic events, subsidence of Delta islands, and other large-scale changes to the Delta

Option 3 is expected to have a greater ability than Options 1 and 2, but less ability than Option 4, to withstand large-scale changes to the Delta that would adversely affect species conservation and covered activities. The levees supporting through-Delta conveyance under Option 3 are at somewhat greater risk of breaching or overtopping during flood events than the levees under Option 2 because Option 2 includes strengthened levees along Middle River and Option 3 does not. Unlike Options 1 and 2, Option 3 provides for alternate conveyance through a peripheral aqueduct should levees fail. The probability of flood-induced levee failures is expected to increase in the future based on predicted future changes in sea level and in changes to river hydrology resulting from climate change (DRMS Draft Stage I 2007). Option 3 is considered to be at less risk than Option 4 because Option 3 has the flexibility to use either of the dual conveyances should one of the conveyances fail.

Risk to Habitat Restoration Actions

Physical and operational habitat restoration actions under Option 3 may be at less risk from seismic or flood events and from the ongoing effects of sea level rise than Option 1, at greater risk than Option 4, and at the same risk as Option 2. Under Option 3, habitat restoration would be focused in the north, central Delta, and Suisun Marsh, and may be more narrowly distributed than under Option 4. A levee failure at or near restoration sites may have a disproportionate adverse effect under Option 3 where restoration sites are more concentrated than under Option 4, in which restoration sites are expected to be distributed over a wider area of the Delta. Similarly, if restoration sites are less geographically dispersed, Option 3 would provide less flexibility than under Option 4 to adjust flow operations at these more concentrated sites in the event of levee failure(s).

Protecting physical habitat restoration against the effects of sea level rise requires restoration sites at higher elevations (sites in the Delta with less subsidence) and with elevation gradients that include an ecotone between tidal and upland habitat (allowing, over decades, the gradual upward elevation shift of all tidal habitats in response to sea level rise). The more limited geographic range available for habitat restoration under Option 3 relative to Option 4 reduces the number and extent of sites with such elevation characteristics that may be available for habitat restoration in the Delta and hence may provide less durability of restored habitat.

Risk to Water Supply Infrastructure

Option 3 would provide more protection to water supply facilities from seismic or flood events and from the ongoing effects of sea level rise than Options 1 and 2. The through-Delta conveyance levees under Option 3 would not be strengthened; consequently, this water supply component of Option 3 is at greater risk than under Options 2 and 4. This risk relative to Option 2, however, is offset because the peripheral aqueduct, which is expected to be engineered to withstand seismic and flood events, would be available for conveyance in the event the ability to convey water using the through-Delta component of Option 3 is disrupted. Because Option 3 includes a peripheral aqueduct similar to Option 4 and additionally includes through-Delta supply for a dual system, Option 3 has greater flexibility than Option 4. Should an unforeseen event require temporary closure of the peripheral aqueduct, Option 3 includes the ability to continue to provide water exports directly from the south Delta.

5.3.1.2 Criterion #12. Relative degree to which the Option could improve ecosystem processes that support the long-term needs of each of the covered species and their habitats with minimal future input of resources

Option 3 may be able to sustain improvements in ecosystem processes through time better than Options 1 and 2 but less than Option 4 for the following reasons:

1. Option 3 may provide a greater amount of habitat to support covered species than under Options 1 and 2, as the dual water transport modes allows for less use of through-Delta pumping.

2. Option 3 may be less sustainable than Option 4 if the operable barriers are determined to present barriers to movement of covered species within the Delta (e.g., sturgeon). If operable barriers are found to be adequately responsive to fishery conditions, then Option 3 may be more sustainable than Options 1 or 2 once operating rules are devised that benefit covered species.

3. Option 3 would be more sustainable through time than Options 1 or 2 because it provides for greater flexibility in managing for a more variable Delta hydrology. Such variability should provide some added benefit in managing for harmful invasive species, reducing recurring costs of Option 3 relative to Options 1 and 2.

4. Option 3 may require greater input of resources and be less sustainable through time than Option 4 because Option 3 limits the area available for restoration of covered species habitat. Thus, there is a reliance of restoration success on a smaller range of habitat improvement or restoration Options.

5.3.1.3 Criterion #13. Relative degree to which the Option can be adapted to address the needs of covered fish species over time

Option 3 is expected to be the more adaptable than Options 1 and 2, but less adaptable than Option 4, to address possible future conservation of the covered fish species for the following reasons:

1. A larger percentage of land area compared to Option 1, but substantially smaller percentage compared to Option 4, within the Delta for restoring high function habitat is available under Option 3 should it be necessary to increase the extent of restored habitat for covered species in the future.

2. The geographic extent of land area that is suitable for habitat restoration is greater than under Option 1, but less than under Option 4; therefore, Option 3 is less adaptable than Option 4 in opportunities to restore habitat in other portions of the Delta that may be required to meet conservation needs of covered species in future.

3. The flexibility to experiment with and adjust Delta hydrology is less constrained than under Options 1 and 2 because the need to maintain a hydrologic barrier to maintain water quality for water supply is not needed when water for export is provided via the peripheral aqueduct. Consequently, Option 3 provides the opportunity for experimenting with flow and water quality conditions (e.g., adjusting operation of the Delta Cross Channel, installing temporary or operable barriers, or augmenting flows to east side tributaries) throughout the Delta during periods that through-Delta conveyance facilities are not in use to identify flow regimes that optimize ecosystem and covered fish species benefits.

5.3.1.4 Criterion #14. Relative degree of reversibility of the Option once implemented

Option 3 is expected to be least practicable among the Options to reverse.

Under Option 3, construction of a peripheral aqueduct with fish screens and construction of attendant in-Delta facilities (e.g., operable barriers and siphon) would entail a substantial investment of capital (see Criterion #10) that would be lost if the facilities were abandoned. Additional costs would be incurred if structures needed to be removed or demolished. Compared to Options 1, 2, and 4, reversing Option 3 would be the least likely to be acceptable to the public because the loss of investment costs would be substantially greater than Options 1 and 2 and somewhat greater than Option 4. Additionally, the costs and land area subject to disturbance (e.g., noise and road closures) that would be associated with removal of the peripheral aqueduct would be expected to be substantial and, if the aqueduct were not removed, some level of ongoing maintenance costs would be required to maintain public safety (e.g., maintenance of fencing and patrolling the abandoned facility).

Taking a different perspective, however, with dual conveyance constructed under Option 3, reversion to a through-Delta-only conveyance approach or to a peripheral-conveyance-only approach, if necessary, could be more rapidly accomplished than under any other Option.

5.4 OTHER RESOURCES IMPACTS CRITERIA

5.4.1.1 Criterion #15. Relative degree to which the Option avoids impacts on the distribution and abundance of other native species in the BDCP planning area

The probability for adverse impacts on other native aquatic species within the Delta is expected to be substantially less compared to current conditions, Option 1, and Option 2, but greater than under Option 4 for the following reasons:

1. During periods of operation south Delta SWP/CVP export facilities under Option 3 entrainment of native aquatic species would result similar to Option 2, but likely less than Option 1 and base conditions because Old River would be isolated from the pump facilities. During periods that the peripheral aqueduct conveyance component of Option 3 is operating, native aquatic organisms could be entrained at the Sacramento River intake. Because the intake would be screened with a state-of-the-art fish barrier to minimize entrainment of aquatic organisms, the level of entrainment of other native aquatic organisms is expected to be less than from the water exported from the south Delta facilities. Consequently, it is expected that the potential entrainment levels of other

native aquatic organisms would be less than under current conditions, Option 1, and Option 2. The potential for entrainment of other aquatic organisms is expected to be greater under Option 3 than Option 4 because under Option 4 water would only be exported from a screened facility on the Sacramento River and no water would be exported directly from the south Delta through the SWP/CVP facilities.

2. Under Option 3, the placement and operation of the barriers along Middle River could impede the movement of other native fish and aquatic organisms to and from the east and central Delta. This would also be a potential impact under Option 2, which includes barriers, but not under Options 1 and 4, which do not include barriers along Middle River. The degree of adverse impact is not known at this time but would be expected to be greatest for species that require such movements to fulfill their lifecycle. Because the barriers are expected to be operable, there is the opportunity to adjust operation of barriers to minimize this potential impact.

3. Potential intertidal and aquatic habitat restoration areas are expanded from Option 1 to include areas in the Delta west of the barriers along Middle River under Option 3. Other native aquatic species could benefit in that portion of the Delta. Technical uncertainties, however, are associated with habitat restoration along Old River that affects the feasibility of conservation actions in this area. These uncertainties include the unknown effects of changes in water quality (e.g., higher salt and selenium content) associated with concentrating San Joaquin River discharge into the habitat restoration area and how best to manage flow conditions (e.g., fluctuating salinity) in the central Delta west of the proposed barriers to provide ecological benefits.

4. Construction of barriers, siphons, and a peripheral aqueduct and attendant facilities could result in temporary impacts on water quality associated with sediment discharge or mobilization of channel bed sediments and disturbance to or mortality of aquatic organisms associated with in-channel operation of equipment. These impacts are expected to be temporary and minor, but would be greater than under Option 1 which does not include any construction activities. Similar types and levels of impacts would be expected under Options 2 and 4 with construction of barriers and siphons and strengthening of levees under Option 2 and construction of a peripheral aqueduct and attendant facilities under Option 4.

The potential for Option 3 impacts on native terrestrial species could result from removal of terrestrial habitats and temporary disturbances (i.e., visual and noise) to wildlife associated with construction of a peripheral aqueduct and attendant facilities, siphons, and barriers. The probability for adverse impacts on terrestrial native species within the Delta is expected to be greatest under Option 3 compared to the other Options for the reasons described below:

1. The probability of impacts on native terrestrial species is expected to be substantially greater than under Options 1 and 2 because no ground-disturbing activities would occur under Option 1 that could affect wildlife and their habitats, and construction of the peripheral aqueduct component of Option 3 would remove a greater amount of habitat and result in greater levels of construction-related disturbance than Option 2. Construction of the peripheral aqueduct and attendant facilities could remove a substantial amount of upland, riparian, wetland, and agricultural land cover types that

support habitat for special-status (e.g., greater sandhill crane and Swainson's hawk) and other native wildlife (e.g., waterfowl). For example, up to about 1,200 acres of these habitats were estimated to be removed with construction of the peripheral aqueduct evaluated by CALFED (CALFED 2000). Because the peripheral aqueduct is a linear facility, habitat would be removed in a relatively narrow band along the east side of the Delta. Consequently, the effects of habitat removal on most terrestrial species are expected to be minimized because habitat would be removed as relatively small patches over a large area and would be restored wherever practicable.

2. Both Options 3 and 4 include construction of a peripheral aqueduct and attendant facilities. However, because Option 3 also includes construction of barriers and a siphon to support its through-Delta conveyance component, impacts of Option 3 are expected to be marginally greater to terrestrial habitats than under Option 4. Construction of the siphon and five barriers could result in temporary disturbances (i.e., visual and noise) to wildlife. Impacts on wildlife habitats are expected to be relatively minor because the construction footprint of barriers and the siphon would be relatively small and impacts would be limited to areas immediately adjacent to affected channels. For example, five gates proposed under the SDIP would result in removal of less than five acres of terrestrial habitat (Department of Water Resources and Reclamation 2005).

3. Construction of the peripheral aqueduct would create a new barrier in some areas to the movement of some species of wildlife that currently use or occupy habitats on both sides of the potential alignment of the peripheral aqueduct. This impact would be common to both Options 3 and 4. The level of this impact would be relatively minor in locations where movement of wildlife is currently constrained by other barriers (e.g., Interstate 5, other roadways, and Delta channels and sloughs).

4. As shown in Figure 3-3, salinity in the west-central Delta under Option 3 could increase during the growing season compared to current conditions. This level of potential change in salinity, however, is not expected to affect crops yields sufficiently to reduce their value as foraging habitat for wildlife (Lund et al. 2007). For example, research conducted by Hoffman et al. (1982) indicated that yields of field corn in the Delta were not affected by salinities of less than 3.7 mS/cm.

5.4.1.2 Criterion #16. Relative degree to which the Option avoids impacts on the human environment

The types of adverse impacts as defined under CEQA and NEPA on the human environment that could be associated with Option 3 are described below.[9] Potential impacts described here for Option 3 would not necessarily be significant or could be expected to be reduced to a less than significant effect with CEQA/NEPA mitigation.

[9] The evaluation of Criterion #16 focuses on the likely range of adverse direct and indirect impacts of the Options in the planning area and not the indirect impacts to water quality and water supply reliability and in the service areas. These issues in the service areas are addressed in Criteria #8 and #11. Options 3 and 4 are expected to be substantially less vulnerable than Options 1 and 2 to future disruption of water supply. Export water quality improvements would be successively greater and attendant impacts on treatment costs, agricultural production, and human health successively reduced under Options 1, 2, 3, and 4 in that order.

Option 3 is expected to have the potential for the largest impacts among the Options within the following NEPA/CEQA impact categories because the extent of construction-related activities that could impact these categories are greater than the other Options:

- Geology and soils—risk for erosion,
- Cultural resources—likelihood for encountering cultural resources,
- Air quality—PM10 emissions associated with ground disturbance and operation of equipment,
- Noise—operation of equipment,
- Utilities and public services—likelihood for affecting utility infrastructure, and
- Energy usage—fuel and electricity used in construction.

Water Quality/Hydrology

The quality of water, as measured by EC, that would be exported from the SWP/CVP facilities under Option 3 would generally be expected, within the range of modeled operations, to be substantially higher than under current conditions and Option 1; generally lower than or similar to Option 2 from August through December and higher from January through July; and substantially lower than Option 4 from May through January and similar to Option 4 from February through April (see Figure 3-2). Improvements in water quality exported from the Delta relative to current conditions and Option 1 would be expected to reduce water treatment costs to meet water quality standards and needs for municipal, agricultural, and residential uses in service areas. Because Option 3 includes facilities to export water using through-Delta facilities or a peripheral aqueduct, the flexibility likely exists to adjust operations between the two conveyance facilities to further improve water quality for export, if needed.

Within the Sacramento River delta (as measured at Emmaton on Sherman Island) and the range of modeled operations most likely to achieve water supply objectives, water quality under Option 3 would generally be lower than Option 1 and compared to current conditions from October through May and generally lower than or similar to Option 1 and current conditions from June through September; generally lower than Option 2 in all months; and generally lower than Option 4 from September through February and higher than or similar Option 4 from March through August. Water quality would be expected to be somewhat higher in the east Delta under Option 3 than under Options 1 and 4 because Option 3 would prevent lower quality San Joaquin River water from entering the east Delta (see Figure 3-4). Changes in Sacramento River water quality are expected to have no or minimal impacts on farming practices or production.

Within the San Joaquin River Delta (as measured on Old River at State Highway 4) and the range of modeled operations most likely to achieve water supply objectives, water quality under Option 3 would generally be lower than Option 1 and current conditions from December through August and similar to or higher than Option 1 and current conditions from September through November; similar to Option 2 in all months; and similar to Option 4 from September through June, but lower than Option 4 during July and August(see Figure 3-4). Changes in water quality in the west-central Delta under Option 3 potentially could affect farming practices or production. Because Option 3 includes operable barriers along Middle River, it provides for operational flexibility to adjust operation of the barriers to improve water quality conditions in the west central Delta, if needed.

Potential impacts associated with construction-related localized and temporary erosion and runoff of sediments into adjacent Delta waters that could temporarily degrade water quality would be greater than Options 1 and 2 because impacts associated with construction of a peripheral aqueduct would be substantially greater than construction-related impacts of those Options. The construction-related impacts of Option 3 would only be marginally greater than Option 4, which does not include construction of operable barriers or the siphon on Victoria Canal.

Aesthetics

Option 3 would have the greatest visual effects because more facilities would be built than for any of the other Options. The barriers, once installed, may be visible from roads and would be visible from boats. The peripheral aqueduct in Option 3 would affect the visual character of the area along its entire length, including the new bridges and siphons needed for east-west passage of traffic, water, and other utilities. Any lights associated with the new facilities could increase night lighting and glare (DWR 2005) at more locations than for the other Options.

Hazards/Hazardous Materials

Option 3 would have the greatest potential for spills of fuel and lubricants as a result of equipment operation and maintenance during construction of new facilities compared to the other Options because more new facilities would be built. Construction activities under Option 3 would have the greatest potential of all the Options to expose people to hazardous materials and waste uncovered during the other Options. The peripheral aqueduct in Option 3 could pose a safety hazard to people who attempt to fish or otherwise use the aqueduct; these effects would be the same as for Option 4 and would not occur in Options 1 and 2.

Transportation/Traffic

Option 3 would likely have substantially greater impacts on transportation and traffic than Options 1 and 2 because it includes construction of a peripheral aqueduct and attendant facilities. Because the aqueduct would be a linear structure, it is expected to result in a substantial disruption of existing transportation infrastructure and traffic patterns by temporarily adding traffic to Delta roadways and potentially requiring modification or rerouting of transportation facilities (e.g., State Highways 4 and 12, local roadways, and railroad lines). Option 3 impacts on transportation and traffic are expected to be similar to Option 4 because construction of the through-Delta facilities under Option 3 is expected to have minimal impacts.

Recreation

Option 3 would likely have the most impacts on recreation among the Options because construction of barriers and siphons could result in temporary or permanent impacts on recreational patterns (e.g., restricting boat access to channels) and construction of a peripheral aqueduct could impact access to lands used for recreational activities or reduce the quality of recreational experiences. Option 1 is not expected to affect recreational uses of the Delta, impacts of Option 2 would be less than Option 3 because it does not include construction of a peripheral aqueduct, and impacts of Option 4 would be somewhat less than Option 3 because it does not include construction of barriers and the siphon at Victoria Canal.

Agricultural Resources

Because the construction footprint of Option 3 is substantially larger, it is expected to result in a greater loss of agricultural land than Options 1 and 2. Construction of a peripheral aqueduct and attendant facilities could remove a substantial amount of agricultural land from production. For example, removal of 700 to 900 acres of agricultural land was estimated to be necessary for construction of the peripheral aqueduct evaluated by CALFED (CALFED 2000). Because the peripheral aqueduct is a linear facility, it is expected to affect multiple landowners. Consequently, the likely impact of removing land from production would be distributed among a number of individual farmers, thus minimizing the extent of impact on individual farmers. Impacts of Option 3 could be greater if irrigation water quality is lowered sufficiently to reduce agricultural productivity in the central-west Delta. This potential impact, however, may be reduced if there is sufficient operational flexibility to manage the operable barriers along Middle River to improve water quality west of the barriers.

Impacts of Option 3 are expected to be similar to Option 4 because the impacts of constructing the through-Delta component of Option 3 would be relatively small and the footprint of the peripheral aqueduct component is expected to be similar to Option 4.

Option 3, however, potentially could have greater impacts than Option 4 on agriculture in the west-central Delta if water quality under Option 3 is sufficiently lower than Option 4 during July and August to affect crop production.

Environmental Justice

Unlike Options 1 and 2, construction of a peripheral aqueduct and attendant facilities under Option 3 would remove Delta land from agricultural production and, therefore, would be more likely to create disproportionate health or environmental effects on minority or low-income populations through this mechanism. Environmental justice-related impacts of Option 3 would be similar to Option 4 because both Options include construction of a peripheral aqueduct and attendant facilities and impacts associated with the through-Delta component of Option 3 would be minimal.

5.4.1.3 Criterion #17. Relative degree of risk of the Option causing impacts on sensitive species and habitats in areas outside of the BDCP planning area

Adverse or beneficial effects on native species and habitats outside the planning area could result from changes in flow regimes downstream of the Delta in Suisun Bay and Marsh and upstream in the Sacramento River and its major tributaries. The potential for adverse effects downstream of the Delta are indicated by differences in Delta outflow among the Options and the potential for adverse effects in the Sacramento River and its tributaries are indicated by differences in end-of-September reservoir storage volumes, which is a measure of the capacity of reservoirs to provide for cold water releases to sustain water temperatures within ranges favored by native aquatic species.

Based on preliminary analyses, the potential for beneficial effects of Option 3 on species and habitats downstream of the planning area is expected to be greater compared to current conditions and Options 1 and 2 because the average annual modeled Delta outflow (20,289 cfs) is higher under Option 3 than these Options and base conditions (about 15,000 cfs). The average annual Delta outflows and benefits to native species and habitats under Option 3 is expected to be similar to Option 4 (20,996 cfs), with Option 3 generally providing for slightly higher outflows in March and April than Option 3 in all water year types.

Under the range of modeled operations, Option 3 is not expected to affect upstream river water temperature conditions relative to current conditions and could provide for cooler releases from Oroville Reservoir compared to current conditions during critical water years. Based on reservoir storage volumes at the end of September, the ability to provide for cold water releases downstream of Shasta, Folsom, and Oroville Reservoirs under Option 3 would be expected to be similar to Options 1, 2, and 4 in most water-year types. During critical water years, Shasta Reservoir storage volume would be less than Options 1 and 2 and similar to Option 4; Folsom Reservoir storage volume would be similar to Options 1 and 3, but greater than Option 4; Oroville Reservoir storage volume would be similar to Options 1 and 2 and greater than Option 4 during dry years; and during critical years, Oroville Reservoir storage volume would be similar to Option 2 and greater than Options 1 and 4.

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6.0 CONSERVATION STRATEGY OPTION 4 EVALUATION

Using the methods described in Section 2, this section presents an evaluation of Option 4. Option 4 is evaluated based on how it addresses each of the evaluation criteria and how it performs relative to the other Options and base conditions.

6.1 BIOLOGICAL CRITERIA

Option 4 includes construction and operation of a state-of-the-art positive barrier fish screen on the Sacramento River in the vicinity of Hood (Figure 1-5). Diversion of water for export would be exclusively from the Hood facility; no SWP or CVP exports would occur from the southern Delta. With the elimination of through-Delta water conveyance under Option 4 physical and hydrological habitat restoration and enhancement measures could be implemented at any location in the Delta (Figure 1-5). Results of the assessment of biological criteria and potential benefits to covered fish species under Option 4 are described in this section.

The evaluation of biological criteria for Option 4 is based on the hydrodynamic parameter values modeled for operational Scenarios A and B. The evaluation discussions presented below for each species and criterion, however, focus on Scenario A because:

- the type of effects of Scenario B on stressors and stressor impact mechanisms for each of the covered fish species are the same as described for Scenario A and a description of the performance of Scenario B would be repetitious;

- Scenario A would be more likely to achieve water supply objectives than Scenario B and, therefore, comparison of hydrodynamic outputs for scenario A across the Options puts each Option on an equivalent basis; and

- The magnitude of the effects of the Option on covered fish species differs between Scenarios A and B and, consequently, CALSIM II and DSM2 modeling results for Scenario B provided information useful in determining the range of flexibility within the Option to improve performance of the Option relative to achieving each of the biological criteria.

Though not described in the criteria evaluation text, the expected performance of Scenario B on each of the important stressors for each of the covered fish species relative to the performance of Scenario A is presented in summary tables at the beginning of each species evaluation section below.

Descriptions of the stressors and impact mechanisms addressed by the Options relative to each of the biological criteria and the tools used to measure changes in stressor effects are described in Section 3, "Conservation Strategy Option 1 Evaluation", and are not repeated in this section.

6.1.1 Delta Smelt

Based on the evaluation presented below of the expected performance of Option 4 for addressing important delta smelt stressors, Option 4 would be expected to have a high beneficial effect on delta smelt production, distribution, and abundance relative to base conditions when operated to meet water supply objectives (Scenario A). If water supply exports are reduced (Scenario B), Option 4 would also be expected to provide a high beneficial effect on delta smelt production, distribution, and abundance relative to base conditions. Option 4 would be expected to provide higher benefits for delta smelt compared to the other Options.

Table 6-1 summarizes the expected effects of implementing Option 4 under Scenarios A and B on important delta smelt stressors relative to base conditions.

Table 6-1. Summary of Expected Effects of Option 4 on Highly and Moderately Important Delta Smelt Stressors

Stressors[1]	Applicable Criteria	Option Effects on Important Species Stressors Relative to Base Conditions	
		Scenario A	Scenario B
Highly Important Stressors			
Reduced food availability	1,3,4,5	High benefit	High benefit
Reduced rearing habitat	2,3	High benefit	High benefit
Reduced turbidity	1,2,3,5	Moderate benefit	Moderate benefit
Reduced spawning habitat	3	High benefit	High benefit
Reduced food quality	1,4,5	High benefit	High benefit
Moderately Important Stressors			
Predation	1,5	High benefit	High benefit
CVP/SWP entrainment	1	High benefit	High benefit
Exposure to toxics	1,2	Moderate adverse effect	Moderate adverse effect

Notes:

1. See Appendix C for descriptions of stressors, stressor impact mechanisms, and stressor effects.
2. It is recognized that the risk of entrainment at the SWP and CVP export facilities may be a high level stressor to delta smelt in some years and a very low level stressor to delta smelt in other years. For purposes of this analysis, the risk of delta smelt entrainment has been characterized, on average, as a moderate level stressor to the population.

6.1.1.1 Criterion #1. Relative degree to which the Option would reduce species mortality attributable to non-natural mortality sources, in order to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species.

Based on the following evaluation of Option 4 effects on applicable delta smelt stressors, Option 4 is expected to provide high benefits for delta smelt by reducing the effects of non-natural sources of mortality relative to base conditions.

Reduced Food Availability and Quality

The effects of Option 4 on delta smelt food availability and quality are evaluated under Criterion #4 below. As described in the Criterion #4 evaluation, Option 4 would be expected to provide a high beneficial effect on food availability and a high beneficial effect on food quality for the delta smelt relative to base conditions.

Reduced Turbidity

The effects of Option 4 on turbidity are evaluated under Criterion #2 below. As described in the Criterion #2 evaluation, Option 4 would be expected to provide moderate beneficial increase in turbidity conditions for delta smelt.

Predation

As described below under Criterion #2, Option 4 would be expected to moderately improve turbidity conditions relative to base conditions and, therefore, would be expected to reduce the vulnerability of delta smelt to predation. The proportion of the Delta (75%) within which physical habitat restoration could potentially be implemented is substantially greater than under the other Options (see Figure 1-5).

Based on the potential for improvement in turbidity conditions and the proportion of the Delta available for potential restoration, Option 4 would be expected to provide a high benefit by reducing the predation vulnerability of delta smelt relative to base conditions.

Entrainment by CVP/SWP Facilities

Under Option 4, all SWP and CVP diversions would occur from the Sacramento River near Hood. Risk for entrainment of delta smelt at the Hood intake facility would be minimal because the intake would be equipped with a positive barrier fish screen that would be expected to be highly effective in reducing the vulnerability of all but the early larval stages of delta smelt to entrainment. Furthermore, most delta smelt are believed to spawn downstream of the Hood intake location, thus reducing the proportion of the delta smelt population that is vulnerable to entrainment.[1] Removing the SWP and CVP exports from the south Delta under Option 4 would be expected to virtually eliminate the risk of delta smelt entrainment losses as a result of export operations. PTM modeling results also indicate that no entrainment of particles inserted downstream of Hood would be entrained at the intake facility. Based on this assessment, entrainment of delta smelt as a result of SWP and CVP export operations is expected to be nearly eliminated under Option 4 relative to base conditions.

[1] Results of fishery surveys conducted by CDFG and USFWS have shown that the majority of delta smelt inhabit the Sacramento River downstream of Walnut Grove and Georgiana Slough although a small number of delta smelt have been collected upstream of Hood in some years.

Exposure to Toxics

The effects of Option 4 on delta smelt exposure to toxics are evaluated under Criterion #2 below. As described in the Criterion #2 evaluation, Option 4 would be expected to have a moderate adverse increase in delta smelt exposure to toxics.

6.1.1.2 Criterion #2. Relative degree to which the Option would provide water quality and flow conditions necessary to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species.

Based on the following evaluation of Option 4 effects on applicable delta smelt stressors, Option 4 is expected to have a high beneficial effect on water quality and flow conditions that support delta smelt relative to base conditions.

Reduced Rearing Habitat

Results of hydrologic modeling indicate that the position of X_2 in April would be located 0.2 km upstream relative to base conditions and therefore would likely have no effect on the availability of rearing habitat. PTM modeling results indicate that a marginally to moderately higher number of particles are moved downstream past Chipps Island. Net downstream flows and Sacramento River flows at Rio Vista during March and April, which serve to transport larval smelt to downstream rearing habitats, however, would be reduced relative to base conditions (see Appendices F and H). As described below, Option 4 would be expected to improve turbidity conditions, thus improving the foraging efficiency of delta smelt and reducing their vulnerability to predation. Additionally, Option 4 would establish net westerly flows throughout the Delta that would improve transport and migration of delta smelt. The potential restoration of rearing habitats as described under Criterion #3 would also be expected to improve rearing habitat conditions. Consequently, overall Option 4 would be expected to have a high beneficial effect on rearing habitat accessibility and conditions relative to base conditions.

Reduced Turbidity

Option 4 is expected to moderately improve turbidity conditions for delta smelt relative to base conditions. Peak total Delta inflows from January through March are reduced from base conditions, indicating that turbidity inputs from Delta tributaries could be reduced from base conditions in those months. PTM modeling results for the central Delta indicate, however, that residence time would be substantially higher, thus creating the potential for increases in turbidity associated with primary and secondary production (see Appendices F and H). Restoration of aquatic shallow subtidal and intertidal habitats that could reduce the adverse effects of non-native aquatic pelagic and benthic organisms that filter sediment and organic materials from Delta waters could be located within approximately 75% of the Delta (Figure 1-5). Although peak Delta inflows could be reduced, improved turbidity conditions associated with increased hydraulic residence time and habitat restorations would be such that, overall, Option 4 would be expected to provide a moderate beneficial improvement in turbidity conditions for delta smelt relative to base conditions.

Exposure to Toxics

Dilution flows from the Sacramento River and other Delta tributaries are one way of reducing concentrations of toxics and their effect on delta smelt. Modeling results indicate that Option 4 would be expected to reduce dilution flows relative to base conditions, thus potentially increasing concentrations of toxics (see Appendices F and H). Furthermore, because the volume of water coming from the Sacramento River into the Delta would be reduced under Option 4, the contribution of the San Joaquin River water to water quality conditions within the Delta would be higher. Because San Joaquin River water is known to contain higher concentrations of toxics than Sacramento River water, Option 4 could increase the risk of exposing delta smelt to toxics. Although the effects of toxics on delta smelt are uncertain, Option 4 has the potential for having a moderate adverse effect on delta smelt by increasing the exposure of delta smelt to higher concentrations of toxics. Under Option 4, however, there are potential opportunities to restore intertidal wetlands in the south Delta that could filter toxics from the San Joaquin River before it discharges into the central Delta, which would reduce the likelihood for toxic effects on delta smelt.

6.1.1.3 Criterion #3. Relative degree to which the Option would increase habitat quality, quantity, accessibility, and diversity in order to enhance and sustain production (reproduction, growth, survival), abundance, and distribution; and to improve the resiliency of each of the covered species' populations to environmental change and variable hydrology.

Based on the following evaluation of Option 4 effects on applicable delta smelt stressors, Option 4 is expected to provide high benefits relative to habitat conditions for the delta smelt.

Within the planning area, delta smelt habitat conditions are governed by hydrodynamic conditions and the extent and quality of habitat within the planning area. Under Option 4, these conditions relative to base conditions would be affected by the conveyance configuration of Option 4 and restoration of physical habitat that could potentially be sited within Suisun Bay and Marsh and within 75% of the planning area, which encompasses the known and potential range of delta smelt within the Delta.

Reduced Food Availability

The effects of Option 4 on delta smelt food availability are evaluated under Criterion #4 below. As described in the Criterion #4 evaluation, Option 4 would be expected to provide a high beneficial effect on food supply for the delta smelt relative to base conditions.

Reduced Rearing Habitat

Under Option 4, in addition to the flow benefits for rearing habitat conditions described above under Criterion #2, habitat could be restored within Suisun Bay and Marsh and approximately 75% of the Delta to provide high quality shallow aquatic subtidal and intertidal habitat (Figure 1-4), which encompasses a larger proportion of the delta smelt rearing range than the area that potentially would be available and suitable for restoration under the other Options. Consequently, relative to base conditions and the other Options, Option 4 would be expected to provide a high benefit for delta smelt rearing habitat.

Reduced Turbidity

The effects of Option 4 on turbidity are evaluated under Criterion #2 above. As described in the Criterion #2 evaluation, Option 4 would be expected to provide moderate beneficial increases in turbidity conditions.

Reduced Spawning Habitat

The primary impact mechanism believed to affect spawning habitat is the reclamation and channelization of historical shallow subtidal and intertidal wetlands that has presumably reduced the amount of habitat available for spawning by delta smelt. Under Option 4, physical aquatic and subtidal and intertidal habitats could potentially be restored at sites located over 75% of the Delta (Figure 1-5), which encompasses a substantially larger proportion of the likely spawning range of delta smelt than restoration that could be implemented under the other Options. Consequently, to the extent that functioning delta smelt spawning habitat can be successfully restored based on current understanding of its habitat requirements, restoration under Option 4 would be expected to provide a high benefit (see Appendix H) relative to base conditions and other Options.

6.1.1.4 Criterion #4. Relative degree to which the Option would increase food quality, quantity, and accessibility (e.g., phytoplankton, zooplankton, macro-invertebrates, forage fish) to enhance production (reproduction, growth, survival) and abundance for each of the covered fish species.

Overall, Option 4 would be expected to provide high benefits for improving food availability and quality for delta smelt.

Reduced Food Availability

The potential opportunities for habitat restoration that could be implemented under Option 4 would all be located within the geographic range of delta smelt and could create conditions that disfavor non-native species that indirectly or directly affect food abundance (e.g., overbite clam (*Corbula*), threadfin shad), thereby improving food availability for delta smelt relative to base conditions (Figure 1-5). Because habitat restorations could potentially be sited within a larger proportion of the delta smelt's range within the Delta (75% of the Delta would be potentially available and suitable restoring delta smelt habitat), habitat restoration under Option 4 is expected to improve food availability relative to the other Options and base conditions.

The magnitude of peak flows from January through March, the period during which Delta inflows have been greatest historically, gives an indication of the potential for floodplain inundation relative to base conditions. Modeled peak Delta inflows under Option 4 during January through March are substantially lower relative to base conditions (see Appendices F and H). Therefore, relative to base conditions, Option 4 would be expected to have a low adverse effect on the transport of organic material and nutrients from floodplains into the Delta. An increase in the extent of shallow water tidal and subtidal habitat in the Delta under Option 4 would provide additional opportunities to inundate areas having high production and contribute to nutrient and organic material transport through the Delta. The opportunities for in-Delta inundated aquatic habitat are greater under Option 4 than the other three Options evaluated.

Based on PTM modeling results for exported particles, the removal of food organisms, nutrients, and organics by diversions would be substantially lower relative to base conditions. Under Option 4, all SWP and CVP diversions would be made directly from the Sacramento River, thereby substantially reducing the export of nutrients, organic material, phytoplankton, and zooplankton from the Delta. PTM modeling results for particles released into the central Delta, an indictor of hydrologic residence time, indicated that hydraulic residence time within the central Delta would be higher relative to base conditions. Increased residence time is generally beneficial for delta smelt food supply, however, high residence time could have adverse effects on central Delta biota if it is too great. Dissolved oxygen levels can be depressed by high biological oxygen demand resulting from high densities of phytoplankton and reduced hydraulic flushing. Particle tracking models were run for a period of 40 days and, even after this duration, 90% of the particles injected at Middle River remained in the central Delta under the 50% exceedance hydrology. However, in most other scenarios and insertion locations, high residence time does not appear to be a concern under Option 4. Based on these results, Option 4 would be expected to provide a moderate benefit for delta smelt associated with a reduction in exports of nutrients and organic material that support delta smelt food supplies.

Historically, much of the energy in the Delta ecosystem was derived from wetland tules (The Bay Institute 1998). Therefore, combined with the wetland restoration potential in the Delta under Option 4, the increases in residence time within the Delta, and the reduction in the export of nutrients, organics, and zooplankton from the Delta, Option 4 is expected to provide a high beneficial increase in the availability of food for delta smelt.

Reduced Food Quality

Restoration of shallow water tidal and subtidal habitats under Option 4 could improve nutrient production and production of suitable zooplankton species (e.g., native calanoid copepods) as forage for delta smelt. Under Option 4, physical aquatic subtidal and intertidal habitats could be restored at sites located over 75% of the Delta (Figure 1-5), which encompasses a substantially larger proportion of the likely spawning range of delta smelt than restoration that could be implemented under the other Options. Consequently, relative to the other Options, Option 4 would be expected to provide a potentially high benefit for food quality (see Appendix H).

6.1.1.5 Criterion #5. Relative degree to which the Option would reduce the abundance of non-native competitors and predators to increase native species production (reproduction, growth, survival), abundance and distribution for each of the covered fish species.

Option 4 could reduce the effects of non-native competitors and predators on delta smelt primarily through restoration of intertidal and subtidal aquatic habitats at potential locations throughout the Delta. For reasons described in above, Option 4 would be expected to provide a high beneficial effect by reducing the adverse effects of populations of non-native food competitors relative to base conditions. For reasons described under Criteria #1 and #2, Option 4 could provide a moderate beneficial effect by reducing the risk of delta smelt predation relative to base conditions. Additionally, because the intake under Option 4 would be located on the Sacramento River upstream near Hood, Delta hydrodynamics would largely revert to a more natural east to west flow pattern through the Delta. Option 4 presents opportunities to adaptively manage Delta hydrodynamics to create hydrodynamic conditions that would be expected to favor the delta smelt and disfavor predators and competitors to improve conditions for the delta smelt. Although the ability to control non-native species by varying hydrodynamic conditions in the Delta is uncertain, Option 4 provides a greater opportunity for doing so than Options 1 and 2.

6.1.1.6 Criterion #6. Relative degree to which the Option improves ecosystem processes in the BDCP planning area to support aquatic and associated habitats.

Based on the proportion of the planning area suitable for potential restoration under Option 4 relative to the other Options and modeling results for hydraulic residence time (see Appendix H), Option 4 would be expected to provide a low beneficial improvement in ecosystem function relative to base conditions.

Under the range of operations and the potential opportunities to restore/enhance high quality aquatic habitat within the Delta habitat the effectiveness of Option 4 in improving ecosystem processes is considered to be high. These changes would be expected to improve ecosystem processes within the central and western regions of the Delta when compared to base conditions. In addition, the ability to divert water directly from the Sacramento River at Hood while eliminating the export operations within the south Delta would be expected to substantially improve the hydrodynamics of the Delta and improve the quality of habitat available for delta smelt. Under these operating conditions Option 4 offers the opportunity to improve the processes affecting habitat conditions within the Delta (e.g., providing net westerly flows, reducing or eliminating reverse flow conditions, etc.). These potential changes to the estuarine processes within the Delta are expected to benefit delta smelt and other species. It is uncertain, however, if increasing the proportion of lower quality San Joaquin River water present in the Delta (a function of reducing Sacramento River inflow and eliminating export of San Joaquin River water from the Delta) into the central and western Delta would impair ecosystem processes.

6.1.1.7 Criterion #7. Relative degree to which the Option can be implemented within a timeframe to meet the near-term needs of each covered fish species (post BDCP authorization).

In the near-term, until construction of Option 4 conveyance features and facilities is completed, this Option would use the existing conveyance facilities to meet water supply objectives. As for Option 1, implementation of physical habitat restoration under Option 4 in the north and west Delta can be initiated immediately following authorization of the BDCP and thus could be implemented in a manner that would meet the near term needs of delta smelt.

6.1.2 Longfin Smelt

Based on the evaluation presented below of the expected performance of Option 4 for addressing important longfin smelt stressors, Option 4 would be expected to have a high beneficial effect on longfin smelt production, distribution, and abundance relative to base conditions when operated to meet water supply objectives (Scenario A). If water supply exports are reduced (Scenario B), Option 4 would also be expected to provide a high beneficial effect on longfin smelt production, distribution, and abundance relative to base conditions. Option 4 would be expected to provide higher benefits for longfin smelt compared to the other Options.

Stressors that affect longfin smelt are presented in Figure 2-2 and are described in Appendix C. The effect of these stressors on the longfin smelt population vary among years in response to environmental conditions (e.g., seasonal hydrology) and may also interact with each other in additive or synergistic ways. The effects of these stressors include both the incremental contribution of a stressor to the population as well as the cumulative effects of multiple stressors over time. The assessment evaluates the degree to which Option 4 would be expected to address these stressors.

Table 6-2 summarizes the expected effects of implementing Option 4 under Scenarios A and B on important longfin smelt stressors relative to base conditions.

Table 6-2. Summary of Expected Effects of Option 1 on Highly and Moderately Important Longfin Smelt Stressors

Stressors[1]	Applicable Criteria	Option Effects on Important Species Stressors Relative to Base Conditions	
		Scenario A	Scenario B
Highly Important Stressors			
Reduced access to spawning habitat	2	No net effect	No net effect
Reduced access to rearing habitat	2	Very low benefit	Low benefit
Reduced food	1,4,5	High benefit	High benefit
Predation	1,5	High benefit	High benefit
Reduced turbidity	1,2, 3,5	Moderate benefit	Moderate benefit
Reduced spawning habitat	3	High benefit	High benefit
Reduced food quality	1,4,5	High benefit	High benefit
Moderately Important Stressors			
CVP/SWP entrainment[2]	1	High benefit	High benefit
Reduced rearing habitat	2	Low benefit	Low benefit
Exposure to toxics	2	Moderate adverse effect	Moderate adverse effect

Notes:

1. See Appendix C for descriptions of stressors, stressor impact mechanisms, and stressor effects.
2. Although it is recognized that the risk of entrainment at the SWP and CVP export facilities may, in some years, be a high level stressor to longfin smelt, and in some years represents a very low level stressor to longfin smelt, for purposes of the analysis the risk of longfin smelt entrainment under each of the Options has been characterized, on average, as a moderate level stressor to the population.

6.1.2.1 *Criterion #1. Relative degree to which the Option would reduce species mortality attributable to non-natural mortality sources, in order to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species.*

Based on the following evaluation of Option 4 effects on applicable longfin smelt stressors, Option 4 is expected to provide high benefits for longfin smelt by reducing the effects of non-natural sources of mortality relative to base conditions.

Reduced Food Availability and Quality

Reduced food availability and quality can result in non-natural levels of mortality. The effects of Option 4 on longfin smelt food availability and quality are evaluated under Criterion #4 below. As described in the Criterion #4 evaluation, Option 4 would be expected to provide a high beneficial effect on food availability and quality for longfin smelt relative to base conditions.

Reduced Turbidity

Reduced turbidity may increase the vulnerability of longfin smelt to predation and reduce foraging efficiency. The effects of Option 4 on turbidity are evaluated under Criterion #2 below. As described in the Criterion #2 evaluation, Option 4 would be expected to provide moderate beneficial increases in turbidity conditions relative to base conditions.

Predation

As described below under Criterion #2, Option 4 would be expected to moderately improve turbidity conditions relative to base conditions and, therefore, would be expected to reduce the vulnerability of longfin smelt to predation. The proportion of the Delta (75%) within which physical habitat restoration could potentially be implemented is substantially greater than under the other Options (see Figure 1-5). Based on the potential for improvement in turbidity conditions and the proportion of the Delta available for restoration, Option 4 would be expected to provide a high benefit by reducing the predation vulnerability of longfin smelt relative to base conditions.

Entrainment by CVP/SWP Facilities

Under Option 4, all SWP and CVP diversions would occur from the Sacramento River near Hood. Risk for entrainment of longfin smelt at the Hood intake facility would be minimal because the intake would be equipped with a positive barrier fish screen that would be expected to be highly effective in reducing the vulnerability of all but the early larval stages of longfin smelt to entrainment. Furthermore, most longfin smelt are believed to spawn downstream of the Hood intake location, thus reducing the proportion of the longfin smelt population that is vulnerable to entrainment.[2] Removing the SWP and CVP exports from the south Delta under Option 4 would be expected to virtually eliminate the risk of longfin smelt

[2] Results of fishery surveys conducted by CDFG and USFWS have shown that the majority of longfin smelt inhabit the Sacramento River downstream of Walnut Grove and Georgiana Slough although a small number of longfin smelt have been collected upstream of Hood in some years

entrainment losses as a result of export operations. PTM modeling results also indicated that no particles inserted downstream of Hood would be entrained at the intake facility. Based on this assessment, entrainment of longfin smelt as a result of SWP or CVP export operations is expected to be nearly eliminated under Option 4 relative to base conditions.

Exposure to Toxics

The effects of Option 4 on longfin smelt exposure to toxics are evaluated under Criterion #2 below. As described in the Criterion #2 evaluation, Option 4 would be expected to have a moderate adverse increase in longfin smelt exposure to toxics.

6.1.2.2 Criterion #2. Relative degree to which the Option would provide water quality and flow conditions necessary to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species.

Based on the following evaluation of Option 4 effects on applicable longfin smelt stressors, Option 4 is expected to provide very low benefits for water quality and flow conditions that support longfin smelt relative to base conditions.

Reduced Access to Spawning Habitat

Access of adult longfin smelt to spawning habitat is thought to be a function of river flows and availability and quality of habitat. Under Option 4 flows within the Sacramento River during the late winter and early spring longfin smelt spawning period are expected to be reduced when compared to base conditions. Lower winter and early spring flows may reduce upstream attraction and movement of adult longfin smelt and would also be expected to contribute to reduce downstream transport of larval and early juvenile smelt. Flows on the San Joaquin River have been assumed, for purposes of these analyses, to be similar under base conditions and Option 4. Option 4 includes the opportunity to potentially enhance intertidal and subtidal habitat at a wide range of locations throughout Delta that would be expected to benefit longfin smelt when compared to base conditions.

Reduced Access to Rearing Habitat

PTM modeling results indicate that a marginally to moderately higher number of particles would be moved past Chipps Island or into Suisun Marsh. Net downstream flows and Sacramento River flows at Rio Vista during March and April, which serve to transport larval smelt to downstream rearing habitats, however, would be reduced relative to base conditions (see Appendices F and H) which potentially could result in a marginal reduction in larval longfin smelt survival. Consequently, Option 4 would be expected to have a very low beneficial effect on accessibility of rearing habitat.

Reduced Turbidity

Option 4 is expected to moderately improve turbidity conditions for longfin smelt relative to base conditions. Peak total Delta inflows from January through March are reduced from base conditions, indicating that turbidity inputs from Delta tributaries could be reduced from base conditions in those months. PTM modeling results for the central Delta indicate, however, that residence time would be substantially higher, thus creating the potential for increases in turbidity associated with primary and secondary production (see Appendices F and H). Restoration of aquatic subtidal and intertidal habitats that could reduce the abundance and/or impacts of non-native aquatic and benthic organisms that filter sediment and organic materials from Delta waters could potentially be located within approximately 75% of Delta (Figure 1-5). Although peak Delta inflows could be reduced, improved turbidity conditions associated with increased hydraulic residence time and habitat restorations would be such that, overall, Option 4 would be expected to provide a moderate beneficial improvement in turbidity conditions for longfin smelt relative to base conditions.

Exposure to Toxics

Dilution flows from the Sacramento River and other Delta tributaries are one way of reducing concentrations of toxics and their effect on longfin smelt. Modeling results indicate that Option 4 would be expected to reduce dilution flows relative to base conditions, thus potentially increasing concentrations of toxics (see Appendices F and H). Furthermore, because the volume of water coming from the Sacramento River into the Delta would be reduced under Option 4, the contribution of the San Joaquin River water to water quality conditions within the Delta will be higher. Because San Joaquin River water is known to contain higher concentrations of toxics than Sacramento River water, Option 4 could increase the risk of exposing longfin smelt to toxics. Although the effects of toxics on longfin smelt are uncertain, Option 4 has the potential for having a moderate adverse effect by increasing the exposure of longfin smelt to higher concentrations of toxics. Under Option 4, however, there are opportunities to restore intertidal and subtidal wetlands and seasonally inundated floodplains in the south Delta that could filter toxics from the San Joaquin River before it discharges into the central Delta, which would reduce the likelihood for toxic effects on longfin smelt.

Reduced Rearing Habitat

Results of hydrologic modeling indicate that the position of X_2 in April would be located 0.2 km upstream relative to base conditions and, therefore would likely have no effect on the availability of rearing habitat. As described below, Option 4 would be expected to improve turbidity conditions, thus improving the foraging efficiency of longfin smelt and reducing their vulnerability to predation. Consequently, overall Option 4 would be expected to have a low beneficial effect on rearing habitat conditions relative to base conditions.

6.1.2.3 Criterion #3. Relative degree to which the Option would increase habitat quality, quantity, accessibility, and diversity in order to enhance and sustain production (reproduction, growth, survival), abundance, and distribution; and to improve the resiliency of each of the covered species' populations to environmental change and variable hydrology.

Based on the following evaluation of Option 4 effects on applicable longfin smelt stressors, Option 4 is expected to provide moderate benefits relative to habitat conditions for the longfin smelt.

Within the planning area, longfin smelt habitat conditions are governed by hydrodynamic conditions and the extent and quality of suitable habitat. Relative to base conditions, these conditions under Option 4 would be affected by the conveyance configuration and potential restoration of physical habitat that could be located over a wide range of locations representing approximately 75% of the planning area.

Reduced Access to Spawning and Rearing Habitats

The effects of Option 4 on the accessibility of spawning and rearing habitats are evaluated under Criterion #2 above. As described in the Criterion #2 evaluation, Option 4 would be expected to affect longfin smelt access to spawning habitat and would be expected to reduce seasonal flows within the lower reaches of the Sacramento River that serve to transport larval and early longfin smelt to downstream juvenile rearing habitat.

Reduced Food Availability and Quality

Reduced food availability and quality can result in non-natural levels of mortality. The effects of Option 4 on longfin smelt food availability and quality are evaluated under Criterion #4 below. As described in the Criterion #4 evaluation, Option 4 would be expected to provide a high beneficial effect on food availability and quality for longfin smelt relative to base conditions.

Reduced Turbidity

Habitat conditions that support non-native filter feeders and aquatic plants can reduce turbidity. The effects on turbidity associated with these impact mechanisms are evaluated under Criterion #2 above. As described in the Criterion #2 evaluation, restoring habitat under Option 4 would be expected to have a moderate beneficial effect on turbidity conditions for longfin smelt relative to base conditions.

Reduced Spawning Habitat

The primary impact mechanism believed to affect spawning habitat is the reclamation and channelization of historical intertidal and subtidal wetlands that has presumably reduced the amount of habitat available for spawning by longfin smelt. Under Option 4, physical aquatic subtidal and intertidal habitats could potentially be restored at sites located over 75% of the Delta (Figure 1-5), which encompasses a substantially larger proportion of the likely spawning range of longfin smelt than restoration that could be implemented under the other Options. Consequently, relative to the other Options and to the extent that functioning longfin smelt spawning habitat can be successfully restored based on current understanding of its habitat requirements, restoration under Option 4 would be expected to provide a high benefit (see Appendix H) relative to base conditions.

Reduced Rearing Habitat

The effects on rearing habitat associated with Option 4 are evaluated under Criterion #2 above. Option 4 is expected to have a low beneficial effect on rearing habitat conditions relative to base conditions.

6.1.2.4 Criterion #4. Relative degree to which the Option would increase food quality, quantity, and accessibility (e.g., phytoplankton, zooplankton, macro-invertebrates, forage fish) to enhance production (reproduction, growth, survival) and abundance for each of the covered fish species.

Overall, Option 4 would be expected to provide high benefits for improving food availability and quality for longfin smelt.

Reduced Food Availability

The habitat restoration that would be implemented under Option 4 would all be located within the geographic range of longfin smelt and could create conditions that disfavor non-native species that indirectly or directly affect food abundance (e.g., overbite clam (*Corbula*), threadfin shad), thereby improving food availability for longfin smelt relative to base conditions (Figure 1-5). Because habitat restorations could potentially be sited within a larger proportion of the longfin smelt's range within the Delta (75% of the Delta could be available for restoration/enhancement), habitat restoration under Option 4 is expected to improve food availability relative to the other Options and base conditions.

The magnitude of peak flows from January through March, the period during which inflows have been greatest into the Delta historically, gives an indication of the potential for floodplain inundation relative to base conditions. Modeled peak Delta inflows under Option 4 during January through March are substantially lower relative to base conditions (see Appendices F and H). Therefore, relative to base conditions, Option 4 would be expected to have a low adverse effect on the mobilization and transport of organic material and nutrients from floodplains into the Delta. The potential to increase the extent of shallow water intertidal and subtidal habitat within the Delta under Option 4 would provide additional opportunities to inundate areas having high production and contribute to nutrient and organic material transport through the Delta. The opportunities for in-Delta inundated aquatic habitat are greater under Option 4 than the other three options evaluated.

Based on PTM modeling results for exported particles, the removal of food organisms, nutrients, and organics by diversions would be substantially lower relative to base conditions. Under Option 4, all SWP and CVP diversions would be made directly from the Sacramento River, thereby substantially reducing the export of nutrients, organic material, phytoplankton, and zooplankton from the Delta. PTM modeling results for particles released into the central Delta, an indictor of hydrologic residence time, indicated that hydraulic residence time within the central Delta was much higher relative to base conditions. Increased residence time is generally beneficial for longfin smelt food supply, however, high residence time could have adverse effects on central Delta biota if it is too great. Dissolved oxygen levels can be depressed by high biological oxygen demand resulting from high densities of phytoplankton and reduced hydrologic flushing. Particle tracking models were run for a period of 40 days and, even after this duration, 90% of the particles injected at Middle River remained in the central Delta under the 50% exceedance hydrology. However, in most other scenarios and insertion locations, high residence time does not appear to be a concern under Option 4. Based on these results, Option 4 would be expected to provide a moderate benefit for longfin smelt associated with a reduction in exports of nutrients and organic material that support longfin smelt food supplies.

It has been hypothesized that exposure of phytoplankton and zooplankton to toxics (e.g., pesticides, herbicides) that enter the Delta from point and non-point sources may contribute to ongoing low abundance of longfin smelt zooplankton prey species (Weston et al. 2004, Luoma 2007). Though this relationship is uncertain, Option 4 could potentially increase the exposure of primary and secondary producers to elevated concentrations of these toxics because dilution flows would be lower than base conditions.

Historically, much of the energy in the Delta ecosystem was derived from wetland tules (The Bay Institute 1998). Therefore, combined with the wetland restoration potential in the Delta under Option 4, the increases in residence time within the Delta, and the reduction in the export of nutrients, organics, and zooplankton from the Delta, Option 4 is expected to provide a high beneficial increase in the availability of food for longfin smelt.

Reduced Food Quality

Restoration of shallow water intertidal and subtidal habitats under Option 4 could improve nutrient production and production of suitable zooplankton species (e.g., native calanoid copepods) as forage for longfin smelt. Under Option 4, physical aquatic subtidal and intertidal habitats could potentially be restored at sites located over 75% of the Delta (Figure 1-5), which encompasses a substantially larger proportion of the range of rearing and foraging juvenile and adult longfin smelt than restoration that could be implemented under the other Options. Consequently, relative to the other Options, Option 4 would be expected to provide a potentially high benefit for food quality (see Appendix H).

6.1.2.5 Criterion #5. Relative degree to which the Option would reduce the abundance of non-native competitors and predators to increase native species production (reproduction, growth, survival), abundance and distribution for each of the covered fish species.

Option 4 could reduce the effects of non-native competitors and predators on longfin smelt primarily through restoration of intertidal and subtidal aquatic habitats located throughout the Delta. For reasons described above, Option 4 would be expected to provide a moderate beneficial effect by reducing populations and/or the impacts of non-native food competitors relative to base conditions. For reasons described under Criteria #1 and #2, Option 4 could provide a moderate beneficial effect by reducing the risk of longfin smelt predation relative to base conditions. Additionally, because the intake under Option 4 would be located upstream near Hood, Delta hydrodynamics would largely revert to a more natural east to west flow pattern through the Delta and presents opportunities to restore and adaptively manage hydrodynamic conditions that favor the longfin smelt and disfavor predators and competitors to improve conditions for the longfin smelt. Although the ability to control non-native species by varying hydrodynamic conditions in the Delta is uncertain, Option 4 provides a greater opportunity for doing so than Options 1, 2, or 3.

6.1.2.6 Criterion #6. Relative degree to which the Option improves ecosystem processes in the BDCP planning area to support aquatic and associated habitats.

Based on the proportion of the planning area suitable for potential restoration under Option 4 relative to the other Options and modeling results for hydraulic residence time (see Appendix H), Option 4 would be expected to provide a high beneficial improvement in ecosystem function relative to base conditions. Operations under Option 4 would return Delta hydrodynamic conditions to a more normal east-west direction and would avoid reverse flow conditions. The changes in hydrodynamic conditions under Option 4 would directly contribute to improving estuarine processes.

Under the range of operations and the potential opportunities to restore/enhance high quality aquatic habitat within the Delta habitat the effectiveness of Option 4 in improving ecosystem processes is considered to be high. These changes would be expected to improve ecosystem processes throughout the Delta when compared to base conditions. In addition, the ability to divert water directly from the Sacramento River at Hood while eliminating the export operations within the south Delta would be expected to substantially improve the hydrodynamics of the Delta and improve the quality of habitat available for longfin smelt. Under these operating conditions Option 4 offers the opportunity to improve the processes affecting habitat conditions within the Delta (e.g., providing net westerly flows, reducing or eliminating reverse flow conditions, etc.). These potential changes to the estuarine processes within the Delta are expected to benefit longfin smelt and other species. It is uncertain, however, if increasing the proportion of low quality San Joaquin River water present in the Delta (a function of reducing Sacramento River inflow and eliminating export of San Joaquin River water from the Delta) into the central Delta would impair ecosystem processes.

6.1.2.7 Criterion #7. Relative degree to which the Option can be implemented within a timeframe to meet the near-term needs of each covered fish species (post BDCP authorization).

In the near-term, until construction of Option 4 conveyance features and facilities is completed, Option would use the existing conveyance facilities to meet water supply objectives. As for Option 1, implementation of physical habitat restoration under Option 4 in the north and west Delta can be initiated immediately following authorization of the BDCP and thus could be implemented in a manner that would meet the near term needs of longfin smelt.

6.1.3 Sacramento River Salmonids

Overall, Option 4 is expected to provide high benefit to Sacramento River Chinook salmon and steelhead compared to base conditions. Operations under Option 4, including diversion from the Sacramento River using a state-of-the-art positive barrier fish screen, would substantially reduce or potentially eliminate adverse impacts related to entrainment of juvenile salmonids from the Sacramento River. The potential opportunities for habitat restoration and enhancement of both physical habitat and natural hydrology under Option 4 would be the greatest among the Options.

Table 6-3 and 6-4 summarizes the expected effects of implementing Option 4 under Scenarios A and B on important delta smelt stressors relative to base conditions.

Table 6-3. Summary of Expected Effects of Option 4 on Highly and Moderately Important Sacramento River Chinook Salmon Stressors

Applicable Criteria	Stressor[1]	Option Effects on Important Species Stressors Relative to Base Conditions	
		Scenario A	Scenario B
Highly Important Stressors			
2,3	Reduced staging and spawning habitat	Very low benefit	Very low benefit
2,3	Reduce rearing and outmigration habitat	Moderate benefit	Moderate benefit
1	Predation by non-natives	High benefit	High benefit
Moderately Important Stressors			
1	Harvest	No net effect	No net effect
1	Reduced genetic diversity/integrity	No net effect	No net effect
1,	SWP/CVP entrainment	High benefit	High benefit
1,2	Exposure to toxics	Moderate adverse effect	Moderate adverse effect
2,3	Increased water temperature	No net effect	No net change

Notes:
1. See Appendix C for descriptions of stressors, stressor impact mechanisms, and stressor effects.

Table 6-4. Summary of Expected Effects of Option 4 on Highly and Moderately Important Sacramento River Steelhead Stressors

Applicable Criteria	Stressor[1]	Option Effects on Important Species Stressors Relative to Base Conditions	
		Scenario A	Scenario B
Highly Important Stressors			
2,3	Reduced staging and spawning habitat	Very low benefit	Very low benefit
1,4	SWP/CVP entrainment	High benefit	High benefit
2,3	Reduced rearing and outmigration habitat	Moderate benefit	Moderate benefit
1	Predation by non-natives	High benefit	High benefit
Moderately Important Stressors			
1	Exposure to toxics	Moderate adverse effect	Moderate adverse effect
1	Reduced genetic diversity/ integrity	No net effect	No net effect
1	Harvest	No net effect	No net effect
2,3	Increased water temperature	No net effect	No net effect

Notes:
1. See Appendix C for descriptions of stressors, stressor impact mechanisms, and stressor effects.

6.1.3.1 Criterion #1. Relative degree to which the Option would reduce species mortality attributable to non-natural mortality sources, in order to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species.

Predation by non-native species

Successful restoration of the Delta can promote benefits to native species at the expense of non-natives. Option 4 would allow 75% of the Delta to be potentially restored (Figure 1-5), the highest level among the four Options included in this assessment. Therefore, this Option is expected to have high benefits to Sacramento River salmonids by reducing the impacts of competition by non-native species, assuming that restoration will reduce the abundance of non-natives and/or enhance the survival and abundance of native species.

Entrainment

Under Option 4 all SWP and CVP diversions would occur from the Sacramento River through a positive barrier fish screen designed and operated specifically to avoid entrainment and impingement of juvenile salmon, steelhead, and other fish species. Removing the SWP and CVP exports from the south Delta under Option 4 would reduce the risk of salmonid entrainment by approximately 95%. This is based on the assumption that the positive barrier fish screen without a need for salvage will be more effective than the current louvers. Therefore, entrainment of juvenile Sacramento salmonids as a result of SWP or CVP export operations is expected to be substantially reduced under Option 4 when compared to base conditions.

Exposure to toxics

Dilution flows for toxic materials entering the Delta can be measured by Delta inflow and flow at Rio Vista. Relative to base conditions, flows at Rio Vista and total Delta inflows under Options 4 are moderately lower in both March and April (see Appendices G and H). This indicates that potential dilution of toxics from the San Joaquin River watershed or from the Delta would be moderately lower under Option 4 relative to base conditions resulting in a potential increase in salmonid exposure to toxics. Further, because the volume of water coming from the Sacramento River into the Delta would be reduced under Option 4, the contribution of the San Joaquin River water to water quality conditions within the Delta would be higher. Because San Joaquin River water is known to contain higher concentrations of toxics than Sacramento River water, this change would be expected to further increase the probability of salmonid exposure to toxics farther downstream. Therefore, overall, Option 4 would be expected to provide a moderate increase in the risk of salmonid exposure to toxics.

6.1.3.2 Criteria 2. Relative degree to which the Option would provide water quality and flow conditions necessary to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species.

Water quality changes that impact Sacramento River salmonids can be measured as differences in exposure to toxics, water temperature, and dissolved oxygen relative to base conditions. Flow changes that impact Sacramento River salmonids affect rearing habitat and access to staging and spawning habitat. Option 2 is expected to result in a very low adverse decrease in water quality and flow related conditions relative to base conditions.

Exposure to Toxics

As discussed in Criterion 1, exposure to toxics is expected to moderately increase under Option 4.

Rearing habitat

The location of X_2 would be upstream by 0.2 km, which is a negligible adverse effect to salmonids. Model output indicates that both Rio Vista flows and total Delta outflow under Option 4 during March and April would be lower than base conditions for all water year types (see Appendices G and H). Chinook salmon that outmigrate during winter months (e.g., late fall-run Chinook salmon) experience similar lower flows at Rio Vista and total Delta outflows during this period. Overall, quality and accessibility of rearing habitat to Sacramento River salmonids would be reduced under Option 4.

Because residence time in the Central Delta is greatly increased under Option 4, there would be a higher probability of localized dissolved oxygen sags than under base conditions. The interaction between changes in residence times, phytoplankton production, and dissolved oxygen concentrations within the tidally dominated areas of the Delta are complex and the certainty of future predictions of changes in water quality is low.

Access to staging and spawning habitat

Under Option 4, less Sacramento River water would be directed into the Delta to maintain water quality standards. Also, there would be a more direct pathway of migration cues down the Sacramento River rather than diffused throughout the Delta. However, there would be a reduction in inflows due to the export of water at Hood. Therefore, there is expected to be a low increase in attraction flows and migration cues for both adult and juvenile salmonids.

6.1.3.3 Criterion #3. Relative degree to which the Option would increase habitat quality, quantity, accessibility, and diversity in order to enhance and sustain production (reproduction, growth, survival), abundance, and distribution; and to improve the resiliency of each of the covered species' populations to environmental change and variable hydrology.

Overall, Option 3 is expected to provide moderate increases in quality, quantity, diversity, and accessibility of habitat for Sacramento River salmonids.

Rearing habitat

Results of the hydrologic modeling indicate that there would be a negligible effect of Option 4 on X_2 location during the spring and, therefore, on the quantity, quality, and diversity of rearing habitat for juvenile salmonids. The reduction in net downstream flows is expected to cause a low reduction in survival of juvenile salmonids migrating towards rearing habitat. The proportion of the Delta available for restoration and enhancement of physical habitat and natural hydrology (Figure 1-5) would extend throughout the geographic range of salmonid migration and rearing habitat within the Delta. Overall, Option 4 is expected to have a moderate beneficial effect on the quality, quantity, diversity, and accessibility to habitat for Central Valley Chinook salmon and steelhead.

Access to staging and spawning habitat

As described in Criterion 2, there is expected to be a low increase in attraction flows and migratory cues to spawning habitat under Option 4. Therefore, Option 4 is expected to have a very low benefit to spawning habitat of Sacramento River salmonids.

6.1.3.4 Criterion# 4. Relative degree to which the Option would increase food quality, quantity, and accessibility (e.g., phytoplankton, zooplankton, macro-invertebrates, forage fish) to enhance production (reproduction, growth, survival) and abundance for each of the covered fish species.

Juvenile Chinook salmon and steelhead forage on a variety of macroinvertebrates (e.g., copepods, amphipods) and small fish during their residency within the Delta. The abundance of these prey species varies in response to a number of factors that include availability of nutrients, organic carbon, phytoplankton and zooplankton production. Reduced food availability or quality, however, are not identified as important stressors for Sacramento River salmonids. Consequently, benefits of increasing food quantity and quality under the Options would not be expected to result in a population level response relative to base conditions.

6.1.3.5 Criterion #5. Relative degree to which the Option would reduce the abundance of non-native competitors and predators to increase native species production (reproduction, growth, survival), abundance and distribution for each of the covered fish species.

The degree to which Option 4 can reduce the adverse effects of non-native competitors and predators on Sacramento River salmon and steelhead can be approximated by determining the percentage of the Delta that would potentially be available for restoration and enhancement under this Option. Under Option 4 the potential area of the Delta that could be restored or enhanced is approximately 75% of the legal Delta (Figure 1-5). The amount of habitat available for restoration under Option 4 is more than double that available under Options 1, 2, or 3. The area within the Delta where restoration could potentially occur extends throughout nearly the entire geographic range of salmon and steelhead rearing and migration habitat within the Delta. As a result, Option 4 could provide a high benefit to salmonids by mitigating the adverse effects of non-native species.

6.1.3.6 Criterion #6. Relative degree to which the Option improves ecosystem processes in the BDCP planning area to support aquatic and associated habitats.

Under the range of operations and the potential opportunities to restore/enhance high quality aquatic habitat within the Delta habitat the effectiveness of Option 4 in improving ecosystem processes is considered to be high. These changes would be expected to improve ecosystem processes within the central and western regions of the Delta when compared to base conditions. In addition, the ability to divert water directly from the Sacramento River at Hood while eliminating the export operations within the south Delta would be expected to substantially improve the hydrodynamics of the Delta and improve the quality of habitat available for Sacramento River salmonids. Under these operating conditions Option 4 offers the opportunity to improve the processes affecting habitat conditions within the Delta (e.g., providing net westerly flows, reducing or eliminating reverse flow conditions, etc.). These potential changes to the estuarine processes within the Delta are expected to benefit Sacramento River salmonids and other species. It is uncertain, however, if increasing the proportion of lower quality San Joaquin River water present in the Delta (a function of reducing Sacramento River inflow and eliminating export of San Joaquin River water from the Delta) into the central Delta would impair ecosystem processes.

6.1.3.7 Criterion #7. Relative degree to which the Option can be implemented within a timeframe to meet the near-term needs of each covered fish species (post BDCP authorization).

Habitat restoration under Option 4 can be initiated immediately following authorization of the BDCP and thus could be implemented in a manner that would meet the near term needs of Sacramento River salmonids. The implementation period for implementation of Option 4 is the same as the other Options.

6.1.4 San Joaquin River Salmonids

Based on the evaluation presented below of the expected performance of Option 4 for addressing important San Joaquin River salmonid stressors, Option 4 would be expected to have a moderate beneficial effect on San Joaquin River salmonid production, distribution, and abundance relative to base conditions when operated to meet water supply objectives (Scenario A). If water supply exports are reduced (Scenario B), Option 2 would be expected to provide a low beneficial effect on Sacramento River salmonid production, distribution, and abundance relative to base conditions.

Table 6-5 and 6-6 summarizes the expected effects of implementing Option 4 under Scenarios A and B on important delta smelt stressors relative to base conditions.

Table 6-5. Summary of Expected Effects of Option 4 on Highly and Moderately Important San Joaquin River Chinook Salmon Stressors

Applicable Criteria	Stressor[1]	Option Effects on Important Species Stressors Relative to Base Conditions	
		Scenario A	Scenario B
Highly Important Stressors			
2,3	Reduced staging and spawning habitat	Low benefit	Low benefit
2,3	Reduced rearing and outmigration habitat	Moderate benefit	Moderate benefit
1,2	Exposure to toxics	Moderate adverse effect	Moderate adverse effect
1,2	Predation by non-natives	High benefit	High benefit

Table 6-5. Summary of Expected Effects of Option 4 on Highly and Moderately Important San Joaquin River Chinook Salmon Stressors (continued)

Applicable Criteria	Stressor[1]	Option Effects on Important Species Stressors Relative to Base Conditions	
		Scenario A	Scenario B
Moderately Important Stressors			
1	Reduced genetic diversity/ integrity	No net effect	No net effect
1	Harvest	No net effect	No net effect
1,4	SWP/CVP entrainment	High benefit	High benefit
2,3	Increased water temperature	No net effect	No net effect

Notes:

1. See Appendix C for descriptions of stressors, stressor impact mechanisms, and stressor effects.

Table 6-6. Summary of Expected Effects of Option 4 on Highly and Moderately Important San Joaquin River Steelhead Stressors

Applicable Criteria	Stressor[1]	Option Effects on Important Species Stressors Relative to Base Conditions	
		Scenario A	Scenario B
Highly Important Stressors			
3	Reduced staging and spawning habitat	Low benefit	Low benefit
3	Reduced rearing and outmigration habitat	Moderate benefit	Moderate benefit
1	Exposure to toxics	Moderate adverse effect	Moderate adverse effect
1	Reduced genetic diversity/ integrity	No net effect	No net effect
1	Predation by non-natives	High benefit	High benefit
Moderately Important Stressors			
1,3,4,5	SWP/CVP entrainment	High benefit	High benefit
1	Harvest	No net effect	No net effect
1	Increased water temperature	No net effect	No net effect

Notes:

1. See Appendix C for descriptions of stressors, stressor impact mechanisms, and stressor effects.

6.1.4.1 *Criterion #1. Relative degree to which the Option would reduce species mortality attributable to non-natural mortality sources, in order to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species.*

Overall, Option 4 is expected to contribute to a high level of reduction in non-natural mortality to San Joaquin River Chinook salmon and steelhead.

Predation by non-native species

Restoration of the Delta, if designed properly, can reduce conditions for non-native predators to the benefit of San Joaquin River salmonids. Option 4 would allow 75% of the Delta to be potentially restored (Figure 1-5), the highest level among the four Options included in this assessment. Therefore, this Option is expected to provide a high benefit to San Joaquin River Chinook salmon. The benefit to steelhead, because they typically outmigrate at larger sizes that are less vulnerable to predation, is expected to be slightly lower, but still considered high under this analysis.

Entrainment

Under Option, 4 all SWP and CVP diversions would be made from the Sacramento River using a state-of-the-art positive barrier fish screen. Fish screens designed to meet the CDFG, USFWS, and NMFS criteria have proven to be effective in substantially reducing the risk of entrainment or impingement to juvenile and adult fish, such as salmon and steelhead. Based on the proposed location of the diversion at Hood, San Joaquin River salmonids would not be expected to occur within the vicinity of the diversion. Under Option 4 the risk of San Joaquin River salmon and steelhead entrainment losses as a direct result of SWP and CVP export operations would be eliminated. Therefore, this Option would provide a high reduction in mortality associated with entrainment.

Exposure to toxics

As discussed under Criterion 3 below, Option 4 is expected to cause a moderate increase in the exposure risk to toxics of San Joaquin River salmonids relative to base conditions.

6.1.4.2 Criterion #2. Relative degree to which the Option would provide water quality and flow conditions necessary to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species.

Overall, Option 4 would be expected to provide a very low adverse effect to water quality and flow conditions for San Joaquin River salmonids.

Exposure to toxics

Hydrologic modeling output indicates that, relative to base conditions, flows at Rio Vista under Option 4 would typically be lower in all water years in both March and April (Table ____). Delta inflows would also be lower under Option 4 relative to base conditions (Table ___). This indicates that dilution inflows of toxics would be moderately lower under Option 4, resulting in a potential increase in salmonid exposure to elevated concentrations of toxics. Further, because the volume of water coming from the Sacramento River into the Delta would be reduced under Option 4, the contribution of the San Joaquin River water to the Delta would be higher. Because San Joaquin River water is known to contain higher concentrations of toxics than Sacramento River water, this change would be expected to further increase the probability of San Joaquin River salmonid exposure to toxics. Therefore, overall, Option 4 would be expected to cause a moderate increase in the risk of salmonid exposure to toxics.

Rearing habitat

The location of X_2 would be upstream by 0.2 km, which is a negligible adverse effect to salmonids. Model output indicates that both Rio Vista flows and total Delta outflow, which help transport outmigrating salmon downstream to rearing habitat, under Option 4 during March and April would be lower than base conditions for all water year types (Table ____). The potential effects of reduced flows through the Delta on the survival of juvenile salmon and steelhead under Option 4, with the removal of the export facilities in the south Delta, is unknown. Overall, water quality and flow conditions under Option 4 would cause a low adverse effect to the quality and accessibility of rearing habitat to San Joaquin River salmonids.

SWP and CVP operations and the associated hydrologic conditions expected to occur within the Delta under Option 4 are not expected to result in dissolved oxygen depression greater than baseline conditions. The assumption that San Joaquin River flows would be the same under Option 4 as base conditions suggests that this Option would not affect localized depressions in dissolved oxygen levels such as those observed in the Stockton ship channel. A possible exception would be the accumulation of high algal concentrations within the Delta resulting from increased nutrient concentrations, increased residence times, and reduced flushing. The Delta would continue to experience tidal flushing as well as the net westerly flow from the tributaries. The possibility that dissolved oxygen concentrations within Delta channels would be reduced to adverse levels under Option 4 is uncertain.

Access to staging and spawning habitat

Because the Options evaluated in this analysis assumed that San Joaquin River flows would be the same as base conditions under all Options no change in flow-survival (e.g., temperature related) or attraction flow relationships would be expected under any of the Options. Under Option 4, however, the location of the diversion on the Sacramento River would be expected to result in slightly improved hydrologic conditions (e.g., net westerly flows) within the Delta channels and improve attraction flows and migration cues for salmonids migrating into and out of the San Joaquin River.

6.1.4.3 Criterion #3. Relative degree to which the Option would increase food quality, quantity, and accessibility (e.g., phytoplankton, zooplankton, macro-invertebrates, forage fish) to enhance production (reproduction, growth, survival) and abundance for each of the covered fish species.

Overall, Option 4 is expected to provide a high level of benefit to San Joaquin River salmonid habitats relative to base conditions.

Rearing habitat

Results of the hydrologic modeling indicate that there would be a negligible effect of Option 4 on X_2 location during the spring and, therefore, on the quantity, quality, and diversity of rearing habitat for juvenile salmonids.

The reduction in net downstream flows is expected to cause a low reduction in survival of juvenile salmonids migrating towards rearing habitat, however there is a high degree of uncertainty in the flow-survival relationships that may occur under Option 4 operations. The relocation of SWP and CVP diversions to the Sacramento River would result in an improvement in Delta flow patterns (e.g., avoid reverse flows) that would benefit juvenile and adult salmonid migration through the Delta.

Under Option 4, a large portion (~75%) of the Delta is potentially available for restoration/enhancement (Figure 1-5) including areas located along the lower San Joaquin River and the eastern region of the Delta that would not be included under Options 1, 2, or 3. These habitat improvements, including the potential to increase seasonally inundated floodplain habitat within the southern and central Delta would be expected to offer substantially improved conditions for San Joaquin River salmonids when compared to base conditions or the other three Options evaluated. In addition, because SWP and CVP exports would no longer occur in the south Delta, hydrodynamic conditions would improve throughout the region and the risk of entrainment at the south Delta export facilities would be eliminated, thereby increasing opportunities for high quality habitat restoration. The areas where restoration would potentially occur encompass virtually the entire geographic distribution of the juvenile salmonids within the Delta. Therefore, Option 4 would provide the highest opportunity for restoration among the four Options evaluated.

Access to staging and spawning habitat

As discussed under Criterion 3, access to spawning habitat would not change among Options.

6.1.4.4 *Criterion #4. Relative degree to which the Option would increase food quality, quantity, and accessibility (e.g., phytoplankton, zooplankton, macro-invertebrates, forage fish) to enhance production (reproduction, growth, survival) and abundance for each of the covered fish species.*

Juvenile Chinook salmon and steelhead forage on a variety of macroinvertebrates (e.g., copepods, amphipods) and small fish during their residency within the Delta. The abundance of these prey species varies in response to a number of factors that include availability of nutrients, organic carbon, phytoplankton and zooplankton production. Reduced food availability or quality, however, are not identified as important stressors for San Joaquin River salmonids. Consequently, benefits of increasing food quantity and quality under the Options would not be expected to result in a population level response relative to base conditions.

6.1.4.5 *Criterion #5. Relative degree to which the Option would reduce the abundance of non-native competitors and predators to increase native species production (reproduction, growth, survival), abundance and distribution for each of the covered fish species.*

The degree to which Option 4 can reduce the adverse effects of non-native competitors and predators on San Joaquin River salmon and steelhead can be approximated by determining the percentage of the Delta that would potentially be available for restoration/enhancement under this Option. Under Option 4 the potential area of the Delta that could be restored or enhanced is approximately 75% of the legal Delta (Figure 1-5). The amount of habitat available for restoration under Option 4 is more than double that available under Options 1, 2, or 3. The area within the Delta where restoration could potentially occur extends throughout nearly the entire geographic range of salmon and steelhead rearing and migration habitat within the Delta. As a result, Option 4 could provide a high benefit to salmonids by mitigating the adverse effects of non-native species.

6.1.4.6 Criterion #6. Relative degree to which the Option improves ecosystem processes in the BDCP planning area to support aquatic and associated habitats.

Under the range of operations and the potential opportunities to restore/enhance high quality aquatic habitat within the Delta habitat the effectiveness of Option 4 in improving ecosystem processes is considered to be high. These changes would be expected to provide the potential to improve ecosystem processes throughout the Delta when compared to base conditions. In addition, the ability to divert water directly from the Sacramento River at Hood while eliminating the export operations within the south Delta would be expected to substantially improve the hydrodynamics of the Delta and improve the quality of habitat available for San Joaquin River salmonids. Under these operating conditions Option 4 offers the opportunity to improve the processes affecting habitat conditions within the Delta (e.g., providing net westerly flows, reducing or eliminating reverse flow conditions, etc.). These potential changes to the estuarine processes within the Delta are expected to benefit San Joaquin River salmonids and other species. It is uncertain, however, if increasing the proportion of low quality San Joaquin River water present in the Delta (a function of reducing Sacramento River inflow and eliminating export of San Joaquin River water from the Delta) into the central Delta would impair ecosystem processes.

6.1.4.7 Criterion #7. Relative degree to which the Option can be implemented within a timeframe to meet the near-term needs of each covered fish species (post BDCP authorization).

Habitat restoration under Option 4 can be initiated immediately following authorization of the BDCP and thus could be implemented in a manner that would meet the near term needs of San Joaquin River salmonids. The implementation period for implementation of Option 4 is the same as the other Options.

6.1.5 Sturgeon

Based on the evaluation presented below of the expected performance of Option 4 for addressing important green and white sturgeon stressors, Option 4 would be expected to have a moderate beneficial effect on green and white sturgeon production, distribution, and abundance relative to base conditions when operated to meet water supply objectives (Scenario A). If water supply exports are reduced (Scenario B), Option 4 would be expected to provide a similar level of benefit for sturgeon production, distribution, and abundance relative to base conditions.

Stressors that affect sturgeon are presented in Figures 2-7 and 2-8 and are described in Appendix C. The effect of these stressors on the green and white sturgeon populations vary among years in response to environmental conditions (e.g., seasonal hydrology) and may also interact with each other in additive or synergistic ways. The effects of these stressors include both the incremental contribution of a stressor to the population as well as the cumulative effects of multiple stressors over time. The assessment of Option 4 evaluates the degree to which Option 4 would be expected to address these stressors.

Tables 6-7 and 6-8, respectively, summarize the expected effects of implementing Option 1 under Scenarios A and B on important sturgeon stressors relative to base conditions.

Table 6-7. Summary of Expected Effects of Option 4 on Highly and Moderately Important Green Sturgeon Stressors

Stressors[1]	Applicable Criteria	Option Effects on Important Species Stressors Relative to Base Conditions	
		Scenario A	Scenario B
Highly Important Stressors			
Reduced spawning habitat	3	No net effect	No net effect
Exposure to toxics	1,2,3	Moderate adverse effect	Moderate adverse effect
Harvest	1	No net effect	No net effect
Moderately Important Stressors			
Reduced rearing habitat	1,2,3	Moderate benefit	Moderate benefit
Increased water temperature (upstream)	1,2,3	No net effect	No net effect
Predation	1,3	No net effect	No net effect
Reduced turbidity	1,2,3	No net effect	No net effect

Notes:
1. See Appendix C for descriptions of stressors, stressor impact mechanisms, and stressor effects.

Table 6-8. Summary of Expected Effects of Option 4 on Highly and Moderately Important White Sturgeon Stressors

Stressors[1]	Applicable Criteria	Option Effects on Important Species Stressors Relative to Base Conditions	
		Scenario A	Scenario B
Highly Important Stressors			
Harvest	1	No net effect	No net effect
Reduced spawning habitat	3	No net effect	No net effect
Exposure to toxics	1,2,3	Moderate adverse effect	Moderate adverse effect
Moderately Important Stressors			
Reduced rearing habitat	1,2,3	Moderate benefit	Moderate benefit
Increased water temperature (upstream)	1,2,3	No net effect	No net effect
Predation	1,3	No net effect	No net effect
Reduced turbidity	1,2,3	No net effect	No net effect

Notes:
1. See Appendix C for descriptions of stressors, stressor impact mechanisms, and stressor effects.

Harvest, reduced spawning habitat, predation, reduced turbidity, and increased water temperatures are not important stressors that would be affected by or affected differently (i.e., harvest, reduced spawning habitat) under the Options and, therefore, are not described in the criteria evaluations below (see Table 2-3 and Appendix C). These stressors could only be addressed through changes in regulation and law enforcement (for harvest) or through conservation actions implemented outside of the planning area. Any effects within the planning area of the Options on the non-harvest stressors described above would not be expected to have any benefits to sturgeon at the population level. As described in Table 2-3, the ability to address harvest and reduced spawning habitat within the planning area would be the same among the Options. Consequently, these stressors are initially identified under the applicable criteria below, but are not evaluated under the criteria.

6.1.5.1 Criterion #1. Relative degree to which the Option would reduce species mortality attributable to non-natural mortality sources, in order to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species.

Based on the following evaluation of Option 4 effects on applicable green and white sturgeon stressors, Option 4 is expected to provide a very low increase in the risk for non-natural mortality of sturgeon.

Exposure to Toxics

Exposure of green and white sturgeon to toxic substances can result in mortality. The effects of Option 4 on exposure to toxics are evaluated under Criteria #2 and #4 below. As described in the Criteria #2 and #4 evaluations, Option 4 would be expected to result in a moderate adverse effect on the exposure of green and white sturgeon to toxics.

6.1.5.2 Criterion #2. Relative degree to which the Option would provide water quality and flow conditions necessary to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species.

Based on the following evaluation of Option 4 effects on applicable green and white sturgeon stressors, Option 4 is expected to provide a very low adverse effect for water quality and flow conditions that support green and white sturgeon relative to base conditions.

Exposure to toxics

Based on how Option 4 would be expected to affect Sacramento River inflow and total Delta inflows relative to modeling results for base conditions and the Options, dilution flows under Option 4 would be lower relative to base conditions and could have a moderate adverse effect on the exposure of sturgeon to toxics (see Appendices G and H).

Reduced Rearing Habitat

Under Option 4, X_2 position would move marginally upstream (0.2 km) relative to base conditions (see Appendices F and H), indicating that the extent of available rearing habitat could be reduced relative to base conditions. In addition, Option 4 would be expected to improve westerly flows through the central Delta as a migration cue for both juvenile and adult sturgeon migration. The effect of these changed hydraulic conditions is unknown, because the frequency of occurrence of green or white sturgeon juveniles and adults within the eastern region of the Delta is unknown. In general, improvement in the flow patterns within the Delta under Option 4 (e.g., net westerly flows, avoid reverse flow conditions, increased residence times, etc.) are expected to benefit habitat conditions for juvenile and adult sturgeon, their food resources, and other fish species.

6.1.5.3 *Criterion #3. Relative degree to which the Option would increase habitat quality, quantity, accessibility, and diversity in order to enhance and sustain production (reproduction, growth, survival), abundance, and distribution; and to improve the resiliency of each of the covered species' populations to environmental change and variable hydrology.*

Within the planning area, green and white sturgeon habitat conditions are governed by hydrodynamic conditions and the extent and quality of habitat within the planning area. Under Option 4, these conditions relative to base conditions would be affected by the conveyance configuration of Option 4 and the opportunities for restoration of physical habitat that could be sited within Suisun Bay and Marsh and throughout the Delta planning area, which represents approximately 75% of the planning area.

Based on the following evaluation of Option 4 effects on applicable green and white sturgeon stressors, Option 4 are expected to provide moderate habitat benefits for green sturgeon relative to base conditions.

Exposure to Toxics

As described under Criterion #2 above, Option 4 could have a moderate adverse effect on the risk for exposure of sturgeon to toxics relative to base conditions. A major source for bioaccumulation of selenium in sturgeon is consumption of non-native *Corbula* and *Corbicula*, which capture selenium from Delta waters. Restoration of aquatic shallow subtidal and intertidal habitats could create conditions that favor the production of alternative prey (e.g., bay shrimp) that reduce the risk of bioaccumulation of materials such as selenium for juvenile and adult sturgeon. The potential success of reducing the risk of toxics on sturgeon through habitat improvements and increased production of alternative prey resources is uncertain. Under Option 4, habitat could potentially be restored within Suisun Bay and Marsh and approximately 75% of the Delta to provide high quality aquatic habitat under this Option (Figure 1-5), which encompasses a larger proportion of the rearing range of green and white sturgeon than restoration that could be implemented under the other Options. Consequently, relative to base conditions and the other Options, Option 4 would be expected to provide a moderate benefit for improving green and white sturgeon rearing habitat.

Reduced Rearing Habitat

The primary impact mechanism believed to affect the extent of rearing habitat and rearing habitat conditions is the reclamation of historical aquatic subtidal and intertidal habitats and channelization of river channels. Under Option 4, habitat could be restored within Suisun Bay and Marsh and approximately 75% of the Delta to provide high quality aquatic habitat under this Option (Figure 1-5), which encompasses a larger proportion of the rearing range of green and white sturgeon than restoration that could be implemented under the other Options. Consequently, relative to base conditions and the other Options, Option 4 would be expected to provide a moderate benefit for green and white sturgeon rearing habitat.

6.1.5.4 Criterion #4. Relative degree to which the Option would increase food quality, quantity, and accessibility (e.g., phytoplankton, zooplankton, macro-invertebrates, forage fish) to enhance production (reproduction, growth, survival) and abundance for each of the covered fish species.

Based on the following evaluation of Option 4 effects on applicable green and white stressors, Option 4 is expected to provide moderate food supply benefits for green and white sturgeon relative to base conditions.

Exposure to Toxics

As described under Criterion #3 above, restoration of rearing habitat could reduce the relative importance of non-native *Corbula* and *Corbicula* as a primary food resource for sturgeon thus improving the quality of food for sturgeon by reducing their exposure to selenium. Relative to base conditions and the other Options, Option 4 would be expected to provide moderate benefits for green and white sturgeon food supply.

6.1.5.5 Criterion #5. Relative degree to which the Option would reduce the abundance of non-native competitors and predators to increase native species production (reproduction, growth, survival), abundance and distribution for each of the covered fish species.

Predation in the form of illegal and legal harvest would not be changed under any of the Options from base conditions.

6.1.5.6 Criterion #6. Relative degree to which the Option improves ecosystem processes in the BDCP planning area to support aquatic and associated habitats.

Based on the proportion of the planning area available for potential restoration under Option 4 relative to the other Options and modeling results for hydraulic residence time (see Appendix H), Option 4 would be expected to provide a high beneficial improvement in ecosystem function relative to base conditions.

Under the range of operations and the potential opportunities to restore/enhance high quality aquatic habitat within the Delta habitat the effectiveness of Option 4 in improving ecosystem processes is considered to be high. These changes would be expected to improve ecosystem processes throughout the Delta when compared to base conditions. In addition, the ability to divert water directly from the Sacramento River at Hood while eliminating the export operations within the south Delta would be expected to substantially improve the hydrodynamics of the Delta and improve the quality of habitat available for juvenile and adult green and white sturgeon. Under these operating conditions Option 4 offers the opportunity to improve the processes affecting habitat conditions within the Delta (e.g., providing net westerly flows, reducing or eliminating reverse flow conditions, etc.). These potential changes to the estuarine processes within the Delta are expected to benefit sturgeon and other species. It is uncertain, however, if increasing the proportion of low quality San Joaquin River water present in the Delta (a function of reducing Sacramento River inflow and eliminating export of San Joaquin River water from the Delta) into the central Delta would impair ecosystem processes.

6.1.5.7 Criterion #7. Relative degree to which the Option can be implemented within a timeframe to meet the near-term needs of each covered fish species (post BDCP authorization).

In the near-term, until construction of Option 4 conveyance features and facilities is completed, Option 4 would use the existing conveyance facilities to meet water supply objectives. As for Option 1, implementation of physical habitat restoration under Option 4 in the north and west Delta can be initiated immediately following authorization of the BDCP and thus could be implemented in a manner that would meet the near term needs of sturgeon.

6.1.6 Splittail

Based on the evaluation presented below of the expected performance of Option 4 for addressing important splittail stressors, Option 4 would be expected to have a high beneficial effect on splittail production, distribution, and abundance relative to base conditions when operated to meet water supply objectives (Scenario A). If water supply exports were reduced (Scenario B), Option 4 would also be expected to provide a high beneficial effect on splittail production, distribution, and abundance relative to base conditions. Option 4 would be expected to provide a greater level of benefit for splittail than the other Options.

Table 6-9 summarizes the expected effects of implementing Option 4 under Scenarios A and B on important splittail stressors relative to base conditions.

Table 6-9. Summary of Expected Effects of Option 4 on Highly and Moderately Important Splittail Stressors

Applicable Criteria	Stressor[1]	Option Effects on Important Species Stressors Relative to Base Conditions	
		Option 3A	Option 3B
Highly Important Stressors			
2,3	Reduced juvenile rearing/adult habitat	High benefit	High benefit
2,3	Reduced spawning/larval rearing habitat	High benefit	High benefit
1,4	Reduced food	High benefit	High benefit
1,2	Exposure to toxics	Moderate adverse effect	No effect
Moderately Important Stressors			
1,5	Predation by non-natives	High benefit	High benefit
1,3,4,5	SWP/CVP entrainment[2]	High benefit	High benefit
1	Harvest	No net effect	No net effect

Notes:

1. See Appendix C for descriptions of stressors, stressor impact mechanisms, and stressor effects.
2. It is recognized that the risk of entrainment at the SWP and CVP export facilities may be a high level stressor to splittail in some years and a very low level stressor in other years, for purposes of the analysis the risk of splittail entrainment under each of the Options has been characterized, on average, as a moderate level stressor to the population.

6.1.6.1 *Criterion #1. Relative degree to which the Option would reduce species mortality attributable to non-natural mortality sources, in order to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species.*

Based on the following evaluation of Option 4 effects on applicable splittail stressors, Option 4 is expected to provide high benefits for splittail by reducing the effects of non-natural sources of mortality relative to base conditions.

Reduced Food Availability

Habitat conditions can affect the availability and quality of splittail food. The effects of Option 4 on splittail food availability are evaluated under Criterion #4 below. As described in the Criterion #4 evaluation, Option 4 would be expected to provide a high beneficial effect on food supply for the splittail relative to base conditions.

Exposure to Toxics

The effects of Option 4 on exposure to toxics are evaluated under Criterion #2 below. As described in the Criterion #2 evaluation, Option 4 would be expected to have a moderate adverse effect on the risk of exposure of splittail to toxics. It is uncertain, however, if the potential increase in concentrations of toxics in the central Delta would adversely affect splittail.

Predation

Under Option 4, approximately 75% of the Delta would potentially be available for restoration/enhancement (Figure 1-5), which, if designed properly, would reduce the potential adverse impacts of predation by non-natives. This entire area would be located within the geographic range of splittail throughout the Delta. The proportion of the planning area within which habitat could potentially be implemented is greater under Option 4 than under any of the other Options. Habitat restoration under Option 4 would be expected to provide a high benefit for potentially reducing predation impacts relative to base conditions and the other Options. However, there is a high degree of uncertainty regarding the biological response of splittail, other native fish and macroinvertebrate species, and non-native species to large-scale habitat restoration/enhancement within the Delta.

Entrainment by CVP/SWP Facilities

Under Option 4, all SWP and CVP diversions would occur from the Sacramento River near Hood. Risk for entrainment of splittail at the Hood intake facility would be minimal because the intake would be equipped with a positive barrier fish screen that would be expected to be highly effective in reducing the vulnerability of splittail to entrainment. Removing the SWP and CVP exports from the south Delta under Option 4 would be expected to virtually eliminate the risk of splittail entrainment losses as a result of export operations. Based on this assessment, entrainment of splittail as a result of SWP or CVP export operations is expected to be nearly eliminated under Option 4 relative to base conditions.

6.1.6.2 Criterion #2. Relative degree to which the Option would provide water quality and flow conditions necessary to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species.

Based on the following evaluation of Option 4 effects on applicable splittail stressors, Option 4 is expected to have a low adverse effect on water quality and flow conditions that support splittail relative to base conditions.

Exposure to toxics

Modeling results indicate that Option 4 would be expected to reduce dilution flows relative to base conditions, thus potentially increasing concentrations of toxics (see Appendices F and H). Furthermore, because the volume of water coming from the Sacramento River into the Delta would be reduced under Option 4, the contribution of the San Joaquin River to water quality conditions within the Delta will be higher. Because San Joaquin River water is known to contain higher concentrations of toxics than Sacramento River water, Option 4 could increase the risk of exposing splittail to toxics. Although the effects of toxics on splittail are uncertain, Option 4 has the potential for having a moderate adverse effect on splittail by increasing the exposure of delta smelt to higher concentrations of toxics. Under Option 4, however, there are potential opportunities to restore intertidal and subtidal wetlands in the south Delta that could filter toxics from the San Joaquin River before it discharges into the central Delta, which would reduce the likelihood for toxic effects on splittail.

Reduced Rearing Habitat

Sacramento River inflows during March and April under Option 4 that facilitate the downstream movement of juvenile splittail are expected to be lower relative to base conditions. Expected changes in peak Delta inflows during January through March indicate that Option 4 would have a lower probability of floodplain inundation relative to base conditions in wetter years (see Appendices F and H). The potential restoration of rearing habitats as described under Criterion #3, however, would be expected to improve rearing habitat conditions. Consequently, overall Option 4 would be expected to have high beneficial effects on rearing habitat conditions relative to base conditions.

Reduced Spawning/Larval Rearing Habitat

Expected changes in peak Delta inflows during January through March indicate that, under Option 4, there would be a lower probability of floodplain inundation during wetter years relative to base conditions (see Appendices F and H). The potential restoration of spawning/larval rearing habitats as described under Criterion #3, however, would be expected to improve spawning/larval rearing habitat conditions. Consequently, overall Option 4 would be expected to have high beneficial effects on rearing habitat conditions relative to base conditions.

6.1.6.3 Criterion #3 Relative degree to which the Option would increase habitat quality, quantity, accessibility, and diversity in order to enhance and sustain production (reproduction, growth, survival), abundance, and distribution; and to improve the resiliency of each of the covered species' populations to environmental change and variable hydrology.

Based on the following evaluation of Option 4 effects on applicable splittail stressors, Option 4 is expected to provide high benefits relative to habitat conditions for splittail.

Within the planning area, splittail habitat conditions are governed by hydrodynamic conditions and the extent and quality of habitat. Under Option 4, these conditions relative to base conditions would be affected by the conveyance configuration of Option 4 and the opportunities for restoration of physical habitat that could be sited at locations throughout the Delta extending over approximately 75% of the planning area.

Reduced Rearing and Spawning Habitat

Under Option 4, habitat could potentially be restored within Suisun Bay and Marsh and approximately 75% of the Delta to provide high quality shallow aquatic subtidal and intertidal habitat (Figure 1-5), which encompasses a larger proportion of the splittail spawning and rearing range than restoration that could be implemented under the other Options. In addition, substantial increases in hydraulic residence time under Option 4 also provide for lower velocity habitats that are expected to be more suitable for splittail relative to base conditions. In addition, operations under Option 4 would contribute directly to restoring natural flow patterns within the Delta channels, reducing water velocities, increasing residence times, and avoiding reverse flows, which are all expected to contribute to improved habitat conditions. Consequently, relative to base conditions and the other Options, Option 4 would be expected to provide a high benefit for splittail rearing and spawning habitat.

Reduced Food Availability

Habitat conditions can affect the availability and quality of splittail food. The effects of Option 4 on splittail food availability are evaluated under Criterion #4 below. As described in the Criterion #4 evaluation, Option 4 would be expected to provide a high beneficial effect on food supply for the splittail relative to base conditions.

6.1.6.4 Criterion #4 Relative degree to which the Option would increase food quality, quantity, and accessibility (e.g., phytoplankton, zooplankton, macro-invertebrates, forage fish) to enhance production (reproduction, growth, survival) and abundance for each of the covered fish species.

Overall, Option 4 would be expected to provide high benefits for improving food supply for splittail.

Reduced Food Availability

Option 4 could decrease the frequency, duration, and extent of seasonally inundated floodplain habitat within the Sacramento or San Joaquin rivers, which could reduce food availability in those areas in some years. Hydraulic residence would be substantially increased in the central Delta and would be expected to substantially increase phytoplankton, zooplankton, and macroinvertebrate production within the Delta relative to base conditions. Restoration of shallow subtidal and intertidal habitats under Option 4 would also be expected to improve food supply. Consequently, Option 4 would be expected to provide a high benefit for splittail food supply.

The habitat restoration that could be implemented under Option 4 would all be located within the geographic range of splittail and could create conditions that disfavor non-native species that indirectly or directly affect food abundance (e.g., overbite clam (*Corbula*), threadfin shad), thereby improving food availability for splittail relative to base conditions (Figure 1-5). The potential opportunity for habitat restoration is expected to improve food availability relative to base conditions and the other Options.

Option 4 would be expected to provide a high beneficial increase in food availability by eliminating the export of nutrients and organic material that support primary and secondary production by eliminating SWP/CVP exports from the south Delta. In addition, under Option 4, water with high nutrient loads from the San Joaquin River would no longer be subject to exports as under base conditions and the resulting increased nutrient loads, in combination with increased residence times, would be expected to stimulate phytoplankton and zooplankton production.

6.1.6.5 Criterion #5. Relative degree to which the Option would reduce the abundance of non-native competitors and predators to increase native species production (reproduction, growth, survival), abundance and distribution for each of the covered fish species.

Based on the following evaluation of Option 4 effects on applicable splittail stressors, Option 4 is expected to provide high benefits for splittail relative to the effects of non-native competitors and predators.

Option 4 could reduce the effects of non-native competitors and predators on splittail primarily through restoration of intertidal and shallow subtidal aquatic habitats at locations distributed throughout the Delta. For reasons described above, Option 4 would be expected to provide a high beneficial effect by reducing the impacts of populations of non-native food competitors relative to base conditions. Additionally, restoration of net westerly flows would restore Delta hydrodynamics to a more natural condition relative to base conditions and the other Options, which may create habitat conditions unfavorable for some non-native species. Although the ability to control non-native species by varying hydrodynamic and salinity conditions in the Delta is uncertain, Option 4 provides a greater opportunity for doing so than under Options 1 and 2, but somewhat less than Option 3.

6.1.6.6 Criterion #6. Relative degree to which the Option improves ecosystem processes in the BDCP planning area to support aquatic and associated habitats.

Based on the proportion of the planning area available and suitable for potential restoration under Option 4 relative to the other Options and modeling results for hydraulic residence time (see Appendix H), Option 4 would be expected to provide a high beneficial improvement in ecosystem function relative to base conditions.

Based on the large proportion of the Delta available for restoring natural hydrology and for restoring and enhancing high quality aquatic habitat, the effectiveness of Option 4 in improving ecosystem processes is considered to be high. These changes would be expected to improve ecosystem processes throughout the Delta when compared to base conditions. In addition, the ability to divert water from the Sacramento River at Hood while eliminating the export operations in the south Delta would be expected to substantially improve the hydrodynamics of the Delta and improve the quality of habitat available for splittail. Under these operating conditions Option 4 offers the opportunity to improve the processes affecting habitat conditions within the Delta (e.g., providing net westerly flows, reducing or eliminating reverse flow conditions, etc.). These potential changes to the estuarine processes within the Delta are expected to benefit splittail and other species. It is uncertain, however, if increasing the proportion of lower quality San Joaquin River water present in the Delta (a function of reducing Sacramento River inflow and eliminating export of San Joaquin River water from the Delta) into the central and western Delta would impair ecosystem processes.

6.1.6.7 Criterion #7. Relative degree to which the Option can be implemented within a timeframe to meet the near-term needs of each covered fish species (post BDCP authorization).

In the near-term, until construction of Option 4 conveyance features and facilities is completed, this Option would use the existing conveyance facilities to meet water supply objectives. Similar to Option 1, implementation of physical habitat restoration under Option 4 in the north and west Delta can be initiated immediately following authorization of the BDCP and thus could be implemented in a manner that would meet the near term needs of juvenile and adult splittail.

6.2 PLANNING CRITERIA

6.2.1.1 Criterion #8: Relative degree to which the Option allows covered activities to be implemented in a way that meets the goals and purposes of those activities

Overall, Option 4 is anticipated to have a greater ability to meet CVP/SWP water supply goals than Options 1 and 2 and a lesser ability than Option 3.

Hydrodynamic modeling results indicate that the ability of Option 4 to achieve the water delivery reliability and facility operation goals of the CVP/SWP would be less than Option 3 and Option 1 (Scenario A). However, Option 1 water supply reliability is expected to be less than that modeled under Scenario 1A because of regulatory restrictions imposed on pumping in the south Delta. Option 4 may, therefore, provide higher supply reliability than Option 1. Hydrodynamic modeling results indicate higher supply reliability under Option 4 than under Option 1 (Scenario B) and Option 2 (Figure 3-1).

Model simulations for Option 4 have indicated the potential for reduced CVP/SWP exports in the range of 100 to 800 TAF/YR as compared to current conditions, depending on the level of Rio Vista flow requirements, X_2 objectives, and salinity requirements. While CVP/SWP export reliability approaches current conditions under the less restrictive end of the range (Scenario A), significant upstream versus downstream tradeoffs were identified. Modeled Rio Vista flow requirements, in particular, caused excessive drawdown of upstream storage under this Option.

Several iterations of Rio Vista criteria and refined operations were modeled to protect upstream storage during critical periods while simultaneously achieving Rio Vista requirements. The final model simulations are the result of this iterative approach, but still exhibit decreased storage during dry periods. The upstream versus downstream tradeoffs demonstrate a potential decrease in operational flexibility of the SWP and CVP system operations overall. Further analysis of this tradeoff and further refinements in operating criteria should be considered if this Option is carried forward.

Export water quality would be significantly improved under Option 4 as compared to current conditions and Options 1, Option 2, and Option 3 (Figure 3-2). The export water quality is equivalent to Sacramento River at Hood quality, which is significantly higher quality than that from the south Delta under current conditions and any other Option considered in this evaluation.

6.2.1.2 Criterion #9: The relative feasibility and practicability of the Option, including the ability to fund, engineer, and implement

Option 4 has a high implementation costs and substantial direct effects on the human environment (likely requiring substantial regulatory authorizations), but provides a more flexible approach to addressing the combined goals of species conservation and habitat restoration using practicable technologies.

The geographic area for habitat restoration under Option 4 is the broadest among the Options, maximizing the flexibility in choosing the most cost effective and ecologically effective restoration sites relative to the other Options. Flow operations in the Delta under Option 4 are the least constrained because of the absence of south Delta export facilities and in-Delta barriers. Habitat restoration, therefore, is most feasible as more geographic sites could be made to support the hydrologic conditions conducive to successful habitat restoration for covered species.

The technology for canal and siphon construction for the peripheral aqueduct is proven. A technical uncertainty common to Options 3 and 4 would be the ability to construct a state-of-the-art fish screen on the Sacramento River that will successfully reduce entrainment at the intake of the peripheral aqueduct to negligible levels. Cost practicability of this Option is addressed in Criterion #10, below.

6.2.1.3 Criterion #10: Relative costs (including infrastructure, operations, and management) associated with implementing the Option

Delta Infrastructure Costs

Delta infrastructure costs for Option 4 are expected to be higher than for Options 1 and 2. Option 4 costs relative to Option 3 are uncertain. If the peripheral aqueduct for Option 3 is smaller than for Option 4 and levee strengthening costs for Option 3 are minimized, Option 3 may have lower infrastructure costs than Option 4. Alternatively, if the peripheral aqueduct were the same size for both Options, infrastructure costs for Option 3 would exceed those for Option 4.

Option 4 infrastructure costs primarily depend on the size of the peripheral aqueduct. As part of the analysis for DRMS Phase II, URS Corporation estimated capital costs for three different peripheral aqueduct capacities: 5,000, 10,000, and 15,000 cfs (DRMS Phase II 2007). The DRMS evaluation assumed the same total volume of water would be diverted under the three capacities, but noted that operational flexibility would significantly diminish as aqueduct capacity decreased. Estimated capital construction costs for the three different aqueduct sizes are shown in Table 6-1. Construction cost estimates exhibit significant economies of scale; a three-fold increase in aqueduct capacity increases estimated capital costs only by a factor of 1.6.[3]

Table 6-1. Summary of DRMS Phase II Peripheral Aqueduct Cost Estimates by Canal Capacity[4]

Canal Capacity	Estimated Cost (2007 Dollars)	Average Cost Per cfs
5,000 cfs	$3.0 Billion	$600,000
10,000 cfs	$4.0 Billion	$400,000
15,000 cfs	$4.8 Billion	$320,000

The DRMS Phase II report provided a more detailed cost breakdown for the 15,000 cfs aqueduct. The estimate is based on previous conceptual level designs and includes contingency, surveys, design, engineering, construction management, and contract administration costs. The estimate does not include financing or environmental mitigation costs; factors that may somewhat reduce the economy of scale of the larger sizes. Route alignment and material quantities for the cost estimate were taken primarily from a cost analysis completed by Washington Group International (WGI) in 2006 (Washington Group International 2006).

The WGI report described two main routes for the peripheral aqueduct. The Route 1 alignment follows the alignment for the originally proposed peripheral aqueduct. The Route 2 alignment shifts a portion of the aqueduct westward to reduce right-of-way costs and avoid residential encroachment. Both the DRMS and WGI cost estimates described herein are based on the Route 2 alignment.

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[3] Note that these estimates do not include costs for mitigating construction impacts, which may not exhibit economies of scale to the same degree as construction costs. For example, if the right-of-way footprint for the three aqueduct sizes was roughly the same and siphon construction required roughly the same amount of mitigation, environmental mitigation costs may not vary significantly with aqueduct capacity. Regardless, the general finding of economies of scale is expected to hold due to the likely magnitude of mitigation costs relative to construction costs. For example, supposing unit mitigation cost was the same for all aqueduct sizes, say 15% of the unit construction cost for the 15,000 cfs canal, then a three-fold increase in canal capacity would increase total construction costs (including mitigation) by a factor of 1.7 instead of a factor of 1.6.

[4] Costs in Table 6-1 are drawn from Table 9-2 and Section 15.3.1 of the DRMS Phase II Building Blocks Report. Construction and engineering/management contingencies were added to the intake facility fish screening costs taken from Section 15.3.1 to make them commensurate with the other peripheral aqueduct cost items presented in Section 9 of the DRMS report.

The WGI and DRMS Phase II cost breakdowns for a 15,000 cfs peripheral aqueduct are shown in Table 6-2. DRMS Phase II estimated capital costs of $4.8 billion. WGI estimated capital costs of $3.8 billion. Some of the difference in estimated costs is due to the following differences in design and cost assumptions used in the two evaluations:

- WGI used a higher unit cost for fish screen facilities than DRMS, resulting in approximately a $100-million difference in assumed fish screening cost.
- DRMS assumed higher canal embankment than WGI. The DRMS estimate assumed an embankment elevation of 3 feet above the mean highest high water level. DRMS canal costs are $175 million higher than WGI canal costs.
- DRMS added flow shutoff gates at some of the siphons to prevent large flood events from extending flooding from one island to the next through open siphons. DRMS siphon costs are $344 million higher than WGI siphon costs.
- DRMS included costs for mobilization and demobilization of equipment, materials, and labor, adding $135 million to the estimate.
- Higher DRMS construction costs, including mobilization and demobilization, result in the DRMS construction contingency, engineering, construction management, and administration estimates to exceed the WGI estimates by $459 million.

The likely range in cost for a peripheral aqueduct with a 15,000 cfs canal capacity was developed using the cost estimates from Table 6-2. Taking the lowest estimate for each construction line item in the table created the low end of the range. The high end of the range was similarly created by taking the highest estimate for each line item. Construction contingency and engineering/construction management/administration costs were then added to each estimate. This resulted in a capital cost range of $3.6 to $5.0 billion. Cost ratios calculated from the data in Table 6-1 were then used to scale costs to create cost ranges for 10,000 and 5,000 cfs canals. Results are shown in Table 6-3.

Table 6-2. 15,000 cfs Peripheral Aqueduct Cost Breakdown (millions of 2007 dollars)

Item Description	DRMS Phase II	WGI
Intake, fish screens	282	422
Bridges and culverts	89	56
Pumping plant	230	217
Siphons and controls	1,099	755
Earth Canal	885	710
Control structures for SWP and CVP, maintenance facility, supervisory control and data acquisition systems (i.e., programmable controls)	117	96
Subtotal	2,702	2,256
Mobilization/demobilization (5% of subtotal)	135	0
Subtotal	2,837	2,256
Construction contingencies (30% of subtotal)	851	677

Table 6-3. 15,000 cfs Peripheral Aqueduct Cost Breakdown (millions of 2007 dollars) **(continued)**

Item Description	DRMS Phase II	WGI
Subtotal	3,688	2,933
Engineering, construction management, and administration (30% and 28% of subtotal, respectively)	1,106	821
Estimated Capital Cost	**4,794**	**3,754**

Table 6-4. Option 4 Delta Infrastructure Capital Cost Range by Peripheral Aqueduct Capacity

Canal Capacity	Low Estimate	High Estimate
5,000 cfs	$2.3 Billion	$3.1 Billion
10,000 cfs	$3.0 Billion	$4.2 Billion
15,000 cfs	$3.6 Billion	$5.0 Billion

Delta Conveyance Disruption Costs

Option 4 avoids the vulnerability of water exports associated with existing through-Delta conveyance, and thus offers significant risk reduction over Option 1. Option 4 is also expected to provide greater risk reduction than Option 2, although its relative advantage would depend on the type and extent of levee improvements undertaken as part of Option 2. Option 4 is expected to provide less risk reduction than Option 3, which has the advantage of conveyance redundancy through the use of dual conveyance facilities.

Compared to Options 1 and 2, Option 4 would be much less vulnerable to events that resulted in failure of the levee system and caused saline water to be drawn into the Delta with significant disruption of CVP and SWP pumping for periods lasting from months to years. DRMS Phase I estimated that, under current Delta conditions, over the next 25 years the likelihood of such an event capable of shutting down CVP and SWP exports for at least ten months was between 50% and 60%, while the likelihood of an event capable of shutting down exports for up to two years was between 30% and 40%. Under the latter scenario, water exports would decrease by 6 to 9 MAF during the repair and recovery period and economic impacts were estimated to range between $10 and $50 billion. The frequency and duration of disruption of water supply and the associated recovery cost under Option 4 would be substantially less than under Options 1 and 2 with the potential to save $10s of billions.

While the risk of export disruption is lower for Option 4 relative to Options 1 and 2, it does not eliminate all risk to Delta water supplies from seismic and flood events. The DRMS Phase II report noted that large events would be expected to result in some damage to canal embankments. However, this damage was expected to be more limited, easier to repair, and would result in much less disruption to water exports. Additionally, the DRMS Phase II report noted that a peripheral aqueduct, if designed with turnouts to the south Delta, could also facilitate water supply recovery efforts by providing additional fresh water to the south Delta for flushing out brackish floodwater.

Export Water Quality Costs

Of the four Options under consideration, Option 4 is expected to have the lowest costs (i.e., greatest cost savings) related to export water quality. Currently, water exported from the Delta comes from both the Sacramento and San Joaquin Rivers, with flows from the Sacramento River comprising the largest share. The export pumps occasionally reverse the flows of the San Joaquin, Middle, and Old Rivers, resulting in a flushing action that raises total organic carbon and bromide levels in exported water (DRMS Phase II August 2007).[5] Additionally, as water travels through the Delta, its quality is further degraded by tidal influences and returns from agricultural drainages. Option 4 would relocate the diversion point for export water to the Sacramento River near Hood, thereby lowering total organic carbon, bromide, and total dissolved solids levels in export water (DRMS Phase II August 2007). This Option would result in lower water quality treatment and impact costs relative to Options 1 and 2. Option 3's water quality costs might be on par with Option 4's if the dual conveyance facilities of Option 3 were operated to benefit water quality, but Option 4 would be expected to have lower costs if the dual conveyance operations were primarily governed by other considerations.

Water quality improvements under Option 4 would benefit agricultural and urban users of Delta export water. Urban users would benefit from reduced treatment costs and avoided equipment damage and human health costs. South-of-Delta agricultural users may benefit to some extent from slower salt buildup in soils and less need for flushing salts from the root zone.[6] Salt loading is of particular concern in Southern California urban areas. A 1999 study of the problem (USBR 1999) estimated a $95 million annual benefit to urban treatment systems for each 100-mg/L reduction in total dissolved solids of SWP water. Updating to 2007 dollars, the annual benefit would be on the order of $120 million per 100-mg/L reduction in total dissolved solids. Hydrodynamic modeling results for Option 4 indicate that it could lower total dissolved solids in SWP export water by approximately 150 to 200 mg/L.[7] Using the USBR study findings, the present value of avoided salinity damages in Southern California over the next 25 years could, therefore, be on the order of $2.0 to $2.5 billion.[8]

DRMS Phase II noted that construction of a peripheral aqueduct may adversely affect agricultural irrigation water quality in some parts of the Delta, particularly the south Delta, due

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[5] DRMS Phase II Report, Section 9.

[6] Improved agricultural export water quality benefits would probably be negligible for south-of-Delta farmland. For impaired lands on the west side of the San Joaquin Valley, the binding constraint is drainage. Without improvements to drainage, improvements in the quality of delivered irrigation water would not be expected to significantly improve productivity on impaired lands. For non-impaired lands, improvements to water quality would provide only negligible production benefits, if any. Over the long-run, better water quality could slow salt buildup and reduce the need for flushing salts from the soil. (Mark Roberson, *pers comm.*).

[7] This estimate is based on converting EC results for export water quality presented in BDCP-ModelingResults_082707.ppt to total dissolved solids using EC to total dissolved solids conversion equations from http://www.iep.ca.gov/suisun/facts/salin/index.html.

[8] The present value calculation of avoided damages uses a real discount rate of 6.0%, per DWR guidance.

to lower flows from the Sacramento River entering the Delta and a return to a more natural pattern in San Joaquin River flows. This reduction in water quality, particularly salinity increases, could adversely impact agricultural productivity in the south Delta, which would offset, to some extent, the benefits associated with improvements in export water quality. DRMS Phase II concluded that additional water quality modeling is needed to define in-Delta water quality impacts and costs of a peripheral aqueduct.

Habitat Restoration Costs

Because it is assumed the overall amount of habitat restoration would be roughly the same across the four Options (though the locations could differ), restoration cost estimates developed with currently available information would not distinguish Option 4 from the other three Options. While it is recognized that unit costs of restoration may vary to some degree according to the range and location of restoration activity, sufficient information on unit restoration cost differentials is not available at this time to distinguish among the four Options. Thus, habitat restoration costs are not treated as a significant distinguishing feature among the four Options.

6.3 FLEXIBILITY/DURABILITY/SUSTAINABILITY CRITERIA

6.3.1.1 Criterion #11: Relative degree to which the Option will be able to withstand the effects of climate change (e.g., sea level rise and changes in runoff), variable hydrology, seismic events, subsidence of Delta islands, and other large-scale changes to the Delta

Option 4 is expected to have the greater ability than Options 1 and 2 to withstand large-scale changes to the Delta that would adversely affect water conveyance. Option 4 would have less ability to withstand catastrophic events than Option 3 because Option 3 includes all of the peripheral aqueduct components as Option 4 plus through-Delta conveyance that provides flexibility to respond to catastrophes. Option 4 is expected to have the greatest ability among the Options to withstand large-scale changes to the Delta that would adversely affect species habitat restoration actions.

Risk to Habitat Restoration Actions

Physical and operational habitat restoration actions under Option 4 are at less risk from seismic or flood events and from the ongoing effects of sea level rise relative to the other Options. Unlike the other Options, restoration actions under Option 4 could be implemented throughout the Delta. Consequently, a levee failure at or near restoration sites would have proportionately smaller adverse effects under Option 4 where restoration sites may be less concentrated than under the other Options where restoration sites would be expected to be distributed within a narrower portion of the Delta. Similarly, because restoration sites may be less concentrated, Option 4 may provide more flexibility than the other Options to adjust flow operations at these dispersed sites in the event of levee failure(s).

Protecting physical habitat restoration against the effects of sea level rise requires restoration sites at higher elevations (sites in the Delta with less subsidence) and with elevation gradients that include an ecotone between tidal and upland habitat (allowing, over decades, the gradual upward elevation shift of all tidal habitats in response to sea level rise). The larger geographic area of habitat restoration opportunities under Option 4 relative to the other Options increases the number and extent of sites with such elevation characteristics available for habitat restoration in the Delta and, therefore, provides the opportunity for more durability of restored habitat.

Risk to Water Supply Infrastructure

Option 4 would provide the greatest durability of water supply facilities from seismic or flood events and from the ongoing effects of sea level rise of all the Options because all of the conveyance elements (i.e., the peripheral aqueduct) and attendant facilities constructed under Option 4 are expected to be engineered to standards that would withstand probable future seismic and flood events. With the intake on the Sacramento River in the northern Delta, Option 4 water supply is better protected from the effects of salinity intrusion from sea level rise over the long-term than are south and central Delta intake facilities under Options 1 and 2. Option 4 would have less ability to avoid the disruption of export water supply from catastrophic events than Option 3 because Option 3 includes all of the peripheral aqueduct components as Option 4 plus through-Delta conveyance that provides flexibility to respond to catastrophes.

6.3.1.2 Criterion #12: Relative degree to which the Option could improve ecosystem processes that support the long-term needs of each of the covered species and their habitats with minimal future input of resources

Option 4 may be able to sustain improvements in ecosystem processes through time better than Options 1, 2, and 3 for the following reasons:

1. Option 4 would provide the greatest amount of habitat available for management or restoration to improve populations of covered species, thus providing the greatest opportunity for covered species resilience through variable hydrological conditions and climate change effects. This should lead to lower cost to manage through time.

2. Option 4 provides the most opportunity to manage for a more variable Delta hydrology. Although not likely to eliminate recurring costs, this operational flexibility would be expected to reduce the costs associated with controlling harmful invasive species more than the other three Options.

3. Option 4 does not require the continued management, study, and adaptive management associated with the operable barrier installations of Options 2 and 3; thus, Option 4 would require less continued input of resources in this area.

4. Depending on the size of the diversion and effectiveness of the fish screening facility, Option 4 would likely rarely entrain fish. Therefore, it would likely eliminate or greatly reduce costs associated with trucking, hauling, and release of entrained fish, and reduce or eliminate cuts in restricting the timing of export pumping for protection of covered species.

6.3.1.3 Criterion #13: Relative degree to which the Option can be adapted to address the needs of covered fish species over time

Option 4 is expected to provide the greatest flexibility and adaptability among the Options for addressing possible future conservation of the covered fish species for the following reasons:

1. Compared to the other Options, Option 4 provides for the greatest geographic extent and percentage of land area available for habitat restoration should it be necessary to increase the extent of restored habitat for covered species in the future.

2. The flexibility to experiment and adjust Delta hydrology is the least constrained among the Options because the need to maintain a hydrologic barrier to maintain water quality for water supply is not needed. Consequently, Option 4 provides the greatest opportunity for experimenting with flow and water quality conditions (e.g., adjusting operation of the Delta Cross Channel, installing temporary or operable barriers, or augmenting flows to east side tributaries) throughout the Delta to identify flow regimes that optimize ecosystem and covered fish species benefits.

6.3.1.4 Criterion #14: Relative degree of reversibility of the Option once implemented

Option 4 is expected to be less practicable to reverse than Options 1 and 2, but more practicable to reverse than Option 3.

Under Option 4, construction of a peripheral aqueduct with fish screen would entail a substantial investment of capital (see Criterion #10) that would be lost if these facilities were abandoned. Additional costs would be incurred if structures needed to be removed or demolished. Compared to Options 1 and 2, reversing Option 4 would be less likely to be acceptable to the public because the loss of investment costs would be substantially greater than Options 1 and 2. Additionally, the costs and land area subject to disturbance (e.g., noise and road closures) that would be associated with removal of the peripheral aqueduct would be expected to be substantial and, if the aqueduct were not removed, some level of ongoing maintenance costs would be required to maintain public safety (e.g., maintenance of exclosure fencing and patrolling of facility). Reversal of Option 4 could be considered to be more reversible than Option 3 because reversal of Option 3 would also entail loss of investment costs associated with construction of the Option 3 through-Delta conveyance components. However, with dual conveyance under Option 3, reversion to a through-Delta-only conveyance approach, if necessary, would be more rapidly accomplished than Option 4.

6.4 OTHER RESOURCES IMPACTS CRITERIA

6.4.1.1 Criterion #15: Relative degree to which the Option avoids impacts on the distribution and abundance of other native species in the BDCP planning area

The probability for adverse impacts on other native aquatic species within the Delta is expected to be substantially less compared to current conditions and the other Options for the reasons described below:

1. Under Option 4, other native fish and aquatic organisms could be entrained into the peripheral aqueduct at the Sacramento River intake. Placement of state-of-the-art positive barrier fish screens at the intake, however, is expected to minimize entrainment levels and result in minimal impacts on other native aquatic organisms. Consequently, the levels of entrainment of aquatic organisms under Option 4 are expected to be less than levels of entrainment that would be expected from exporting water from the south Delta compared to current conditions and Options 1 through 3.

2. Potential intertidal and aquatic habitat restoration areas are expanded from Options 1 through 3 to include most of the planning area. Because San Joaquin River water would not be exported under Option 4, the proportion of Delta inflow provided by the San Joaquin River would be greater under Option 4 than under the other Options. Because San Joaquin River water quality (e.g., elevated concentrations of salts and selenium) is lower than Sacramento River water quality, there are technical uncertainties associated with restoring aquatic and intertidal habitats in portions of the Delta receiving inflow from the San Joaquin River. This technical uncertainty also applies to Options 2 and 3. The degree of any impacts that could be associated with increasing the proportion of San Joaquin River water entering the Delta, however, would be expected to be somewhat higher under Options 2 and 3, which concentrate San Joaquin River flows along Old River.

3. Construction of the peripheral aqueduct and attendant facilities could result in temporary impacts on water quality associated with sediment discharge or mobilization of channel bed sediments and disturbance to or mortality of aquatic organisms associated with in-channel operation of equipment to construct channel crossings (siphons). These impacts are expected to be temporary and minor, but would be greater than under Options 1 and 2. These impacts would be expected to be somewhat less than under Option 3 because Option 3 includes construction of barriers and a siphon in addition to a peripheral aqueduct and attendant facilities.

The potential for Option 4 impacts on native terrestrial species could result from removal of terrestrial habitats and temporary disturbances (i.e., visual and noise) to wildlife associated with construction of the peripheral aqueduct and attendant facilities. Impacts on wildlife habitats are expected to be substantially greater than under Options 1 and 2 and marginally less than Option 3 for the reasons described below:

1. The probability of impacts on native terrestrial species is expected to be substantially greater under Option 4 than under Options 1 and 2 because no ground-disturbing activities would occur under Option 1 that could affect wildlife and their habitats, and construction of a peripheral aqueduct and attendant facilities would remove a substantially greater amount of habitat and result in greater levels of construction-related disturbance than Option 2. Construction of the peripheral aqueduct and attendant facilities could remove a substantial amount of upland, riparian, wetland, and agricultural land cover types that support habitat for special-status (e.g., greater sandhill crane and Swainson's hawk) and other native wildlife (e.g., waterfowl). For example, up to about 1,200 acres of these habitats were estimated to be removed with construction of the peripheral aqueduct evaluated by CALFED (CALFED 2000). Because the peripheral

aqueduct is a linear facility, habitat would be removed in a relatively narrow band along the east side of the Delta. Consequently, the effects of habitat removal on most terrestrial species are expected to be minimized because habitat would be removed as relatively small patches over a large area and would be restored wherever practicable.

2. Both Options 3 and 4 include construction of a peripheral aqueduct and attendant facilities. However, because Option 3 also includes construction of barriers and a siphon to support its through-Delta conveyance component, impacts of Option 3 on native terrestrial species are expected to be marginally greater to terrestrial species than under Option 4.

3. Construction of the peripheral aqueduct would create a new barrier in some areas to the movement of some species of wildlife that currently use or occupy habitats on both sides of the potential alignment of the peripheral aqueduct. This impact would be common to both Options 4 and 3. The level of this impact would be relatively minor in locations where movement of wildlife is currently constrained by other barriers (e.g., Interstate 5, other roadways, and Delta channels and sloughs).

4. Under Option 4, the west-central Delta could be managed for variable salinity as a tool for species conservation and result in higher salinities during the growing season compared to base conditions. This change in salinity, however, is not expected to affect crops yields sufficiently to reduce their value as foraging habitat for wildlife (Lund et al. 2007). For example, research conducted by Hoffman et al. (1982) indicated that yields of field corn in the Delta were not affected by salinities of less than 3.7 mS/cm.

6.4.1.2 *Criterion #16: Relative degree to which the Option avoids impacts on the human environment*

The types of adverse impacts as defined under CEQA and NEPA on the human environment that could be associated with Option 4 are described in this section.[9] Potential impacts described here for Option 4 would not necessarily be significant or could be expected to be reduced to a less than significant effect with CEQA/NEPA mitigation.

Option 4 is expected to have greater potential for impacts than Options 1 and 2 and marginally fewer impacts than Option 3 within the following NEPA/CEQA impact categories because the extent of construction-related activities that could impact these categories are greater than Options 1 and 2 and slightly less than Option 3:

- Geology and soils—risk for erosion,

[9] The evaluation of Criterion #16 focuses on the likely range of adverse direct and indirect impacts of the Options in the planning area and not the indirect impacts to water quality and water supply reliability and in the service areas. These issues in the service areas are addressed in Criteria #8 and #11. Options 3 and 4 are expected to be substantially less vulnerable than Options 1 and 2 to future disruption of water supply. Export water quality improvements would be successively greater and attendant impacts on treatment costs, agricultural production, and human health successively reduced under Options 2, 3, and 4 in that order.

- cultural resources—likelihood for encountering cultural resources,
- air quality—PM10 emissions associated with ground disturbance and operation of equipment,
- noise—operation of equipment,
- utilities and public services—likelihood for affecting utility infrastructure, and
- energy usage—fuel and electricity used in construction.

Water Quality/Hydrology

The quality of water, as measured by EC, that would be exported from the SWP/CVP facilities under Option 4 would generally be substantially higher compared to current conditions and to the other Options (see Figure 3-2). Improvements in water quality exported from the Delta relative to current conditions and the other Options, therefore, would be expected to reduce water treatment costs to meet water quality standards and needs for municipal, agricultural, and residential uses in service areas.

Within the Sacramento River Delta (as measured at Emmaton on Sherman Island) and the range of modeled operations most likely to achieve water supply objectives, water quality under Option 4 would generally be higher than Option 1 and compared to current conditions from September through January and generally lower than or similar to Option 1 and current conditions from February through August; generally similar to or higher than Option 2 from May through July and lower than Option 2 from August through April; and generally higher than Option 3 from September through February and lower than or similar Option 3 from March through August (see Figure 3-3). Water quality would be expected to be somewhat higher in the east Delta under Option 4 than under Option 1 because Option 4 would reduce the flow of lower quality San Joaquin River water entering the east Delta. Changes in Sacramento River water quality are expected to have no or minimal impacts on farming practices or production.

Results of hydrodynamic modeling suggest that, within the San Joaquin River Delta (as measured on Old River at State Highway 4) under the range of operations most likely to achieve water supply objectives, water quality under Option 4 would generally be lower than Option 1 and current conditions from December through August and similar to or higher than Option 1 and current conditions from September through November. Option 4 would be similar to Options 2 and 3 from September through June, but higher than Options 2 and 3 during July and August. Changes in water quality in the west-central Delta under Option 4 could potentially affect farming practices or production (see Figure 3-4).

Potential impacts associated with construction-related localized and temporary erosion and runoff of sediments into adjacent Delta waters that could temporarily degrade water quality would be greater than Options 1 and 2 because impacts associated with construction of a peripheral aqueduct would be substantially greater than construction-related impacts of those Options. Impacts of Option 4 would be only marginally less than Option 3, which includes construction of five barriers and a siphon at Victoria Canal in addition to the peripheral aqueduct.

Aesthetics

The visual impacts of Option 4 would be slightly less than for Option 3 because Option 3 includes construction of through-Delta facilities as well as a peripheral aqueduct, and greater than for Options 1 and 2 because these Option involve construction of fewer facilities near areas of human use.

Hazards/Hazardous Materials

Option 4 would have a slightly lower potential for spills of fuel and lubricants as a result of equipment operation and maintenance during construction of new facilities compared to Option 3 because fewer new facilities would be built. The potential for such spills, however, would be greater than for Options 1 and 2 because more facilities would be built in Option 4 than for either of those Options. Similarly, construction activities under Option 4 would have a slightly lower potential to expose people to hazardous materials and waste uncovered during construction than for Option 3 due to the smaller amount of ground disturbance and a greater potential for such exposure than under Options 1 and 2 due to the larger amount of ground disturbance in Option 4. The peripheral aqueduct in Option 4 could pose a safety hazard to people who attempt to fish or otherwise use the aqueduct; this hazard would be the same as for Option 3 but would not occur in Options 1 and 2.

Transportation/Traffic

Option 4 involves new construction of an aqueduct over 40 miles long, so impacts on transportation and traffic would be substantial. Impact mechanisms would include adding traffic to Delta roadways and potentially requiring modification or rerouting of transportation facilities (e.g., State Highways 4 and 12, local roadways, and railroad lines). Effects would be much greater than under Options 1 or 2. Option 4 impacts on transportation and traffic are expected to similar to Option 3 because construction of the through-Delta facilities under Option 3 is not expected to substantially increase impacts.

Recreation

Option 4 would have greater impacts on recreation than Options 1 and 2 because construction of a peripheral aqueduct could impact access to lands used for recreational activities or reduce the quality of recreational experiences. Option 1 is not expected to affect recreational uses of the Delta and impacts of Option 2 would be less than Option 4 because it does not include construction of a peripheral aqueduct. Option 3 would be expected to have slightly greater impacts on recreation than Option 4 because, in addition to including construction of a peripheral aqueduct, it includes construction of barriers that could adversely affect recreational boating in the Delta.

Agricultural Resources

Because the construction footprint of Option 4 is substantially larger, it is expected to result in a greater loss of agricultural land than Options 1 and 2. Construction of a peripheral aqueduct and attendant facilities could remove a substantial amount of agricultural land from production. For example, removal of 700 to 900 acres of agricultural land was estimated to be necessary for construction of the peripheral aqueduct evaluated by CALFED (CALFED 2000). Because the peripheral aqueduct is a linear facility, it is expected to affect multiple landowners. Consequently, the likely impact of removing land from production would be distributed among a number of individual farmers, thus minimizing the extent of impact on any individual farmers. Impacts on agricultural production under Option 4 relative to Option 1 would be greater if water quality is lowered sufficiently under Option 4 in the central-west Delta.

Impacts of Option 4 are expected to be similar to Option 3 because the likely impacts of constructing the through-Delta component of Option 3 would be minimal and the footprint of the peripheral aqueduct component is expected to be similar to Option 3.

Option 4, however, potentially could have fewer impacts than Option 3 on agriculture in the west-central Delta if water quality under Option 3 is sufficiently lower than Option 4 during July and August to affect crop production.

Environmental Justice. Unlike Options 1 and 2, construction of a peripheral aqueduct and attendant facilities under Option 4 would remove Delta land from agricultural production and, therefore, would be more likely to create disproportionate health or environmental effects on minority or low-income populations through this mechanism. Environmental justice-related impacts of Option 4 would be similar to Option 3 because both Options include construction of a peripheral aqueduct and attendant facilities and impacts associated with the through-Delta component of Option 3 would be minimal.

6.4.1.3 Criterion #17: Relative degree of risk of the Option causing impacts on sensitive species and habitats in areas outside of the BDCP planning area

Adverse or beneficial effects on native species and habitats outside the planning area could result from changes in flow regimes downstream of the Delta in Suisun Bay and Marsh and upstream in the Sacramento River and its major tributaries. The potential for adverse effects downstream of the Delta are indicated by differences in Delta outflow among the Options and the potential for adverse effects in the Sacramento River and its tributaries are indicated by differences in end-of-September reservoir storage volumes, which is a measure of the capacity of reservoirs to provide for cold water releases to sustain water temperatures within ranges favored by native aquatic species.

Based on preliminary analyses, the potential for beneficial effects on species and habitats downstream of the planning area is expected to be greater under Option 4 compared to current conditions and Options 1 and 2 because the modeled average annual outflows under Option 4 (20,996 cfs) is higher than current conditions and Options 1 and 2. The overall range of Delta outflows and likely affect native species and habitats under Option 4 is expected to be similar to Option 3 (20,289 cfs), with Option 4 generally providing for slightly lower outflows in biologically important months of March and April than Option 1, 2, and 3. It is expected, however, that opportunities could exist to manage operations under Options 4 to improve Delta outflows during sensitive periods to improve downstream conditions for native aquatic species.

Hydrodynamic modeling results suggest that, based on reservoir storage volumes at the end of September, the ability to provide for cold water releases downstream of Shasta, Folsom, and Oroville Reservoirs under Option 4 would be expected to be similar to base conditions and the other Options in most water-year types. During critical water years, Shasta Reservoir storage volume would be less than Options 1 and 2 and similar to base conditions and Option 3; Folsom Reservoir storage volume would be less than base conditions and the other Options; and during dry and critical years, Oroville Reservoir storage volume would be less than base conditions and the other Options. Because maintenance of cold water conditions at Oroville Reservoir is controlled by regulatory requirements, it is likely that Delta operations would be required to adjust (and be different than those modeled for Option 4) to avoid adverse effects on the cold water pool. Maintenance of cold water pool volumes at Shasta and Folsom Reservoirs to protect downstream habitat for spawning and rearing salmonids could be managed under Option 4, in part, by modifications to reservoir releases and downstream exports.

7.0 COMPARISON OF THE OPTIONS

This section provides a summary comparison of the relative performance of the four Options in addressing the seventeen evaluation criteria. The purpose of this section is to provide a summary comparison of the performance of the Options relative to each other and, in some cases, to base conditions. Details of the evaluations of the Options against the criteria are presented in Sections 3, 4, 5, and 6 of this report and all comparative conclusions presented here are more fully described in those previous sections. In this section, the criteria are grouped into and presented by the categories:

- biological criteria,
- planning criteria,
- flexibility/durability/sustainability criteria, and
- other resource impacts criteria.

The comparative evaluation of the Options in relation to the biological criteria is presented by fish species as individual species (e.g., delta smelt) or groups of species (e.g., green and white sturgeon). The comparative evaluation of Options for the other groups of criteria is presented by criterion (e.g., planning criteria #8). Table 7-1 presents the comparative performance of each Option in addressing the needs of the covered fish species relative to the biological criteria. Table 7-2 presents the comparison of the performance of each Option relative to the planning, flexibility/durability/sustainability, and other resource impacts criteria. Table 7-3 presents the overall performance of the Options against the major categories of criteria.

Note that the summary evaluation of Option 2 presented here is expressed for Option 2 with a pump facility at the siphon. As described in Section 2.2 and Section 4, it is unlikely that Option 2 as currently configured would be considered for development of the conservation strategy because hydrodynamic modeling results indicate that with a gravity siphon it could not meet water supply objectives. Consequently, the summary tables presented in this section present the evaluation results for Option 2 with the pump facility rather than for Option 2 as originally described in previous BDCP documents. Section 4 presents the criteria evaluation results for Option 2 with and without the pump facility. Hydrodynamic model runs for Option 2 have recently been conducted with the pump facility included, but results at the time of publication of this report are preliminary. Some of the new modeling outputs are used in the evaluation. The evaluation of Option 2, therefore, is based more on best professional judgment and more coarse estimates of outcomes than the other Options.

The comparison evaluation presented in this section is built on the discussions in Section 3, 4, 5, and 6 and on information presented in Appendix H. Appendix H contains more detailed scaling of the performance of each of the Options relative to the metrics used to evaluate each of the covered fish species and each of the evaluation criteria. Summary comparisons provided in Tables 7-1, 7-2, and 7-3 consolidate the more detailed information provided in this section and Appendix H.

Table 7-1. Comparison of Options by Covered Fish Species

Species	Performance Rank[1]			
	Option 1	Option 2	Option 3	Option 4
Delta smelt	●	●●	●●●	●●●●
Longfin smelt	●	●●	●●●	●●●●
Sacramento River Salmonids	●●●	●●●	●●●	●●●●
San Joaquin River Salmonids	●	●●	●●●	●●●●
White Sturgeon	●	●●●	●●●	●●●●
Green Sturgeon	●●●	●●●	●●●	●●●●
Sacramento splittail	●●	●●	●●●	●●●●

Notes:
1. Based on information presented in Tables H-1 to H-9 addressing Biological Criteria #1-7.
Species performance ranks are:
●●●● = Best performing,
●●● = Second best performing,
●● = Third best performing,
● = Lowest performing
Where ranks are equal the two Options receive same rank

Table 7-2. Comparison of Options by Planning, Feasibility/Durability /Sustainability, and Other Resource Impacts Criteria

Criterion	Performance Rank[1]			
	Option 1	Option 2	Option 3	Option 4
Planning Criteria				
8. Water supply goals	●●	●	●●●●	●●●
9. Feasibility/practicability	●●●●	●●●●	●●●●	●●●●
10. Minimize cost	●	●●	●●●	●●●●
Flexibility/Sustainability/Durability Criteria				
11. Durability to catastrophic events	●	●●	●●●●	●●●
12. Minimize ongoing resource input for long-term conservation	●	●●	●●●	●●●●
13. Flexibility/adaptability	●	●●	●●●	●●●●
14. Reversibility	●●●●	●●●	●●	●●
Other Resource Impacts Criteria				
15. Avoidance of impacts on other native species (in-Delta)	●●●●	●●	●	●●●
16. Avoidance of impacts on human environment (in-Delta)[2]	●●●●	●●●	●	●●
17. Avoidance of impacts on native species (outside Delta)	●●	●●	●●●●	●●●

Notes:
1. Derived from information presented in Sections 7.2, 7.3, and 7.4.
2. Does not include indirect effects in export service areas.
Criteria performance ranks are:
●●●● = Best performing,
●●● = Second best performing,
●● = Third best performing,
● = Lowest performing
Where ranks are equal the two Options receive same rank

Table 7-3. Overall Comparison of Options by Criteria Category (Rank)[1]

Evaluation Criteria Category	Conservation Strategy Option			
	Option 1	Option 2	Option 3	Option 4
Biological	●	●●	●●●	●●●●
Planning	●	●	●●●●	●●●●
Flexibility/ Sustainability/Durability	●	●●	●●●	●●●●
Impacts on Other Resources	●●●●	●●●	●	●●

Notes:

1. Derived from information presented in Tables 7.1 and 7.2.
   Criteria performance ranks are:
   ●●●● = Best performing,
   ●●● = Second best performing,
   ●● = Third best performing,
   ● = Lowest performing

Where ranks are equal the two Options receive same rank

7.1 COMPARISON OF THE OPTIONS RELATIVE TO BIOLOGICAL CRITERIA

This section provides a comparison of the performance of each Option for benefiting each of the covered fish species based on the biological criteria evaluations presented in Sections 3.1, 4.1, 5.1, and 6.1. Appendix H provides a summary description of the performance of each Option relative to the evaluation criteria and metrics. Table 7-1 presents a comparison of the performance of each Option for each fish species or species group. Tables 7-4 through 7-12 summarize the performance of each Option relative to important stressors for each of the species.

7.1.1 Delta Smelt

Option 4 would provide the greatest benefit to delta smelt because it ranks consistently best in relieving highly important and moderately important stressors (Table 7-4). Option 3 would provide the second greatest benefit to delta smelt, followed by Option 2. Option 1 would provide the lowest benefit to delta smelt because it consistently ranked lowest in relieving important stressors to delta smelt. All Options, however, provide benefits for delta smelt relative to base conditions.

Option 1 would provide the lowest benefit to delta smelt. Although Option 1 would relieve multiple stressors, it consistently ranks lowest in performance among the Options. Option 1 is ranked lowest in benefits to quantity and quality of food, rearing and spawning habitat, turbidity, predation, and CVP/SWP entrainment. Option 1 performs best among the Options in reducing exposure of delta smelt to toxics, though this effect does not differ from base conditions.

Table 7-4. Summary of Option Effects on Important Delta Smelt Stressors

Stressors[1]	Option Effects Relative to Important Species Stressors			
	Option 1[2,3]	Option 2[2,3]	Option 3[2,3]	Option 4[2,3]
Highly Important Stressors				
Reduced food	● 3	●● 3	●●● 3	●●●● 3
Reduced rearing habitat	● 3	●● 3	●●● 3	●●●● 3
Reduced turbidity	● 3	●● 3	●●● 3	●●● 3
Reduced spawning habitat	●● 2	●●● 2	●●● 2	●●●● 2
Reduced food quality	●● 1	●●● 1	●●● 1	●●●● 1
Moderately Important Stressors				
Predation	●● 1	●●● 1	●●● 1	●●●● 1
CVP/SWP entrainment	⊗ 4	●● 2	●●●● 3	●●●● 4
Exposure to toxics	⊗ 4	○○ 1	○○○ 1	○○○ 1

Notes:

1. See Appendix C for descriptions of stressors, stressor impact mechanisms, and stressor effects.
2. Effects (relative to base conditions):
   ● = very low benefit,
   ●● = low benefit,
   ●●● = moderate benefit,
   ●●●● = high,
   ⊗ = no change,
   ○ = very low adverse effect,
   ○○ = low adverse effect,
   ○○○ = moderate adverse effect,
   ○○○○ = high adverse effect.
3. Relative degree of certainty (indicated below the effects symbols) of the magnitude of Option effect on the stressor:
   4 = High
   3 = Moderate
   2 = Low
   1 = little or no certainty.

Relative degree of certainty assigned here is based on a qualitative combination of the certainty levels assigned to impact mechanisms relative to stressors (Appendix C) and the certainty level assigned to tools relative to metrics (Section 2).

Option 2 would provide the third highest benefit to delta smelt. Like Option 3, Option 2 would need to maintain export water quality standards in the southern Delta, but, unlike Option 3, this need would extend to all flow conditions in all water year types under Option 2. As a result, the ability to increase food quantity and accessibility and increase turbidity would be reduced under Option 2. Further, entrainment at CVP/SWP pumps would be greater under Option 2 than under Options 3 and 4.

Option 3 would provide the second highest benefit to delta smelt. A primary difference between Option 3 and Option 4 is the need under Option 3 to meet export water quality standards in the south Delta, and the adverse effects of increased reverse flows within Middle River, when the south Delta export facilities are operating, resulting in a reduced area available for potential habitat restoration. Option 3 provides the best opportunity to increase turbidity and reduce CVP/SWP entrainment. Option 3 provides the second highest opportunity (after Option 4) to increase delta smelt rearing and spawning habitat, increase food quantity, quality, and accessibility, and reduce predation by non-natives.

Option 4 would perform best among the Options for delta smelt because it would provide the best opportunity to relieve four of the five highly important stressors. This Option provides the greatest increase in food quantity and quality by providing the largest area, with the greatest geographic distribution, in which to restore habitat that, if appropriately designed, would promote the growth and abundance of native prey species and reduce abundances of non-native competitors and predators. Food quantity would also likely improve under Option 4 by reducing exports of nutrients and organic carbon by CVP/SWP pumps and increasing hydraulic residence time throughout the Delta. Turbidity levels, which positively affect both risk of predation and foraging efficiency of delta smelt, would likely be highest under Option 4. The quantity, quality, and accessibility of probable spawning habitat would be the greatest under Option 4 by allowing the greatest area of the Delta to be available for restoration. CVP/SWP entrainment of delta smelt would be virtually eliminated under Option 4 because there would be no south Delta diversions and the Hood diversion is located upstream of the main distribution of the delta smelt population. One major stressor to delta smelt that Option 4 could increase is exposure to toxics as a result of reduced Sacramento River dilution flows and increased relative contribution of lower quality San Joaquin River water. Opportunities for pollutant source control to reduce the potential risk of toxicity effects would be equally applicable across all Options.

7.1.2 Longfin Smelt

Option 4 would allow the greatest benefit to longfin smelt because it performs best in relieving highly important and moderately important stressors (see Table 7-5). Option 3 would provide the second greatest benefit to longfin smelt, Option 2 would rank third, and Option 1 would provide the lowest benefit to longfin smelt because it relieved stressors the least amount. All Options, however, provide benefits for delta smelt relative to base conditions.

Option 1 would provide the lowest benefit to longfin smelt. Although Option 1 would relieve multiple stressors, it consistently ranks lowest in performance among the Options. Option 1 would rank lowest in potential benefits to longfin smelt in terms of quantity and quality of food, rearing and spawning habitat, turbidity, predation, and CVP/SWP entrainment. Option 1 performs best among the Options in reducing exposure of longfin smelt to toxics, though this effect is identical to base conditions.

Table 7-5. Summary of Option Effects on Important Longfin Smelt Stressors

Stressors[1]	Option Effects Relative to Important Species Stressors			
	Option 1[2,3]	**Option 2[2,3]**	**Option 3[2,3]**	**Option 4[2,3]**
Highly Important Stressors				
Reduced access to spawning habitat	⊗ 2	⊗ 2	○ 2	⊗ 2
Reduced access rearing habitat	⊗ 3	⊗ 3	●● 3	● 3
Reduced food	● 3	●● 3	●●● 3	●●●● 3
Predation	●● 1	●●● 1	●●● 1	●●●● 1
Reduced turbidity	● 3	●● 3	●●● 3	●●● 3
Reduced spawning habitat	● 2	●● 2	●● 2	●●●● 2
Reduced food quality	● 1	●●● 1	●●● 1	●●●● 1
Moderately Important Stressors				
CVP/SWP entrainment	⊗ 4	●● 2	●●●● 3	●●●● 4
Reduced rearing habitat	⊗ 3	⊗ 3	●● 3	●● 3
Exposure to toxics	⊗ 4	○○ 1	○○○ 1	○○○ 1

Notes:
1. See Appendix C for descriptions of stressors, stressor impact mechanisms, and stressor effects.
2. Effects (relative to base conditions):
   ● = very low benefit,
   ●● = low benefit,
   ●●● = moderate benefit,
   ●●●● =high,
   ⊗ = no change,
   ○ = very low adverse effect,
   ○○ = low adverse effect,
   ○○○ = moderate adverse effect,
   ○○○○ = high adverse effect.
3. Relative degree of certainty (indicated below the effects symbols) of the magnitude of Option effect on the stressor:
   4 = High
   3 = Moderate
   2 = Low
   1 = little or no certainty.

Relative degree of certainty assigned here is based on a qualitative combination of the certainty levels assigned to impact mechanisms relative to stressors (Appendix C) and the certainty level assigned to tools relative to metrics (Section 2).

Option 2 would provide the third highest benefit to longfin smelt. Like Option 3, Option 2 would need to rely on the use of the Middle River channel for water conveyance to the export facilities and maintain export water quality standards in the south Delta, but, unlike Option 3, this need would extend to all flow conditions in all water year types under Option 2. Therefore, the ability to increase food quantity and accessibility and increase turbidity would be reduced under Option 2. Entrainment at CVP/SWP pumps would increase under Option 2 when compared with operations under either Options 3 or 4.

Option 3 would provide the second highest benefit to longfin smelt. A primary difference between Option 3 and Option 4 is the requirement under Option 3 to meet export water quality standards in the south Delta when south Delta pump facilities are operating, resulting in a reduced area available for potential habitat restoration. In addition, operation under Option 3 would continue to use Middle River as the primary pathway for water conveyance from the Sacramento River to the south Delta export facilities and therefore would degrade opportunities for habitat enhancement in the Middle River area and east side tributaries. Along with Option 4, Option 3 provides the best opportunity to increase turbidity and reduce CVP/SWP entrainment. Option 3 provides the second highest opportunity (after Option 4) to increase longfin smelt rearing and spawning habitat, increase food quantity, quality, and accessibility, and reduce predation by non-natives.

Option 4 would provide the greatest benefit to longfin smelt among the Options because it would provide the best opportunity to relieve multiple highly important stressors. Option 4 provides the greatest increase in food quantity and quality by providing the largest area, with the greatest geographic distribution, in which to restore habitat that, if appropriately designed, would promote abundances native prey species and reduce abundances of non-native competitors. Option 4 also provide hydrodynamic conditions, including reduced channel velocities and increased residence times, that would be expected to result in greater phytoplankton and zooplankton production within the Delta. Food quantity would also likely increase under Option 4 by reducing exports of nutrients and organic carbon by CVP/SWP pumps and increasing hydraulic residence time throughout the Delta. Turbidity levels would likely be greatest under Option 4. The quantity, quality, and accessibility of probable spawning habitat would be the greatest under Option 4 by allowing the largest area of the Delta to be available for restoration. Option 4 would also rank highest in reducing the risk of predation by non-native species by providing the greatest area of the Delta to be available for restoration, which, if appropriately designed, would reduce conditions for non-native predators. CVP/SWP entrainment of longfin smelt would decrease under Option 4 because there would be no south Delta diversions and the Hood diversion is upstream of the main distribution of the longfin smelt population. In addition, the diversion at Hood would be equipped with a state-of-the-art positive barrier fish screen that would be expected to effectively exclude juvenile and adult longfin smelt, and other fish species, from being entrained as a result of diversion operations. One major stressor to longfin smelt that Option 4 could increase is exposure to toxics due to reduced Sacramento River dilution flows and increased relative contribution of lower quality San Joaquin River water.

7.1.3 Sacramento River Salmonids

Option 4 is expected to provide the highest level of benefit for Sacramento River salmonids relative to base conditions and the other Options. Options 1, 2, and 3 would all be expected to provide similar benefits (Tables 7-6 and 7-7).

The evaluation only addressed flow conditions that would facilitate access of salmonids to staging and spawning habitats because those habitats are located upstream of the planning area. Both Chinook salmon (fall-/late fall-run, spring-run, and winter-run) and Central Valley steelhead located in the Sacramento River were combined in this summary because results of the evaluation of each Options were the same among the runs and species.

The overall performances of Options 1, 2, and 3 for Sacramento River salmonids are largely indistinguishable. Each Option scores highly with respect to relieving some stressors and poorly with respect to relieving others. For example, Option 3 performs well with respect to CVP/SWP entrainment, but scores poorly with respect to exposure to toxics. Options 1 and 2 perform well in reducing rearing and spawning habitat, but have no other benefits to Sacramento River salmonids. Because of the high natural variability and resulting level of uncertainty associated with the Delta ecosystem, it is not possible to distinguish among these Options with reasonable confidence.

Option 4 would perform best among the Options for Sacramento River salmonids because it would relieve, to the greatest degree, all of the stressors identified as highly important including non-native predation, rearing and outmigration habitat, staging and spawning habitat, and CVP/SWP entrainment.

Table 7-6. Summary of Option Effects on Important Sacramento River Chinook Salmon Stressors

Stressors[1]	Option Effects Relative to Important Species Stressors			
	Option 1[2,3]	Option 2[2,3]	Option 3[2,3]	Option 4[2,3]
Highly Important Stressors				
Reduced staging and spawning habitat	⊗ 2	⊗ 2	○ 2	● 2
Reduced rearing and outmigration habitat	●● 3	●● 3	● 3	●●● 3
Predation by non-native species	●● 1	●● 1	●● 1	●●●● 1
Moderately Important Stressors				
Harvest	⊗ 4	⊗ 4	⊗ 4	⊗ 4
Reduced genetic diversity/ integrity	⊗ 4	⊗ 4	⊗ 4	⊗ 4
CVP/SWP entrainment	⊗ 4	⊗ 3	●●● 3	●●●● 3
Exposure to toxics	⊗ 4	⊗ 1	○○○ 1	○○○ 1
Increased water temperature	⊗ 4	⊗ 4	⊗ 4	⊗ 4

Notes:

1. See Appendix C for descriptions of stressors, stressor impact mechanisms, and stressor effects.
2. Effects (relative to base conditions):
   ● = very low benefit,
   ●● = low benefit,
   ●●● = moderate benefit,
   ●●●● =high,
   ⊗ = no change,
   ○ = very low adverse effect,
   ○○ = low adverse effect,
   ○○○ = moderate adverse effect,
   ○○○○ = high adverse effect.
3. Relative degree of certainty (indicated below the effects symbols) of the magnitude of Option effect on the stressor:
   4 = High
   3 = Moderate
   2 = Low
   1 = little or no certainty.

Relative degree of certainty assigned here is based on a qualitative combination of the certainty levels assigned to impact mechanisms relative to stressors (Appendix C) and the certainty level assigned to tools relative to metrics (Section 2).

Table 7-7. Summary of Option Effects on Important Sacramento River Steelhead Stressors

Stressors[1]	Option Effects Relative to Important Species Stressors			
	Option 1[2,3]	Option 2[2,3]	Option 3[2,3]	Option 4[2,3]
Highly Important Stressors				
Reduced staging and spawning habitat	⊗ **2**	⊗ **2**	○ **2**	● **2**
CVP/SWP entrainment	⊗ **4**	⊗ **3**	●●● **3**	●●●● **3**
Reduced rearing and outmigration habitat	●● **3**	●● **3**	● **3**	●●● **3**
Predation by non-native species	●● **1**	●● **1**	●● **1**	●●●● **1**
Moderately Important Stressors				
Exposure to toxics	⊗ **4**	⊗ **1**	○○○ **1**	○○○ **1**
Reduced genetic diversity/ integrity	⊗ **4**	⊗ **4**	⊗ **4**	⊗ **4**
Harvest	⊗ **4**	⊗ **4**	⊗ **4**	⊗ **4**
Increased water temperature	⊗ **4**	⊗ **4**	⊗ **4**	⊗ **4**

Notes:

1. See Appendix C for descriptions of stressors, stressor impact mechanisms, and stressor effects.
2. Effects (relative to base conditions):
   ● = very low benefit,
   ●● = low benefit,
   ●●● = moderate benefit,
   ●●●● =high,
   ⊗ = no change,
   ○ = very low adverse effect,
   ○○ = low adverse effect,
   ○○○ = moderate adverse effect,
   ○○○○ = high adverse effect.
3. Relative degree of certainty (indicated below the effects symbols) of the magnitude of Option effect on the stressor:
   4 = High
   3 = Moderate
   2 = Low
   1 = little or no certainty.

Relative degree of certainty assigned here is based on a qualitative combination of the certainty levels assigned to impact mechanisms relative to stressors (Appendix C) and the certainty level assigned to tools relative to metrics (Section 2).

7.1.4 San Joaquin River Salmonids

Option 4 would provide the greatest benefit to San Joaquin River salmonids because it ranks consistently best in relieving highly important and moderately important stressors (see Tables 7-8 and 7-9). Option 3 would provide the second greatest benefit to San Joaquin River salmonids, followed by Option 2. Option 1 would provide the lowest benefit to San Joaquin River salmonids because it consistently ranked lowest in relieving important stressors to San Joaquin River salmonids.

Based on the evaluation of the potential effects of the Options on important San Joaquin River salmonid stressors (Tables 7-8 and 7-9), Option 1 is expected to provide the lowest level of

Table 7-8. Summary of Option Effects on Important San Joaquin River Chinook Salmon Stressors

Stressors[1]	Option Effects Relative to Important Species Stressors			
	Option 1[2,3]	Option 2[2,3]	Option 3[2,3]	Option 4[2,3]
Highly Important Stressors				
Reduced staging and spawning habitat	⊗ 3	⊗ 2	● 2	●● 2
Reduced rearing and outmigration habitat	●● 3	●● 2	●● 2	●●● 3
Exposure to toxics	⊗ 4	○○ 1	○○○ 1	○○○ 1
Predation by non-native species	● 1	●● 1	●● 1	●●●● 1
Moderately Important Stressors				
Reduced genetic diversity/ integrity	⊗ 4	⊗ 4	⊗ 4	⊗ 4
Harvest	⊗ 4	⊗ 4	⊗ 4	⊗ 4
CVP/SWP entrainment	⊗ 4	● 3	●●● 3	●●●● 3
Increased water temperature	⊗ 4	⊗ 4	⊗ 4	⊗ 4

Notes:

1. See Appendix C for descriptions of stressors, stressor impact mechanisms, and stressor effects.
2. Effects (relative to base conditions):
   ● = very low benefit,
   ●● = low benefit,
   ●●● = moderate benefit,
   ●●●● =high,
   ⊗ = no change,
   ○ = very low adverse effect,
   ○○ = low adverse effect,
   ○○○ = moderate adverse effect,
   ○○○○ = high adverse effect.
3. Relative degree of certainty (indicated below the effects symbols) of the magnitude of Option effect on the stressor:
   4 = High
   3 = Moderate
   2 = Low
   1 = little or no certainty.

Relative degree of certainty assigned here is based on a qualitative combination of the certainty levels assigned to impact mechanisms relative to stressors (Appendix C) and the certainty level assigned to tools relative to metrics (Section 2).

Table 7-9. Summary of Option Effects on Important San Joaquin River Steelhead Stressors

Stressors[1]	Option Effects Relative to Important Species Stressors			
	Option 1[2,3]	Option 2[2,3]	Option 3[2,3]	Option 4[2,3]
Highly Important Stressors				
Reduced staging and spawning habitat	⊗ 3	⊗ 2	● 2	●● 2
Reduced rearing and outmigration habitat	● 3	●● 2	●● 2	●●● 3
Exposure to toxics	⊗ 4	○○ 1	○○○ 1	○○○ 1
Reduced genetic diversity/ integrity	⊗ 4	⊗ 4	⊗ 4	⊗ 4
Predation by non-native species	● 1	●● 1	●● 1	●●●● 1
Moderately Important Stressors				
CVP/SWP entrainment	● 4	● 3	●●● 3	●●●● 3
Harvest	⊗ 4	⊗ 4	⊗ 4	⊗ 4
Increased water temperature	⊗ 4	⊗ 4	⊗ 4	⊗ 4

Notes:

1. See Appendix C for descriptions of stressors, stressor impact mechanisms, and stressor effects.
2. Effects (relative to base conditions):
   ● = very low benefit,
   ●● = low benefit,
   ●●● = moderate benefit,
   ●●●● =high,
   ⊗ = no change,
   ○ = very low adverse effect,
   ○○ = low adverse effect,
   ○○○ = moderate adverse effect,
   ○○○○ = high adverse effect.
3. Relative degree of certainty (indicated below the effects symbols) of the magnitude of Option effect on the stressor:
   4 = High
   3 = Moderate
   2 = Low
   1 = little or no certainty.

Relative degree of certainty assigned here is based on a qualitative combination of the certainty levels assigned to impact mechanisms relative to stressors (Appendix C) and the certainty level assigned to tools relative to metrics (Section 2).

benefits relative to base conditions and the other Options because it consistently provides the lowest benefit to reducing the effects of both very high and moderately high stressors. The only stressor for which Option 1 would provide the greatest benefit is the exposure of San Joaquin River salmonids to toxics, but this effect would be no greater than base conditions. Option 2 is expected to provide the third highest benefit to San Joaquin River salmonids. Option 2 is expected to perform marginally better than Option 1 by providing increased rearing and outmigration habitat and reducing the risk to predation by non-native species. Option 2 would perform lower than Option 1 with respect to exposure to toxics. It is expected that the effects of Option 2 on all other stressors will be similar to Option 1.

Option 3 is expected to provide the second highest benefit to San Joaquin River salmonids. Option 3 is expected to perform marginally better than Option 2 by providing increased staging and spawning habitat and reducing entrainment risk. Option 3 would perform lower than Option 2 with respect to exposure to toxics. It is expected that the effects of Option 3 on all other stressors will be similar to Option 2.

Option 4 is expected provide the highest level of benefit relative to base conditions and the other Options because it is likely to be more effective than the other Options in:

- improving access to staging and spawning habitat,
- improving rearing and outmigration habitat conditions,
- reducing predation risk, and
- reducing SWP/CVP entrainment risk.

7.1.5 Green and White Sturgeon

The important stressors for green and white sturgeon that are addressed by each of the Options include exposure to toxics and reduced rearing habitat. The remaining important stressors for this species can only be addressed outside of the planning area (see Appendix C). Option 4 would be expected to have a moderate beneficial effect relative to base conditions and would be expected to provide the greatest benefit among the Options for green and white sturgeon (Tables 7-10 and 7-11). Options 2 and 3 would have a low beneficial effect relative to base conditions for both sturgeon species. Option 1 is expected to provide a low benefit for green sturgeon and a very low benefit for white sturgeon relative to base conditions (Tables 7-10 and 7-11).

Based on the evaluation of the potential effects of the Options on sturgeon stressors (Tables 7-10 and 7-11), Options 1, 2, and 3 are expected to provide a low level of benefit for green sturgeon relative to base conditions. These Options provide a lower level of benefit than under Option 4 because they provide fewer geographic opportunities for restoring habitat in the range of the green sturgeon within the planning. Option 1 is expected to provide a very low level of benefit for white sturgeon relative to base conditions and the other Options because it provides the fewest opportunities for restoring habitat in the range of the white sturgeon within the planning area.

Options 2 and 3 are expected to provide a low level of benefit to white sturgeon relative to base conditions, a higher benefit relative to Option 1, and a lower level of benefit relative to Option 4 because these Options provide greater geographic opportunities for restoring habitats in the Delta relative to Option 1, but fewer opportunities relative to Option 4.

Table 7-10. Summary of Option Effects on Important Green Sturgeon Stressors

Stressors[1]	**Option Effects Relative to Important Species Stressors**			
	Option 1[2,3]	**Option 2[2,3]**	**Option 3[2,3]**	**Option 4[2,3]**
Highly Important Stressors				
Reduced spawning habitat	⊗ **3**	⊗ **3**	⊗ **3**	⊗ **3**
Exposure to toxics	⊗ **4**	⊗ **1**	○○○ **1**	○○○ **1**
Harvest	⊗ **4**	⊗ **4**	⊗ **4**	⊗ **4**
Moderately Important Stressors				
Reduced rearing habitat	●● **3**	●● **3**	●● **3**	●●● **3**
Increased water temperature (upstream)	⊗ **3**	⊗ **3**	⊗ **3**	⊗ **3**
Predation	⊗ **4**	⊗ **4**	⊗ **4**	⊗ **4**
Reduced turbidity	⊗ **4**	⊗ **4**	⊗ **4**	⊗ **4**

Notes:

1. See Appendix C for descriptions of stressors, stressor impact mechanisms, and stressor effects.
2. Effects (relative to base conditions):
   ● = very low benefit,
   ●● = low benefit,
   ●●● = moderate benefit,
   ●●●● =high,
   ⊗ = no change,
   ○ = very low adverse effect,
   ○○ = low adverse effect,
   ○○○ = moderate adverse effect,
   ○○○○ = high adverse effect.
3. Relative degree of certainty (indicated below the effects symbols) of the magnitude of Option effect on the stressor:
   4 = High
   3 = Moderate
   2 = Low
   1 = little or no certainty.

Relative degree of certainty assigned here is based on a qualitative combination of the certainty levels assigned to impact mechanisms relative to stressors (Appendix C) and the certainty level assigned to tools relative to metrics (Section 2).

Table 7-11. Summary of Option Effects on Important White Sturgeon Stressors

Stressors[1]	Option Effects Relative to Important Species Stressors			
	Option 1[2,3]	Option 2[2,3]	Option 3[2,3]	Option 4[2,3]
Highly Important Stressors				
Harvest	⊗ 4	⊗ 4	⊗ 4	⊗ 4
Reduced spawning habitat	⊗ 3	⊗ 3	⊗ 3	⊗ 3
Exposure to toxics	⊗ 4	○ 1	○○○ 1	○○○ 1
Moderately Important Stressors				
Reduced rearing habitat	● 3	●● 3	●● 3	●●● 3
Increased water temperature (upstream)	⊗ 3	⊗ 3	⊗ 3	⊗ 3
Predation	⊗ 4	⊗ 4	⊗ 4	⊗ 4
Reduced turbidity	⊗ 4	⊗ 4	⊗ 4	⊗ 4

Notes:
1. See Appendix C for descriptions of stressors, stressor impact mechanisms, and stressor effects.
2. Effects (relative to base conditions):
   ● = very low benefit,
   ●● = low benefit,
   ●●● = moderate benefit,
   ●●●● =high,
   ⊗ = no change,
   ○ = very low adverse effect,
   ○○ = low adverse effect,
   ○○○ = moderate adverse effect,
   ○○○○ = high adverse effect.
3. Relative degree of certainty (indicated below the effects symbols) of the magnitude of Option effect on the stressor:
   4 = High
   3 = Moderate
   2 = Low
   1 = little or no certainty.

Relative degree of certainty assigned here is based on a qualitative combination of the certainty levels assigned to impact mechanisms relative to stressors (Appendix C) and the certainty level assigned to tools relative to metrics (Section 2).

Option 4 is expected to provide a moderate benefit for green and white sturgeon relative to base conditions and the greatest benefit among the Options because it provides greater geographic opportunities for restoring aquatic shallow water subtidal and intertidal habitats. Unlike Options 1 and 2, there would be a reduction in Delta inflows under Options 3 and 4 that could have a low adverse effect on exposure of sturgeon to toxics because the ability of inflows to dilute toxic concentrations would be reduced.

Options 3 and 4 perform lower than Options 1 and 2 with regard to exposure of green sturgeon and white sturgeon to toxics because Sacramento River inflows to the Delta, which are assumed to dilute concentrations of toxics, are lower relative to base conditions and Options 1 and 2. However, the effects of reductions in Sacramento River inflows under Options 3 and 4 on increasing the exposure of sturgeon to toxics are highly uncertain. Allowing San Joaquin River water, which has a high selenium load, to discharge into the Delta with reduced dilution from the Sacramento River under Options 2, 3, and 4 could increase the bioaccumulation of selenium in sturgeon. This evaluation assumes that, because source control reductions in San Joaquin River selenium loads have been mandated by the Regional Water Quality Board to be in place by 2012, selenium concentrations would not become elevated from base conditions under Options 2, 3, and 4. If source controls are unsuccessful and selenium concentrations were to increase in the Delta, Options 2, 3, and 4 would be expected to have an overall adverse effect on sturgeon.

7.1.6 Sacramento Splittail

The important stressors on Sacramento splittail that are addressed by each of the Options include reduced juvenile rearing/adult habitat; reduced food availability; reduced spawning/larval rearing habitat; exposure to toxics; predation; and SWP/CVP entrainment (Appendix C). Based on the evaluation of the potential effects of the Options on important splittail stressors (see Table 7-12), Option 4 is expected provide the highest level of benefit relative to base conditions. Option 3 is expected to perform better than Options 1 and 2.

Table 7-12. Summary of Option Effects on Important Sacramento Splittail Stressors

Stressors[1]	Option Effects Relative to Important Species Stressors			
	Option 1[2,3]	Option 2[2,3]	Option 3[2,3]	Option 4[2,3]
Highly Important Stressors				
Reduced juvenile rearing/adult habitat	●● 3	●● 3	●●● 3	●●●● 3
Reduced spawning/larval rearing habitat	●● 3	●● 3	●●● 3	●●●● 3
Reduced food	● 3	●● 3	●●● 3	●●●● 3
Exposure to toxics	⊗ 3	○○ 3	○○○ 3	○○○ 3
Moderately Important Stressors				
Predation	●● 3	●●● 3	●●● 3	●●●● 3
SWP/CVP entrainment	● 3	●● 3	●●●● 3	●●●● 3
Harvest	⊗ 4	⊗ 4	⊗ 4	⊗ 4

Notes:
1. See Appendix C for descriptions of stressors, stressor impact mechanisms, and stressor effects.
2. Effects (relative to base conditions):
   ● = very low benefit,
   ●● = low benefit,
   ●●● = moderate benefit,
   ●●●● =high,
   ⊗ = no change,
   ○ = very low adverse effect,
   ○○ = low adverse effect,
   ○○○ = moderate adverse effect,
   ○○○○ = high adverse effect.
3. Relative degree of certainty (indicated below the effects symbols) of the magnitude of Option effect on the stressor:
   4 = High
   3 = Moderate
   2 = Low
   1 = little or no certainty.

Relative degree of certainty assigned here is based on a qualitative combination of the certainty levels assigned to impact mechanisms relative to stressors (Appendix C) and the certainty level assigned to tools relative to metrics (Section 2).

Options 1 and 2 would be expected to provide a low level of benefit relative to base conditions and lower levels of benefit compared to Options 3 and 4 primarily because they are not expected to improve food availability or address entrainment as effectively as those Options.

Option 3 is expected to perform better than Options 1 and 2, because it is more likely to improve habitat conditions and food availability and reduce the effects of entrainment losses to a greater extent than those Options.

Option 4 is expected to provide a greater level of benefit than the other Options because it is more likely to improve habitat conditions and food availability and reduce effects of predation and entrainment losses to a similar or greater degree than the other Options.

7.2 COMPARISON OF THE OPTIONS RELATIVE TO THE PLANNING CRITERIA

This section provides a comparison of the performance of each Option relative to each of the planning criteria based on the planning criteria evaluations presented in Sections 3.2, 4.2, 5.2, and 6.2. Table 7-13 presents a summary description of the performance of each Option relative to the planning criteria evaluation metrics. Table 7-2 presents a comparison of the performance of each Option relative to each of the planning criteria.

Table 7-13. Comparison of the Performance of the Options Relative to the Planning Criteria Metrics[1]

Metric	Option 1	Option 2 (with pump)	Option 3	Option 4
Criterion #8. Relative degree to which the Option allows covered activities to be implemented in a way that meets the goals and purposes of those activities.				
P1. Water supply reliability	**Low** – continued regulatory restrictions would reduce reliability	**Moderate** – engineered solution to limiting gravity siphon would increase export capability	**High** – dual system provides greatest reliability of export operations	**Moderate** – isolated conveyance reduces regulatory constraints; limits due to loss of San Joaquin and east side supplies
P2. Operational flexibility	**Very Low** – single source in south Delta with regulatory constraints	**Very Low** – single source in south Delta with regulatory constraints	**High** – dual system provides greatest flexibility of export operations	**Moderate** – regulatory constraints mostly avoided but single source from Sacramento R. is limiting
P3. Quality of water exported from the SWP/CVP facilities	**Very Low** – continued issues with salts and organics	**Low** –improvement in water quality over Option 1 with separation from San Joaquin R.	**Moderate** – dominated by high quality Sacramento R. water	**High** – all high quality Sacramento R. water

Table 7-13. Comparison of the Performance of the Options Relative to the Planning Criteria Metrics[1] (continued)

Metric	Option 1	Option 2 (with pump)	Option 3	Option 4
Criterion #9. The relative feasibility and practicability of the Option, including the ability to fund, engineer, and implement				
P4. Relative feasibility and practicability to address habitat conservation and water supply goals	**Moderate**— , constraints to achieving conservation and supply goals; regulatory constraints	**Moderate**— technological challenges and constraints to achieving dual goals	**Moderate**—some technological challenges, flexibility to achieve dual goals, many regulatory approvals	**Moderate**— some technological challenges, flexibility to achieve dual goals, many regulatory approvals
Criterion #10. Relative costs (including infrastructure, operations, and management) associated with implementing the Option.				
P5. Ability to control construction costs for implementing the Option	**High** – no new facility construction costs	**Moderate** – substantially smaller construction cost ($0.5-2.8B) relative to Options 3 and 4	**Very Low** – likely to have greater construction costs ($3.5-8.8B) than Option 4, but substantially higher costs than Option 2	**Low** – likely to have lower construction costs ($3.6-5.0B) than Option 3, but substantially higher costs than Option 2
Criterion #10. Relative costs (including infrastructure, operations, and management) associated with implementing the Option.				
P5. Ability to control construction costs for implementing the Option	**High** – no new facility construction costs	**Moderate** – substantially smaller construction cost ($0.5-2.8B) relative to Options 3 and 4	**Very Low** – likely to have greater construction costs ($3.5-8.8B) than Option 4, but substantially higher costs than Option 2	**Low** – likely to have lower construction costs ($3.6-5.0B) than Option 3, but substantially higher costs than Option 2
P6. Ability to avoid redirected costs to service areas from adverse effects of low water quality on municipal treatment, agricultural production, and human health	**Very Low** - No export water quality improvement relative to current condition. No savings in water treatment costs; continued salt build-up on farmland; long-term human health issues/costs	**Moderate** – Potential savings in water treatment costs of $1.0-$1.5 billion over the next 25 years.	**High**- Potential savings in water treatment costs of $1.5-$2.0 billion over the next 25 years; reduced salt build-up rate on farmland; reduced human health issues/costs	**High**- Potential savings in water treatment costs of $2.0-$2.5 billion over the next 25 years; reduced salt build-up rate on farmland; reduced human health issues/costs

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Table 7-13. Comparison of the Performance of the Options Relative to the Planning Criteria Metrics[1] (continued)

Metric	Option 1	Option 2 (with pump)	Option 3	Option 4
Criterion #10. Relative costs (including infrastructure, operations, and management) associated with implementing the Option.				
P7. Ability to avoid costs for extensive and frequent recovery and repair following catastrophic events	**Low** –Least ability to avoid habitat loss and export disruption costs; 50% chance over next 25 years of major disruption in Delta exports resulting in tens of billions of dollars in economic damages	**Moderate** – Reinforced levees provide some protection, but less durable than peripheral aqueduct; less vulnerable to seismic and flood events than Option 1, but still sizable risk from levee failures resulting in water supply disruption.	**High** –Significantly reduces risks to water supply from levee failures. Potential savings of $10's billions over long term. Dual system provides most flexibility to respond to catastrophe at lowest cost; lower cost with less extensive and less frequent losses from seismic or flood events.	**High** –Significantly reduces risks to water supply from levee failures. Potential savings of $10's billions over long term. Does not provide conveyance redundancy of Option 3; lower cost with less extensive and less frequent losses from seismic or flood events.

Notes:
1. See Table 2-5 for explanations of tools and scales used to score high, moderate, low, and very low for each metric

7.21.1 Criterion #8. Relative degree to which the Option allows covered activities to be implemented in a way that meets the goals and purposes of those activities.

Criterion #8 addresses the ability of the Options to achieve the water supply goals of the CVP and SWP. For the purposes of this evaluation, CVP/SWP export water reliability, project operational flexibility, and export water quality were used for describing the relative capability of each Option to meet this criterion. Option 3 is expected to perform the best with regard to meeting the goals and purposes of the covered activities, with Option 4 second (Table 7-13). Option 2 is ranked third and Option 1 fourth.

Option 1 has the lowest export water quality with highest salinity and organics. Although the existing engineered system of Option 1 allows for high export reliability, regulatory restrictions significantly reduce reliability with the Option 1 structural configuration of through-Delta conveyance and limited protection of fish from pump facilities.

Option 2 provides higher quality water than Option 1, but the gravity-fed siphon appears to be a design flaw that would need to be solved for Option 2 to provide reliable water supply. Assuming an engineered solution with a low-head pump facility at the siphon under Option 2, anticipated water supply reliability is expected to be equal to or higher than Option 1 and base conditions. Physical constraints to operations (i.e., channel capacity of Victoria Canal) would need to be addressed for Option 2 to function in meeting supply reliability goals.

Hydrodynamic modeling results suggest that Option 3 provides the greatest combination of water supply reliability, flexibility of operations, and water quality. The dual facility operation allows opportunistic use of the most effective and efficient facility when hydrologic, hydrodynamic, and regulatory conditions limit the use of the other facility.

Option 4 performs well in meeting the goals of the covered activities, but its water reliability is constrained by the reliance on Sacramento River water only with the intake isolated from using east side tributary and San Joaquin River waters. Export water quality under Option 4 is consistently the highest of all Options.

7.2.1.2 Criterion #9. The relative feasibility and practicability of the Option, including the ability to fund, engineer, and implement.

Criterion #9 addresses the feasibility and practicability of implementing each of the Options. The evaluation of this criterion was based on a qualitative assessment of the certainty of technologies for successfully engineering new facilities, likely level of regulatory uncertainties, implementation cost, and practicability of the Option to meet both planning and conservation goals. All Options were determined to be of equivalent feasibility and practicability with each Option having different strengths and constraints contributing to this conclusion (Table 7-13).

While Option 1 could be considered the most feasible Option because it would be of lowest initial cost, would not test any new technologies, and would avoid the new regulatory compliance, this Option does not offer a strong solution to meeting the key goals of species conservation and water supply reliability and would continue to face regulatory uncertainty for Delta operations. Option 1 is considered of moderate feasibility.

Option 2 would require some technological challenges in developing a siphon and pump system, modifying channels to support high flows, and operating the barriers to maximize opportunities for both conservation and water supply conveyance. Option 2 is considered of moderate feasibility.

Option 3 provides a flexible approach to addressing the combined goals of species conservation and habitat restoration using practicable technologies. This Option has the highest initial construction costs and construction of the both peripheral aqueduct and in-Delta facilities would require challenging regulatory compliance. Option 3 is considered of moderate feasibility.

Option 4 provides a highly flexible approach to addressing the combined goals of species conservation and habitat restoration using practicable technologies. Construction of the peripheral aqueduct would require challenging regulatory compliance and substantial cost. Option 4 is considered of moderate feasibility.

7.2.1.3 Criterion #10. Relative costs (including infrastructure, operations, and management) associated with implementing the Option.

The Options were evaluated in terms of expected construction costs, Delta conveyance disruption costs, and redirected water quality costs. Because this evaluation assumes that the overall amount of habitat restoration would be roughly the same for each Option, costs for habitat restoration were not used to differentiate the four Options and therefore were not calculated. It is important to emphasize that much of the data and information relied on for the cost evaluation was cursory in nature. In all cases professional judgment was used to assess order-of-magnitude and relative costs. Key parts of the evaluation relied on information developed for the Delta Risk Management Strategy (Draft Phase I and Draft Phase II Reports 2007), some of which may be revised or updated as work products from that effort are refined and finalized. As new information comes to light the ordering of relative costs presented here could be affected. Therefore findings regarding the relative costs of the four Options should be viewed as preliminary rather than definitive. For example, the cost analysis does not include an assumption that levee improvements might be conducted by other programs for other reasons with associated direct cost savings and economic benefits to in-Delta uses such as species conservation.

The evaluation concluded that Option 4 would have the lowest long-term costs with Option 3 slightly higher or equivalent to Option 4. Option 2 ranked third because the long-term cost savings were estimated to be less than Options 3 and 4. The cost of Option 1 was estimated to be the highest as a result of on-going costs over the long-term.

Option 1 is anticipated to have the highest overall cost of all Options over the long term. While the cost of construction is anticipated to be much lower[1] than the other Options, the periodic cost of recovery from seismic and flood events and the on-going cost of municipal water treatment are expected to overcome the construction cost savings over time. Anticipated risk and cost of catastrophic loss under Option 1 is much higher than other Options, possibly as much as $10-50 Billion in costs at a 50% chance of occurrence in the next 25 years. Option 1 is not expected to significantly improve water quality over existing conditions and therefore would not accrue the substantial water treatment cost savings as other Options – ranging from $1.0-2.5 Billion over the next 25 years.

Options 2 would have a higher overall cost than Options 3 and 4 and a lower overall cost than Option 1. While construction costs for Option 2 are $3 to $5 billion less than Option 3 and $3 to $4.5 billion less than Option 4, the risk of catastrophic loss of conveyance and the cost for recovery from such events under Option 2 is much higher than under Options 3 and 4 and the cost savings to water treatment in service areas is less under Option 2 than under Options 3 and 4. For these reasons, Option 2 is anticipated to result in higher overall costs over the long term than Options 3 and 4. Option 2 would have lower overall cost than Option 1 because the savings over time in recovery costs from seismic or flood events and in water treatment costs under Options 2 is anticipated to overcome the initial $0.5-2.8 billion higher construction costs.

Option 3 would be expected to have the second lowest overall cost over the long term. This low cost is the result of savings from lower frequency of catastrophic events shutting down the water supply system and lower per-event costs for recovery from catastrophic events, and from substantial on-going savings resulting from reduced costs for water treatment in service areas. These savings are expected to recover over time the construction cost differences between Option 3 and Options 1 and 2. Option 3, as configured, is considered more expensive than

[1] Note, however, that additional construction cost under Option 1 to improve CVP and SWP screening and salvage facilities could be on the order of $1.3 billion and were not included in the cost comparison here.

Option 4 because the initial construction costs would be higher, on-going operational costs would be higher (operating and maintaining 2 facilities rather than 1), and savings on water treatment costs would be less. The on-going cost of Option 3, however, could be reduced by the value of increased water delivery capability from the operational flexibility provided by multiple intakes. Option 3 may have a lower risk of supply cutoff from seismic or flood events and, therefore, a lower long-term cost for recovery following catastrophic events than Option 4, but it cannot be concluded whether this difference is substantial enough to offset other costs over time.

Option 4 would be expected to have the lowest overall cost over the long term (Table 7-13). This low cost is the result of savings from lower frequency of catastrophic events shutting down the water supply system and lower per-event costs for recovery from catastrophic events, and from substantial on-going savings resulting from reduced costs for water treatment in service areas. These savings are expected to recover over time the construction cost differences between Option 4 and Options 1 and 2.

7.3 COMPARISON OF THE OPTIONS RELATIVE TO FLEXIBILITY/ DURABILITY/ SUSTAINABILITY CRITERIA

This section provides a comparison of the performance of each Option relative to each of the criteria based on the evaluations presented in Sections 3.3, 4.3, 5.3, and 6.3. Table 7-14 presents a summary description of the performance of each Option relative to the evaluation metrics and Table 7-2 compares the performance of each Option relative to each of the criteria.

Table 7-14. Comparison of the Performance of the Options Relative to Flexibility/Durability/Sustainability Criteria Metric[1]

Metric	Option 1	Option 2 (with pump)	Option 3	Option 4
Criterion #11. Relative degree to which the Option will be able to withstand the effects of climate change (e.g., sea level rise, changes in runoff), variable hydrology, seismic events, subsidence of Delta islands, and other large-scale changes to the Delta.				
F1. Ability of infrastructure supporting conveyance to avoid disruption in water supply resulting from effects of seismic and flood events and sea level rise	**Very Low**—no protective upgrades to conveyance facilities	**Low** —new levees provide some protection to conveyance facilities in south Delta but not in north Delta	**High**—peripheral aqueduct is more durable to seismic and flood events than through-Delta conveyance and redundancy of dual system provides extra protection	**High**—peripheral aqueduct is more durable to seismic and flood events than through -Delta conveyance
F2. Ability of the Option to avoid loss of restored habitat from future seismic and flood events and sea level rise	**Low**—least flexibility for locating restoration to adapt to sea level rise and avoid catastrophic loss	**Moderate** – more area than Option 1 but less than Option 4 for locating restoration to avoid large losses	**Moderate** – more area than Option 1 but less than Option 4 for locating restoration to avoid large losses	**High** – large area for locating restoration provides more opportunity for locating sites to address sea level rise and avoid catastrophic loss

Table 7-14. Comparison of the Performance of the Options Relative to Flexibility/Durability/Sustainability Criteria Metric[1] (continued)

Metric	Option 1	Option 2 (with pump)	Option 3	Option 4
Criterion #12. Relative degree to which the Option could improve ecosystem processes that support the long term needs of each of the covered species and their habitats with minimal future input of resources.				
F3. Ability of the Option to support species conservation without continual input of large amounts of resources to maintain conservation benefits	**Low**—ongoing costs associated with mitigating entrainment losses (likely more than Option 2) and very limited flexibility for adaptively managing Delta flow patterns	**Low**—ongoing costs associated with mitigating entrainment losses (likely less than Option 1) and limited flexibility for adaptively managing Delta flow patterns	**Moderate**—dual conveyance feature provides opportunities to reduce entrainment mitigation costs and some flexibility for adaptively managing Delta flow patterns	**High**—greatest opportunities to adaptively managing habitat restoration and Delta flow patterns to benefit fish species; minimal ongoing entrainment mitigation costs
Criterion #13. Relative degree to which the Option can be adapted to address needs of covered fish species over time.				
F4. Flexibility to experiment with and adjust water management to address current and future ecological uncertainties to benefit covered fish species	**Low**—existing conveyance configuration presents few opportunities for managing Delta flow patterns	**Low**—operable barriers provide limited flexibility for adaptively managing Delta flow patterns	**Moderate**—dual conveyance feature provides more flexibility to adaptively managing Delta flow patterns using operable barriers	**High**—greatest opportunities for adaptively managing Delta flow patterns across large area to benefit covered fish species
F5. Spatial flexibility for restoring additional physical habitat for covered fish species	**Low**—fewest opportunities among Options for restoration (~28% of planning area available); Suisun Marsh included in Option 1 and all other Options	**Low**—opportunities for restoration in the north and central Delta (~35% of planning area available)	**Low**—opportunities for restoration in the north and central Delta (~35% of planning area available)	**High**—greatest opportunities for restoration throughout the Delta (~75% of planning area available)
Criterion #14. Relative degree of reversibility of the Option once implemented.				
F6. Relative practicability to reverse the Option	**High**—greatest ability to reverse because no costs associated with removal of infrastructure relative to current conditions	**Moderate**—loss of capital investment associated with abandonment or removal of new infrastructure	**Very Low**—substantial loss of investment associated with abandonment or removal of a peripheral aqueduct and other new infrastructure; politically difficult to reverse	**Low**—substantial loss of investment associated with abandonment or removal of a peripheral aqueduct and other new infrastructure; politically difficult to reverse

Notes:
1. See Table 2-6 for explanations of tools and scales used to score high, moderate, low, and very low for each metric

7.3.1.1 Criterion #11. Relative degree to which the Option will be able to withstand the effects of climate change (e.g., sea level rise, changes in runoff), variable hydrology, seismic events, subsidence of Delta islands, and other large-scale changes to the Delta

Criterion #11 addresses the ability of the Options to withstand predicted possible large-scale changes to the Delta. The evaluation of this criterion was based on a qualitative assessment of the durability of each Option to withstand the effects of catastrophic events, such as earthquake or flood and climate change-caused sea level rise, on habitat restoration and water supply conveyance. Options 3 and 4 afford the greatest protection from catastrophic disruption of water supply and Option 4 the greatest protection from loss of restored habitat. Option 1 offers the least protection from catastrophic events and sea level rise. Option 2 falls between Options 1 and Options 3 and 4 in avoiding these risks.

Option 1 is expected to be at the greatest risk of water supply disruption from catastrophic levee failures that could result from seismic and flood events because Option 1 does not include improvements to protect conveyance facilities (Table 7-14). Option 1 would support the least durable habitat restoration sites because a smaller area (approximately 28% of the planning area) is available for locating these sites. Greater clustering of restoration sites results in more vulnerability to larger losses of habitat with localized levee failures. In addition, habitat restoration under Option 1 is less likely to be located at sites that could be adapted to address sea level rise because there are fewer locations from which to choose. All Options, however, include restoration outside the planning area at Suisun Marsh, an area that likely is less subject to habitat loss from seismic or flood events than much of the planning area.

Option 2 affords a better level of protection of water supply from catastrophic events, but is still at a higher risk than Options 3 and 4 because the levees that direct conveyance through the north Delta are at greater risk of failure from seismic and flood events than the peripheral aqueduct included in Options 3 and 4 (the aqueduct would be expected to be engineered to withstand probable seismic and flood events). Option 2 provides more area (approximately 35% of the planning area) than Option 1 to distribute restoration sites more broadly to avoid large losses from localized levee failures. Because Option 2 provides more area for habitat restoration than Option 1 it provides more flexibility to locate restoration sites in areas suitable to withstand sea level rise.

Option 3 would provide more protection to water supply from seismic and flood events than Options 1 and 2 because the peripheral aqueduct component of Option 3 is more durable in a seismic or flood event than through-Delta conveyance. Option 3 offers redundancy in the protection of water supply delivery through its dual system and each conveyance offers a back-up to the other should one fail. Option 3 is the only Option with this feature. Option 3 provides more area (approximately 35% of the planning area) than Option 1 to distribute restoration sites more broadly to avoid large losses from localized levee failures. Because Option 3 provides more area for habitat restoration than Option 1 it provides more flexibility to locate restoration sites in areas suitable to withstand sea level rise. Option 3 is comparable to Option 2 in the protection of restoration sites and less protective of restoration sites than Option 4.

Option 4 would provide more protection to water supply facilities from seismic or flood events than Options 1 and 2 because the peripheral aqueduct component is expected to be more durable than in-Delta levees. Option 4 does not have the conveyance redundancy that provides a back-up system for water supply that is part of Option 3. Relocating the intake to the vicinity of Hood reduces the potential for sea level rise to affect water quality. Option 4 provides substantially more area (approximately 75% of the planning area) than all other Options for habitat restoration and, therefore, the most flexibility to find sites suitable to address sea level rise and to better distribute sites to avoid large habitat losses from localized levee failures.

7.3.1.2 Criterion #12. Relative degree to which the Option could improve ecosystem processes that support the long term needs of each of the covered species and their habitats with minimal future input of resources.

This criterion addresses the performance of each Option with regard to avoiding the need for future on-going input of resources to support the conservation of covered species. The evaluation determined that Option 4 would rank highest in sustainability and avoiding such costs. Option 3 ranked second and Options 1 and 2 lowest because of on-going costs of in-Delta facilities operations and fish salvage to achieve conservation objectives (Table 7-14).

Options 1 and 2 would entail ongoing management actions (i.e., salvage and hauling) and costs to address entrainment of covered fish species at the SWP/CVP export facilities and provide limited flexibility for adaptively managing Delta flows to meet species needs in the future. Use of the Delta for both fish habitat and through-Delta conveyance often results in competing operational priorities. Options 1 and 2 are wholly dependent on through-Delta conveyance and therefore are more likely to incur the costs associated with export restrictions. Option 2 requires the on-going cost of barrier management and monitoring to maintain the conservation benefits the barriers provide for fish.

Option 3 would be more likely to sustain ecosystem processes into the future than Options 1 and 2. This Option's dual conveyance facilities provide opportunities to adjust the timing of through-Delta pumping to minimize the likelihood for fish entrainment and its associated salvage costs. Use of the Delta for both fish habitat and through-Delta conveyance often results in competing operational priorities. Option 3, therefore, is considered less likely than Option 4 to sustain ecosystem processes with minimal future inputs because of ongoing costs that would be associated with barrier management and monitoring.

Option 3 also may require ongoing management actions depending on operational rules and changes in fish status as a result of overall conservation actions.

Option 4 provides the greatest habitat sustainability with the lowest future input of resources of the Options because it allows for the largest area of the Delta to be used for physical and hydrological habitat restoration (Table 7-14). Natural processes could be allowed to support fish habitat, as opposed to more engineered solutions required under Options that must balance within-Delta operations between habitat and water supply conveyance. Habitat management under Option 4 is expected to require less input of funds and other resources to sustain fish populations. In addition, the much reduced level of entrainment under Option 4 would avoid the need for funding ongoing fish salvage at CVP and SWP intake facilities or to incur the costs associated with export restrictions.

7.3.1.3 Criterion #13. Relative degree to which the Option can be adapted to address needs of covered fish species over time

Criterion #13 addresses the ability to which the Options can be adapted to address the potential future needs of the covered fish species. The evaluation of this criterion was based on a qualitative assessment of the likely flexibility under each Option to adaptively manage Delta flows and restore additional habitat areas to address current uncertainties and future needs of the covered fish species. Option 4 is the most flexible in allowing for adaptive management of both hydrologic patterns and location of habitat restoration in the Delta. Options 2 and 3 are ranked second because of constraints on adaptive management. Option 1 ranked last with the most limited flexibility.

Option 1 is considered to be the least adaptable of the Options because, to meet water supply objectives, opportunities to adaptively manage Delta flow patterns are minimal. This Option lacks the flexibility for restoring habitats in the central, south, and east Delta if needed to meet the future needs of covered fish species. Under Option 1, only about 28% of the Delta is available for restoration of natural hydrology.

Option 3 is more constrained than Option 4, but does provide opportunities to adaptively manage Delta flows, having the ability to opportunistically convey water through-Delta or via a peripheral aqueduct to maximize benefits for covered species. The operable barriers along Middle River under Option 3 and 2 limit the opportunities for managing Delta flows to a much smaller proportion of the Delta than under Option 4. Under Options 2 only about 35% of the Delta is available for restoration of natural hydrology. With the opportunity to use the peripheral aqueduct, Option 3 would have greater flexibility than Option 2 in the operation of the in-Delta barriers to manage hydrologic conditions east of Middle River for the benefit of covered fish species and other aquatic organisms. The extent of areas available for habitat restoration and adaptive management is more limited under Option 3 than under Option 4.

Option 4 is expected to provide the greatest flexibility among the Options to adaptively manage Delta flows and restored physical habitat for the benefit of covered fish species (Table 7-14). Because it is not constrained by the need to maintain the export quality of water in a through-Delta conveyance, Option 4 provides for the greatest geographic extent and percentage of the Delta area available for habitat restoration should it be necessary to increase the extent of or redistribute restored habitat for covered species in the future. Under Option 4, approximately 75% of the Delta would be available for restoration of natural hydrology and therefore would provide the best locations for physical habitat restoration.

7.3.1.4 Criterion #14. Relative degree of reversibility of the Option once implemented

Criterion #14 addresses the relative ability to reverse each of the Options once they are implemented. The evaluation of this criterion was based on a qualitative assessment of the practicability for reversing the Options based on likely levels of engineering feasibility, public acceptance, and costs for doing so. Option 1 is expected to be the most reversible based on the assumption of limited new facilities (Table 7-14). Option 2 would be more reversible than Options 3 and 4 because it does not involve the peripheral aqueduct. Option 4 ranked third because of greater limits on reversing a completed peripheral aqueduct. Option 3 ranked last because it includes the largest amount of initial capital investment.

Option 1 is considered to be the most easily reversed of the Options because no costs associated with the removal of infrastructure would be incurred relative to current conditions.

Option 2 is less reversible than Option 1, but is considered to be substantially more reversible than Options 3 and 4, which would entail removal or abandonment of a peripheral aqueduct at likely enormous cost and loss of capital investment. Likely costs associated with reversing Option 3, which would also include removal or abandonment of Delta barriers, would be somewhat higher than Option 4. Because costs associated with reversing Options 3 and 4 and the consequent loss of capital investment would be substantial, the probability for obtaining the level of public acceptance necessary to reverse these Options is considered low.

7.4 COMPARISON OF THE OPTIONS RELATIVE TO OTHER RESOURCE IMPACTS CRITERIA

This section provides a comparison of the performance of each Option relative to each of the criteria for impacts on other resources. The summary provided here is based on the evaluations presented in Sections 3.3, 4.3, 5.3, and 6.3. Table 7-15 presents a summary description of the performance of each Option relative to the evaluation metrics provided in Section 2. Table 7-2 provides a summary comparison of the performance of each Option relative to each of the criteria.

Table 7-15. Comparison of the Performance of the Options Relative to Other Resource Criteria Metrics[1]

Metric	Option 1	Option 2 (with pump)	Option 3	Option 4
Criterion #15. Relative degree to which the Option avoids impacts on the distribution and abundance of other native species in the BDCP Planning Area.				
O1. Ability to avoid temporary and permanent impacts on terrestrial habitat in the planning area	**High**—no impacts would occur because no new facilities would be constructed	**Low**—impacts on terrestrial habitats from levee improvements could be between 500-1,000 acres.	**Very Low**—may incur substantial impacts on terrestrial habitats associated with construction of a peripheral aqueduct (likely over 1,000 acres)	**Very Low**—may incur substantial impacts on terrestrial habitats associated with construction of a peripheral aqueduct (likely over 1,000 acres)
O2. Ability to avoid entrainment of other native aquatic species at SWP/CVP pumps under the Option	**Low**—Ongoing entrainment of aquatic organisms in south Delta	**Low**—Ongoing entrainment of aquatic organisms in south and central Delta; possible adverse effects of barriers to fish movement	**Moderate**—Reduction in entrainment of aquatic organisms in south Delta and minimal entrainment anticipated at intake of peripheral aqueduct; possible adverse effects of barriers to fish movement	**High**—No entrainment of aquatic organisms in south Delta and minimal entrainment anticipated at intake of peripheral aqueduct

Table 7-15. Comparison of the Performance of the Options Relative to Other Resource Criteria Metrics[1] (continued)

Metric	Option 1	Option 2 (with pump)	Option 3	Option 4
Criterion #16. Relative degree to which the Option avoids impacts on the human environment.				
O3. Ability to avoid disruption of transportation/traffic patterns	**High**—facilities would not be constructed, therefore, infrastructure would not be affected	**Moderate**—Levee improvement work could affect rail line, Highway 4 and county roads	**Low**—construction of a peripheral aqueduct would affect a substantial number of roads and rail lines	**Low**—construction of a peripheral aqueduct would affect a substantial number of roads and rail lines
O4. Ability to avoid removal of agricultural land for construction of new facilities	**High**—facilities would not be constructed, therefore, agricultural lands would not be affected	**Moderate**—Improvements to about 34 miles of levees could result in removal of agricultural land from production	**Very Low**—construction of a peripheral aqueduct would likely remove a substantial amount of land from production	**Very Low**—construction of a peripheral aqueduct would likely remove a substantial amount of land from production
O5. Ability to avoid reductions in irrigation water quality for agriculture in the Delta	**High**—unlikely to change in-Delta water quality conditions relative to existing conditions	**Moderate**—potential to lower water quality west of Middle R. barriers during growing season, but increase in water quality east of the Middle River barriers	**Moderate**—potential to lower water quality west of Middle R. barriers during growing season, but increase in water quality east of the Middle River barriers	**Moderate**—potential to lower water quality in the south and central Delta during the growing season
O6. Ability to provide high quality export water for use in service areas	**Very Low**—quality of exported water is expected to be similar to current conditions	**Low**—quality of exported water is expected to be improved relative to current conditions	**Moderate**—quality of exported water is expected to be improved relative to current conditions and better than Option 2	**High**—quality of exported water would be substantially better than current conditions and among the Options
O7. Ability to avoid impacts on other, non-biological CEQA/NEPA resources (e.g., cultural resources, air quality, noise, environmental justice)	**High**—facilities would not be constructed, therefore, unlikely to affect other resources relative to existing conditions	**Low**—large construction footprint from levee improvements, but mitigation costs relatively low	**Very Low**—relatively large construction footprint increases potential for substantial impacts and high mitigation costs	**Very Low**—relatively large construction footprint increases potential for substantial impacts and high mitigation costs

Table 7-15. Comparison of the Performance of the Options Relative to Other Resource Criteria Metrics[1] (continued)

Metric	Option 1	Option 2 (with pump)	Option 3	Option 4
Criterion #17. Relative degree of risk of the Option causing impacts on sensitive species and habitats in areas outside of the BDCP Planning Area.				
O8. Ability to provide Delta outflows beneficial to species in Suisun Marsh and Bay	**Moderate**—provides Delta outflows (15,000 cfs) similar to base conditions (15,000 cfs)	**Moderate**—similar Delta outflows to base conditions	**High**—increases Delta outflows (20,000 cfs) from base conditions (15,000 cfs)	**High**—increases Delta outflows (21,000 cfs) from base conditions (15,000 cfs)
O9. Provides potential for Sacramento, American, and Feather River water temperatures beneficial to native fish species, measured by end-of-September Shasta, Folsom, and Oroville Reservoir storage volumes	**Moderate**—improves storage volumes during critical water years relative to current conditions	**Moderate**—improves storage volumes during critical water years relative to current conditions	**High**—improves storage volumes during critical water years relative to current conditions and Options 1, 2, and 4	**Low**—might affect storage volumes during dry and critical water years relative to current conditions and the other Options

Notes:
1. See Table 2-7 for explanations of tools and scales used to score high, moderate, low, and very low for each metric

7.4.1.1 Criterion #15: Relative degree to which the Option avoids impacts on the distribution and abundance of other native species in the BDCP Planning Area

Criterion #15 addresses the degree to which each of the Options avoids potential impacts on native species (other than the covered species) in the planning area. The evaluation of this criterion was based on a qualitative assessment of the likely degree of impacts on native aquatic organisms and terrestrial species present in the Delta. Option 1 would have the least impact on terrestrial species but potentially the greatest impact on aquatic species. Ranked second, Option 4 avoids much of the impacts on aquatic species but has large effects on terrestrial species. Option 2 was ranked third because it has the largest effects on aquatic species and substantial effects on terrestrial species from levee construction. Ranked lowest, Option 3 impacts aquatic species and has large effects on terrestrial species.

Without new facilities, Option 1 would have no construction impacts on native terrestrial species, but on-going entrainment of native aquatic species at the pump facilities would continue. Option 1 would be expected to have greater entrainment of aquatic organisms than the other Options because of the location and more exposed condition of the pump facilities.

Option 2 would have minor impacts on terrestrial and aquatic species associated with construction of operable barriers and the siphon, but 34 miles of levee improvements could result in substantial impacts on riparian and terrestrial species on islands surrounding Middle River and Victoria Canal. Option 2 would have a higher probability for entraining aquatic organisms from the south Delta than Options 3 or 4 because south Delta exports under Option 3 would be much reduced and exports would not be taken from the south Delta under Option 4. The placement and operation of the barriers along Middle River under Options 2 could result in impacts on native aquatic organisms if the barriers sufficiently impede the movement of aquatic species to and from the east and central Delta. Because the barriers are expected to be operable, there is the opportunity to adjust operation of barriers to minimize these potential impacts.

Overall, Option 3 is anticipated to have the largest impacts on native species in the planning area as a result of the large construction impacts of the peripheral aqueduct and additional impact of the barriers and siphon (Table 7-15). Options 3 would result in substantial impacts on terrestrial native species due to construction of a peripheral aqueduct across over 40 miles of upland, riparian, and wetland habitats. The placement and operation of the barriers along Middle River under Options 3 could result in impacts on native aquatic organisms if the barriers sufficiently impede the movement of aquatic species to and from the east and central Delta. Because the barriers are expected to be operable, there is the opportunity to adjust operation of barriers to minimize these potential impacts.

Options 4 would result in substantial impacts on terrestrial native species due to construction of a peripheral aqueduct across over 40 miles of upland, riparian, and wetland habitats. Option 4 is expected to have the least impacts on native aquatic organisms. Water would not be exported from the south Delta, thereby eliminating the probability of entrainment at the SWP/CVP pumping facilities. Operation of a state-of-the-art fish screen at the intake of the peripheral aqueduct is expected to minimize entrainment of aquatic organisms. The loss of food from the Sacramento River may result in greater impacts on aquatic food supply in the Delta than under Options 1 and 2.

7.4.1.2 Criterion #16. Relative degree to which the Option avoids impacts on the human environment.

Criterion #16 addresses the relative degree to which implementation of each Option could impact the human environment. The evaluation of this criterion was based on a qualitative assessment of likely impacts on NEPA/CEQA resource categories. The evaluation of Criterion #16 focuses on the likely range of adverse direct and indirect impacts of the Options in the planning area and not the indirect impacts to water quality and water supply reliability and in the service areas. These issues in the service areas are addressed in Criteria #8 and #11. Option 1 is expected to have the least adverse effects on the human environment with limited new construction. Option 2 was ranked second with more moderate construction impact due to the extent and location of new facilities. Option 4 ranked third and Option 3 last with the large amount of construction impacts associated with new facilities.

Option 1 would have the least overall impacts on the human environment because it would not entail any construction that could disrupt use of the Delta or degrade the human environment and water quality conditions for agriculture in the Delta would be similar to existing conditions (Table 7-15). Although Option 1 would have the fewest direct impacts, it is expected to result in the lowest export water quality with consequent adverse effects on treatment costs, agricultural production, and human health. Option 1 is also the most vulnerable among the Options to future disruption of water supply to service areas as a result of catastrophic events.

Option 2 is expected to have fewer impacts than Options 3 and 4 because improvements of levees under Option 2 is anticipated to affect fewer resources and with less magnitude of impact than the peripheral aqueduct construction. Option 2, is expected to provide higher water quality and be less vulnerable to supply disruption than Option 1, but portions of the conveyance system would still be vulnerable to future disruption and loss of water supply to service areas.

Options 3 and 4 entail construction of a peripheral aqueduct which could lead to substantial permanent (e.g., removal of agricultural land from production; changes in land use) and temporary (e.g., noise, traffic, air quality) impacts. Because Option 3 includes construction of dual conveyance facilities, it would result in greater overall impacts on the human environment than the other Options. Options 3 and 4 are expected to be substantially less vulnerable than Options 1 and 2 to future disruption of water supply. Export water quality improvements would be successively greater and attendant impacts on treatment costs, agricultural production, and human health successively reduced under Options 2, 3, and 4 in that order.

7.4.1.3 Criterion #17. Relative degree of risk of the Option causing impacts on sensitive species and habitats in areas outside of the BDCP planning area.

Other Resource Impacts Criterion #17 addresses the degree of risk for causing impacts on other sensitive species and habitats outside of the planning area. The evaluation of this criterion was based on hydrodynamic modeling results for Delta outflows and end-of-September reservoir storage volumes as indicators of how each of the Options may affect species and habitats downstream and upstream of the Delta, respectively. Option 3 ranked highest because it is most flexible in supporting both upstream and downstream operations beneficial to biological resources (Table 7-15). Option 4 ranked second because of its ability to support greater Delta outflows than Options 1 and 2. Options 1 and 2 were considered similar in their effects on species outside the planning area.

Options 1 and 2 are expected to have a neutral effect relative to base conditions on species and habitats downstream of the Delta because outflows provided under Options 1 and 2 are expected to be similar to base conditions.

Options 3 and 4 would provide average annual Delta outflows higher than Options 1 and 2 and base conditions. Delta outflows during critical months of March and April in critical dry years are similar across all Options. Because they generally would provide for greater Delta outflows, Option 3 and 4 would be the less likely to impact species and habitats in Suisun Marsh and Bay and other downstream locations.

In most water year types, the capacity for providing cold water releases from Shasta, Folsom, and Oroville Reservoirs would be similar under each of the Options and to current conditions. Reservoir storage volumes under Option 4 may be less than under the other Options in dry and critical water years and therefore may be the least likely to provide for cold water releases in those years (Table 7-15). If selected, operations under Option 4 would need to be refined so that cold water temperature requirements are met.

7.5 CONCLUSIONS – OVERALL COMPARISON OF THE OPTIONS

7.5.1 Biological Criteria

The comparison of overall biological benefits of the Options focused primarily on the estuarine species that are most dependent on the Delta (delta smelt, longfin smelt, and splittail). These species are at greater population-level vulnerability to in-Delta impacts than salmon, steelhead, and sturgeon.

Option 4 would provide the greatest benefits among all Options to the estuarine species most dependent on the Delta (Table 7-3). Option 4 would provide the most opportunity to address important stressors to delta smelt, longfin smelt, and splittail. Option 4 also would perform well for salmonids relative to other Options.

Option 3 would provide the next greatest benefits to the most vulnerable estuarine fish and also would perform well for salmonids.

Option 2 would not perform as well as Options 4 for any species; it would provide comparable benefit to salmonids and sturgeon as Option 3, but provides lower benefit to the more vulnerable estuarine species. Option 2 would outperform or match Option 1 for all species.

Option 1 performs the poorest for covered fish species. Option 1 would be outperformed by all other Options for delta smelt, longfin smelt, San Joaquin River salmonids and white sturgeon. Option 1 is matched in performance by all other Options for Sacramento River salmonids, green sturgeon, and splittail.

7.5.2 Planning Criteria

Options 3 and 4 both address planning criteria well and rank higher than Options 1 and 2 in all cases (Table 7-3). Option 4 may be slightly more cost effective and practicable than Option 3, but Option 3 provides greater flexibility to meet water supply goals. Overall Options 3 and 4 were tied for first rank.

Options 1 and 2 were both considered poor in meeting planning criteria. Option 1 was considered too limiting to meet dual habitat conservation and water supply goals and too expensive in the long term due to large on-going costs of low export water quality. Option 2 includes a number of technical challenges for both conservation and water supply objectives. Option 2 costs are relatively high because of levee construction, more limited improvement in export water quality, and additional high cost facilities likely to be necessary (e.g., pump facility and fish screens).

7.5.3 Flexibility/Durability/Sustainability Criteria

Option 4 has the most flexibility and adaptability to adjust conservation approaches both for physical habitat restoration and flow management with the least input of future resources (Table 7-3). Options 3 and 4 both rank highest for durability in the face of sea level rise and catastrophic seismic and flood events. Options 3 and 4 are the least reversible as they involve the most input of resources. Overall Option 4 was ranked highest for flexibility, durability and sustainability. Option 3 ranked second because of its more limited adaptability due to smaller area available for restoration of natural hydrology and physical habitat restoration for covered fish species.

Option 2 is less durable than Options 3 and 4 and more durable than Option 1 in the face of catastrophic events and sea level rise. Option 2 is less flexible than Option 3 and much less flexible than Option 4 to conduct adaptive management to address the needs of covered fish species and with a minimum input of future resources.

Option 1 was ranked the lowest because of it high risk to loss of habitat and water supply from catastrophic events and sea level rise. While Option 1 is obviously the most reversible, it has the least flexibility to adapt water operations and physical habitat restoration to meet the future needs of species without substantial input of resources.

7.5.4 Other Resource Impacts Criteria

Option 1 ranked highest for avoiding direct impacts on other biological and human resources because of the minimal amount of new infrastructure required (Table 7-3). The high indirect effects of Option 1 in service areas were not addressed in this category, but were addressed in the planning criteria under costs. If indirect effects on the human environment of Options 1 in water service areas over the long-term were included in the evaluation of other resource impacts criteria grouping rather than in the planning criteria, then Option 1 may have been ranked lowest for other resource impacts.

Option 2, with a smaller construction impact footprint than Options 3 or 4, ranked second in avoiding impacts. Impacts on biological resources both inside and outside the Delta would be higher than Option 4.

Option 4 ranked third in avoiding impacts. It was ranked behind Option 2 because of the greater direct impacts human environment and ahead of Option 3 because it does not include the new in-Delta facilities of Option 3.

Option 3 ranked last as it would involve the most new construction and would have the most direct impacts on biological resources and the human environment in the Delta. Options 3 and 4 allowed for the most Delta Outflow and would be expected to benefit aquatic species in Suisun Marsh and Bay.

7.5.5 Overall Conclusions

Each Option offers opportunities and constraints to meeting conservation and water supply goals. The conclusions presented in this evaluation regarding which Option would be most successful in meeting the various criteria are dependent on many assumptions used in the analysis, reflecting the uncertainties in the current state of knowledge. Drawing more general conclusions about how each option performs across all of the criteria compounds these assumptions and their uncertainties. Thus, hard and fast conclusions about the overall performance of any particular option should be approached cautiously.

With the above caveats in mind, the conclusion of this report is that both Options 3 and 4 appear to provide significant improvements over the first two options across the biological, planning and flexibility criteria, and both, in turn, score less well in the "other resource impacts" category.

Options 1, 2, and 3 all geographically split the Delta in some way to accommodate the dual use for water conveyance and species conservation. Option 1 focuses physical habitat restoration in the north and west Delta to avoid the conflict at sites in the central and south Delta between conveyance hydrology and the restoration of natural hydrology. Options 2 and 3 split the Delta through engineered structures to separate conveyance to the east and habitat conservation to the west. In doing so, Options 2 and 3 fall in between the extent of habitat opportunities provided by Option 1 (the lowest) and Option 4 (the highest).

Option 3 appears to perform better than all other options in its ability to meet water supply planning goals and objectives, and in its resiliency in response to catastrophic events. Its performance biologically is consistently superior to Options 1 and 2, but is less robust than Option 4. Its dual conveyance feature may provide significant operational flexibility over and above the other options.

Option 4 appears to provide the greatest opportunity to meet the greatest number of criteria. It allows for the most opportunities over a much larger proportion of the Delta to combine the restoration of natural hydrology beneficial to covered fish species with the restoration of physical habitat for those species. It separates geographically and hydrologically the frequently conflicting requirements (structural and operational) of export water conveyance and aquatic species conservation (allowing for the greatest flexibility in accomplishing habitat conservation). Finally, it provides high long-term water supply reliability with the highest export water quality at the lowest overall cost. A key constraint of Option 4 is the limitation of export capabilities to a single north Delta intake – a limitation which affects both water supply reliability and Delta inflows for conservation.

In summary, this evaluation describes how each of the Options performs in relation to a wide range of criteria. This information will assist the Steering Committee over the course of the fall in selecting an option to carry forward into the planning process. The Steering Committee may select of the four options as is, or it may further refine an option into a new hybrid to take into the planning process.

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8.0 OPPORTUNITIES FOR CONSERVATION ELEMENTS AVAILABLE UNDER ALL OPTIONS

This section describes conservation elements and ecological stressors not addressed in the four Options evaluated in this report. These other conservation elements could be important to the conservation of covered species and could be included in the BDCP as it is developed.

The four Options evaluated in this report are not fully formed conservation strategies and, as such, they include only a subset of the conservation elements anticipated for the BDCP. The Options address only a subset of the important stressors affecting covered species. The focus of the Options is modification of water conveyance facilities that allow for changes in the hydrodynamic operation of the Delta and restoration of physical habitat that provides for an increase in the quantity and quality of habitat. These conservation elements primarily address stressors associated with the following:

- direct entrainment losses at the SWP and CVP export facilities;
- indirect mortality associated with fish passage into the central and southern Delta;
- aquatic habitat diversity, quality, quantity, and complexity;
- increased salmon juvenile rearing areas; and
- increased production of organic carbon, phytoplankton, and zooplankton as part of the food web of the Delta ecosystem.

A number of other important stressors are not addressed by the conservation elements in the four Options that may significantly affect the population dynamics of one or more of the covered fish species (see Appendix B). Additional conservation elements have been identified that could be applied to any of the four Options to address these stressors and may be incorporated into the BDCP as the planning process progresses. The additional conservation elements discussed here and other actions that could be implemented to increase the biological benefits associated with modified conveyance facilities and habitat restoration and enhancement opportunities are described for Options 1 through 4. Additional conservation elements could be implemented in or outside the Delta depending on where the greatest benefit to a species could be achieved. Additional in-Delta conservation elements available under all Options and the fish stressors they address are presented in Table 8-1.

Table 8-1. Conservation Elements Available under All Options that would Address Covered Fish Species Stressors in the BDCP Planning Area

Conservation Element	Stressor Addressed [a]	Covered Species Addressed [b]
Reduce the risk of acute and chronic toxicity to fish, macroinvertebrates, phytoplankton, and zooplankton (macroinvertebrates and plankton are important food and food-web components of fish habitat) throughout the Delta by reducing and avoiding point and non-point source discharges of toxicants and contaminants into the Delta	Exposure to Toxics	**Splittail** **Delta smelt** **Longfin smelt** **White sturgeon** **Green sturgeon** **Chinook salmon (all runs)** **Steelhead**
Reduce the risk of acute and chronic effects to fish, macroinvertebrates, phytoplankton, and zooplankton throughout the Delta by reducing and avoiding localized adverse water quality conditions, such as dissolved oxygen depression within the Stockton deep water ship channel associated with managed wetland discharges	Reduced Rearing and Out-migration Habitat	**Chinook salmon (all runs)** **Steelhead**
Reduce and avoid adverse impacts of non-native species on native species (e.g., competition for habitat and food, predation, changes in physical habitat, etc.) throughout the Delta by implementing management actions designed to reduce and avoid the introduction of additional non-native aquatic species into the Delta ecosystem Reduce adverse impacts of non-native species on native species (e.g., competition for habitat and food, predation, changes in physical habitat, etc.) throughout the Delta by implementing and expanding activities designed to reduce or control the abundance or distribution of non-native species currently inhabiting the Delta	Non-native Species Reduced Food	**Splittail** **Delta smelt** **Longfin smelt** **Chinook salmon (all runs)** **Steelhead**
Reduce the effects of harvest mortality on juvenile and adult fish to increase population abundance and resiliency and to take advantage of habitat restoration and enhancement opportunities in re-building fish stocks by modifying recreational and commercial fishing regulations within the ocean and the Delta Reduce the effects of illegal harvest mortality (poaching) on juvenile and adult fish to increase population abundance and resiliency and to take advantage of habitat enhancement opportunities in re-building fish stocks by increased enforcement and prosecution of regulations prohibiting illegal harvest and poaching	Harvest	**Splittail** **White sturgeon** **Green sturgeon** **Chinook salmon (all runs)** **Steelhead**

Table 8-1. Conservation Elements Available under All Options that would Address Covered Fish Species Stressors in the BDCP Planning Area (continued)

Conservation Element	Stressor Addressed [a]	Covered Species Addressed [b]
Reduce entrainment mortality of larval and juvenile fish and macroinvertebrates at unscreened agricultural, municipal, and industrial water diversions located throughout the Delta by installing positive barrier fish screens on currently unscreened water diversions	Entrainment at non-SWP and CVP Diversions	Splittail Delta smelt Longfin smelt White sturgeon Green sturgeon Chinook salmon (all runs) **SR Steelhead** SJR Steelhead
Reduce adverse effects of hatchery production on the genetics and population dynamics of Chinook salmon, steelhead, and potentially other fish species throughout the Delta by modifying hatchery production and management practices	Reduced Genetic Diversity/Integrity	**Chinook salmon (all runs)** **Steelhead**
Increase the availability of tidally influenced subtidal and intertidal aquatic habitat to benefit fish and macroinvertebrates and increase organic carbon, phytoplankton, and zooplankton productions within the Delta through managed breaches flooding of selected Delta islands to increase habitat for fish and wildlife Increase the production of organic carbon, phytoplankton, and/or zooplankton that can subsequently be used to supplement food availability within the Delta food web for a wide variety of aquatic species by managing selected Delta islands for the purpose of producing food supplies that would be discharged into the Delta to augment the food web Increase habitat diversity and complexity and potentially reduce the abundance or geographic distribution of non-native fish and macroinvertebrates within the western and central regions of the Delta by implementing a variable salinity regime to provide additional habitat variability and diversity ranging from the managed freshwater Delta as under current conditions or increasing salinity intrusion further upstream into the Delta. [Note: For conveyance facilities options, the ability to implement variable salinity regimes as a habitat enhancement opportunity are constrained to the greatest degree under Option 1, limited to west of the Middle River under Options 2 and 3, and least constrained under conveyance Option 4 (based on maintaining drinking water quality at the SWP and CVP export facilities).]	Reduced Food Reduced Habitat	**Splittail** **Delta smelt** **Longfin smelt** **White sturgeon** **Green sturgeon** **Chinook salmon (all runs)** **Steelhead**

Table 8-1. Conservation Elements Available under All Options that would Address Covered Fish Species Stressors in the BDCP Planning Area (continued)

Notes:

a. See Appendix B for the stressor impact mechanisms for each species that are addressed by conservation elements.

b. **Bolded** text indicates that the conservation element addresses highly or moderately important stressors identified in Appendix B for the species. Non-bolded text indicates that the conservation element addresses other stressors identified in Appendix B that could affect the species.

CVP = Central Valley Project.

SWP = State Water Project.

The various life stages of some of the covered fish species are dependent on habitats located outside of the Delta. Highly and moderately important stressors on the life stages of these species that result from impact mechanisms that operate outside of the Delta cannot be directly addressed by improving conditions for these species within the Delta. Consequently, the degree of population benefits that would be afforded to these species under the options evaluated and the potential additional conservation elements listed in Table 8-1 are necessarily limited. These outside-the-Delta stressors and impact mechanisms are presented in Table 8-2.

Table 8-2. Stressors and Impact Mechanisms that Affect Covered Species Outside of the Planning Area

Stressor [a,b]	Impact Mechanisms [a]
Sacramento Splittail	
Reduced juvenile/adult rearing habitat (partially addressed in the Delta)	Reclamation of wetlands and islands reduced the shallow, low velocity, brackish habitat (Splittail rearing habitat)
Reduced spawning/larval rearing habitat	• Upstream reservoir operations dampen high flows, thus reducing the extent and duration of floodplain inundation (Splittail spawning habitat) • Riprapped levees reduce the low velocity, shallow water habitat used for spawning and early larval rearing habitat
Reduced food	Upstream reservoir operations dampen high flows and do not allow nutrients and production on floodplains to be tapped
Delta Smelt and Longfin Smelt	
Reduced food (partially addressed in the Delta)	• Upstream reservoir operations dampen high flows and do not allow nutrients and production on floodplains to be tapped • Upstream nutrients and production are exported by pumps with the exported water
Reduced turbidity	Upstream water management and channelization reduces sediment input

Table 8-2. Stressors and Impact Mechanisms that Affect Covered Species Outside of the Planning Area (continued)

Stressor [a,b]	Impact Mechanisms [a]
Sacramento River Chinook Salmon	
Reduced staging and spawning habitat	• Man-made structures (e.g., dams, weirs, boat, and locks) prohibit access to upstream staging and spawning habitat • Removal of gravel by humans or increased sedimentation has reduced gravel availability needed for spawning • Low flows from upstream dams do not provide attraction cues needed by spawning adults to gain access to natal spawning grounds
Reduced rearing and out-migration habitat	• Man-made structures (e.g., dams, weirs, and boat locks) prohibit access to rearing habitat • Upstream reservoir operations dampen high flows, thus reducing the extent and duration of inundation of floodplains and other flow-dependent habitat (salmon rearing habitat and out-migration pathway)
Unnatural mortality (partially addressed in the Delta)	• Reduction in spatial complexity (habitat diversity) of channels reduces refuge space from predators • In-stream gravel pits attract non-native warm water predators and lack cover for salmon • Non-native submerged aquatic vegetation provides suitable habitat for non-native predators that prey on salmon
San Joaquin River Chinook Salmon	
Reduced staging and spawning habitat	• Man-made structures (e.g., dams, weirs, and boat locks) prohibit access to upstream staging and spawning habitat • Low flows from upstream dams do not provide attraction cues needed by spawning adults to gain access to natal spawning grounds • Removal of gravel by humans or increased sedimentation has reduced gravel availability needed for spawning
Reduced rearing and out-migration habitat	• Upstream reservoir operations dampen high flows, thus reducing the extent and duration of inundation of floodplains and other flow-dependent habitat (salmon rearing habitat and out-migration pathway) • Man-made structures (e.g., dams, weirs, and boat locks) prohibit access to rearing habitat

Table 8-2. Stressors and Impact Mechanisms that Affect Covered Species Outside of the Planning Area (continued)

Stressor [a,b]	Impact Mechanisms [a]
Unnatural mortality (partially addressed in the Delta)	• Non-native submerged aquatic vegetation provides suitable habitat for non-native predators that prey on salmon • In-stream gravel pits attract non-native warm water predators and lack cover for salmon • Reduction in spatial complexity (habitat diversity) of channels reduces refuge space from predators
Sacramento River Steelhead	
Reduced staging and spawning habitat	• Man-made structures (e.g., dams, weirs, and boat locks) prohibit access to upstream staging and spawning habitat • Low flows from upstream dams do not provide attraction cues needed by spawning adults to gain access to natal spawning grounds • Removal of gravel by humans or increased sedimentation has reduced gravel availability needed for spawning
Reduced rearing and out-migration habitat	• Upstream reservoir operations dampen high flows, thus reducing the extent and duration of inundation of floodplains and other flow-dependent habitat (steelhead rearing habitat and out-migration pathway) • Man-made structures (e.g., dams, weirs, and boat locks) prohibit access to upstream staging and spawning habitat
Unnatural mortality (partially addressed in the Delta)	• Non-native submerged aquatic vegetation provides suitable habitat for non-native predators that prey on steelhead • In-stream gravel pits attract non-native warm water predators and lack cover for steelhead • Reduction in spatial complexity (habitat diversity) of channels reduces refuge space from predators
San Joaquin River Steelhead	
Reduced staging and spawning habitat	• Man-made structures (e.g., dams, weirs, and boat locks) prohibit access to upstream staging and spawning habitat • Removal of gravel by humans or increased sedimentation has reduced gravel availability needed for spawning • Low flows from upstream dams do not provide attraction cues needed by spawning adults to gain access to natal spawning grounds

Table 8-2. Stressors and Impact Mechanisms that Affect Covered Species Outside of the Planning Area (continued)

Stressor [a,b]	Impact Mechanisms [a]
Reduced rearing and out-migration habitat	• Man-made structures (e.g., dams, weirs, and boat locks) prohibit access to rearing habitat • Upstream reservoir operations dampen high flows, thus reducing the extent and duration of inundation of floodplains and other flow-dependent habitat (salmon rearing habitat and out-migration pathway)
Unnatural mortality (partially addressed in the Delta)	• Non-native submerged aquatic vegetation provides suitable habitat for non-native predators that prey on steelhead • In-stream gravel pits attract non-native warm water predators and lack cover for steelhead • Reduction in spatial complexity (habitat diversity) of channels reduces refuge space from predators
White Sturgeon and Green Sturgeon	
Reduced spawning habitat	Artificial barriers (e.g., dams, weirs, and boat locks) prohibit access to upstream spawning habitat
Increased water temperature (in and near spawning habitat)	Reduced flows from upstream reservoirs increase hydrologic resident time, allowing water to warm
Unnatural mortality (in and near spawning habitat)	Predation by non-native species
Reduced turbidity (in and near spawning habitat)	Upstream water management and channelization reduces sediment input

Notes:

a. Derived from the covered fish species stressor tables in Appendix B.

b. Highly important stressors are shown in standard font and moderately important stressors are shown in italicized font.

Implementing conservation actions outside of the BDCP planning area is not precluded by the BDCP Planning Agreement. If necessary to achieve the goals of the BDCP, conservation actions could be identified for areas outside the planning area that address the stressors and impact mechanisms identified in Table 8-2

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Appendix A. Description of Hydrodynamic Analytical Tools and Summary of Modeling Results

This appendix presents descriptions of analytical tools (A.1), and a summary of modeling results (A.2). The following tables and figures are presented:

APPENDIX A. DESCRIPTION OF HYDRODYNAMIC ANALYTICAL TOOLS AND SUMMARY OF MODELING RESULTS

A.1 DESCRIPTION OF ANALYTICAL TOOLS

A.1.1 CALSIM II PLANNING MODEL

The California Department of Water Resources (DWR)/U. S. Bureau of Reclamation (USBR) CALSIM II planning model was used to simulate the operation of the CVP and SWP over a range of hydrologic conditions. CALSIM is a generalized reservoir-river basin simulation model that allows for specification and achievement of user-specified allocation targets, or goals (Draper et al., 2002). The current application to the Central Valley system is called CALSIM II and represents the best available planning model for the SWP and CVP system operations.

The CALSIM simulation model uses single time-step optimization techniques to route water through a network of storage nodes and flow arcs based on a series of user-specified relative priorities for water allocation and storage. Physical capacities and specific regulatory and contractual requirements are input as linear constraints on system operation using the water resources simulation language (WRESL). The process of routing water through the channels and storing water in reservoirs is performed by a mixed-integer linear programming (MIP) solver. For each time step, the solver maximizes the objective function to determine a solution that delivers or stores water according to the specified priorities and satisfies all system constraints. The sequence of solved MIP problems represents the simulation of the system over the period of analysis.

CALSIM II includes a new hydrology developed jointly by DWR and USBR. Water diversion requirements (demands), stream accretions and depletions, rim basin inflows, irrigation efficiency, return flows, non-recoverable losses, and groundwater operation are components that make up the hydrology used in CALSIM II. Sacramento Valley and tributary rim basin hydrologies are developed using a process designed to adjust the historical sequence of monthly stream flows to represent a sequence of flows at a future level of development. Adjustments to historic water supplies are determined by imposing future level land use on historical meteorological and hydrologic conditions. The resulting hydrology represents the water supply available from Central Valley streams to the CVP and SWP at a future level of development.

CALSIM II also uses an Artificial Neural Network (ANN), developed by DWR, to simulate flow-salinity relationships so that salinity requirements at critical locations in the Delta can be maintained while implementing new operations. The ANN model approximates DSM2 model-generated salinity at the following key locations for the purpose of modeling Delta water quality standards: Sacramento River at Emmaton, San Joaquin River at Jersey Point, Sacramento River at Collinsville, and Old River at Rock Slough. The ANN model incorporates antecedent Delta conditions as well as "carriage water" type influences.

CALSIM II uses logic for determining deliveries to north-of-Delta and south-of-Delta CVP and SWP contractors. The delivery logic uses runoff forecast information, which incorporates uncertainty and standardized rule curves. The rule curves relate storage levels and forecasted water supplies to project delivery capability for the upcoming year. The delivery capability is then translated into SWP and CVP contractor allocations which are satisfied through coordinated reservoir-export operations.

Additional information on the CALSIM II model can be found on the DWR Modeling Support Branch website at http://modeling.water.ca.gov/.

A.1.2 DELTA SIMULATION MODEL (DSM2)

DSM2 is a one-dimensional hydrodynamic and water quality simulation model used to simulate hydrodynamics, water quality, and particle tracking in the Sacramento-San Joaquin Delta (DWR, 2002). DSM2 represents the best available planning model for Delta tidal hydraulic and salinity modeling. It is appropriate for describing the existing conditions in the Delta, as well as performing simulations for the assessment of incremental environmental impacts caused by facilities and operations. The DSM2 model has three separate components: HYDRO, QUAL, and PTM. The relationship between HYDRO, QUAL and PTM is shown in A-1.

The HYDRO module is a one-dimensional, implicit, unsteady, open channel flow model that DWR developed from FOURPT, a four-point finite difference model originally developed by the USGS in Reston, Virginia. DWR adapted the model to the Delta by revising the input-output system, including open water elements, and incorporating water project facilities, such as gates, barriers, and the Clifton Court Forebay. HYDRO simulates velocities and water surface elevations. HYDRO provides the flow input for QUAL and PTM.

The QUAL module is a one-dimensional water quality transport model that DWR adapted from the Branched Lagrangian Transport Model originally developed by the USGS in Reston, Virginia. DWR added many enhancements to the QUAL module, such as open water areas and gates. A Lagrangian feature in the formulation eliminates the numerical dispersion that is inherently in other segmented formulations, although the tidal dispersion coefficients must still be specified. QUAL simulates fate and transport of conservative and non-conservative water quality constituents given a flow field simulated by HYDRO.

PTM simulates pseudo 3-D transport of neutrally buoyant particles based on the flow field simulated by HYDRO. The PTM module simulates the transport and fate of individual particles traveling throughout the Delta. The model uses velocity, flow, and stage output from the HYDRO module to monitor the location of each individual particle using assumed vertical and lateral velocity profiles and specified random movement to simulate mixing. PTM has multiple applications ranging from visualization of flow patterns to simulation of discrete organisms such as fish eggs and larvae.

Additional information on DSM2 can be found on the DWR Modeling Support Branch website at http://modeling.water.ca.gov/.

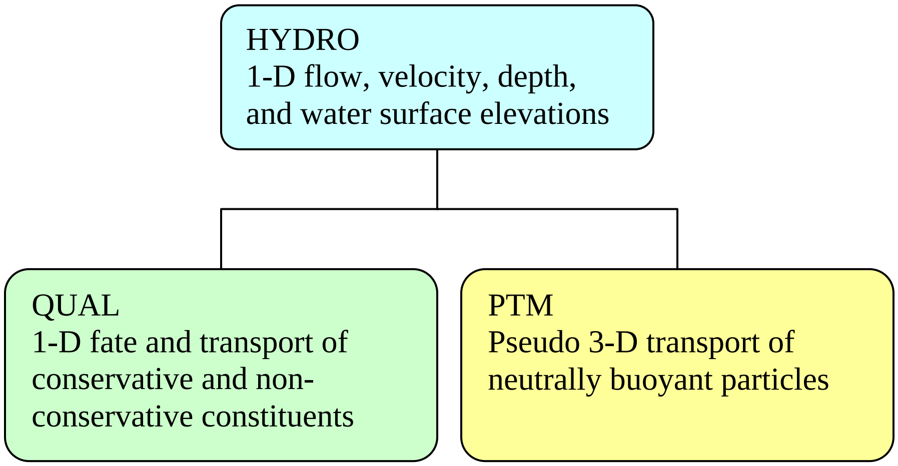

Figure A-1. Schematic of DSM2 Modules

A.1.3 MODELING LIMITATIONS

While the CALSIM II and DSM2 models are the best available planning tools for integrated Central Valley hydrology, CVP/SWP systems operation, and Delta hydrodynamic and water quality analyses, there are several limitations with the models and analytical process that should be highlighted. As was discussed previously, the modeling performed for this evaluation report should be considered "screening-level", consistent with the objectives and timeframe for this report. More refined modeling analyses should be performed to evaluate individual options further.

One of the main limitations of the CALSIM II model is the time step of simulation and data input. CALSIM II includes monthly hydrologic data sets and simulates operations and river flows on the same time step. Average flows over the monthly time step will obscure daily variations that may occur in the rivers due to dynamic system-routing effects or natural hydrologic variability. The monthly time step also requires averaging (usually day-weighted) to simulate operations for regulatory criteria that are specified for a portion of a month. Special procedures have been developed for VAMP-, X2-, and export-based sub-monthly criteria. The averaging process can lead to either under- or over-estimation of water availability or costs associated with the criteria.

The CALSIM II model also uses generalized rules to specify the operations of the CVP and SWP systems. These rules have been developed based on significant CVP/SWP operator input, but still represent coarse estimates of project operations over all hydrologic conditions. The results from a single CALSIM II simulation may not necessarily represent the exact operations for a specific month or year, but should reflect long-term trends. CALSIM II is most appropriately applied as a comparative tool to reflect how changes in facilities and operations may affect the CVP-SWP as has been used in these study. The model should be used with caution to prescribe seasonal or to guide real-time operations, predict flows or water deliveries for any real-time operations.

Additional information is provided through the CALSIM II Peer Review Process which can be found at http://baydeltaoffice.water.ca.gov/modeling/hydrology/CalSimII/index.cfm.

There are also limitations inherent in the use of a one-dimensional model, such as DSM2, to predict hydrodynamics and salt transport in a complicated physical environment like the Sacramento/San Joaquin Delta. A one-dimensional model assumes that a single average velocity, over the channel cross section, can adequately represent velocity in a channel, meaning that variations both across the width of the channel and through the water column are negligible. DSM2 does not have the ability to model short-circuiting of flow through a reach, where a majority of the flow in a cross section is confined to a small portion of the cross section. DSM2 also does not explicitly account for dispersion due to flow accelerating through channel bends.

A.2 SUMMARY OF KEY OBSERVATIONS FROM MODELING RESULTS

Table A-1 presents a summary of key observations from the modeling results. This table presents a synopsis of operation controls, Delta flows, exports, water quality, and particle transport and fate modeling results. In addition, a sampling of modeling results for Below Normal years are provided in Figures A-3 through A-14 to provide the reader with a “feel” for the conditions resulting from each option. Detailed modeling results for each option are presented in Appendices D-G.

Option 1

The most significant change in the “less restrictive” scenario of Option 1 is the removal of the export-inflow ratio control. The removal of this control allows greater exports, but results in lower outflows and increased X2 position under certain conditions. The D-1641 Agricultural standards tend to control more frequently as compared to the Base.

Under the “more restrictive” scenario of Option 1, the Old and Middle River flow restrictions dominate the control of project operations. Significant export curtailments are necessary to achieve these restrictions. Delta outflows, QWEST, and Old and Middle River flows are all increased in this scenario as exports are reduced. Upstream reservoir storage tends to be higher in this scenario due to reduced project reservoir releases under this reduced export capability.

Option 2

The most significant observation from the modeling of Option 2 is that the siphon capacity significantly affects the function of this option. The 4,500 cfs siphon capacity also tends to limit the range of conditions between the “less restrictive” and “more restrictive” scenarios. Export curtailments, as compared to the Base condition, are significant in both scenarios. The reduced exports cause increased QWEST and Delta outflows and pushes X2 more westward.

Water quality, however, is improved in Middle River and at the export facilities due to the more direct path for Sacramento River water to flow to the south Delta. Emmaton and Jersey Point water quality also improves as the Delta outflow is increased. Conversely, the EC in Old River is increased and now more closely resembles that of the San Joaquin River. Residence times in the central Delta are expected to be significantly longer than the Base under this option and very few particles reach the export pumps except for those inserted into Middle River.

Option 3

Option 3 allows significant flexibility in terms of CVP/SWP operations and as such allows export similar or greater than the Base study. Despite preferentially operating the peripheral aqueduct diversion, approximately 20% of the total diversions continue to come from south Delta diversions. The Rio Vista flow requirements are the primary control on operations and also contribute to some of the water solely available for south Delta diversions. The additional requirements for Rio Vista under the “more restrictive” scenario contribute to lower exports as compared to the “less restrictive” scenario. To a lesser extent, the introduction of QWEST and Middle River restrictions control project operations.

Water quality at the export facilities is improved due to a greater proportion of the total exports being derived from the Sacramento River. Water quality at Emmaton and Jersey Point, however, is higher than the Base due to slight reductions in Delta outflow. Particle tracking simulations indicate that the longer residence times are expected in the central Delta under this option. In general, results indicate particle fate similar to Option 2 when the siphon is being operated and similar to Option 4 when the peripheral aqueduct diversion is being operated. However, it should be noted that there are periods of simultaneous operation of both diversion facilities.

Option 4

The modeling of Option 4 was challenging due to the resulting tradeoffs of Rio Vista flow requirements and upstream storage conditions. The addition of the greater flow requirements at Rio Vista caused increased releases from upstream reservoirs. These releases caused Oroville reservoir storage, in particular, to be drawn down further than would likely be permissible during critical periods. The reduction in exports is primarily due to this reduced water supply condition upstream.

As anticipated, water quality at the export facilities is significantly improved and is the same as Sacramento River water quality. EC at Emmaton and Jersey Point is generally reduced as the lack of south Delta diversions reduces intrusion of Bay salt. More complicated, however, is the EC in Old River which is reduced in the fall but increased in winter and spring as San Joaquin River and Bay salt contribute to varying degrees. Longer central Delta residence times are expected under this option and no particles were observed to enter the Isolated Facility. However, due to longer residence times more particles are observed in the modeling to be drawn into the in-Delta Agricultural diversions.

Table A-1. Key Observations from Modeling Results

Scenario	Operations Control	Delta Flows	Exports	Other System Responses	Water Quality	Particle Transport and Fate
1A	• Export-inflow ratio controls removed • DCC change in June from Base • More frequent Ag water quality controls	• SJR flow shift in Apr-May due to different implementation of VAMP • Rio Vista flow increase and QWEST decrease in June due to DCC change	• Increase (~110 TAF/YR) primarily due to exclusion of export-inflow ratio standard	• Upstream storage conditions similar to Base	• Export and Old River (Hwy 4) EC decreased in Dec-Mar due to increase in exports (more Sac water) • Slight increase in Emmaton/Jersey Pt EC due to reduced outflow/QWEST	• Similar to Base conditions
1B	• OMR flow restrictions is <u>primary</u> control • X2 controls in Apr-Jun	• Delta outflow and Rio Vista flow increased due to export reductions and X2 requirements	• Decrease (~3.8 MAF/YR) primarily due to OMR flow requirements	• Upstream storage higher than Base as projects release less water due to limited export capability	• Export/OR (Hwy 4) EC significantly increased in Dec-May due to decrease in exports (less Sac water) • Emmaton/Jersey Pt EC reduced due to higher outflow/QWEST	• Longer central Delta residence times • Greater lag time for particles to reach pumps, but general patterns similar to 1A

Table A-1. Key Observations from Modeling Results (continued)

Scenario	Operations Control	Delta Flows	Exports	Other System Responses	Water Quality	Particle Transport and Fate
2A	• Siphon capacity is primary control	• QWEST flow significantly increased • Rio Vista flow increased Feb-Jun (X2), decreased Jul-Sep (balanced conditions) • Delta outflow increased due to lower exports • OMR flows greater than -4,000 cfs	• Decrease (~2.8 MAF/YR) primarily due to siphon capacity	• Upstream storage higher than Base as projects release less water due to limited export capability	• Export EC lower than Base in all months • OR Hwy4 higher than Base in all months, except Oct-Nov due to SJR contribution • Emmaton/Jersey Pt EC reduced due to higher outflow	• Longer central Delta residence times if particles are not in Middle River • Very few particles reach export pumps except those inserted into Middle River • Most particles move past Chipps when released in vicinity of confluence
2B	• Siphon capacity is primary control • Greater X2 and Rio Vista controls	• QWEST positive • Rio Vista flow increased Feb-Jun (X2), decreased Jul-Sep (balanced conditions) • Delta outflow increased due to lower exports • OMR flows greater than -4,000 cfs	• Decrease (~3.4 MAF/YR) primarily due to siphon capacity	• Upstream storage higher than Base as projects release less water due to limited export capability	• Export EC lower than Base in all months • OR Hwy4 higher than Base in all months, except Oct-Nov due to SJR contribution • Emmaton/Jersey Pt EC reduced due to higher outflow	• Longer central Delta residence times if particles are not in Middle River • Very few particles reach export pumps except those inserted into Middle River • Most particles move past Chipps when released in vicinity of confluence • Shorter residence times in central Delta compared to 2A

Table A-1. Key Observations from Modeling Results (continued)

Scenario	Operations Control	Delta Flows	Exports	Other System Responses	Water Quality	Particle Transport and Fate
3A	• SWP/CVP diversion through Isolated Facility and siphon • Rio Vista and X2 dominate controls	• QWEST increased Oct-May, similar to Base Jun-Sep • Rio Vista flow decreased and controlling • Delta outflow reduced Oct-May, similar to Base Jun-Sep • OMR flows generally greater than -4,000 cfs	• Increase (~400 TAF/YR) from Base due to increased flexibility	• Upstream storage conditions similar to Base	• Export EC lower than Base in all months – greater Sac R proportion • OR Hwy4 higher than Base in all months, except Oct-Nov • Emmaton/Jersey Pt EC higher than Base in all months due to reduced Sac R flows to mix with higher bay salt	• Similar to 2A when siphon exports are occurring • Similar to 4 when no south Delta exports – long central Delta
3B	• SWP/CVP diversion through Isolated Facility and siphon • Rio Vista and X2 dominate controls	• QWEST positive • Rio Vista flow decreased and controlling • Delta outflow increased Feb-Jun, similar to Base Jul-Jan • OMR flows generally greater than -3,000 cfs	• Similar to Base	• Upstream storage conditions similar to Base	• Export EC lower than Base in all months – greater Sac R proportion • OR Hwy4 higher than Base in all months, except Oct-Nov • Emmaton/Jersey Pt EC higher than Base in all months due to reduced Sac R flows to mix with higher bay salt	• Similar to 2A when siphon exports are occurring • Similar to 4 when no south Delta exports – long central Delta • Shorter central Delta residence times compared to 3A

Table A-1. Key Observations from Modeling Results (continued)

Scenario	Operations Control	Delta Flows	Exports	Other System Responses	Water Quality	Particle Transport and Fate
4A	• SWP/CVP diversion through Isolated Facility only • Rio Vista and Delta water quality <u>dominate</u> controls	• QWEST positive • Rio Vista flow decreased and controlling • Delta outflow reduced Feb-Jun • OMR flows generally greater than -1,000 cfs	• Slight decrease (~70 TAF/YR) from Base due to lower storage conditions	• Upstream storage was lower than Base due to Rio Vista minimum flow requirements • Upstream vs downstream tradeoff significant	• Export EC lower than Base in all months – Sac R water quality • OR Hwy4 lower in fall, but increased in winter-spring • Emmaton/Jersey Pt EC reduced due to less ocean salt intrusion with no south Delta diversion	• Longer central Delta residence times • No particles drawn into exports • Due to longer residence times, more particles taken by Ag intakes
4B	• SWP/CVP diversion through Isolated Facility only • Rio Vista minimum flow requirements and X2 <u>dominate</u> controls	• QWEST positive • Rio Vista flow decreased and controlling • Delta outflow increased by ~ 1.2 MAF/YR due to X2/Rio Vista requirements • OMR flows generally greater than -1,000 cfs	• Decrease (~770 TAF/YR) from Base due to lower storage conditions	• Upstream storage was lower than Base due to Rio Vista minimum flow requirements • Upstream vs downstream tradeoff significant	• Export EC lower than Base in all months – Sac R water quality • OR Hwy4 lower in fall, but increased in winter-spring • Emmaton/Jersey Pt EC reduced due to less ocean salt intrusion with no south Delta diversion	• Similar to 4A

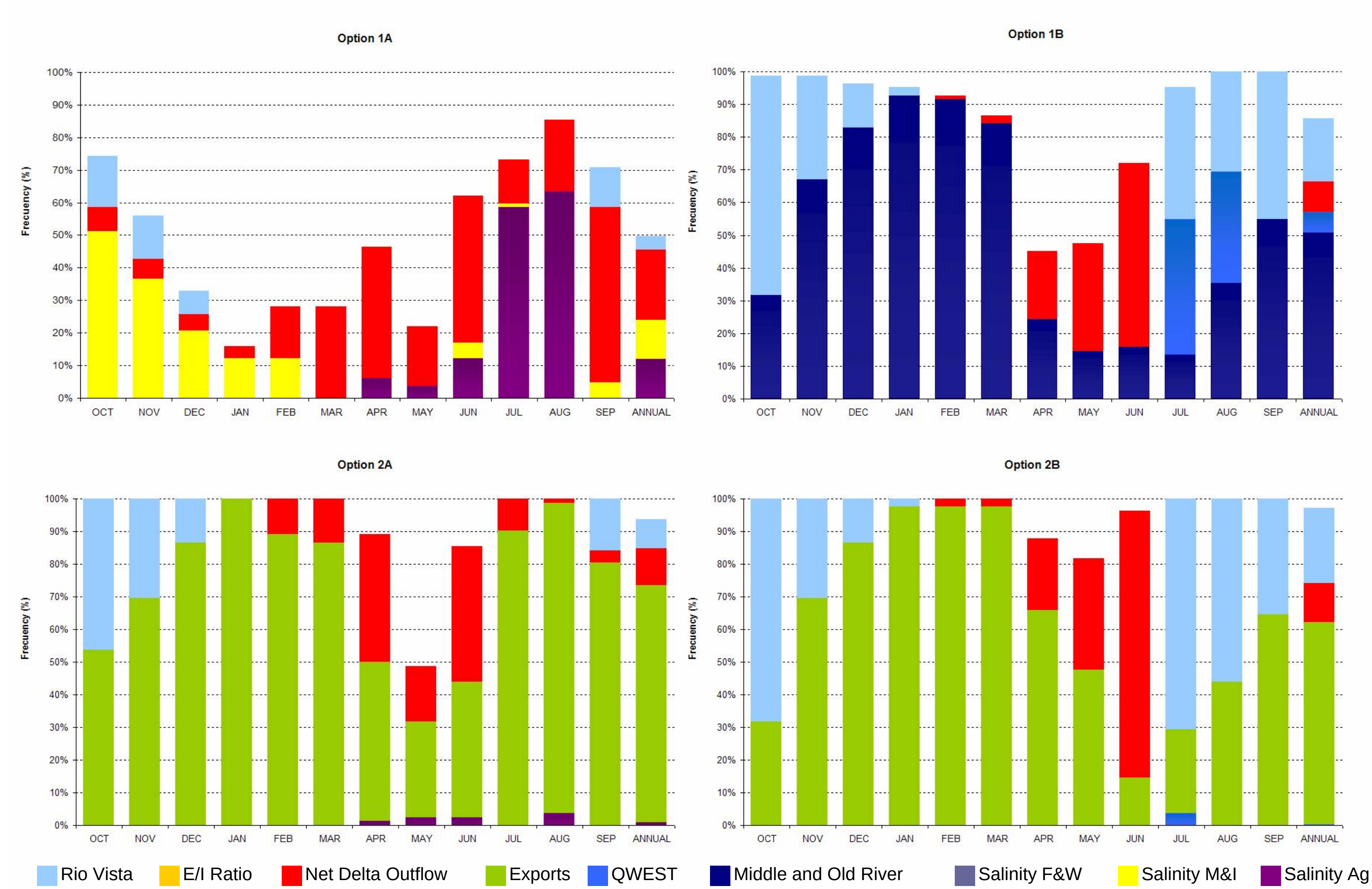

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Figure A-2a. Simulated Delta operational controls in Option 1 and Option 2

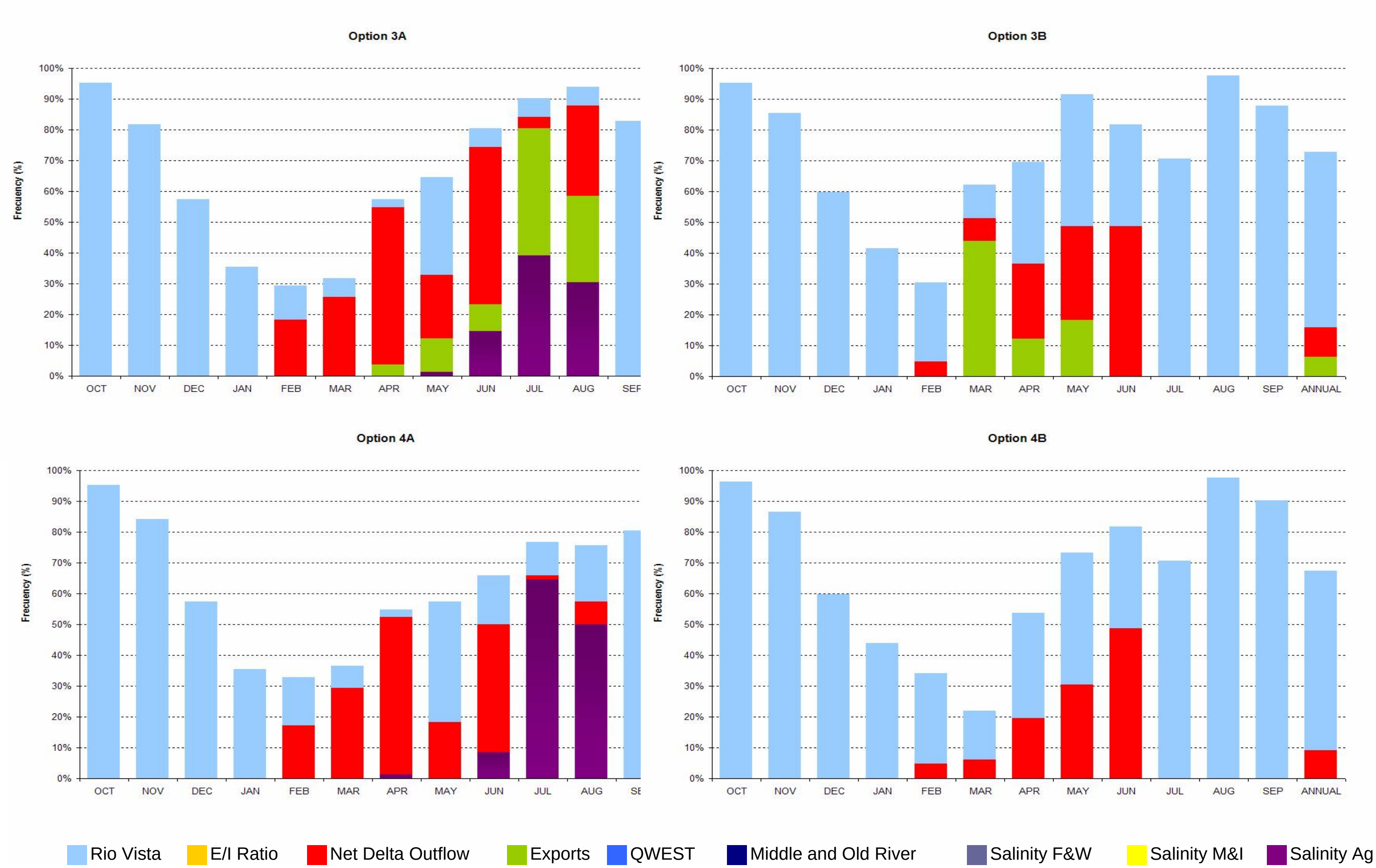


Figure A-1b. Simulated Delta operational controls in Option 3 and Option 4

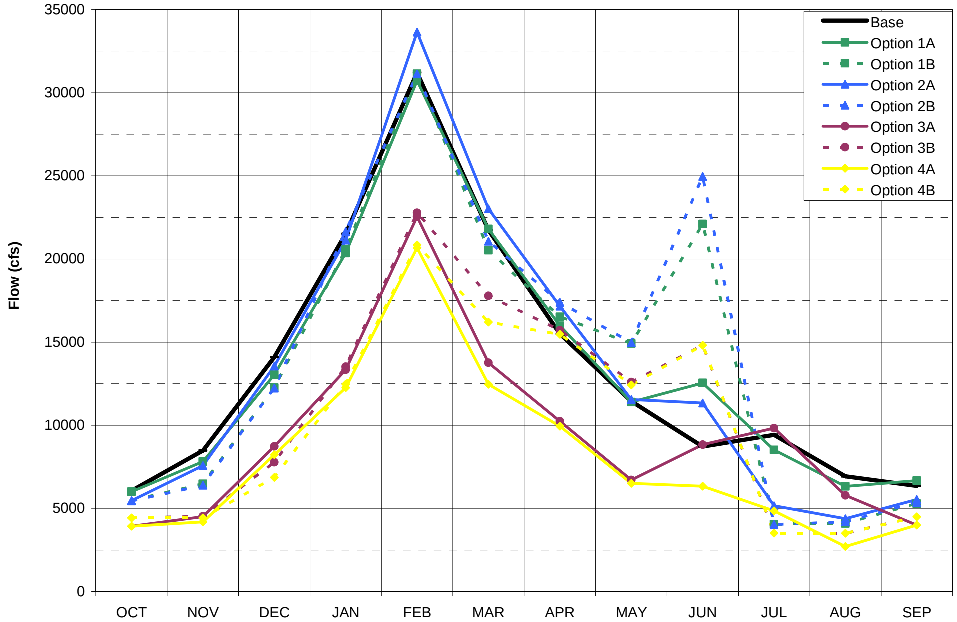


Figure A-2. Sacramento River at Rio Vista monthly average flow for below normal years

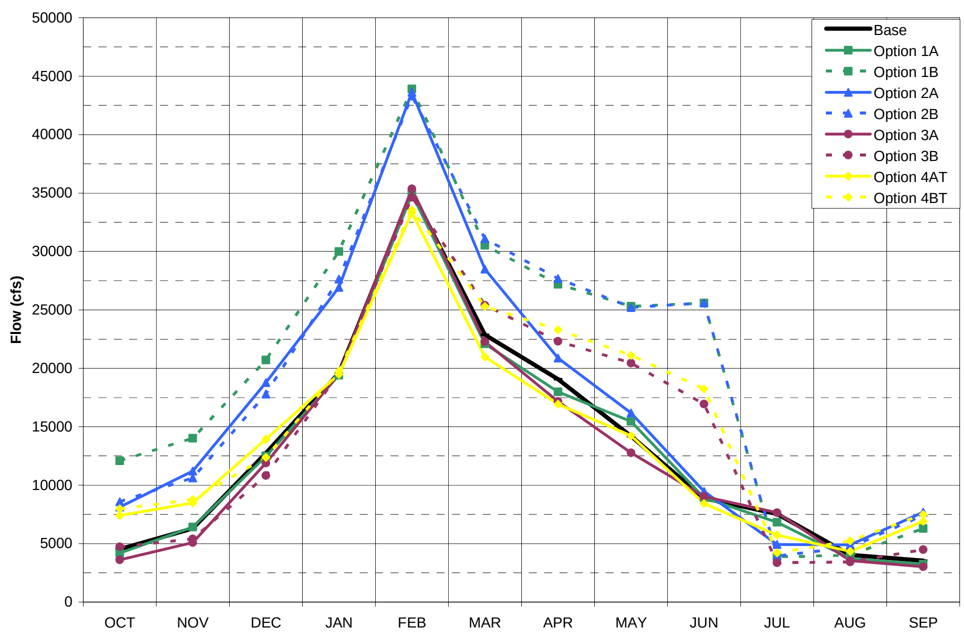


Figure A-3. Delta outflow monthly average flow for below normal years

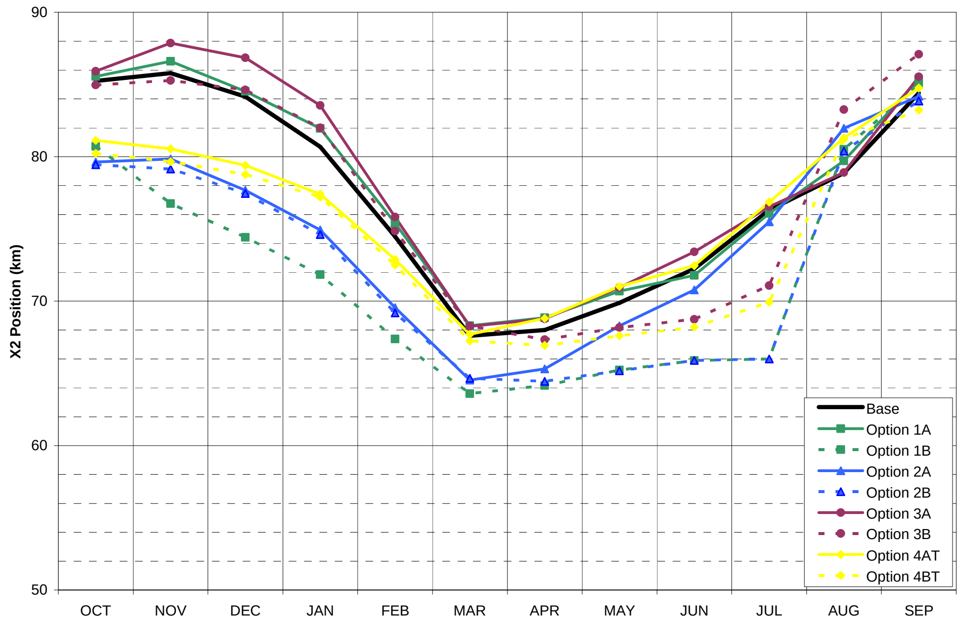


Figure A-4. Monthly average X2 position for below normal years

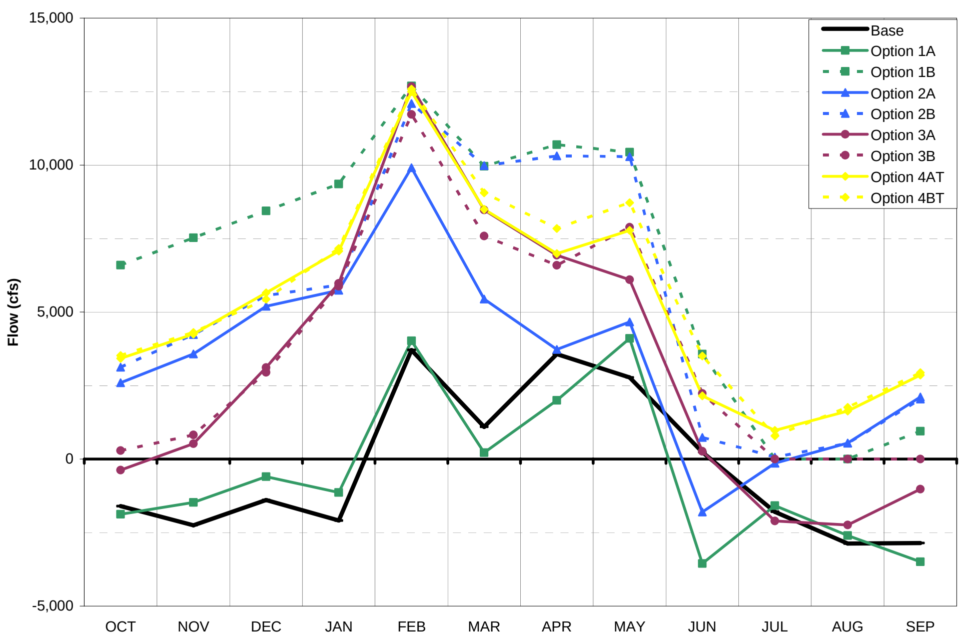


Figure A-5. QWEST monthly average flow for below normal years

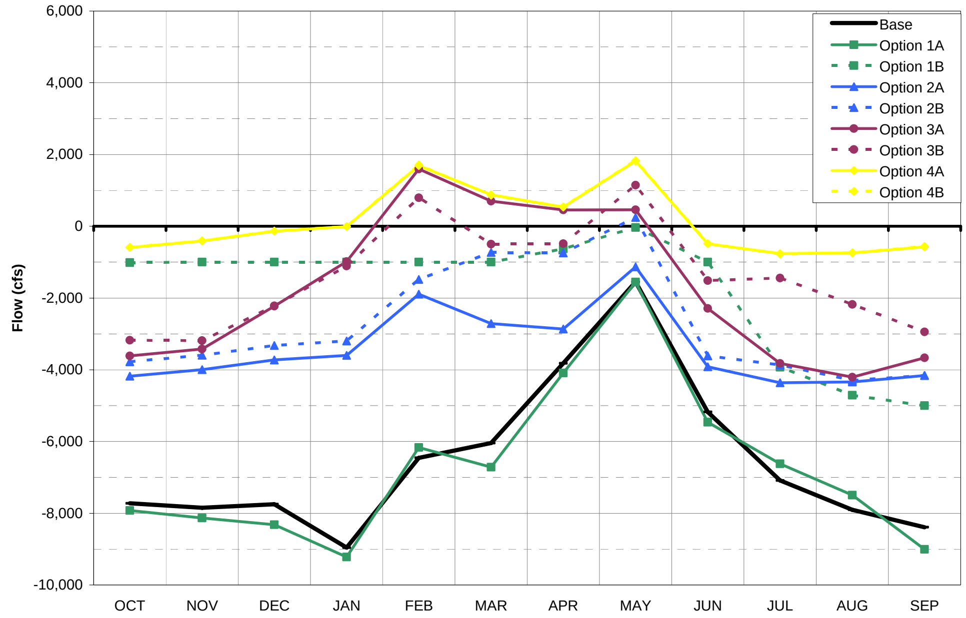


Figure A-6. Combined Old and Middle River monthly average flow for below normal years

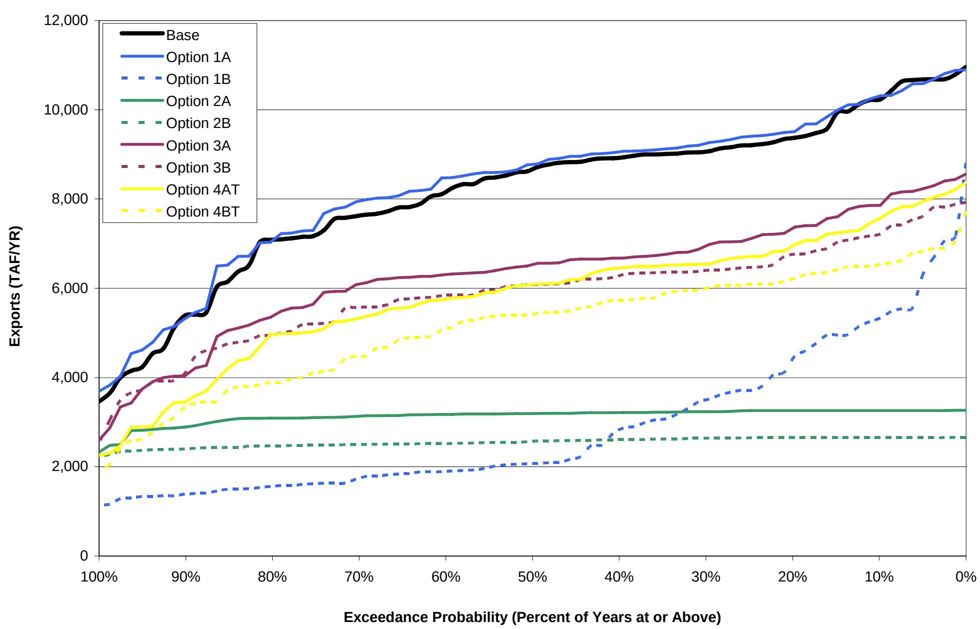


Figure A-7. CVP/SWP annual export reliability

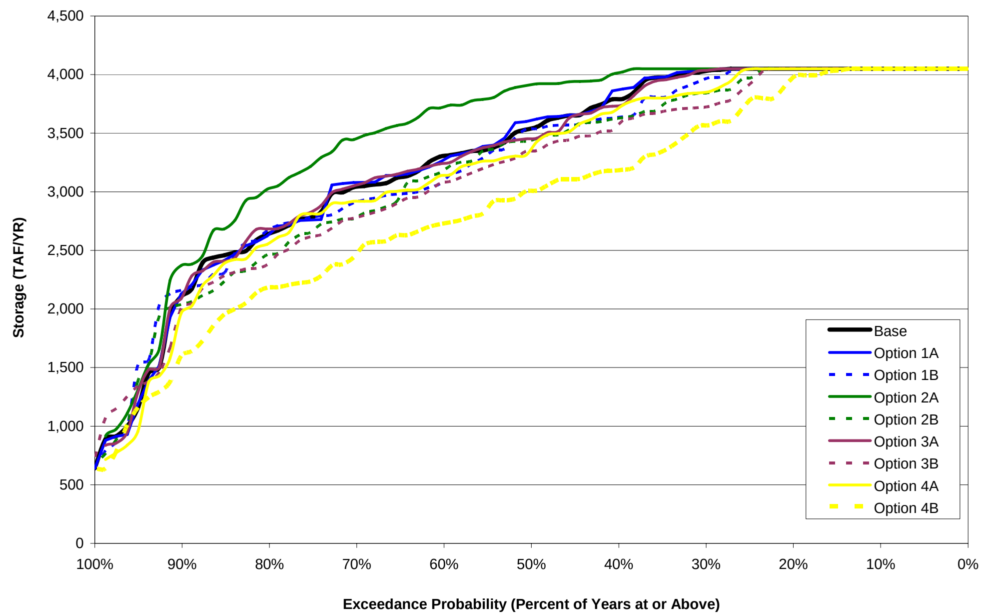


Figure A-8. CVP north of Delta end of September storage (Shasta plus Folsom) exceedance probability

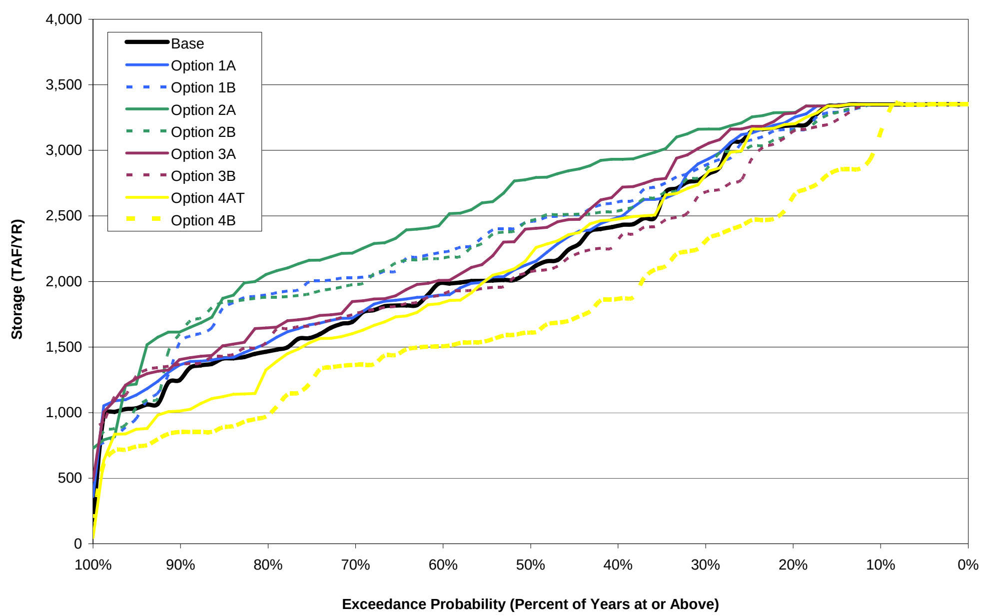
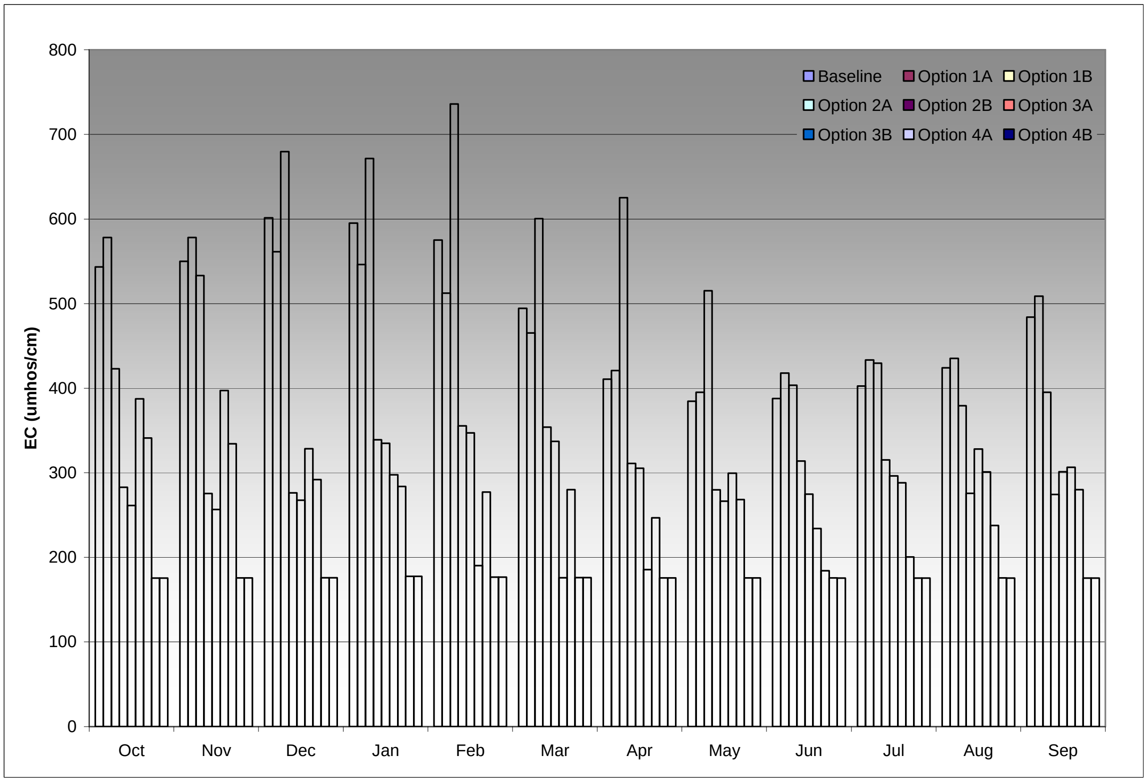


Figure A-9. SWP north of Delta end of September storage (Oroville) exceedance probability



Note: EC for Baseline, Option 1A and Option 1B is blended between Banks and Tracy. EC for Option 3A and Option 3B is blended between IF and Siphon

Figure A-10. Average export water quality, 1975-1991

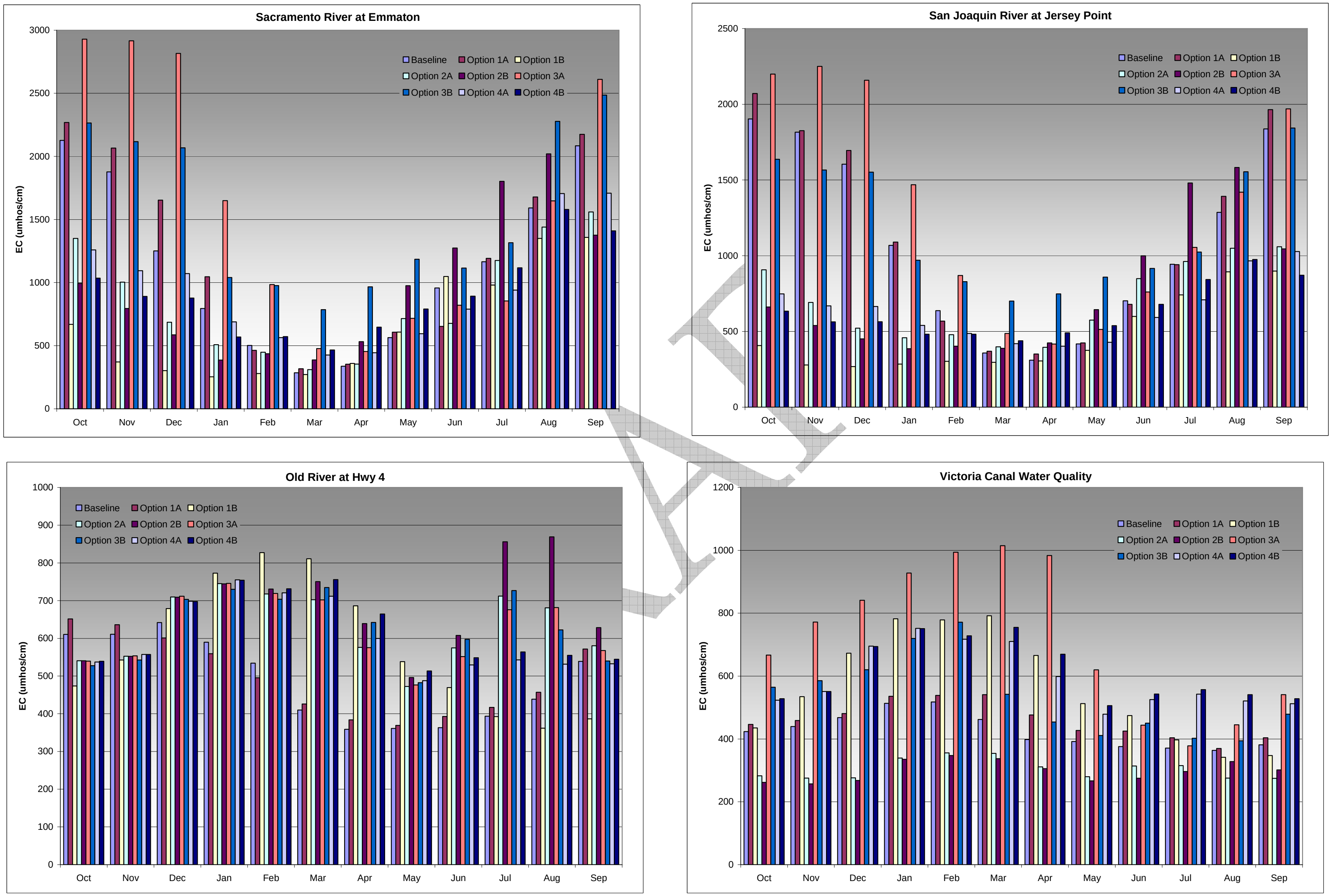


Figure A-11. In Delta average water quality, 1975-1991

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Appendix B. Input Assumptions and Flow Parameter Values Used In CALSIM II and DMS2 Modeling

This appendix presents the input assumptions and flow parameters and values for the 4 Options, as well as the following tables and figures:

Table B-1. Option evaluation report base condition assumptions for CALSIM II Model

Table B-2. Flow Parameters and Values for Option 1

Table B-3. Flow Parameters and Values for Option 2

Table B-4. Flow Parameters and Values for Option 3

Table B-5. Flow Parameters and Values for Option 4

Table B-6. Summary of model operational parameters for BDCP Conservation Strategy Options 1 - 4

APPENDIX B. INPUT ASSUMPTIONS AND FLOW PARAMETER VALUES USED IN CALSIM II AND DMS2 MODELING

This appendix presents the modeling assumptions, flow parameters, and parameter values used to model the hydrodynamic performance of each of the Options under a range of possible operations. CALSIM II inputs and base condition assumptions are provided in Table B-1. Flow parameters and values are provided for each of the Options 1-4 in Tables B-2 through B5, respectively. These flow parameters were developed to allow for coarse modeling of the Options to provide information necessary to perform the evaluation of the Options. They are not designed nor intended to represent proposed operational flow parameter values for the system by either the SAIC team or any entity on the Steering Committee, nor should they be misconstrued as such. The range of operational flow parameters was defined in two operational scenarios developed by SAIC: "Scenario A" and "Scenario B." These scenarios were selected for the purpose of evaluating a range of operational conditions under each Option. It should be recognized that many different combinations of parameter settings could have been used as model inputs and that these two operational scenarios represent simplified and arbitrarily selected examples. Table B-6 presents a side-by-side summary of the flow parameter input values for all four Options.

In addition to the assumptions and input parameters presented in Tables B-1 through B-5, the following sections describe modeling assumptions for each Option.

Option 1 Assumptions

The following assumptions were used in modeling Option 1:

- Water conveyance and south of Delta storage are assumed to not limit pumping operations– model evaluation parameter.
- Upstream reservoir storage and releases will be made in accordance with current requirements to support salmon and steelhead habitat and maintain suitable water temperatures and compliance with existing agreements and regulatory requirements including FERC conditions and ESA requirements.

Option 2 Assumptions

The following assumptions were used in modeling Option 2:

- Water conveyance and south of Delta storage are assumed to not limit diversion operations– model evaluation parameter.
- Upstream reservoir storage and releases will be made in accordance with current requirements to support salmon and steelhead habitat and maintain suitable water temperatures and compliance with existing agreements and regulatory requirements including FERC conditions and ESA requirements.
- The barriers would be closed year-round, but may be periodically opened to promote flushing and improved water quality within the Old River region.

- A gravity siphon would be installed between Victoria Canal and Clifton Court Forebay to allow the San Joaquin River flows to follow Old River into the central Delta.

Option 3 Assumptions

The following assumptions were used in modeling Option 3:

- Water conveyance and south of Delta storage are assumed to not limit diversion operations– model evaluation parameter.
- Upstream reservoir storage and releases will be made in accordance with current requirements to support salmon and steelhead habitat and maintain suitable water temperatures and compliance with existing agreements and regulatory requirements including FERC conditions and ESA requirements.
- The barriers would be closed year-round, but may be periodically opened to promote flushing and improved water quality within the Old River region.
- A gravity siphon would be installed between Victoria Canal and Clifton Court Forebay to allow the San Joaquin River flows to follow Old River into the central Delta.
- Option 3 assumes that a dual conveyance system could be operated including:
    - Through-Delta conveyance in which SWP and CVP opportunistic export operations from the existing south Delta facilities.
    - A completely isolated conveyance that assumes SWP and CVP export operations could occur exclusively from a state-of-the-art positive barrier fish screen located on the Sacramento River in the general vicinity of Hood and isolated water conveyance canal with an intertie to both the SWP and CVP export facilities in the south Delta. The existing south Delta export facilities could be used in conjunction with the isolated facility for water diversions from the Delta.
    - Under the assumptions used to evaluate Option 3 it has been assumed that the isolated conveyance facility would be preferentially operated at all times. The dual conveyance would be operated only when one or more of the operational parameters are controlling exports at the isolated facility (e.g., Rio Vista flows) and opportunities exist to supplement water exports by also operating the south Delta export facilities. For purposes of this assessment it has been assumed that the dual facility would be operated in accordance with both the Option 2 and Option 4 criteria depending on the export operations of both the isolated facility and/or south Delta exports.

Option 4 Assumptions

The following assumptions were used in modeling Option 4:

- Water conveyance and south of Delta storage are assumed to not limit diversion operations– model evaluation parameter.

- Upstream reservoir storage and releases will be made in accordance with current requirements to support salmon and steelhead habitat and maintain suitable water temperatures and compliance with existing agreements and regulatory requirements including FERC conditions and ESA requirements.

- Option 4 assumes SWP and CVP pumping operations would occur exclusively from a state-of-the-art positive barrier fish screen located on the Sacramento River in the general vicinity of Hood and isolated water conveyance canal with an intertie to both the SWP and CVP diversion facilities in the south Delta. The existing south Delta diversion facilities would not be used for water diversions from the Delta.

Table B-1. Option Evaluation Report Base Condition Assumptions for CALSIM II Model

Table B-1
CALSIM II Inputs
Bay-Delta Conservation Plan – Evaluation Report Assumptions

	Base (=Existing) Condition Assumption
Planning horizon	2004[a]
Demarcation date	June 1, 2004[a]
Period of simulation	82 years (1922-2003)
HYDROLOGY	
Level of development	2005 level[b]
Sacramento Valley (excluding American River)	
CVP	Land-use based, limited by contract amounts[d]
SWP (FRSA)	Land-use based, limited by contract amounts[e]
Non-project	Land-use based
Federal refuges	Recent historical Level 2 deliveries[f]
American River	
Water rights	2004[g]
CVP	2004[g]
PCWA	No CVP contract water supply
San Joaquin River[i]	
Friant Unit	Limited by contract amounts, based on current allocation policy
Lower Basin	Land-use based, based on district level operations and constraints
Stanislaus River	Land-use based, based on New Melones Interim Operations Plan[j]
South of Delta (CVP/SWP project facilities)	
CVP	Demand based on contracts amounts[d]
CCWD	124 TAF CVP contract supply and water rights[k]
SWP	Demand varies based pattern used for 2004 OCAP Today studies; Table B transfers that occurred in 2005 and 2006 are not included
Article 56	Based on 2002-2006 contractor requests
Article 21	MWD demand up to 100 TAF/month from December to March, total of other demands up to 84 TAF/month in all months[e,l]
Federal refuges	Recent historical Level 2 deliveries[f]

Table B-1
CALSIM II Inputs
Bay-Delta Conservation Plan – Evaluation Report Assumptions

	Base (=Existing) Condition Assumption
FACILITIES	
Systemwide	Existing facilities[a]
Sacramento Valley	
Shasta Lake	Existing, 4,552 TAF capacity
Colusa Basin	Existing conveyance and storage facilities
Upper American River	PCWA American River pump station not included
Lower Sacramento River	Freeport Regional Water Project not included
Delta Region	
SWP Banks Pumping Plant	6,680 cfs capacity[a]
CVP C.W. Bill Jones Pumping Plant (Tracy PP)	4,200 cfs plus diversions upstream of DMC constriction
Los Vaqueros Reservoir	Existing storage capacity, 100 TAF, (Alternative Intake Project not included)
San Joaquin River	
Millerton Lake (Friant Dam)	Existing, 520 TAF capacity
South of Delta (CVP/SWP project facilities)	
South Bay Aqueduct Enlargement	None
California Aqueduct East Branch Enlargement	None
WATER MANAGEMENT ACTIONS (CALFED)	
Water Transfer Supplies (available long term program)	
Phase 8[n]	None
Lower Yuba River Accord	Not included
REGULATORY STANDARDS	
Trinity River	
Minimum flow below Lewiston Dam	Trinity EIS Preferred Alternative (369-815 TAF/yr)
Trinity Reservoir end-of-September minimum storage	Trinity EIS Preferred Alternative (600 TAF as able)
Clear Creek	
Minimum flow below Whiskeytown Dam	Downstream water rights, 1963 USBR Proposal to USFWS and NPS, and USFWS discretionary use of CVPIA 3406(b)(2)
Upper Sacramento River	
Shasta Lake end-of-September minimum storage	SWRCB WR 1993 Winter-run Biological Opinion (1900 TAF)

Table B-1
CALSIM II Inputs
Bay-Delta Conservation Plan – Evaluation Report Assumptions

	Base (=Existing) Condition Assumption
Minimum flow below Keswick Dam	Flows for SWRCB WR 90-5 and USFWS discretionary use of CVPIA 3406(b)(2)
Feather River	
Minimum flow below Thermalito Diversion Dam	1983 DWR, DFG Agreement (600 cfs)
Minimum flow below Thermalito Afterbay outlet	1983 DWR, DFG Agreement (750-1,700 cfs)
Yuba River	
Minimum flow below Daguerre Point Dam	Interim D-1644 Operations[q]
American River	
Minimum flow below Nimbus Dam	SWRCB D-893[r] (see accompanying Operations Criteria), and USFWS discretionary use of CVPIA 3406(b)(2)
Minimum Flow at H Street Bridge	SWRCB D-893
Lower Sacramento River	
Minimum flow near Rio Vista	SWRCB D-1641
Mokelumne River	
Minimum flow below Camanche Dam	FERC 2916-029, 1996 (Joint Settlement Agreement) (100-325 cfs)
Minimum flow below Woodbridge Div. Dam	FERC 2916-029, 1996 (Joint Settlement Agreement) (25-300 cfs)
Stanislaus River	
Minimum flow below Goodwin Dam	1987 USBR, DFG agreement, and USFWS discretionary use of CVPIA 3406(b)(2)
Minimum dissolved oxygen	SWRCB D-1422
Merced River	
Minimum flow below Crocker-Huffman Diversion Dam	Davis-Grunsky (180-220 cfs, Nov-Mar), Cowell Agreement, and FERC 2179 (25-100 cfs)
Tuolumne River	
Minimum flow at Lagrange Bridge	FERC 2299-024, 1995 (Settlement Agreement) (94-301 TAF/yr)
San Joaquin River	
San Joaquin River below Friant Dam/Mendota Pool	None
Maximum salinity near Vernalis	SWRCB D-1641

Table B-1
CALSIM II Inputs
Bay-Delta Conservation Plan – Evaluation Report Assumptions

	Base (=Existing) Condition Assumption
Minimum flow near Vernalis	SWRCB D-1641, and Vernalis Adaptive Management Plan per San Joaquin River Agreement
Sacramento River–San Joaquin River Delta	
Delta Outflow Index (Flow and Salinity)	SWRCB D-1641
Delta Cross Channel gate operation	SWRCB D-1641
Delta exports	SWRCB D-1641, USFWS discretionary use of CVPIA 3406(b)(2)
OPERATIONS CRITERIA: RIVER-SPECIFIC	
Upper Sacramento River	
Flow objective for navigation (Wilkins Slough)	3,500-5,000 cfs based on CVP water supply condition
American River	
Folsom Dam flood control	Variable 400/670 flood control diagram (without outlet modifications)
Flow below Nimbus Dam	Discretionary operations criteria corresponding to SWRCB D-893 required minimum flow
Sacramento Area Water Forum Mitigation Water	None
Feather River	
Flow at Mouth of Feather River (above Verona)	Maintain DFG/DWR flow target of 2,800 cfs for Apr-Sep dependent on Oroville inflow and FRSA allocation
Stanislaus River	
Flow below Goodwin Dam	1997 New Melones Interim Operations Plan
San Joaquin River	
Salinity at Vernalis	D1641
OPERATIONS CRITERIA: SYSTEMWIDE	
CVP water allocation	
CVP Settlement and Exchange	100% (75% in Shasta critical years)
CVP refuges	100% (75% in Shasta critical years)
CVP agriculture	100%-0% based on supply (South-of-Delta allocations are reduced due to D-1641 and 3406(b)(2) allocation-related export restrictions)
CVP municipal & industrial	100%-50% based on supply (South-of-Delta allocations are reduced due to D-1641 and 3406(b)(2) allocation-related export

Table B-1
CALSIM II Inputs
Bay-Delta Conservation Plan – Evaluation Report Assumptions

	Base (=Existing) Condition Assumption
	restrictions)
SWP water allocation	
North of Delta (FRSA)	Contract specific
South of Delta (including North Bay Aqueduct)	Based on supply; equal prioritization between Ag and M&I based on Monterey Agreement
CVP-SWP coordinated operations	
Sharing of responsibility for in-basin-use	1986 Coordinated Operations Agreement (2/3 of the North Bay Aqueduct diversions are considered as Delta Export, 1/3 of the North Bay Aqueduct diversion is considered as in-basin-use)
Sharing of surplus flows	1986 Coordinated Operations Agreement
Sharing of restricted export capacity for project-specific priority pumping	Equal sharing of export capacity under SWRCB D-1641; use of CVPIA 3406(b)(2) restricts only CVP exports
Dedicated CVP conveyance at Banks	None
North-of-Delta accounting adjustments	None
Sharing of export capacity for lesser priority and wheeling-related pumping	Cross Valley Canal wheeling (max of 128 TAF/yr), CALFED ROD defined Joint Point of Diversion (JPOD)
San Luis Low Point	San Luis Reservoir is allowed to operate to a minimum storage of 100 TAF
CVPIA 3406(b)(2)	
Policy Decision	Per May 2003 Dept. of Interior Decision:
Allocation	800 TAF, 700 TAF in 40-30-30 dry years, and 600 TAF in 40-30-30 critical years
CVPIA 3406(b)(2) (continued)	
Actions	1995 WQCP, Upstream fish flow objectives (Oct-Jan), VAMP (Apr 15-May 15) CVP export restriction, 3,000 cfs CVP export limit in May and June (D-1485 striped bass cont.), Post-VAMP (May 16-31) CVP export restriction, Ramping of CVP export (June), Upstream Releases (Feb-Sep)
Accounting adjustments	Per May 2003 Interior Decision, no limit on responsibility for non-discretionary D-1641 requirements with 500 TAF target, no reset with the storage metric and no offset with the release and export metrics, 200 TAF target on costs from Oct-Jan

Table B-2. Flow Parameters and Values for Option 1

Parameter[1]	Range (Water Year Type)[2]		Rationale[3]
	Scenario A	**Scenario B**	
Delta Salinity Standards			
Year-round	Manage to meet D-1641 agricultural and M&I water quality	Meet D-1641 M&I standards – do not control for agricultural or Suisun Marsh standards	Meet water quality standards for CCWD
Sacramento River at Rio Vista			
Sept	3,000 cfs (All)	4,500cfs (All)	Adult Chinook salmon attraction and migration flows
Oct	4,000 cfs (W, AN, BN, D) 3,000 cfs (C)	4,500 cfs (W, AN, BN, D) 4,000 cfs (C)	Adult Chinook salmon attraction and migration flows
Nov-Dec	4,500 cfs (W, AN, BN, D) 3,500 cfs (C)	4,500 cfs (W, AN, BN, D) 4,000 cfs (C)	Juvenile salmon and steelhead migration/survival, pre-spawning migration by delta smelt, splittail, and others
Jan	No criterion	4,500 cfs (All)	Juvenile salmon and steelhead migration/survival, pre-spawning migration by delta smelt, splittail, and others
Feb-Jun	No criterion	No criterion	Evaluation parameter
Jul-Aug	No criterion	4,000 cfs (All)	Steelhead and salmon rearing within the mainstem river; support resident fish habitat
San Joaquin River flow at Vernalis			
May	VAMP flow requirements	D-1641 flow requirements (higher objective)	The flow range was selected to reflect the current range of conditions intended to improve juvenile Chinook salmon emigration survival
Jul-Sep	No criterion	No criterion	Evaluation parameter
Oct	1,400 cfs (All)	2,000 cfs (All)	Attraction flows and improved water quality (DO and temperature) for adult salmon migration – equivalent to D-1641
Nov-Jan	D-1641 water quality requirements	1,500 cfs (All)	Salmon fry rearing and dispersal, nutrient transport to Delta, splittail spawning and larval rearing and dispersal
Feb-Apr and Jun	D-1641 flow requirements (lower objective)	D-1641 flow requirements (higher objective)	D-1641 X2 contribution results in a range of San Joaquin River flows
X_2			
Feb-June	D-1641 X_2 locations	64 km (W) 65 km (AN) 66 km (BN) 74 km (D) 81 km (C)	The range of X_2 locations during the late winter-spring is intended to (1) reflect the current regulatory requirements, and (2) an expansion of low-salinity habitat further downstream within Suisun Bay (66 km)
Jul-Jan	Model output	Model output	Evaluation parameter
Total Delta Outflow			
Feb-June	Model output	Model output	Evaluation parameter
Jul-Jan	3,000 cfs (All)	3,000 cfs (All)	Minimal outflow to prevent modeling from drawing unrealistic low outflows outside of the X2 period
Hydraulic Residence Time in Selected Delta Channels			
Year-round	Model output	Model output	Evaluation parameter

Parameter[1]	Range (Water Year Type)[2]		Rationale[3]
	Scenario A	**Scenario B**	
Delta Cross Channel Gates			
Feb-Jun	Closed (All)	Open (All)	The range in DCC operations was intended to reflect (1) reduced movement of juvenile salmon and steelhead into the interior Delta; improved juvenile salmon survival, and (2), improved hydrodynamics for delta smelt within the central Delta and reduced vulnerability to SWP/CVP diversions
Jul-Jan	Open (All)	Open (All)	Improve hydrodynamics and water quality within the central Delta; reduce the potential barrier to fish movement into and out of the central delta
Head of Old River Barrier			
Mar-May	Closed (All)	Open (All)	The range in HORB operations was intended to reflect two alternative hypotheses that include (1) reduced movement of juvenile salmon and steelhead into the southern Delta; improved salmonid survival and reduced vulnerability to SWP/CVP diversions, and (2) improved hydrodynamics for delta smelt and reduced vulnerability to SWP/CVP diversions
Jun-Aug	Open (All)	Open (All)	Increase flows and flushing within the southern Delta to improve water quality
Sep-Nov	Closed (All)	Open (All)	The range of HORB gate operations was intended to reflect two alternative hypotheses that include (1) improved attraction flows and water quality for adult salmon within the lower San Joaquin River, and (2) improved hydrodynamics for delta smelt and reduced vulnerability to SWP/CVP diversions
Dec-Feb	Closed (All)	Open (All)	The range of HORB gate operations was intended to reflect two alternative hypotheses that include (1) reduced movement of salmon fry into the southern Delta; improved salmonid survival and reduced vulnerability to SWP/CVP diversions, and (2) improved hydrodynamics for delta smelt and reduced vulnerability to SWP/CVP diversions
Old and Middle River Flows (Combined)			
Mar-Jun	No criterion	>-1,000 cfs (All)	The range of reverse flows are intended to reflect two alternative hypotheses that include (1) reverse flows that have been hypothesized to reduce the movement of juvenile salmon and steelhead, delta smelt, longfin smelt, and splittail into Old and Middle River, improve survival; and (2) maintain a net westerly flow thought to benefit juvenile salmon migration rate and survival; reduce the vulnerability of planktonic fish eggs and larvae to diversion effects; non-SWP/CVP diversions contribute to reverse flows in Old and Middle River of approximately 1,000 cfs

Parameter[1]	Range (Water Year Type)[2]		Rationale[3]
	Scenario A	**Scenario B**	
Jul-Sep	No criterion	>-5,000 cfs (All)	The range of values are intended to reflect alternative hypotheses regarding the effects of increased diversions and reverse flows during the summer on Delta habitat and vulnerability of delta smelt and other fish to SWP/CVP salvage; reduce vulnerability of resident fish to salvage; reduce entrainment of nutrients
Oct-Nov	No criterion	>-1,000 cfs (All)	The range of values are intended to reflect alternative hypotheses regarding the effects of increased diversions and reverse flows during the fall on Delta habitat and vulnerability of delta smelt and other fish to SWP/CVP salvage; non-SWP/CVP diversions contribute to reverse flows in Old and Middle River of approximately 1,000 cfs; a larger reduction in reverse flows is expected to contribute to a greater fall attraction flow for adult salmon returning to the San Joaquin River
Dec-Feb	No criterion	>-1,000 cfs (All)	The range of winter reverse flows is intended to reflect two alternative hypotheses that include (1) results of analyses by Pete Smith and Sheila Green that show an increase in delta smelt salvage as reversed flows increase, with a rapid increase in salvage as reverse flows exceed approximately 5,000 to 6,000 cfs, and (2) analyses show that delta smelt salvage increases as reverse flows increase and therefore a reduction in the magnitude of reverse flows is expected to contribute to a reduction in delta smelt losses; non-SWP/CVP diversions contribute to reverse flows in Old and Middle River of approximately 1,000 cfs; a larger reduction in reverse flows is intended to contribute to a greater reduction in salmon fry and steelhead salvage and a lower vulnerability of pre-spawning delta and longfin smelt to SWP/CVP salvage; a greater reduction in reverse flows is expected to result in a greater reduction in nutrient diversions from the Delta and San Joaquin River

Parameter[1]	Range (Water Year Type)[2]		Rationale[3]
	Scenario A	**Scenario B**	
QWEST			
Mar-May	No criterion	Net positive flows (no reverse flow) (All)	The range in QWEST during the spring is intended to reflect two alternative hypotheses including (1) no data or analyses have been developed to demonstrate a relationship between the magnitude of QWEST and adverse impacts to delta smelt, salmon, or other fish species; and (2) net positive flows are expected to reduce movement of juvenile salmon, steelhead, larval and juvenile delta and longfin smelt, juvenile splittail, and other fish from the Sacramento River into the Delta; increase transport of plankton fish eggs, larvae, and juveniles downstream into Suisun Bay; increase the transport of zooplankton and nutrients downstream into Suisun Bay; reduce the vulnerability of fish to SWP/CVP salvage; reduce potential delays in downstream migration of juvenile salmon and other fish
Jun	No criterion	Net positive flows (no reverse flow) (All)	The range in QWEST during June is intended to reflect two alternative hypotheses including (1) no data or analyses have been developed to demonstrate a relationship between the magnitude of QWEST and adverse impacts to delta smelt, salmon, or other fish species; evaluation criterion, and (2) densities of juvenile fish potentially affected by QWEST are reduced in the central Delta by June and therefore the potential benefit is reduced; reduce movement of juvenile salmon, steelhead, larval and juvenile delta and longfin smelt, juvenile splittail, and other fish from the Sacramento River into the Delta; increase transport of plankton fish eggs, larvae, and juveniles downstream into Suisun Bay; increase the transport of zooplankton and nutrients downstream into Suisun Bay; reduce the vulnerability of fish to SWP/CVP salvage; reduce potential delays in downstream migration of juvenile salmon and other fish
Jul-Nov	No criterion	Net positive flows (no reverse flow) (All)	The range of QWEST values is intended to reflect two alternative hypotheses including (1) delta smelt and other fish have reached a size where swimming performance allows volitional habitat selection; many fish are located downstream in Suisun Bay and are not in the area affected by QWEST, and (2) reduce the movement of adult delta smelt from the Sacramento River into the interior Delta and thereby reduce their vulnerability to SWP/CVP diversions
Dec-Feb	No criterion	Net positive flows (no reverse flow) (All)	Reduce the movement of adult delta smelt from the Sacramento River into the interior Delta and thereby reduce their vulnerability to SWP/CVP diversions

Parameter[1]	Range (Water Year Type)[2]		Rationale[3]
	Scenario A	Scenario B	
SWP/CVP VAMP Operations			
April	Model output	VAMP	The range of SWP/CVP diversions is intended to reflect two alternative hypotheses that include (1) opportunistic diversions used as a model evaluation parameter, and (2) start of the peak period of San Joaquin juvenile salmon emigration through the Delta; larval stages of delta smelt, longfin smelt, splittail, and other fish are present in the Delta in relatively high densities and are vulnerable to diversion losses; VAMP diversion rates are intended to provide a higher level of protection from diversion related direct and indirect effects; extend the VAMP period to two months to increase the seasonal period of potential protection
May	VAMP	VAMP	Evaluation parameter; intended to provide increased protection for juvenile salmon emigrating from the San Joaquin, Mokelumne, Cosumnes, and other Central Valley rivers and other species; peak period of smolt migration occurs in May in many years; assumes for modeling that VAMP period is in May however the actual period may vary

Notes:

[1]Operational condition and seasonal time period used as a model input and/or output
[2]A range of values for a given operational condition intended to reflect alternative hypotheses or interpretations of available data. Water year type codes shown in parentheses are:

W = wet
AN = above normal
BN = below normal
D = dry
C = critical
All = value is applied to all water year types

[3]The rationales generally reflect the intended result of the parameter

Table B-3. Flow Parameters and Values for Option 2

Parameter[1]	Range (Water Year Type)[2]		Rationale[3]
	Scenario A	**Scenario B**	
Delta Salinity Standards			
Year-round	Manage to meet D-1641 agricultural water quality	Do not manage specifically to meet water quality standards – variable salinity	Meet water quality standards for CCWD (assumes CCWD diversions from Victoria Canal)
Sacramento River at Rio Vista			
Sept	3,000 cfs (All)	4,500 cfs (All)	Adult Chinook salmon attraction and migration flows
Oct	4,000 cfs (W, AN, BN, D) 3,000 cfs (C)	4,500 cfs (W, AN, BN, D) 4,000 cfs (C)	Adult Chinook salmon attraction and migration flows
Nov-Dec	4,500 cfs (W, AN, BN, D) 3,500 cfs (C)	4,500 cfs (W, AN, BN, D) 4,000 cfs (C)	Juvenile salmon and steelhead migration/survival, pre-spawning migration by delta smelt, splittail, and others
Jan	No criterion	4,500 cfs (All)	Juvenile salmon and steelhead migration/survival, pre-spawning migration by delta smelt, splittail, and others
Feb-Jun	No criterion	No criterion	Evaluation parameter
Jul-Aug	No criterion	4,000 cfs (All)	Steelhead and salmon rearing within the mainstem river; support resident fish habitat
San Joaquin River flow at Vernalis			
May	VAMP flow requirements	D-1641 flow requirements (higher objective)	The flow range was selected to reflect the current range of conditions intended to improve juvenile Chinook salmon emigration survival
Jul-Sep	No criterion	No criterion	Evaluation parameter
Oct	1,400 cfs (All)	2,000 cfs (All)	Attraction flows and improved water quality (DO and temperature) for adult salmon migration – equivalent to D-1641
Nov-Jan	D-1641 water quality requirements	1,500 cfs (All)	Salmon fry rearing and dispersal, nutrient transport to Delta, splittail spawning and larval rearing and dispersal
Feb-Apr and Jun	D-1641 flow requirements (lower objective)	D-1641 flow requirements (higher objective)	D-1641 X_2 contribution results in a range of San Joaquin River flows
X_2			
Feb-June	D-1641 X_2 locations	64 km (W) 65 km (AN) 66 km (BN) 74 km (D) 81 km (C)	The range of X_2 locations during the late winter-spring is intended to reflect (1) the current regulatory requirements and (2) an expansion of low-salinity habitat further downstream within Suisun Bay (66 km)
Jul-Jan	No criterion	No criterion	Evaluation parameter
Total Delta Outflow			
Feb-June	No criterion	No criterion	Evaluation parameter
Jul-Jan	3,000 cfs (All)	3,000 cfs (All)	Minimal outflow to prevent modeling from drawing unrealistic low outflows outside of the X2 period
Hydraulic Residence Time in Selected Delta Channels			
Year-round	No criterion	No criterion	Evaluation parameter

Parameter[1]	Range (Water Year Type)[2]		Rationale[3]
	Scenario A	**Scenario B**	
Delta Salinity Standards			
Delta Cross Channel Gates			
Feb-Jun	Closed (All)	Open (All)	The range in DCC operations was intended to reflect (1) reduced movement of juvenile salmon and steelhead into the interior Delta; improved juvenile salmon survival, and (2), improved hydrodynamics for delta smelt within the central Delta and reduced vulnerability to SWP/CVP diversions
Jul-Jan	Open (All)	Open (All)	Improve hydrodynamics and water quality within the central Delta; reduce the potential barrier to fish movement into and out of the central Delta
SJR Barrier – Installed in the San Joaquin River to direct fish and flows into Old River			
Mar-May	Closed (All)	Closed (All)	Reduce movement of juvenile salmon and steelhead into the southern Delta through the lower San Joaquin River and facilitate juvenile Chinook salmon passage into the central Delta through Old River; improve salmonid survival and reduce their vulnerability to SWP/CVP diversions
Jun-Aug	Closed (All)	Closed (All)	Increase flows and flushing within the southern and central Delta to improve water quality
Sep-Nov	Closed (All)	Closed (All)	Improve attraction flows and water quality for adult salmon within the lower San Joaquin River
Dec-Feb	Closed (All)	Closed (All)	Reduce movement of salmon fry into the southern Delta; improve salmonid survival and reduce their vulnerability to SWP/CVP diversions
Old River Flows			
Year-round	No criterion – No reverse flows are expected from SWP/CVP diversions; model output to assess	No criterion – No reverse flows are expected from SWP/CVP diversions; model output to assess	Reduce vulnerability of delta smelt and other species to SWP/CVP diversions by isolating Old River habitat from the hydraulic influence of the diversion facilities; increase hydraulic residence time in the Old River region to increase primary and secondary production and provide low velocity habitat for delta smelt and other fish species; operate the Old River siphon to allow salmon, other fish, nutrients, phytoplankton, and zooplankton produced in the San Joaquin River to flow into the central Delta
Middle River Flows			
Mar-May	No criterion	>-2,000 cfs (All)	The range in Middle River flows reflects two alternative hypotheses including (1) Middle River has been designated as the water conveyance route for SWP/CVP diversions; channel capacity may be limited by levee scour and water depths, and (2) larval and juvenile delta smelt, splittail, Chinook salmon, steelhead, and other fish produced in the Mokelumne and Cosumnes rivers and east-side channels and sloughs; reduced reverse flows are intended to reduce vulnerability to entrainment and SWP/CVP diversion effects

Parameter[1]	Range (Water Year Type)[2]		Rationale[3]
	Scenario A	**Scenario B**	
Delta Salinity Standards			
Jun	No criterion	>-6,000 cfs (All)	The range in Middle River flows reflects (1) Middle River has been designated as the water conveyance route for SWP/CVP diversions; channel capacity may be limited by levee scour and water depths, and (2) most juvenile fish have grown to a size where swimming performance allows habitat selection or they have moved downstream into Suisun Bay and outside the area of influence; the majority of juvenile salmon and steelhead have emigrated from the Delta
Jul-Sep	No criterion	>-8,000 cfs (All)	Middle River has been designated as the water conveyance route for SWP/CVP diversions; channel capacity may be limited by levee scour and water depths. Most of the sensitive covered fish species are not present in the central and southern Delta during the summer and therefore have reduced vulnerability to SWP/CVP diversions
Oct-Nov	No criterion	>-4,000 cfs (All)	The range in Middle River flows reflects two alternative hypotheses including (1) Middle River has been designated as the water conveyance route for SWP/CVP diversions; channel capacity may be limited by levee scour and water depths, and (2) adult Chinook salmon are migrating upstream into the Mokelumne and Cosumnes rivers; reduced reversed flows in Middle River are intended to reduce migration delays and improve hydrodynamic cues and attraction flows
Dec-Feb	No criterion	>-4,000 cfs (All)	The range in Middle River flows reflects two alternative hypotheses including (1) Middle River has been designated as the water conveyance route for SWP/CVP diversions; channel capacity may be limited by levee scour and water depths, and (2) Chinook salmon fry and steelhead smolts are emigrating through the Delta from the Mokelumne and Cosumnes rivers; reduced reverse flows are intended to reduce vulnerability to diversion effects; early spawning fish have planktonic larval and juveniles within the central Delta that could be vulnerable to hydraulic entrainment within Middle River
QWEST			
Mar-May	No criterion	Net positive flows (no reverse flow) (All)	The range in QWEST reflects two alternative hypotheses including (1) no data or analyses have been developed to demonstrate a relationship between the magnitude of QWEST and adverse impacts to delta smelt, salmon, or other fish species; evaluation criterion, and (2) reduced QWEST is intended to result in reduced movement of juvenile salmon, steelhead, larval and juvenile delta and longfin smelt, juvenile splittail, and other fish from the Sacramento River into the Delta; increased transport of plankton fish eggs, larvae, and juveniles downstream into Suisun Bay; increased transport of zooplankton and nutrients downstream into Suisun Bay; reduced the vulnerability of fish to SWP/CVP diversions; reduced delays in downstream migration of juvenile salmon and other fish

Parameter[1]	Range (Water Year Type)[2]		Rationale[3]
	Scenario A	**Scenario B**	
Delta Salinity Standards			
Jun	No criterion	Net positive flows (no reverse flow) (All)	The range in QWEST reflects two alternative hypotheses including (1) no data or analyses have been developed to demonstrate a relationship between the magnitude of QWEST and adverse impacts to delta smelt, salmon, or other fish species; evaluation criterion, and (2) the densities of juvenile fish potentially affected by QWEST are reduced in the central Delta by June and therefore the potential benefit is reduced; reduced movement of juvenile salmon, steelhead, larval and juvenile delta and longfin smelt, juvenile splittail, and other fish from the Sacramento River into the Delta; increased transport of plankton fish eggs, larvae, and juveniles downstream into Suisun Bay; increased transport of zooplankton and nutrients downstream into Suisun Bay; reduced vulnerability of fish to SWP/CVP diversions; reduce potential delays in downstream migration of juvenile salmon and other fish
Jul-Nov	No criterion	Net positive flows (no reverse flow) (All)	The range of QWEST values are intended to reflect two alternative hypotheses including (1) delta smelt and other fish have reached a size where swimming performance allows volitional habitat selection; many fish are located downstream in Suisun Bay and are not in the area affected by QWEST, and (2) reduce the movement of adult delta smelt from the Sacramento River into the interior Delta and thereby reduce their vulnerability to SWP/CVP diversions
Dec-Feb	No criterion	Net positive flows (no reverse flow) (All)	Reduce the movement of adult delta smelt from the Sacramento River into the interior Delta and thereby reduce their vulnerability to SWP/CVP diversions
SWP/CVP VAMP Diversions			
April	No criterion	VAMP	The range of SWP/CVP diversions is intended to reflect (1) opportunistic diversions used as a model evaluation parameter, and (2) start of the peak period of juvenile salmon emigration through the Delta; larval stages of delta smelt, longfin smelt, splittail, and other fish are present in the Delta in relatively high densities and are vulnerable to diversion losses, VAMP diversion rates are intended to provide a higher level of protection from diversion related direct and indirect effects; extend the VAMP period to two months is intended to increase the seasonal period of protection
May	VAMP	VAMP	VAMP diversion rate reductions are intended to provide increased protection for juvenile salmon emigrating from the Mokelumne and Consumes rivers and other species; peak period of smolt migration occurs in May in many years; assumes for modeling that VAMP period is in May however the actual period may vary

Notes:

[1]Operational condition and seasonal time period used as a model input and/or output
[2]A range of values for a given operational condition intended to reflect alternative hypotheses or interpretations of available data. Water year type codes shown in parentheses are:

W = wet
AN = above normal
BN = below normal
D = dry
C = critical
All = value is applied to all water year types

[3]The rationales generally reflect the intended result of the parameter

Table B-4. Flow Parameters and Values for Option 3

Parameter[1]	Range (Water Year Type)[2]		Rationale[3]
	Scenario A	**Scenario B**	
Delta Salinity Standards			
Year-round	Manage to meet D-1641 agricultural water quality	Do not manage specifically to meet water quality standards – variable salinity	Meet water quality standards for CCWD (assumes CCWD diversions from Victoria Canal)
Sacramento River at Rio Vista			
Sept-Oct	4,000 cfs (W, AN, BN, D) 3,000 cfs (C)	4,500 cfs (W, AN, BN, D) 3,500 cfs (C)	Adult Chinook salmon attraction and migration flows – the range is based on
Nov-Dec	4,000 cfs (W, AN, BN, D) 3,000 cfs (C)	4,500 cfs (W, AN, BN, D) 3,500 cfs (C)	Juvenile salmon and steelhead migration/survival, pre-spawning migration by delta smelt, splittail, and others - the range is based on
Jan-Jun	5,000 cfs (W, AN, BN, D) 3500 cfs (C)	9,000 cfs (W, AN, BN) 5000 cfs (D) 3500 cfs (C)	Juvenile salmon and steelhead migration/survival, pre-spawning migration by delta smelt, splittail, and others - the range is based on Rio Vista flows from CALSIM for below normal and above normal water years
Jul-Aug	2,000 cfs (All)	3,500 cfs (All)	Steelhead and salmon rearing within the mainstem river; support resident fish habitat - the range is based on
San Joaquin River flow at Vernalis			
May	VAMP flow requirements	D-1641 flow requirements (higher objective)	The flow range was selected to reflect the current range of conditions intended to improve juvenile Chinook salmon emigration survival
Jul-Sep	No criterion	No criterion	Evaluation parameter
Oct	1,400 cfs (All)	2,000 cfs (All)	Attraction flows and improved water quality (DO and temperature) for adult salmon migration – equivalent to D-1641
Nov-Jan	D-1641 water quality requirements	1,500 cfs (All)	Salmon fry rearing and dispersal, nutrient transport to Delta, splittail spawning and larval rearing and dispersal
Feb-Apr and Jun	D-1641 flow requirements of approximately 1,420 cfs (lower objective)	D-1641 flow requirements of approximately 2,280 cfs (higher objective)	D-1641 X_2 contribution results in a range of San Joaquin River flows
X_2			
Feb-June	D-1641 X_2 locations	64 km (W) 65 km (AN) 66 km (BN) 74 km (D) 81 km (C)	The range of X_2 locations during the late winter-spring is intended to reflect (1) the current regulatory requirements and (2) an expansion of low-salinity habitat further downstream within Suisun Bay (66 km)
Jul-Jan	No criterion	No criterion	Evaluation parameter
Total Delta Outflow			
Feb-June	No criterion	No criterion	Evaluation parameter
Jul-Jan	3,000 cfs (All)	3,000 cfs (All)	Minimal outflow to prevent modeling from drawing unrealistic low outflows outside of the X2 period
Hydraulic Residence Time in Selected Delta Channels			
Year-round	No criterion	No criterion	Evaluation parameter

Parameter[1]	Range (Water Year Type)[2]		Rationale[3]
	Scenario A	**Scenario B**	
Delta Cross Channel Gates			
Feb-Jun	Closed (All)	Closed (All)	The range in DCC operations was intended to reflect (1) reduced movement of juvenile salmon and steelhead into the interior Delta; improved juvenile salmon survival, and (2), improved hydrodynamics for delta smelt within the central Delta and reduced vulnerability to SWP/CVP diversions
Jul-Jan	Closed (All)	Closed (All)	Improve hydrodynamics and water quality within the central Delta; reduce the potential barrier to fish movement into and out of the central Delta
SJR Barrier – Installed in the San Joaquin River to direct fish and flows into Old River			
Mar-May	Closed (All)	Closed (All)	Reduce movement of juvenile salmon and steelhead into the southern Delta through the lower San Joaquin River and facilitate juvenile Chinook salmon passage into the central Delta through Old River; improve salmonid survival and reduce their vulnerability to SWP/CVP diversions
Jun-Aug	Closed (All)	Closed (All)	Increase flows and flushing within the southern and central Delta to improve water quality
Sep-Nov	Closed (All)	Closed (All)	Improve attraction flows and water quality for adult salmon within the lower San Joaquin River
Dec-Feb	Closed (All)	Closed (All)	Reduce movement of salmon fry into the southern Delta; improve salmonid survival and reduce their vulnerability to SWP/CVP diversions
Old River Flows (only applies when operating South Delta facility)			
Year-round	No criterion – No reverse flows are expected from SWP/CVP diversions; model output to assess	No criterion – No reverse flows are expected from SWP/CVP diversions; model output to assess	Reduce vulnerability of delta smelt and other species to SWP/CVP diversions by isolating Old River habitat from the hydraulic influence of the diversion facilities; increase hydraulic residence time in the Old River region to increase primary and secondary production and provide low velocity habitat for delta smelt and other fish species; operate the Old River siphon to allow salmon, other fish, nutrients, phytoplankton, and zooplankton produced in the San Joaquin River to flow into the central Delta
Middle River Flows (only applies when operating South Delta facility)			
Mar-May	No criterion	>-2,000 cfs (All)	The range in Middle River flows reflects two alternative hypotheses including (1) Middle River has been designated as the water conveyance route for SWP/CVP diversions; channel capacity may be limited by levee scour and water depths, and (2) larval and juvenile delta smelt, splittail, Chinook salmon, steelhead, and other fish produced in the Mokelumne and Cosumnes rivers and east-side channels and sloughs; reduced reverse flows are intended to reduce vulnerability to entrainment and SWP/CVP diversion effects
Jun	No criterion	>-6,000 cfs (All)	The range in Middle River flows reflects (1) Middle River has been designated as the water conveyance route for SWP/CVP diversions; channel capacity may be limited by levee scour and water depths, and (2) most juvenile fish have grown to a size where swimming performance allows habitat selection or they have moved downstream into Suisun Bay and outside the area of influence; the majority of juvenile salmon and steelhead have emigrated from the Delta

Parameter[1]	Range (Water Year Type)[2]		Rationale[3]
	Scenario A	**Scenario B**	
Jul-Sep	No criterion	>-8,000 cfs (All)	Middle River has been designated as the water conveyance route for SWP/CVP diversions; channel capacity may be limited by levee scour and water depths. Most of the sensitive covered fish species are not present in the central and southern Delta during the summer and therefore have reduced vulnerability to SWP/CVP diversions
Oct-Nov	No criterion	>-4,000 cfs (All)	The range in Middle River flows reflects two alternative hypotheses including (1) Middle River has been designated as the water conveyance route for SWP/CVP diversions; channel capacity may be limited by levee scour and water depths, and (2) adult Chinook salmon are migrating upstream into the Mokelumne and Cosumnes rivers; reduced reversed flows in Middle River are intended to reduce migration delays and improve hydrodynamic cues and attraction flows
Dec-Feb	No criterion	>-4,000 cfs (All)	The range in Middle River flows reflects two alternative hypotheses including (1) Middle River has been designated as the water conveyance route for SWP/CVP diversions; channel capacity may be limited by levee scour and water depths, and (2) Chinook salmon fry and steelhead smolts are emigrating through the Delta from the Mokelumne and Cosumnes rivers; reduced reverse flows are intended to reduce vulnerability to diversion effects; early spawning fish have planktonic larval and juveniles within the central Delta that could be vulnerable to hydraulic entrainment within Middle River
QWEST (o**nly applies when operating South Delta facility)**			
Mar-May	No criterion	Net positive flows (no reverse flow) (All)	The range in QWEST reflects two alternative hypotheses including (1) no data or analyses have been developed to demonstrate a relationship between the magnitude of QWEST and adverse impacts to delta smelt, salmon, or other fish species; evaluation criterion, and (2) reduced QWEST is intended to result in reduced movement of juvenile salmon, steelhead, larval and juvenile delta and longfin smelt, juvenile splittail, and other fish from the Sacramento River into the Delta; increased transport of plankton fish eggs, larvae, and juveniles downstream into Suisun Bay; increased transport of zooplankton and nutrients downstream into Suisun Bay; reduced the vulnerability of fish to SWP/CVP diversions; reduced delays in downstream migration of juvenile salmon and other fish

Parameter[1]	Range (Water Year Type)[2]		Rationale[3]
	Scenario A	**Scenario B**	
Jun	No criterion	Net positive flows (no reverse flow) (All)	The range in QWEST reflects two alternative hypotheses including (1) no data or analyses have been developed to demonstrate a relationship between the magnitude of QWEST and adverse impacts to delta smelt, salmon, or other fish species; evaluation criterion, and (2) the densities of juvenile fish potentially affected by QWEST are reduced in the central Delta by June and therefore the potential benefit is reduced; reduced movement of juvenile salmon, steelhead, larval and juvenile delta and longfin smelt, juvenile splittail, and other fish from the Sacramento River into the Delta; increased transport of plankton fish eggs, larvae, and juveniles downstream into Suisun Bay; increased transport of zooplankton and nutrients downstream into Suisun Bay; reduced vulnerability of fish to SWP/CVP diversions; reduce potential delays in downstream migration of juvenile salmon and other fish
Jul-Nov	No criterion	Net positive flows (no reverse flow) (All)	The range of QWEST values are intended to reflect two alternative hypotheses including (1) delta smelt and other fish have reached a size where swimming performance allows volitional habitat selection; many fish are located downstream in Suisun Bay and are not in the area affected by QWEST, and (2) reduce the movement of adult delta smelt from the Sacramento River into the interior Delta and thereby reduce their vulnerability to SWP/CVP diversions
Dec-Feb	No criterion	Net positive flows (no reverse flow) (All)	Reduce the movement of adult delta smelt from the Sacramento River into the interior Delta and thereby reduce their vulnerability to SWP/CVP diversions
SWP/CVP South Delta Diversion Operations			
April	No criterion	VAMP	The range of SWP/CVP diversions is intended to reflect (1) opportunistic diversions used as a model evaluation parameter, and (2) start of the peak period of juvenile salmon emigration through the Delta; larval stages of delta smelt, longfin smelt, splittail, and other fish are present in the Delta in relatively high densities and are vulnerable to diversion losses, VAMP diversion rates are intended to provide a higher level of protection from diversion related direct and indirect effects; extend the VAMP period to two months is intended to increase the seasonal period of protection
May	VAMP	VAMP	VAMP diversion rate reductions are intended to provide increased protection for juvenile salmon emigrating from the Mokelumne and Consumes rivers and other species; peak period of smolt migration occurs in May in many years; assumes for modeling that VAMP period is in May however the actual period may vary

Parameter[1]	Range (Water Year Type)[2]		Rationale[3]
	Scenario A	**Scenario B**	
SWP/CVP Isolated Facility Diversions			
Mar-May	Not to exceed 15,400 cfs	Model output not to exceed 6,000 cfs	The range in diversion rates reflects (1) the location of the point of diversion is upstream of the primary habitat of delta smelt and therefore the risk of entrainment is low; the positive barrier fish screen is expected to be effective in excluding juvenile salmon and other fish from the diversion, and (2) a number of fish species spawn upstream of the point of diversion during the spring and have planktonic eggs and larvae that could be vulnerable to entrainment, reduce the diversion of nutrients and food supply for the Delta during the key spring months
Jun-Feb	Not to exceed 15,400 cfs	No criterion	Evaluation parameter

Notes:

[1]Operational condition and seasonal time period used as a model input and/or output
[2]A range of values for a given operational condition intended to reflect alternative hypotheses or interpretations of available data. Water year type codes shown in parentheses are:
W = wet
AN = above normal
BN = below normal
D = dry
C = critical
All = value is applied to all water year types
[3]The rationales generally reflect the intended result of the parameter

1 **Table B-5. Flow Parameters and Values for Option 4**

Parameter[1]	Range (Water Year Type)[2]		Rationale[3]
	Scenario A	**Scenario B**	
Delta Salinity Standards			
Year-round	Manage to D-1641 agricultural (e.g., Jersey Point) standards	Do not manage specifically to meet water quality standards – variable salinity	Evaluation parameter to assess the range of variable salinity conditions that could occur and assess changes in aquatic habitat conditions as well as impacts on other Delta uses
Sacramento River at Rio Vista			
Sept-Oct	4,000 cfs (W, AN, BN, D) 3,000 cfs (C)	4.500 cfs (W, AN, BN, D) 3,500 cfs (C)	Adult Chinook salmon attraction and migration flows – the range is based on
Nov-Dec	4,000 cfs (W, AN, BN, D) 3,000 cfs (C)	4,500 cfs (W, AN, BN, D) 3,500 cfs (C)	Juvenile salmon and steelhead migration/survival, pre-spawning migration by delta smelt, splittail, and others - the range is based on
Jan-Jun	5,000 cfs (W, AN, BN, D) 3500 cfs (C)	9,000 cfs (W, AN, BN) 5000 cfs (D) 3500 cfs (C)	Juvenile salmon and steelhead migration/survival, pre-spawning migration by delta smelt, splittail, and others - the range is based on Rio Vista flows from CALSIM for below normal and above normal water years
Jul-Aug	2,000 cfs (All)	3,500 cfs (All)	Steelhead and salmon rearing within the mainstem river; support resident fish habitat - the range is based on
San Joaquin River flow at Vernalis			
May	VAMP flow requirements	D-1641 flow requirements (higher objective)	The available relationships show a positive response with increasing spring flows; flows for salmon migration; nutrient transport to Delta; juvenile splittail rearing and dispersal
Jul-Sep	No criterion	No criterion	Evaluation parameter
Oct	1,400 cfs (All)	2,000 cfs (All)	Attraction flows and improved water quality (DO and temperature) for adult salmon migration – equivalent to D-1641
Nov-Jan	D-1641 water quality requirements (lower objective)	1,500 cfs (All)	Salmon fry rearing and dispersal, nutrient transport to Delta, Splittail spawning and larval rearing and dispersal
Feb-Apr and Jun	D-1641 flow requirements (lower objective)	D-1641 flow requirements (higher objective)	D-1641 X_2 contribution results in a range of San Joaquin River flows
X2			
Feb-June (assumes improved habitat in central Delta)	D-1641 X_2 locations	64 km (W) 65 km (AN) 66 km (BN) 74 km (D) 81 km (C) * 25,000 cfs cap on required flow	The range of X_2 locations during the late winter-spring is intended to reflect (1) the current regulatory requirements and (2) an expansion of low-salinity habitat further downstream within Suisun Bay (66 km)
Jul-Jan	No criterion	No criterion	Evaluation parameter
Total Delta Outflow			
Year-round	No criterion	No criterion	Evaluation parameter
Hydraulic Residence Time in Selected Delta Channels			
Year-round	No criterion	No criterion	Evaluation parameter

Parameter[1]	Range (Water Year Type)[2]		Rationale[3]
	Scenario A	**Scenario B**	
Delta Cross Channel Gates			
Feb-Jun	Closed (All)	Closed (All)	Reduce movement of juvenile salmon and steelhead into the interior Delta; improve juvenile salmon survival by reducing vulnerability to in-Delta diversions,
Jul-Jan	Closed (All)	Closed (All)	Open as needed for water quality enhancement within the central and southern Delta
Head of Old River Barrier			
Year-round	Open (All)	Open (All)	Increase flows and flushing within the southern Delta to improve water quality
Old River Flows			
Year-round	No criterion	No criterion	Evaluation criteria
Middle River Flows			
Year-round	No criterion	No criterion	Evaluation criteria
QWEST			
Year-round	No criterion	No criterion	Evaluation criteria
SWP/CVP Diversions			
Mar-May	Not to exceed 15,400 cfs	Not to exceed 6,000 cfs	The range in diversion rates reflects (1) the location of the point of diversion is upstream of the primary habitat of delta smelt and therefore the risk of entrainment is low; the positive barrier fish screen is expected to be effective in excluding juvenile salmon and other fish from the diversion, and (2) a number of fish species spawn upstream of the point of diversion during the spring and have planktonic eggs and larvae that could be vulnerable to entrainment, reduce the diversion of nutrients and food supply for the Delta during the key spring months
Jun-Feb	Not to exceed 15,400 cfs	No criterion	Evaluation parameter

Notes:

[1]Operational condition and seasonal time period used as a model input and/or output
[2]A range of values for a given operational condition intended to reflect alternative hypotheses or interpretations of available data.
Water year type codes shown in parentheses are:

W = wet
AN = above normal
BN = below normal
D = dry
C = critical
All = value is applied to all water year types

[3]The rationales generally reflect the intended result of the parameter

Table B-6. Summary of model operational parameters for BDCP Conservation Strategy Options 1 - 4

Parameter	1A	1B	2A	2B	3A	3B	4A	4B
Delta Salinity Standards	Manage to meet D-1641 agricultural and M&I water quality	Meet D-1641 M&I standards – do not control for agricultural or Suisun Marsh standards	Manage to meet D-1641 agricultural water quality	Do not manage specifically to meet water quality standards – variable salinity	Manage to D-1641 agricultural (e.g., Jersey Point) standards	Do not manage specifically to meet water quality standards – variable salinity	Manage to D-1641 agricultural (e.g., Jersey Point) standards	Do not manage specifically to meet water quality standards – variable salinity
Sacramento River at Rio Vista								
Sep	3,000 cfs (All)	4,500cfs (All)	3,000 cfs (All)	4,500 cfs (All)	4,000 cfs (W, AN, BN, D) 3,000 cfs (C)	4,500 cfs (W, AN, BN, D), 3,500 (C)	4,000 cfs (W, AN, BN, D) 3,000 cfs (C)	4,500 cfs (W, AN, BN, D), 3,500 (C)
Oct	4,000 cfs (W, AN, BN, D), 3,000 cfs (C)	4,500 cfs (W, AN, BN, D), 4,000 cfs (C)	4,000 cfs (W, AN, BN, D), 3,000 cfs (C)	4,500 cfs (W, AN, BN, D), 4,000 cfs (C)	4,000 cfs (W, AN, BN, D) 3,000 cfs (C)	4,500 cfs (W, AN, BN, D), 3,500 (C)	4,000 cfs (W, AN, BN, D) 3,000 cfs (C)	4,500 cfs (W, AN, BN, D), 3,500 (C)
Nov-Dec	4,500 cfs (W, AN, BN, D), 3,500 cfs (C)	4,500 cfs (W, AN, BN, D), 4,000 cfs (C)	4,500 cfs (W, AN, BN, D), 3,500 cfs (C)	4,500 cfs (W, AN, BN, D), 4,000 cfs (C)	4,000 cfs (W, AN, BN, D) 3,000 cfs (C)	4,500 cfs (W, AN, BN, D), 3,500 (C)	4,000 cfs (W, AN, BN, D) 3,000 cfs (C)	4,500 cfs (W, AN, BN, D), 3,500 (C)
Jan	No criterion	4,500 cfs (All)	No criterion	4,500 cfs (All)	5,000 cfs (W, AN, BN, D) 3,500 cfs (C)	9,000 cfs (W, AN, BN) 5,000 cfs (D) 3,500 cfs (C)	5,000 cfs (W, AN, BN, D) 3,500 cfs (C)	9,000 cfs (W, AN, BN) 5,000 cfs (D) 3,500 cfs (C)
Feb-Jun	No criterion	No criterion	No criterion	No criterion	5,000 cfs (W, AN, BN, D) 3,500 cfs (C)	9,000 cfs (W, AN, BN) 5,000 cfs (D) 3,500 cfs (C)	5,000 cfs (W, AN, BN, D) 3,500 cfs (C)	9,000 cfs (W, AN, BN) 5,000 cfs (D) 3,500 cfs (C)
Jul-Aug	No criterion	4,000 cfs (All)	No criterion	4,000 cfs (All)	2,000 cfs (All)	3,500 cfs (All)	2,000 cfs (All)	3,500 cfs (All)
San Joaquin River flow at Vernalis								
May	VAMP flow requirements	D-1641 flow requirements (higher objective)	VAMP flow requirements	D-1641 flow requirements (higher objective)	VAMP flow requirements	D-1641 flow requirements (higher objective)	VAMP flow requirements	D-1641 flow requirements (higher objective)
Jul-Sep	No criterion	No criterion	No criterion	No criterion	No criterion	No criterion	No criterion	No criterion
Oct	1,400 cfs (All)	2,000 cfs (All)	1,400 cfs (All)	2,000 cfs (All)	1,400 cfs (All)	2,000 cfs (All)	1,400 cfs (All)	2,000 cfs (All)
Nov-Jan	D-1641 water quality requirements	1,500 cfs (All)	D-1641 water quality requirements	1,500 cfs (All)	D-1641 water quality requirements	1,500 cfs (All)	D-1641 water quality requirements	1,500 cfs (All)
Feb-Apr and Jun	D-1641 flow requirements (lower objective)	D-1641 flow requirements (higher objective)	D-1641 flow requirements (lower objective)	D-1641 flow requirements (higher objective)	D-1641 flow requirements (lower objective)	D-1641 flow requirements (higher objective)	D-1641 flow requirements (lower objective)	D-1641 flow requirements (higher objective)

Table B-6. Summary of model operational parameters for BDCP Conservation Strategy Options 1 - 4 (Cont.)

Parameter	1A	1B	2A	2B	3A	3B	4A	4B
X2								
Feb-Jun	D-1641 X_2 locations	64 km (W) 65 km (AN) 66 km (BN) 74 km (D) 81 km (C)	D-1641 X_2 locations	64 km (W) 65 km (AN) 66 km (BN) 74 km (D) 81 km (C)	D-1641 X_2 locations	64 km (W) 65 km (AN) 66 km (BN) 74 km (D) 81 km (C)	D-1641 X_2 locations	64 km (W) 65 km (AN) 66 km (BN) 74 km (D) 81 km (C) * 25,000 cfs cap on required flow
Jul-Jan	Model output	Model output	No criterion	No criterion	No criterion	No criterion	No criterion	No criterion
Total Delta Outflow								
Jul-Jan	3,000 cfs (All)	3,000 cfs (All)	3,000 cfs (All)	3,000 cfs (All)	3,000 cfs (All)	3,000 cfs (All)	3,000 cfs (All)	3,000 cfs (All)
Hydraulic Residence Time in Selected Delta Channels								
	Model output	Model output	No criterion	No criterion	No criterion	No criterion	No criterion	No criterion
DCC								
Feb-Jun	Closed (All)	Open (All)	Closed (All)	Open (All)	Closed (All)	Closed (All)	Closed (All)	Closed (All)
Jul-Jan	Open (All)	Open (All)	Open (All)	Open (All)	Closed (All)	Closed (All)	Closed (All)	Closed (All)
HORB								
Mar-May	Closed (All)	Open (All)					Open (All)	Open (All)
Jun-Aug	Open (All)	Open (All)					Open (All)	Open (All)
Sep-Nov	Closed (All)	Open (All)					Open (All)	Open (All)
Dec-Feb	Closed (All)	Open (All)					Open (All)	Open (All)
SJRB – Installed in the San Joaquin River to direct fish and flows into Old River								
Mar-May			Closed (All)	Closed (All)	Closed (All)	Closed (All)		
Jun-Aug			Closed (All)	Closed (All)	Closed (All)	Closed (All)		
Sep-Nov			Closed (All)	Closed (All)	Closed (All)	Closed (All)		
Dec-Feb			Closed (All)	Closed (All)	Closed (All)	Closed (All)		
Old River Flows								
			No criterion – No reverse flows are expected from SWP/CVP diversions; model output to assess	No criterion – No reverse flows are expected from SWP/CVP diversions; model output to assess	No criterion – No reverse flows are expected from SWP/CVP diversions; model output to assess	No criterion – No reverse flows are expected from SWP/CVP diversions; model output to assess	No criterion	No criterion

Table B-6. Summary of model operational parameters for BDCP Conservation Strategy Options 1 - 4 (Cont.)

Parameter	1A	1B	2A	2B	3A	3B	4A	4B
Middle River Flows								
Jun			No criterion	>-6,000 cfs (All)	No criterion	>-6,000 cfs (All)	No criterion	No criterion
Jul-Sep			No criterion	>-8,000 cfs (All)	No criterion	>-8,000 cfs (All)	No criterion	No criterion
Oct-Nov			No criterion	>-4,000 cfs (All)	No criterion	>-4,000 cfs (All)	No criterion	No criterion
Dec-Feb			No criterion	>-4,000 cfs (All)	No criterion	>-4,000 cfs (All)	No criterion	No criterion
Old and Middle River Flows (Combined)								
Mar-Jun	No criterion	>-1,000 cfs (All)						
Jul-Sep	No criterion	>-5,000 cfs (All)						
Oct-Nov	No criterion	>-1,000 cfs (All)						
Dec-Feb	No criterion	>-1,000 cfs (All)						
QWEST								
Mar-May	No criterion	Net positive flows (no reverse flow) (All)	No criterion	Net positive flows (no reverse flow) (All)	No criterion	Net positive flows (no reverse flow) (All)	No criterion	No criterion
Jun	No criterion	Net positive flows (no reverse flow) (All)	No criterion	Net positive flows (no reverse flow) (All)	No criterion	Net positive flows (no reverse flow) (All)	No criterion	No criterion
Jul-Nov	No criterion	Net positive flows (no reverse flow) (All)	No criterion	Net positive flows (no reverse flow) (All)	No criterion	Net positive flows (no reverse flow) (All)	No criterion	No criterion
Dec-Feb	No criterion	Net positive flows (no reverse flow) (All)	No criterion	Net positive flows (no reverse flow) (All)	No criterion	Net positive flows (no reverse flow) (All)	No criterion	No criterion
SWP/CVP VAMP South Delta Diversion Operations								
Apr	Model output	VAMP	No criterion	VAMP	No criterion	VAMP		
May	VAMP	VAMP	VAMP	VAMP	VAMP	VAMP		
SWP/CVP VAMP Isolated facility Diversion Operations								
Mar-May					< 15,400 cfs	< 6,000 cfs	< 15,400 cfs	< 6,000 cfs
Jun-Feb					< 15,400 cfs	No criterion	< 15,400 cfs	No criterion

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Table C-1. Stressors, Stressor Effects, and Impact Mechanisms for Delta Smelt

Stressor	Effect on Species	Important Impact Mechanism	Comments	Relationships to Other Stressors	Citations
Highly Important Stressors					
Reduced food	Starvation, higher susceptibility to disease, reduced reproduction	Non-native species (e.g., *Corbula*) reduce food available to delta smelt by eating/filtering out organics, phytoplankton, and zooplankton.	Can affect larvae, juveniles, and adults in all locations throughout the year, but mostly rearing juveniles and adults in western Delta and Suisun Bay during low production periods **Certainty:** 3		Kimmerer & Orsi 1996, Sweetnam 1999, Jassby et al. 2002, Kimmerer 2002a
		Upstream reservoir operations dampen high flows and reduce the frequency and duration of seasonal floodplain inundation and mobilization and downstream transport of nutrients and organic matter	Widespread stressor throughout geographic range, can affect larvae, juveniles, and adults throughout the year, mainly in drier years, rearing juveniles and adults in western Delta and Suisun Bay when flows are low and exports are high **Certainty:** 3	Increased input of nutrients and organic matter may not benefit smelt if it is removed by SWP, CVP, or in-Delta diversions or competitors, or if hydrologic residence time is too low to utilize it	Jassby et al. 2002, Pelagic Fish Action Plan 2007
		Nutrients and phytoplankton and zooplankton production are exported by SWP, CVP, and in-Delta diversions with water	Widespread stressor throughout geographic range, can affect larvae, juveniles, and adults throughout the year, rearing juveniles and adults in western Delta and Suisun Bay when flows are low and exports are high **Certainty:** 3		Jassby et al. 2002, Pelagic Fish Action Plan 2007

Table C-1. Stressors, Stressor Effects, and Impact Mechanisms for Delta Smelt (continued)

Stressor	Effect on Species	Important Impact Mechanism	Comments	Relationships to Other Stressors	Citations
Highly Important Stressors (cont.)					
		Hydrologic residence time in the Delta, which affects phytoplankton and zooplankton production, is reduced by the need to maintain a hydrologic barrier to keep exported water fresh and the use of Delta channels for water conveyance to the SWP and CVP export facilities	Can affect larvae, juveniles, and adults throughout the year, mostly rearing juveniles and adults in western Delta and Suisun Bay during low production periods **Certainty:** 3		Jassby et al. 2002, Kimmerer 2002a,b, Pelagic Fish Action Plan 2007
		Mortality of prey species that are exposed to toxics can occur, reducing food abundance to delta smelt	Widespread stressor throughout geographic range, can affect larvae, juveniles, and adults throughout the year, rearing juveniles and adults in western Delta and Suisun Bay **Certainty:** 1		Weston et al. 2004, Luoma 2007
Reduced rearing habitat	Reduced growth, increased competition	Water operations have compressed the estuarine salinity field.	Moderately widespread, influences rearing juveniles and adults and spawning in adults, episodic, mainly in Fall when outflow is low **Certainty:** 4		Swanson et al. 2000, Monismith et al. 2002, Kimmerer 2002a,b, Bennett 2005, Sommer 2006, Feyrer et al. 2007, Pelagic Fish Action Plan 2007
Reduced turbidity	Reduced foraging efficiency	Reduction in hydrologic residence time decreases organic material in the Delta	Widespread stressor throughout geographic range, influences rearing juveniles and adults, episodic, mainly in Fall **Certainty:** 3		Basker-Bridges et al. 2004, Feyrer et al. 2007, Pelagic Fish Action Plan 2007

Table C-1. Stressors, Stressor Effects, and Impact Mechanisms for Delta Smelt (continued)

Stressor	Effect on Species	Important Impact Mechanism	Comments	Relationships to Other Stressors	Citations
Highly Important Stressors (cont.)					
		Corbula reduces organic material in the water column	Specific to west Delta and Suisun Bay, influences rearing juveniles and adults. Varies temporally in influence on the species **Certainty:** 4		Kimmerer & Orsi 1996, Sweetnam 1999, Jassby et al. 2002, Kimmerer 2002a
		Egeria and other non-native invasive aquatic plants trap and remove suspended sediments from the water column	Widespread, varies seasonally, influences juveniles and adults **Certainty:** 3		Nestor et al. 2003
		Upstream water management & channelization reduces sediment input	Widespread, varies seasonally, mostly in non-rainy periods, influences juveniles and adults **Certainty:** 3		Jassby et al. 2002
Reduced spawning habitat	Reduction in reproductive success	Reclaiming wetlands and islands reduced shallow freshwater habitat, which is thought to be spawning habitat	Widespread throughout geographic range, affects adults during spawning season (late winter/early spring) **Certainty:** 3		Bennett 2005
Reduced food quality	Increased time needed to forage, starvation, reduced reproduction	Introductions of non-native zooplankton species have displaced native forage species that are less efficient to consume (due to size, protection, and speed) (e.g., *Limnoithona*)	Moderately widespread throughout geographic range, episodic, affects larvae, juveniles and adults **Certainty:** 3		Pelagic Fish Action Plan 2007

Table C-1. Stressors, Stressor Effects, and Impact Mechanisms for Delta Smelt (continued)

Stressor	Effect on Species	Important Impact Mechanism	Comments	Relationships to Other Stressors	Citations
Moderately Important Stressors (cont.)					
Unnatural mortality	Mortality	Non-native submerged aquatic vegetation provides suitable habitat for non-native predators that prey on delta smelt	Widespread throughout geographic range, impacts larvae, juveniles, adults, year-round **Certainty:** 3		Simenstad 1999, Moyle 2002, Toft et al. 2003, Nobriga et al. 2005, Brown & Michniuk 2006
		Reduced turbidity allows visual predators to forage more efficiently on delta smelt	Widespread stressor throughout geographic range, influences all stages, episodic, mainly in Fall **Certainty:** 3		Feyrer et al 2007; Pelagic Fish Action Plan 2007
CVP/SWP entrainment [1]	Mortality, injury, displacement if salvaged successfully	Reverse flows in Old and Middle rivers entrain delta smelt, eventually moving them into the SWP and CVP export facilities	Limited range, adults affected during spawning season (December-March), larvae and juveniles affected during first few months of life (usually Feb-June) **Certainty:** 2	When salinity is high, fish move farther upstream, increasing probability of entrainment into O&M rivers	Bennett 2005, Pelagic Fish Action Plan 2007, Sommer et al. 2007
Exposure to toxics	Sublethal and lethal effects, increased susceptibility to disease	Toxics enter the system from a variety of point and non-point sources including agricultural and urban run-off	Widespread throughout geographic range, can be episodic and chronic, can affect all life stages **Certainty:** 1		Sommer 2006, Bennett unpubl. data, Werner 2006, 2007, Herbold pers. comm., Pelagic Fish Action Plan 2007

[1]Although it is recognized that the risk of entrainment at the SWP and CVP export facilities may, in some years, be a high level stressor to delta smelt, and in some years represents a very low level stressor to delta smelt, for purposes of the analysis the risk of delta smelt entrainment under each of the Options has been characterized, on average, as a moderate level stressor to the population.

Other stressors:

- Propeller entrainment by cargo vessels
- Monitoring mortality
- Reduced dissolved oxygen
- Fish stranding
- Passage barriers
- Reduced habitat diversity
- Entrainment at:
  - Private unscreened diversions
  - DWR owned diversions
  - Rock Slough
  - Mirant Pittsburg and Contra Costa power plants
  - North Bay Aqueduct

Individuals participating in the BDCP technical working sessions for Delta smelt:

Bill Bennett (UC Davis) Chuck Hanson (Hanson Environmental); Diane Windham, Bruce Oppenheim, and Rosalie del Rosario (NMFS); Jim White, Randy Baxter, Alice Low, Kevin Flemming, and Neil Clipperton (DFG); Bill Harrell (DWR); Bill Bennett (UC Davis); Rick Sitts, David Fullerton, and Pete Rhoads (Metropolitan); Ron Kino (Mirant); Campbell Ingram (TNC); and Pete Rawlings and Rick Wilder (SAIC)

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Table C-2. Stressors, Stressor Effects, and Impact Mechanisms for Longfin Smelt

Stressor	Effect on Species	Important Impact Mechanism	Comments	Relationships to Other Stressors	Citations
Highly Important Stressors					
Reduced access to spawning habitat	Increased energy use, sub-optimal spawning habitat, mortality	Low winter/spring outflows move low salinity zone upstream, forcing spawners to move farther upstream to reach spawning habitat	Widespread throughout geographic range, during winter & spring, affects adults. **Certainty** = 3	Movement upstream causes increased probability of entrainment at pumps	Kimmerer 2002a,b; Sommer et al. 2007
Reduced access to rearing habitat	Sub-optimal growth, mortality	Low winter/spring outflow does not transport larvae, acting as passive particles, downstream	Widespread throughout geographic range, during winter & spring, affects larvae. **Certainty** = 3	Increased time upstream increases probability of entrainment at pumps, food supplies for larvae are reduced within the river	Kimmerer 2002a; Sommer et al. 2007
Reduced food	Starvation, reduced reproduction, higher susceptibility to disease	Non-native species (e.g., *Corbula*) reduce food available to longfin smelt by eating/filtering out organics, phytoplankton, and zooplankton.	Can affect larvae, juveniles, and adults in all locations throughout the year, but mostly rearing juveniles and adults in western Delta and Suisun Bay during low production periods. **Certainty** = 4		Kimmerer & Orsi 1996, Sweetnam 1999, Jassby et al. 2002, Kimmerer 2002a, 2004
		Upstream reservoir operations dampen high flows and reduce the frequency and duration of seasonal floodplain inundation and mobilization and downstream transport of nutrients and organic matter	Widespread stressor throughout geographic range, can affect larvae, juveniles, and adults throughout the year, mainly in drier years, rearing juveniles and adults in western Delta and Suisun Bay when flows are low and exports are high. **Certainty** = 3		Jassby et al. 2002, Pelagic Fish Action Plan 2007

Table C-2. Stressors, Stressor Effects, and Impact Mechanisms for Longfin Smelt (continued)

Stressor	Effect on Species	Important Impact Mechanism	Comments	Relationships to Other Stressors	Citations
Highly Important Stressors (cont.)					
		Upstream nutrients and production are exported by SWP, CVP, and in-Delta diversions with water	Widespread stressor throughout geographic range, can affect larvae, juveniles, and adults throughout the year, rearing juveniles and adults in western Delta and Suisun Bay when flows are low and exports are high. **Certainty** = 3		Jassby et al. 2002, Pelagic Fish Action Plan 2007
		Hydrologic residence time, which affects phytoplankton and zooplanktonproduction, is reduced by the need to maintain a hydrologic barrier to keep exported water fresh and the use of Delta channels for water conveyance. .	Can affect larvae, juveniles, and adults throughout the year, mostly rearing juveniles and adults in western Delta and Suisun Bay during low production periods. **Certainty** = 3		Jassby et al. 2002, Kimmerer 2002a,b, 2004, Pelagic Fish Action Plan 2007
		Mortality of prey species that are exposed to toxics can occur, reducing food abundance to longfin smelt	Widespread stressor throughout geographic range, can affect larvae, juveniles, and adults throughout the year, rearing juveniles and adults in western Delta and Suisun Bay **Certainty:** 1		Weston et al. 2004, Luoma 2007
Unnatural predation	Mortality	Non-native submerged aquatic vegetation provides suitable habitat for non-native predators that prey on longfin smelt	Widespread throughout geographic range, impacts larvae, juveniles, adults, year-round. **Certainty** = 3		Simenstad 1999, Moyle 2002, Toft et al. 2003, Nobriga et al. 2005, Brown & Michniuk 2006

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Table C-2. Stressors, Stressor Effects, and Impact Mechanisms for Longfin Smelt (continued)

Stressor	Effect on Species	Important Impact Mechanism	Comments	Relationships to Other Stressors	Citations
Highly Important Stressors (cont.)					
Reduced turbidity	Reduced foraging efficiency, increased vulnerability to predation	Reduction in hydrologic residence time decreases organic material in the Delta, changes in hydrology and scour (riprapped levees) has reduced sediment inputs	Widespread stressor throughout geographic range, influences rearing juveniles and adults, episodic, mainly in Fall. **Certainty** = 3		Pelagic Fish Action Plan 2007, S. Foote unpubl. data,
		Corbula reduces organic material in the water column	Specific to west Delta and Suisun Bay, influences rearing juveniles and adults. Varies temporally in influence on the species. **Certainty** = 4		Kimmerer & Orsi 1996, Jassby et al. 2002, Kimmerer 2002a, 2004
		Egeria and other non-native invasive aquatic plants trap and remove suspended sediments from the water column	Widespread, varies seasonally, influences juveniles and adults. **Certainty** = 3		Nestor et al. 2003
		Upstream water management & channelization reduces sediment input	Widespread, varies seasonally, mostly in non-rainy periods, influences juveniles and adults. **Certainty** = 3		Jassby et al. 2002
Reduced spawning habitat	Reduction in reproductive success	Reclaiming wetlands and islands reduced shallow freshwater habitat, which is thought to be spawning habitat	Widespread throughout spawning range, affects adults during spawning season (late winter/early spring). **Certainty** = 2		Pelagic Fish Action Plan 2007
		Channelization and rip-rapping of channels reduces the amount of shallow water habitat suitable for spawning	Widespread throughout spawning range affects adults during spawning season (late winter/early spring). **Certainty** = 2		Pelagic Fish Action Plan 2007

Table C-2. Stressors, Stressor Effects, and Impact Mechanisms for Longfin Smelt (continued)

Stressor	Effect on Species	Important Impact Mechanism	Comments	Relationships to Other Stressors	Citations
Highly Important Stressors (cont.)					
Reduced food quality	Increased time needed to forage, starvation, reduced reproduction	Introductions of non-zooplankton peciesnatives have displaced native forage species that are less efficient to consume (due to size, protection, and speed) (e.g., *Limnoithona*)	Moderately widespread throughout geographic range, episodic, affects juveniles and adults. **Certainty** = 2		Pelagic Fish Action Plan 2007
Moderately Important Stressors					
CVP/SWP entrainment[1]	Mortality, injury, displacement if salvaged successfully	Reverse flows in Old and Middle rivers (high E:I ratio) entrain longfin smelt, eventually moving them into the SWP and CVP export facilities	Adults affected during spawning season (December-March), larvae and juveniles affected during first few months of life (~Feb-May). **Certainty** = 2	Depends on location of fish, which is influenced by low salinity zone and outflow	T. Swanson unpubl. data, POD Action Plan 2007
Reduced rearing habitat	Reduced growth, increased competition	Water operations have compressed the estuarine salinity field through reductions in seasonal Delta outflow.	Moderately widespread, influences rearing juveniles and adults and spawning in adults, episodic, mainly in Fall when outflow is low. **Certainty** = 3		Kimmerer 2002a,b, Bennett 2005, Sommer 2006, Pelagic Fish Action Plan 2007
Exposure to toxics	Sublethal and lethal effects, increased susceptibility to disease	Toxics enter the system from a variety of point and non-point sources including agricultural and urban run-off	Widespread throughout geographic range, can be episodic and chronic, can affect all life stages. **Certainty** = 1		S. Foote unpubl. data, Pelagic Fish Action Plan 2007

[1]Although it is recognized that the risk of entrainment at the SWP and CVP export facilities may, in some years, be a high level stressor to longfin smelt, and in some years represents a very low level stressor to longfin smelt, for purposes of the analysis the risk of longfin smelt entrainment under each of the Options has been characterized, on average, as a moderate level stressor to the population.

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Other stressors:

- Monitoring mortality
- Propeller entrainment by cargo vessels
- Fish stranding
- Passage barriers
- Other entrainment
    - Private unscreened diversions
    - DWR owned diversions
    - USBR owned diversion (Rock Slough)
    - Mirant Pittsburg/Contra Costa power plants
    - North Bay Aqueduct

Individuals participating in the BDCP technical working sessions for longfin smelt:

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Table C-3. Stressors, Stressor Effects, and Impact Mechanisms for Sacramento River Chinook Salmon (winter-run, spring-run, and fall-/late fall-run)

Stressor	Effect on Species	Important Impact Mechanism	Comments	Relationships to Other Stressors	Citations
Highly Important Stressors					
Reduced staging and spawning habitat	Reduced spawning success, competition for remaining habitat, increased probability of inter-racial breeding, redd superimposition and reduced reproductive success	Man-made structures (e.g., dams, weirs) prohibit access to upstream staging and spawning habitat	Primarily upstream of Delta, during staging and spawning season, in all years, influences spawning adults migrating upstream **Certainty:** 4		USBR 2004, DWR 2005
		Blockage of gravel recruitment from upstream areas by reservoirs, removal of gravel by humans or increased sedimentation has reduced gravel availability needed for spawning	Upstream of the Delta, during staging and spawning season, primarily in low flow years, spawning adults migrating upstream **Certainty:** 3		Yoshiyama et al. 1998
		Low flows from upstream dams do not provide attraction cues needed by spawning adults to gain access to natal spawning grounds, reduced migration cues	Primarily upstream of the Delta, during staging and spawning season, primarily in low flow years, spawning adults migrating upstream **Certainty:** 3		Yoshiyama et al. 1998
Reduced rearing and outmigration habitat	Reduced juvenile growth/survival	Reclaiming wetlands and islands has reduced shallow, low velocity habitat	Throughout the Delta, year-round, all years, influences rearing and outmigrating fry and juveniles **Certainty:** 4		Yoshiyama et al. 1998, Williams 2006
		Man-made structures (e.g., dams, weirs) prohibit access to rearing habitat, increase vulnerability to predation	Primarily upstream of the Delta, year-round, affects rearing juveniles **Certainty:** 4		USBR 2004, DWR 2005, NOAA 2005

Table C-3. Stressors, Stressor Effects, and Impact Mechanisms for Sacramento River Chinook Salmon (winter-run, spring-run, and fall-/late fall-run) **(continued)**

Stressor	Effect on Species	Important Impact Mechanism	Comments	Relationships to Other Stressors	Citations
Highly Important Stressors (cont.)					
		Upstream reservoir operations and reclamation (levee construction) has reduced the frequency and duration of seasonal floodplain inundation, mobilization and downstream transport of nutrients and organic carbon, and other flow-dependent habitat (salmon rearing habitat and outmigration pathway)	Specific to floodplains, during winter/spring with high flows, some years, influences rearing and outmigrating fry and juveniles **Certainty:** 4		Sommer et al. 2001, 2004, Moyle et al. 2007
		Riprapped levees reduce shallow water, low velocity habitat and overbank flow	Throughout the Delta, year-round, all years, influences rearing and outmigrating fry and juveniles **Certainty:** 4		Yoshiyama et al. 1998
Predation by non-native species	Mortality	Reduction in spatial complexity (habitat diversity) of channels reduces refuge space from predators, use of riprapped stabilized channel levees reduces cover habitat and increases vulnerability to predation	Widespread throughout aquatic range, impacts rearing and outmigrating fry and juveniles primarily, year-round **Certainty:** 3		Missildine et al. 2001, Sommer et al. 2001, 2004
		Instream gravel pits and flooded ponds attract non-native warm water predators and lack cover for salmon	Primarily upstream of the Delta, impacts juveniles rearing and migrating downstream **Certainty:** 2		Demko 1998, DWR 2005

Table C-3. Stressors, Stressor Effects, and Impact Mechanisms for Sacramento River Chinook Salmon (winter-run, spring-run, and fall-/late fall-run) (continued)

Stressor	Effect on Species	Important Impact Mechanism	Comments	Relationships to Other Stressors	Citations
Highly Important Stressors (cont.)					
		Non-native submerged aquatic vegetation provides suitable habitat for non-native predators that prey on salmon	Widespread throughout aquatic range, impacts outmigrating fry and juveniles year-round **Certainty:** 3		Simenstad 1999, Moyle 2002, Toft et al. 2003, Nobriga et al. 2005, Brown & Michniuk 2006
Moderately Important Stressors					
Harvest	Mortality	Legal and illegal	Occurs primarily in ocean, but some harvest of spawning adults migrating upstream throughout migration pathways during spawning season, moderately high certainty for legal, moderate certainty for illegal **Certainty**: 3		Yoshiyama 1998, USBR 2004, Williams 2006
Reduced genetic diversity/ integrity	Increased risk of extinction	Hatcheries reduce genetic diversity	Throughout range, year-round, all life stages **Certainty:** 2	Hatchery practices may also increase vulnerability to disease	USFWS 2001, Williams 2006
CVP/SWP entrainment	Mortality, injury, displacement if salvaged successfully	Reverse flows in Old and Middle rivers entrain salmon, eventually moving them into the SWP and CVP export facilities	Limited range, primarily Feb-June, fry and juveniles **Certainty:** 3		USFWS 1987, Brandes & McLain 2001, USBR 2004
Exposure to toxics	Lethal and sub-lethal effects, increased susceptibility to predation	Point and non-point sources	Throughout the Delta, year-round, all years, all life stages while in the Delta **Certainty:** 1		Klabrat et al. 1992, Moyle 2002, USBR 2004

Table C-3. Stressors, Stressor Effects, and Impact Mechanisms for Sacramento River Chinook Salmon (winter-run, spring-run, and fall-/late fall-run) (continued)

Stressor	Effect on Species	Important Impact Mechanism	Comments	Relationships to Other Stressors	Citations
Moderately Important Stressors (cont.)					
Increased water temperature	Physiological stress, reduced spawning success, mortality	Low flows from dam releases, reduced cold water pool storage in upstream reservoirs, reduced riparian vegetation and shading	Widespread throughout the Delta and tributary rivers during spring/summer/fall, occurs primarily in drier years, affects all life stages **Certainty:** 3	Low flows also increase hydrologic residence time, increase juvenile migration time, contribute to localized depressions in DO	USFWS 1999, Myrick & Cech 2001, USBR 2004

Other stressors:

- Increased fine sediments
- Monitoring mortality
- Propeller entrainment by cargo vessels
- Reduced food
- Salinity control/compliance
- Competition with hatchery-reared individuals

Individuals participating in the BDCP technical working sessions for covered salmonids:

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Table C-4. Stressors, Stressor Effects, and Impact Mechanisms for San Joaquin River Chinook Salmon (fall-run)

Stressor	Effect on Species	Important Impact Mechanism	Comments	Relationships to Other Stressors	Citations
Highly Important Stressors					
Reduced staging and spawning habitat	Reduced spawning success, competition for remaining habitat, redd superimposition and reduced reproductive success	Man-made structures (e.g., dams, weirs) prohibit access to upstream staging and spawning habitat	Primarily upstream of Delta, during staging and spawning season (fall/winter), in all years, influences spawning adults migrating upstream **Certainty:** 4		USBR 2004, DWR 2005
		Low flows from upstream dams do not provide attraction cues needed by spawning adults to gain access to natal spawning grounds, reduced migration cues	Primarily upstream of the Delta, during staging and spawning season (fall/winter), primarily in low flow years, spawning adults migrating upstream **Certainty:** 3		Yoshiyama et al. 1998
		Blockage of gravel recruitment from upstream areas by reservoirs, removal of gravel by humans or increased sedimentation has reduced gravel availability needed for spawning	Primarily upstream of the Delta, during staging and spawning season, primarily in low flow years, spawning adults migrating upstream **Certainty:** 3		Yoshiyama et al. 1998
Reduced rearing and outmigration habitat	Reduced juvenile growth/survival	Upstream reservoir operations and reclamation (levee construction) has reduced the frequency and duration of seasonal floodplain inundation , mobilization and downstream transport of nutrients and organic carbon, and other flow-dependent habitat (salmon rearing habitat and outmigration pathway)	Specific to floodplains, during winter/spring with high flows, some years, influences rearing and outmigrating fry and juveniles **Certainty:** 4		Sommer et al. 2001, 2004, Moyle et al. 2007

Table C-4. Stressors, Stressor Effects, and Impact Mechanisms for San Joaquin River Chinook Salmon (fall-run) (continued)

Stressor	Effect on Species	Important Impact Mechanism	Comments	Relationships to Other Stressors	Citations
Highly Important Stressors (cont.)					
		Man-made structures (e.g., dams, weirs, boat locks) prohibit access to rearing habitat	Primarily upstream of the Delta, Jan-Jun, affects rearing juveniles **Certainty:** 4		USBR 2004, DWR 2005, NOAA 2005
		Reclaiming wetlands and islands reduced shallow, low velocity habitat, increase vulnerability to predation	Throughout the Delta, Jan-Jun, all years, influences rearing and outmigrating fry and juveniles **Certainty:** 4		Yoshiyama et al. 1998, Williams 2006
		Low flows due to low inflows or high export rates increase water temperature and residence time, resulting in dissolved oxygen levels	Specific areas of low flow in Delta (e.g., Stockton Shipping Channel), late summer-late fall, affects rearing and outmigrating fry and juveniles and upstream adult migration **Certainty:** 4	Can also cause localized fish kills	USBR 2004, DWR 2006
		Riprapped levees reduce shallow water, low velocity habitat and overbank flow	Throughout the Delta, Jan-Jun, all years, influences rearing and outmigrating fry and juveniles **Certainty:** 4		Yoshiyama et al. 1998
Exposure to toxics	Lethal and sub-lethal effects, increased susceptibility to predation	Point and non-point sources	Throughout the Delta, year-round, all years, all life stages while in the Delta **Certainty:** 2		Saiki et al. 1992, Klaprat et al. 1992, Moyle 2002, USBR 2004
Predation by non-native species	Mortality	Non-native submerged aquatic vegetation provides suitable habitat for non-native predators that prey on salmon	Widespread throughout geographic range, primarily Jan-Jun, impacts outmigrating fry and juveniles **Certainty:** 3		Simenstad 1999, Moyle 2002, Toft et al. 2003, Nobriga et al. 2005, Brown & Michniuk 2006

Table C-4. Stressors, Stressor Effects, and Impact Mechanisms for San Joaquin River Chinook Salmon (fall-run) (continued)

Stressor	Effect on Species	Important Impact Mechanism	Comments	Relationships to Other Stressors	Citations
Highly Important Stressors (cont.)					
		Instream gravel pits and flooded ponds attract non-native warm water predators and lack cover for salmon	Primarily upstream of the Delta, Jan-Jun, impacts juveniles rearing and migrating downstream **Certainty:** 2		Demko 1998, DWR 2005
		Reduction in spatial complexity (habitat diversity) of channels reduces refuge space from predators, use of riprapped stabilized channel levees reduces cover habitat and increases vulnerability to predation	Widespread throughout aquatic range, impacts rearing and outmigrating fry and juveniles primarily, Jan-Jun **Certainty:** 3		Missildine et al. 2001, Sommer et al. 2001, 2004
Moderately Important Stressors					
Reduced genetic diversity/ integrity	Susceptibility to disease	Hatcheries reduce genetic diversity	Throughout range, year-round, all life stages, low certainty	Hatchery practices may also increase vulnerability to disease	USFWS 2001, Williams 2006
Harvest	Mortality	Legal and illegal	Occurs primarily in ocean, but some harvest of spawning adults migrating upstream throughout migration pathways during spawning season **Certainty:** 3		Yoshiyama 1998, USBR 2004, Williams 2006
CVP/SWP entrainment	Mortality, injury, displacement if salvaged successfully	Reverse flows in Old and Middle rivers entrain salmon, eventually moving them into the SWP and CVP export facilities	Limited range, primarily Jan-Jun, fry and juveniles **Certainty:** 3		USFWS 1987, Brandes & McLain 2001, USBR 2004

Table C-4. Stressors, Stressor Effects, and Impact Mechanisms for San Joaquin River Chinook Salmon (fall-run) **(continued)**

Stressor	Effect on Species	Important Impact Mechanism	Comments	Relationships to Other Stressors	Citations
Moderately Important Stressors (cont.)					
Increased water temperature	Physiological stress, reduced spawning success, mortality	Low flows from dam releases, reduced cold water pool storage in upstream reservoirs, reduced riparian vegetation and shading	Widespread throughout the Delta and tributary rivers during spring/summer/fall, occurs primarily in drier years, affects all life stages **Certainty:** 3	Low flows also increase hydrologic residence time, increase juvenile migration time, contribute to localized depressions in DO	USFWS 1999, Myrick & Cech 2001, USBR 2004

Other stressors:

- Increase in fine sediment
- Monitoring mortality
- Propeller entrainment by cargo vessels
- Reduced food
- Salinity control/compliance
- Competition with hatchery-reared individuals
- Other entrainment

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1 **Table C-5. Stressors, Stressor Effects, and Impact Mechanisms for Sacramento River Central Valley Steelhead**

Stressor	Effect on Species	Important Impact Mechanism	Comments	Relationships to Other Stressors	Citations
Highly Important Stressors					
Reduced staging and spawning habitat	Reduced spawning success, competition for remaining habitat, redd superimposition and reduced reproductive success	Man-made structures (e.g., dams, weirs) prohibit access to upstream staging and spawning habitat	Primarily upstream of Delta, September-April, in all years, influences adults migrating upstream **Certainty:** 4		USBR 2004, DWR 2005, NOAA 2005, Lindley et al. 2006
		Low flows from upstream dams do not provide attraction cues needed by spawning adults to gain access to natal spawning grounds, reduced migration cues	Primarily upstream of the Delta, September-April, primarily in low flow years **Certainty:** 3		DWR 2005
		Blockage of gravel recruitment from upstream areas by reservoirs, removal of gravel by humans or increased sedimentation has reduced gravel availability needed for spawning	Upstream of the Delta, September-April, reduces spawning habitat and egg incubation/hatching success **Certainty:** 3		Mesick 1998
Entrainment	Mortality, injury, displacement if salvaged successfully at the SWP and CVP export facilities	Reverse flows in Old and Middle rivers entrain or guide steelhead, increasing their vulnerability to entrainment and salvage at the CVP/SWP export facilities	Limited range, primarily Feb-June, fry and juveniles **Certainty:** 3		USBR 2004, Williams 2006
		Other screened and unscreened diversions	Widespread, primarily Feb-June, fry and juveniles **Certainty:** 2		Herren & Kawasaki 2004, USBR 2004

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Table C-5. Stressors, Stressor Effects, and Impact Mechanisms for Sacramento River Central Valley Steelhead (continued)

Stressor	Effect on Species	Important Impact Mechanism	Comments	Relationships to Other Stressors	Citations
Highly Important Stressors (cont.)					
Reduced rearing and outmigration habitat	Reduced juvenile growth/survival	Upstream reservoir operations dampen high flows, reducing extent and duration of inundation of floodplains, mobilization and downstream transport of nutrients and organic material, and other flow-dependent habitat (steelhead rearing habitat and outmigration pathway)	Specific to floodplains, during winter/spring with high flows, some years, influences rearing and outmigrating fry and juveniles **Certainty:** 4		NOAA 2005, DWR 2005
		Man-made structures (e.g., dams, weirs) prohibit access to upstream juvenile rearing habitat, increase vulnerability to predation	Primarily upstream of the Delta, year-round, affect rearing juveniles **Certainty:** 3		DFG 1996, USBR 2004, DWR 2005, NOAA 2005
		Reclaiming wetlands and islands has reduced shallow, low velocity habitat	Throughout the Delta, year-round, all years, influences rearing juveniles **Certainty:** 4		Williams 2006
		Riprapped levees reduce shallow water, low velocity habitat and overbank flow	Throughout the Delta and upstream reaches of the Sacramento River and many tributaries, year-round, all years, influences rearing juveniles **Certainty:** 4		DFG 1996, DWR 2005

Table C-5. Stressors, Stressor Effects, and Impact Mechanisms for Sacramento River Central Valley Steelhead (continued)

Stressor	Effect on Species	Important Impact Mechanism	Comments	Relationships to Other Stressors	Citations
Highly Important Stressors (cont.)					
Predation by non-native species	Mortality	Non-native submerged aquatic vegetation provides suitable habitat for non-native predators that prey on juvenile steelhead	Widespread throughout geographic range, impacts outmigrating and rearing juveniles year-round **Certainty:** 3		Simenstad 1999, Moyle 2002, Toft et al. 2003, Nobriga et al. 2005, Brown & Michniuk 2006
		Instream gravel pits and flooded ponds attract non-native warm water predators and lack cover for juvenile steelhead	Primarily upstream of the Delta, impacts juveniles rearing and migrating downstream **Certainty:** 2		DWR 2005, NOAA 2005
		Reduction in spatial complexity (habitat diversity) of channels reduces refuge space from predators	Widespread throughout aquatic range, impacts rearing and outmigrating fry and juveniles primarily, year-round **Certainty:** 3		Raleigh et al. 1984, Missildine et al. 2001, NOAA 2005
Moderately Important Stressors					
Exposure to toxics	Lethal and sub-lethal effects, reduced health, growth, survival, and reproductive success	Point and non-point sources	Throughout the Delta, year-round, all years, all life stages while in the Delta **Certainty:** 3		DFG 1996, USBR 2004, Klinck et al. 2005
Reduced genetic diversity/ integrity	Increased risk of extinction	Hatcheries reduce genetic diversity	Throughout range, year-round, all life stages **Certainty:** 2	Hatchery practices may also increase vulnerability to disease	USFWS 2001, Williams 2006
Harvest	Mortality	Legal and illegal	Harvest of adults migrating upstream throughout migration pathways, primarily Sept-Mar, greatest in upstream river reaches **Certainty:** 3		USBR 2004, DWR 2005, Williams 2006

Table C-5. Stressors, Stressor Effects, and Impact Mechanisms for Sacramento River Central Valley Steelhead (continued)

Stressor	Effect on Species	Important Impact Mechanism	Comments	Relationships to Other Stressors	Citations
Moderately Important Stressors (cont.)					
Increased water temperature	Physiological stress, reduced spawning success, increased mortality	Low flows from dam releases, reduced cold water pool storage in upstream reservoirs, reduced riparian vegetation and shading	Widespread throughout the Delta and tributary rivers, during spring/summer/fall, occurs primarily in drier years, affects all life stages, primarily rearing juveniles **Certainty:** 3	Low flows also increase hydrologic residence time, increase juvenile migration time, and contribute to increased vulnerability to predation mortality	McEwan & Jackson 1996, IEP Steelhead PWT 1998, USBR 2004, Myrick & Cech 2004

Other stressors:

- Increase in fine sediment
- Propeller entrainment by cargo vessels
- Monitoring mortality
- Salinity control/compliance
- Cold water management
- Reduced food
- Competition with hatchery-reared individuals

Individuals participating in the BDCP technical working sessions for covered salmonids:

Chuck Hanson (Hanson Environmental); Diane Windham, Bruce Oppenheim, and Rosalie del Rosario (NMFS); Jim White, Randy Baxter, Alice Low, and Neil Clipperton (DFG); Bill Harrell (DWR); Bill Bennett (UC Davis); Rick Sitts, David Fullerton, and Pete Rhoads (Metropolitan); Ron Kino (Mirant); and Campbell Ingram (TNC); and Pete Rawlings and Rick Wilder (SAIC).

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Williams JG. 2006. Central Valley Salmon: A perspective on Chinook and steelhead in the Central Valley of California. San Francisco Estuary and Watershed Science [online serial]. Vol 4, Issue 3 (December 2006), Article 2

1 **Table C-6. Stressors, Stressor Effects, and Impact Mechanisms for San Joaquin River Central Valley Steelhead**

Stressor	Effect on Species	Important Impact Mechanism	Comments	Relationships to Other Stressors	Citations
Highly Important Stressors					
Reduced staging and spawning habitat	Reduced spawning success, competition for remaining habitat, redd superimposition and reduced reproductive success	Man-made structures (e.g., dams, weirs) prohibit access to upstream staging and spawning habitat	Primarily upstream of Delta, September-April, in all years, influences adults migrating upstream **Certainty:** 4		DFG 1996, USBR 2004, DWR 2005, NOAA 2005, Lindley et al. 2006
		Low flows from upstream dams or increased export rates do not provide attraction cues needed by spawning adults to gain access to natal spawning grounds, reduced adult and juvenile migration cues	Primarily upstream of the Delta, September-April, primarily in low flow years, adults migrating upstream **Certainty:** 3		DWR 2005
		Blockage of gravel recruitment from upstream areas by reservoirs, removal of gravel by humans or increased sedimentation has reduced gravel availability needed for spawning	Upstream of the Delta, September-April, reduces spawning habitat and egg incubation/hatching success **Certainty:** 3		Mesick 1998
Reduced rearing and outmigration habitat	Reduced growth/survival	Upstream reservoir operations or water exports dampen high flows, reducing extent and duration of inundation of floodplains and other flow-dependent habitat (steelhead rearing habitat and outmigration pathway)	Specific to floodplains, during winter/spring with high flows, some years, influences rearing and outmigrating fry and juveniles **Certainty:** 4		NOAA 2005, DWR 2005
		Man-made structures (e.g., dams, weirs, boat locks) prohibit access to rearing habitat	Primarily upstream of the Delta, year-round, affects rearing juveniles **Certainty:** 4		DFG 1996, USBR 2004, DWR 2005, NOAA 2005

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1 **Table C-6. Stressors, Stressor Effects, and Impact Mechanisms for San Joaquin River Central Valley Steelhead (continued)**

Stressor	Effect on Species	Important Impact Mechanism	Comments	Relationships to Other Stressors	Citations
Highly Important Stressors (cont.)					
		Reclaiming wetlands and islands has reduced shallow, low velocity habitat	Throughout the Delta, year-round, all years, influences rearing juveniles **Certainty:** 4		Williams 2006
		Riprapped levees reduce shallow water, low velocity habitat and overbank flow	Throughout the Delta, year-round, all years, influences rearing juveniles **Certainty:** 4		DFG 1996, DWR 2005
		Low flows due to low inflows or high export rates increase water temperature and residence time, resulting in dissolved oxygen levels	Specific areas of low flow in Delta (e.g., Stockton Shipping Channel), affects rearing and outmigrating juveniles, during late summer-fall **Certainty:** 4	Can also cause localized fish kills	USBR 2004, DWR 2006
Exposure to toxics	Lethal and sub-lethal effects, increased susceptibility to predation	Point and non-point sources	Throughout the Delta, year-round, all years, all life stages while in the Delta **Certainty:** 3		DFG 1996, USBR 2004, Klinck et al. 2005
Reduced genetic diversity/ integrity	Susceptibility to disease, increased risk of extinction	Hatcheries reduce genetic diversity	Throughout range, year-round, all life stages **Certainty:** 2		USFWS 2001, Williams 2006
Predation by non-native species	Mortality	Reduction in spatial complexity (habitat diversity) of channels reduces refuge space from predators	Widespread throughout aquatic range, impacts rearing and outmigrating fry and juveniles primarily, year-round **Certainty:** 3		Raleigh et al. 1984, Missildine et al. 2001, DWR 2005, NOAA 2005

1 **Table C-6. Stressors, Stressor Effects, and Impact Mechanisms for San Joaquin River Central Valley Steelhead (continued)**

Stressor	Effect on Species	Important Impact Mechanism	Comments	Relationships to Other Stressors	Citations
Highly Important Stressors (cont.)					
		Non-native submerged aquatic vegetation provides suitable habitat for non-native predators that prey on salmon	Widespread throughout geographic range, impacts outmigrating and rearing juveniles year-round **Certainty:** 3		Simenstad 1999, Moyle 2002, Toft et al. 2003, Nobriga et al. 2005, Brown & Michniuk 2006
		Instream gravel pits and flooded ponds attract non-native warm water predators and lack cover for salmon	Primarily upstream of the Delta, impacts juveniles rearing and migrating downstream **Certainty:** 2		DWR 2005, NOAA 2005
Moderately Important Stressors					
CVP/SWP entrainment	Mortality, injury, displacement if salvaged successfully at the SWP and CVP export facilities	Reverse flows in Old and Middle rivers entrain or guide steelhead, increasing their vulnerability to entrainment and salvage at the CVP/SWP export facilities	Limited range, primarily Feb-June, fry and juveniles **Certainty:** 3		DWR & USBR 1999, USBR 2004
Harvest	Mortality	Legal and illegal	Harvest of adults migrating upstream throughout migration pathways, primarily Sept-Mar, greatest in upstream river reaches **Certainty:** 3		Mesick 1998, USBR 2004, DWR 2005, Williams 2006

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Table C-6. Stressors, Stressor Effects, and Impact Mechanisms for San Joaquin River Central Valley Steelhead (continued)

Stressor	Effect on Species	Important Impact Mechanism	Comments	Relationships to Other Stressors	Citations
Moderately Important Stressors (cont.)					
Increased water temperature	Physiological stress, reduced spawning success, increased mortality	Low flows from dam releases, reduced cold water pool storage in upstream reservoirs, reduced riparian vegetation and shading	Widespread throughout the Delta and tributary rivers, during spring/summer/fall, occurs primarily in drier years, affects all life stages, primarily rearing juveniles **Certainty:** 3	Low flows also increase hydrologic residence time, increase juvenile migration time, and contribute to increased vulnerability to predation mortality	McEwan & Jackson 1996, IEP Steelhead PWT 1998, Myrick & Cech 2004, USBR 2004

Other stressors:

- Increase in fine sediment
- Propeller entrainment by cargo vessels
- Other entrainment
- Monitoring mortality
- Salinity control/compliance
- Cold water management
- Reduced food
- Competition with hatchery-reared individuals

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Toft JD, CA Simenstad, JR Cordell, LF Grimaldo. 2003. The effects of introduced water hyacinth on habitat structure, invertebrate assemblages, and fish diets. Estuaries. 26(3):746-758

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Williams JG. 2006. Central Valley Salmon: A perspective on Chinook and steelhead in the Central Valley of California. San Francisco Estuary and Watershed Science [online serial]. Vol 4, Issue 3 (December 2006), Article 2

Table C-7. Stressors, Stressor Effects, and Impact Mechanisms for Green Sturgeon

Stressor	Effect on Species	Important Impact Mechanism	Comments	Relationships to Other Stressors	Citations
Very Important Stressors					
Reduced spawning habitat	Reduced reproductive success	Artificial barriers (dams, weirs) prohibit access to upstream spawning habitat	Upstream only, spawning season (late spring-early summer) in all years, influences spawning adults **Certainty:** 3	Also contributes to reductions in upstream juvenile rearing habitat	CDWR 2005, NOAA Fisheries 2005, Heublein et al 2006
Exposure to toxics	Sublethal and lethal effects, increased susceptibility to disease	*Corbula* and *Corbicula* as a food source contribute to bioaccumulation of toxics like selenium in sturgeon tissue via consumption	Specific to locations with *Corbula* and *Corbicula* presence (e.g., western Delta, Suisun Bay), year-round, affects subadults and non-marine adults **Certainty:** 2		EPIC et al 2001, Moyle 2002, Doroshov 2006
		Point and non-point sources	Widespread, year-round, affects all non-marine lifestages **Certainty:** 1		Klimley 2002
Harvest	Mortality	Illegal (for roe) and incidental harvest as part of the white sturgeon recreational fishery	Problem has increased in past few years, mostly in rivers, year-round mostly spawning females, influences sub-adults and adults **Certainty:** 2		CDFG 2002, M. Donnellan pers comm., Lt. L. Schwall pers comm..
Moderately Important Stressors					
Reduced rearing habitat	Reduced growth rates, increased predation	Reclaiming wetlands and islands reduced in- and off-channel rearing habitat	Widespread in Delta, year-round, juveniles and sub-adults **Certainty:** 1		
		Channelized riprap levees reduce in- and off-channel intertidal and shallow subtidal rearing habitat, including seasonal inundation of floodplain habitat	Widespread in Delta and upstream, year-round, juveniles and sub-adults **Certainty:** 1		

1 **Table C-7. Stressors, Stressor Effects, and Impact Mechanisms for Green Sturgeon (continued)**

Stressor	Effect on Species	Important Impact Mechanism	Comments	Relationships to Other Stressors	Citations
Moderately Important Stressors (cont.)					
Increased water temperature	Increased heat-related physiological stress (heat-shock proteins), increased susceptibility to disease, mortality	Reduced flows from upstream reservoirs increase hydrologic resident time, allowing water to warm, reduced riparian vegetation and shading	Occurs in Feather River, primarily in spring/summer, primarily influences eggs and juveniles Certainty: 3		NOAA Fisheries 2005, Van Eenennaam et al. 2005, Allen et al 2006a,b
Unnatural mortality	Mortality	Predation by non-natives	Only been shown for white sturgeon but likely translates to larval and early juvenile green sturgeon, occurs upstream in and near spawning habitat during and shortly after spawning season, affects larvae and juveniles **Certainty:** 3	Predation risk increases with lower turbidity	Gadomski & Parsely 2005a
		Dredging directly entrains sturgeon	Occurs in specific main channels, year-round, rearing juveniles and sub-adults **Certainty**: 2		
Reduced turbidity	Increased risk of predation	Upstream water management & channelization reduces sediment input	Only been shown for white sturgeon but likely translates to green sturgeon, occurs upstream in and near spawning habitat during and shortly after spawning season, affects larvae **Certainty:** 2		Jassby et al 2002, Gadomski & Parsley 2005b

Other Stressors:

- Unnatural mortality
  - Monitoring mortality
  - Stranding
- Entrainment (SWP, CVP, and others)
- Salinity control
- Reduced food

Individuals participating in the BDCP technical working sessions for sturgeon include:

Diane Windham and Jeff Stuart (NMFS); Scott Cantrell, Tom Schroyer, and Mike Donnellan (DFG); Zoltan Matica and Alicia Seesholtz (DWR); Rick Sitts (Metropolitan); Campbell Ingram (TNC); Josh Israel (UC Davis); Chuck Hanson (Hanson Environmental); Pete Rawlings and Rick Wilder (SAIC).

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Table C-8. Stressors, Stressor Effects, and Impact Mechanisms for White Sturgeon

Stressor	Effect on Species	Important Impact Mechanism	Comments	Relationships to Other Stressors	Citations
Very Important Stressors					
Harvest	Mortality	Legal (recreational fishery)	Moderate spatial range, year-round, affects subadults and adults, angling regulations have been modified to increase protection in recent years **Certainty:** 3		USFWS 1995, M. Donnellan pers. comm.
		Illegal (for roe)	Problem has increased in past few years, mostly in rivers, mostly during spawning season, enforcement efforts have increased in recent years **Certainty:** 2		Lt. L. Schwall pers. comm.
Reduced spawning habitat	Reduced reproductive success	Artificial barriers (dams, weirs) prohibit access to upstream spawning habitat	Upstream only, spawning season (late spring-early summer) in all years, influences spawning adults **Certainty:** 3		Matica pers. comm., J. Israel dissertation
Exposure to toxics	Sublethal and lethal effects, increased susceptibility to disease	*Corbula* and *Corbicula* as a food source contribute to bioaccumulations of toxics like selenium in sturgeon tissue via consumption	Specific to locations with *Corbula* and *Corbicula* presence (e.g., western Delta, Suisun Bay), year-round, affects subadults and adults **Certainty:** 2		Tashjian et al. 2006
		Point and non-point sources	Widespread, year-round, affects all lifestages **Certainty:** 1		Linville 2002, Greenfield et al. 2005, Doroshov 2006

1 **Table C-8. Stressors, Stressor Effects, and Impact Mechanisms for White Sturgeon (continued)**

Stressor	Effect on Species	Important Impact Mechanism	Comments	Relationships to Other Stressors	Citations
Moderately Important Stressors					
Reduced rearing habitat	Reduced growth rates, increased predation	Reclaiming wetlands and islands reduced in- and off-channel rearing habitat	Widespread in Delta, year-round, juveniles and sub-adults **Certainty:** 1		
		Channelized riprap levees reduce in- and off-channel intertidal and shallow subtidal rearing habitat, including seasonal inundation of floodplain habitat	Widespread in Delta, year-round, juveniles and sub-adults **Certainty:** 1		
Increased water temperature	Increased heat-related physiological stress (heat-shock proteins), increased susceptibility to disease, mortality	Reduced flows from upstream reservoirs increase hydrologic resident time, allowing water to warm, reduced riparian vegetation and shading	Occurs in Feather River, primarily in spring/summer, primarily influences eggs and juveniles **Certainty:** 3		Cech et al. 1984, SWRI 2003
Unnatural mortality	Mortality	Predation by non-natives	Occurs upstream in and near spawning habitat during and shortly after spawning season, affects larvae and juveniles **Certainty:** 2	Predation risk increases with lower turbidity	Gadomski & Parsley 2005a
		Dredging directly entrains sturgeon	Occurs in specific main channels, year-round, rearing juveniles and sub-adults **Certainty:** 1		
Reduced turbidity	Increased risk of predation	Upstream water management & channelization reduces sediment input	Only been shown for white sturgeon but likely translates to green sturgeon, occurs upstream in and near spawning habitat during and shortly after spawning season, affects larvae **Certainty:** 2		Jassby et al. 2002, Gadomski & Parsley 2005b

2

Other stressors:

- Unnatural mortality
  - Monitoring mortality
  - Stranding
- Entrainment (SWP, CVP, and others)
- Salinity control
- Reduced food

Individuals participating in the BDCP technical working sessions for sturgeon include:

Diane Windham and Jeff Stuart (NMFS); Scott Cantrell, Tom Schroyer, and Mike Donnellan (DFG); Zoltan Matica and Alicia Seesholtz (DWR); Rick Sitts (Metropolitan); Campbell Ingram (TNC); Josh Israel (UC Davis); Chuck Hanson (Hanson Environmental); Pete Rawlings and Rick Wilder (SAIC).

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Table C-9. Stressors, Stressor Effects, and Impact Mechanisms for Sacramento Splittail

Stressor	Effect on Species	Important Impact Mechanism	Comments	Relationships to Other Stressors	Citations
Highly Important Stressors					
Reduced juvenile/ adult rearing habitat	Reduced growth, increased competition	Reclaiming wetlands and islands reduced shallow, low velocity, brackish habitat (splittail rearing habitat)	Widespread throughout the rearing range of splittail, year-round, affects juveniles and rearing adults **Certainty:** 3		Moyle et al. 2004, Feyrer et al. 2005
Reduced spawning/ larval rearing habitat	Reduced reproductive success, mortality from stranding, reduced growth rate and/or survival of offspring	Upstream reservoir operations reduce the frequency and magnitude of high flows, reducing extent and duration of floodplain inundation (splittail spawning/larval rearing habitat)	Limited to floodplains and other flow-dependant habitat, during late winter & spring, occurs primarily in low flow years, affects spawning adults and larvae **Certainty:** 4		Sommer et al. 1997, 2004, Meng & Matern 2001, Moyle et al. 2004, Feyrer et al. 2005
		Riprapped levees reduce low velocity, shallow water habitat used for spawning and early larval rearing habitat	Moderate geographic scope, most significant in dry years during spawning and early rearing season (late winter/spring), affects spawning adults, larvae, juvenile, and subadult rearing year-round **Certainty:** 3	Importance increases during dry years when floodplains are inaccessible (see previous impact mechanism)	Moyle 2002, Feyrer et al. 2005
Reduced food	Starvation, reduced reproduction, higher susceptibility to disease	Non-native species (e.g., *Corbula*) reduce food available to splittail by eating/filtering out organics, phytoplankton, and zooplankton.	Can affect larvae, juveniles, and adults in all locations throughout the year, but mostly rearing juveniles and adults in western Delta and Suisun Bay during low production periods. **Certainty:** 4	Importance increases during dry years when floodplains are inaccessible	Kimmerer & Orsi 1996, Jassby et al. 2002, Kimmerer 2002a, Moyle et al. 2004

1 **Table C-9. Stressors, Stressor Effects, and Impact Mechanisms for Sacramento Splittail (continued)**

Stressor	Effect on Species	Important Impact Mechanism	Comments	Relationships to Other Stressors	Citations
Highly Important Stressors (cont.)					
		Upstream reservoir operations dampen high flows and do not allow nutrients and production on floodplains to be mobilized and transported downstream	Widespread stressor throughout geographic range, can affect larvae, juveniles, and adults throughout the year, mainly in drier years, rearing juveniles and adults in western Delta and Suisun Bay when flows are low and exports are high. **Certainty:** 3		Jassby et al. 2002, Feyrer et al. 2006, Pelagic Fish Action Plan 2007
		Nutrients and phytoplankton and zooplankton production are exported by SWP, CVP, and in-Delta diversions with water	Widespread stressor throughout geographic range, can affect larvae, juveniles, and adults throughout the year, rearing juveniles and adults in western Delta and Suisun Bay when flows are low and exports are high. **Certainty:** 3	Importance increases during dry years when floodplains are inaccessible	Jassby et al. 2002, Pelagic Fish Action Plan 2007
		Hydrologic residence time in the Delta, which affects production, is reduced by SWP and CVP exports from the south Delta, which moves water more quickly through the Delta channels	Can affect larvae, juveniles, and adults throughout the year, mostly rearing juveniles and adults in western Delta and Suisun Bay during low production periods. **Certainty:** 3	Importance increases during dry years when floodplains are inaccessible	Jassby et al. 2002, Kimmerer 2002a,b, Pelagic Fish Action Plan 2007
Exposure to toxics	Sublethal and lethal effects, increased susceptibility to disease	Toxics enter the system from a variety of point and non-point sources including agricultural and urban run-off	Widespread throughout geographic range, can be episodic and chronic, can affect all life stages **Certainty:** 3		Teh et al. 2002, 2004a,b, 2005; Greenfield et al. in review

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Table C-9. Stressors, Stressor Effects, and Impact Mechanisms for Sacramento Splittail (continued)

Stressor	Effect on Species	Important Impact Mechanism	Comments	Relationships to Other Stressors	Citations
Highly Important Stressors (cont.)					
		Corbula as a food source contribute to bioaccumulations of toxics like selenium in splittail tissue via consumption	Specific to locations with *Corbula* presence (western Delta, Suisun Bay), year-round, affects subadults and adults **Certainty:** 2		Stewart 2000
Moderately Important Stressors					
Unnatural predation	Mortality	Non-native submerged aquatic vegetation provides suitable habitat for non-native predators that prey on splittail	Widespread throughout geographic range, impacts larvae, juveniles, smaller adults, year-round **Certainty:** 3		Simenstad 1999, Moyle 2002, Toft et al. 2003, Nobriga et al. 2005, Brown & Michniuk 2006
SWP/CVP entrainment	Mortality, injury, displacement if salvaged successfully	Reverse flows in Old and Middle rivers entrain or guide splittail, eventually moving them into the SWP and CVP export facilities	Adults affected during spawning season (December-March), larvae and juveniles affected during first few months of life (usually Feb-May **Certainty:** 3	Entrainment generally highest in wet years when population most robust and lowest in dry years	Sommer et al. 1997, Danley et al. 2002, Moyle et al. 2004
Harvest	Mortality	Legal fishery	Unknown geographic range, affects smaller adults (15-25 cm TL), from November through May, numbers of splittail harvested are unknown **Certainty:** 2		Moyle et al. 2004
		Illegal fishery (suspected)	Likely similar spatial and temporal range to legal fishery **Certainty:** 1		

Other stressors:

- Non-natural mortality
  - Non-CVP/SWP entrainment
  - Propeller entrainment by cargo vessel
  - Stranding
- Salinity control

Individuals participating in the BDCP technical working sessions for Sacramento splittail:

Chuck Hanson (Hanson Environmental); Diane Windham (NMFS); Scott Cantrell and Dan Kratville (DFG); Victoria Poage (USFWS); Bill Harrell and Stephani Spaar (DWR); Rick Sitts (Metropolitan); Campbell Ingram (TNC); Bruce Herbold (EPA); BJ Miller; and Pete Rawlings and Rick Wilder (SAIC).

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D. OPTION 1 HYDROLOGIC/HYDRODYNAMIC MODEL RESULTS

Table D-1. Summary Output for the Implementation of Conservation Strategy: Option 1

	Base		Option 1A				Option 1B			
Delta flows[1]	**Annual Average [2] (1)**	**Dry period[3] (2)**	**Annual Average[2] (3)**	**Dry period[3] (4)**	**Change (3)-(1)**	**Change (4)-(2)**	**Annual Average[2] (5)**	**Dry period[3] (6)**	**Change (5)-(1)**	**Change (6)-(2)**
Sacramento River @ Hood	16,229	8,269	16,226	8,302	-3	33	16,202	8,290	-27	21
San Joaquin River @ Vernalis	3,027	1,362	3,033	1,371	6	9	3,023	1,333	-3	-28
Sacramento River @ Rio Vista	13,812	5,164	13,786	5,029	-25	-135	13,380	4,151	-432	-1,013
Delta Outflow	14,991	5,154	14,890	5,038	-101	-115	18,865	7,652	3,874	2,499
SWP/CVP Exports	5,902	3,572	6,013	3,728	112	155	2,100	1,083	-3,802	-2,489
QWEST (cfs)	1,620	-12	1,506	-6	-114	6	7,611	4,879	5,991	4,892
Old and Middle River (cfs)	-5,842	-4,635	-5,964	-4,805	-122	-171	-1,669	-1,929	4,173	2,705
Water quality[4]	**Annual Average [5] (1)**	**Dry period[3] (2)**	**Annual Average[5] (3)**	**Dry period[3] (4)**	**Change (3)-(1)**	**Change (4)-(2)**	**Annual Average[5] (5)**	**Dry period[3] (6)**	**Change (5)-(1)**	**Change (6)-(2)**
X2 (km)	76	82	76	83	0	1	71	78	-5	-4
EC Exports[6]	488		488		0		533		45	
EC at Emmaton	1,128		1,206		78		654		-474	
EC at Jersey Point	1,074		1,114		41		471		-603	
EC at Collinsville	3,816		3,998		182		2,193		-1,622	
EC at Old River, Hwy 4	488		497		9		578		91	
Particle Transport and Fate[7]	**Annual Average [8] (1)**		**Annual Average[8] (2)**		**Change (2)-(1)**		**Annual Average[8] (3)**		**Change (3)-(1)**	
Insertion on Old River @ Quimby Island	57		90		34		27		-29	
Insertion on Middle River @ Mildred Island	59		92		33		30		-29	
Insertion on San Joaquin River near Big Break	9		14		5		1		-8	

Table D-1. Summary Output for the Implementation of Conservation Strategy: Option 1 (continued)

Particle Transport and Fate[7]	Base		Option 1A				Option 1B			
	Annual Average[8] (1)		Annual Average[8] (2)		Change (2)-(1)		Annual Average[8] (3)		Change (3)-(1)	
Insertion on Sacramento River near Cache Slough	13		18		5		2			
Insertion on San Joaquin River near Head of Old River	47		74		27		27		-20	

Notes:

1. Units in TAF unless mentioned otherwise
2. Annual average, 1921-2003
3. Dry period, 1928-1934
4. Units in EC, µMHOS/cm unless mentioned otherwise
5. For EC parameter values represent 16-year monthly Period Averaged; for X2 values represent annual average, 1921-2003
6. EC is blended between EC at Banks and EC at Tracy
7. Percentage of particles entering SWP and CVP pumping stations
8. Average of 1977, 1981 and 1990 releases of % cumulative particles ended up in exports at the end of 40 days

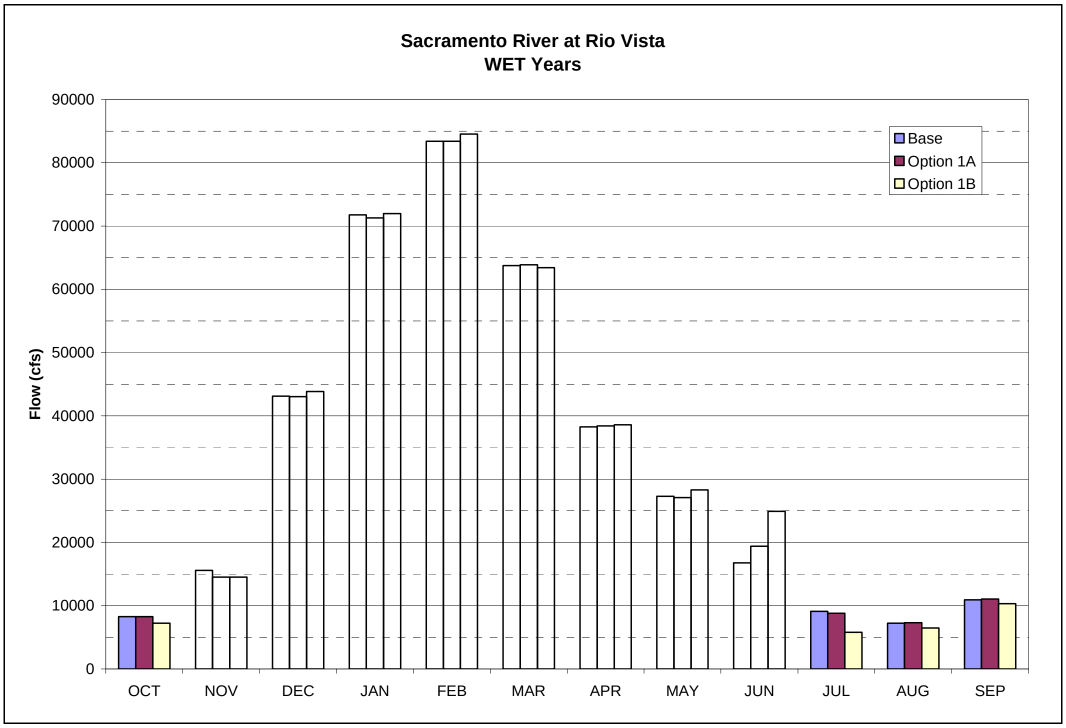


Figure D-1a. Sacramento River at Rio Vista Wet Year Average Flows

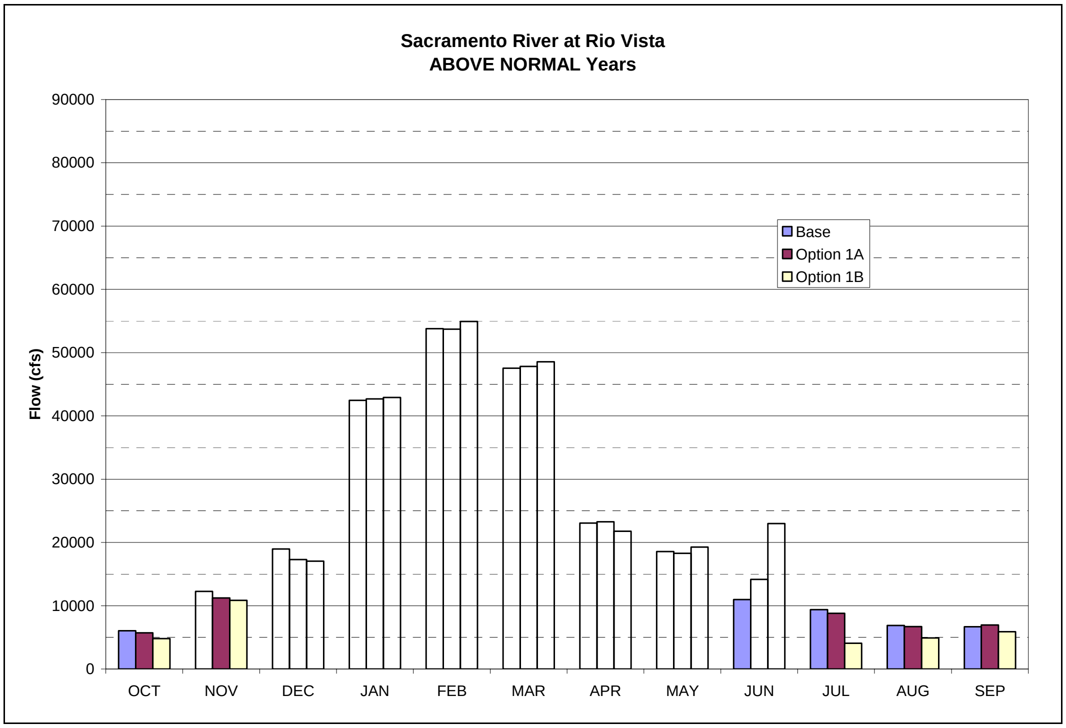


Figure D-1b. Sacramento River at Rio Vista Above Normal Year Average Flows

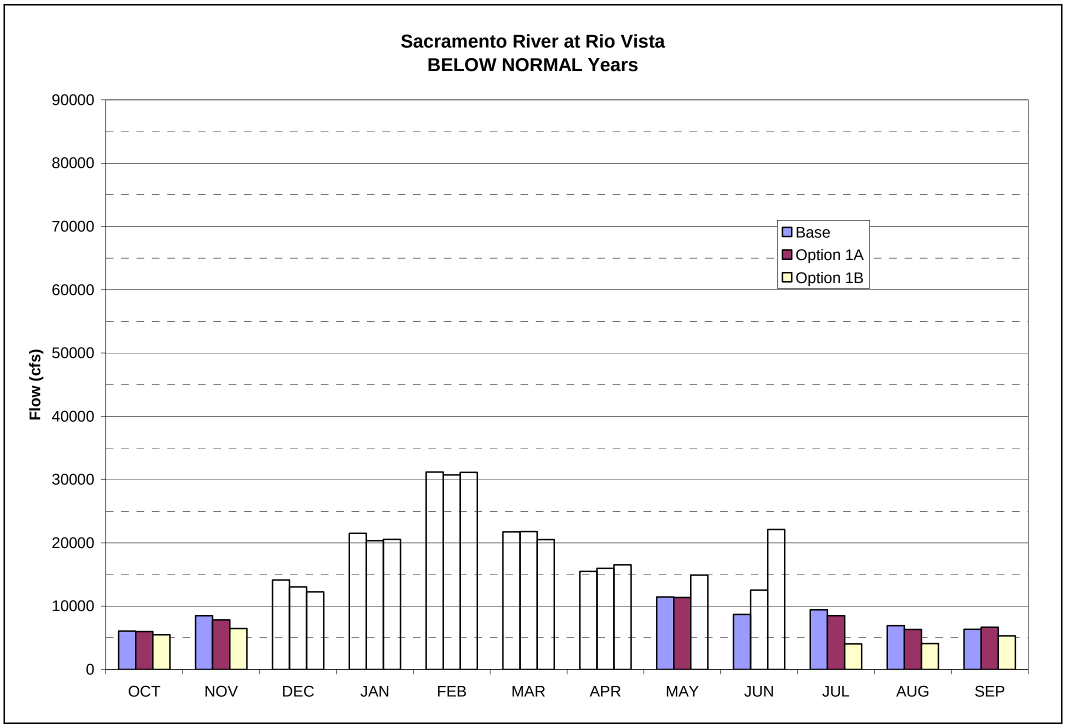


Figure D-1c. Sacramento River at Rio Vista Below Normal Year Average Flows

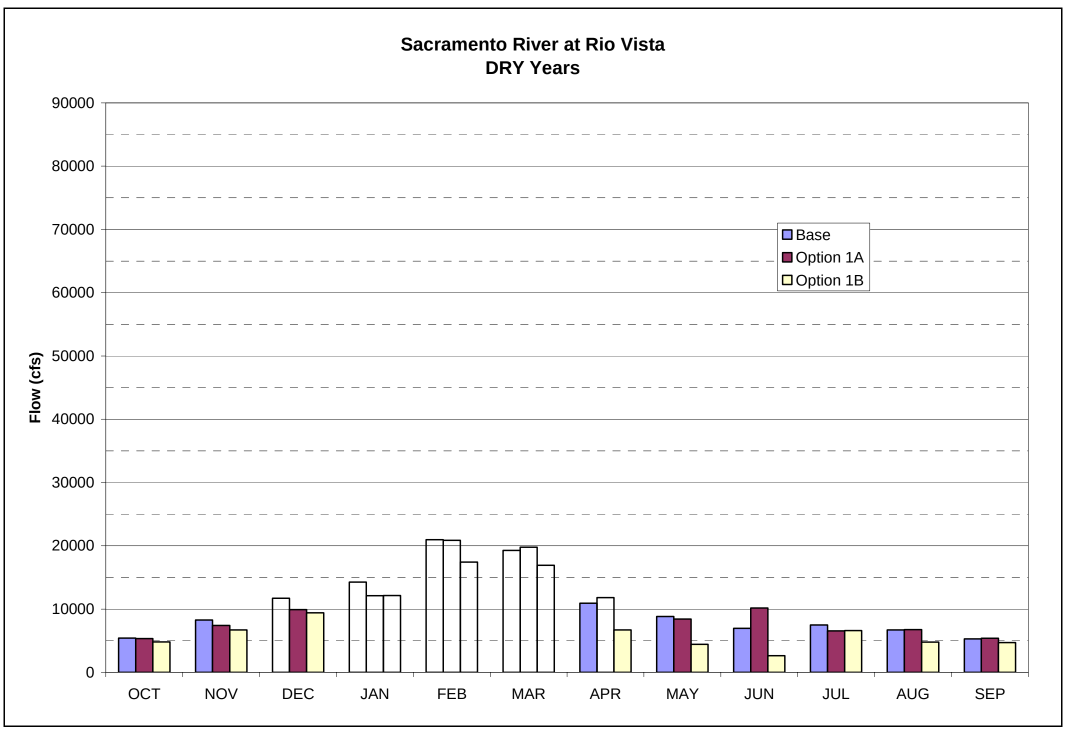


Figure D-1d. Sacramento River at Rio Vista Dry Year Average Flows

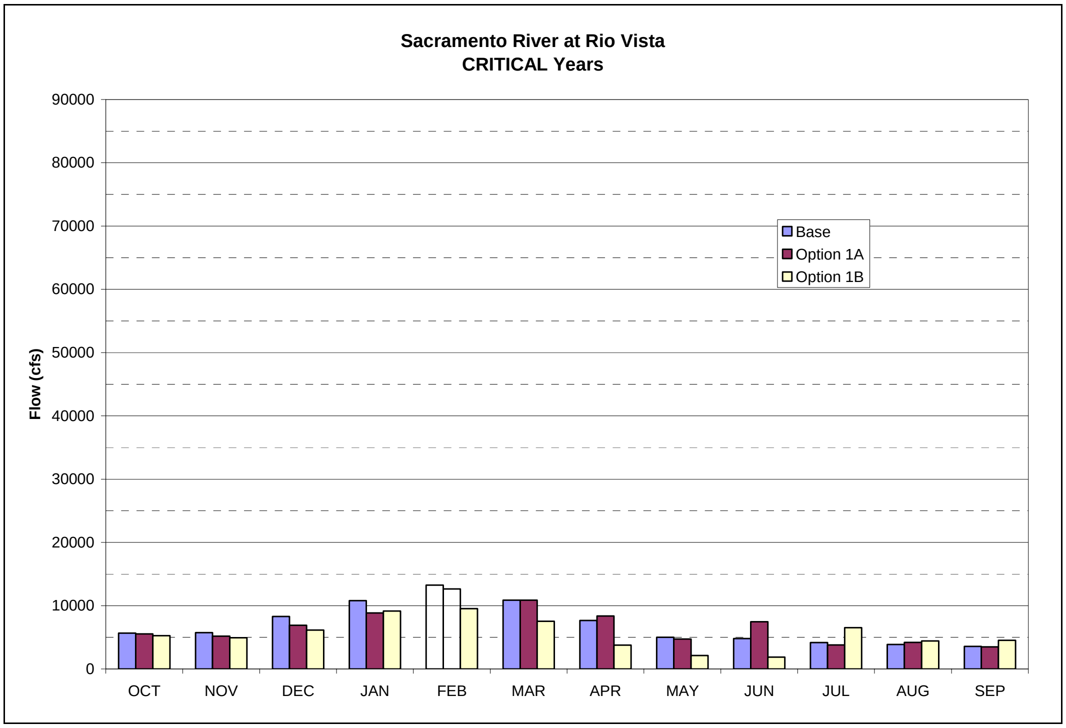


Figure D-1e. Sacramento River at Rio Vista Critical Year Average Flows

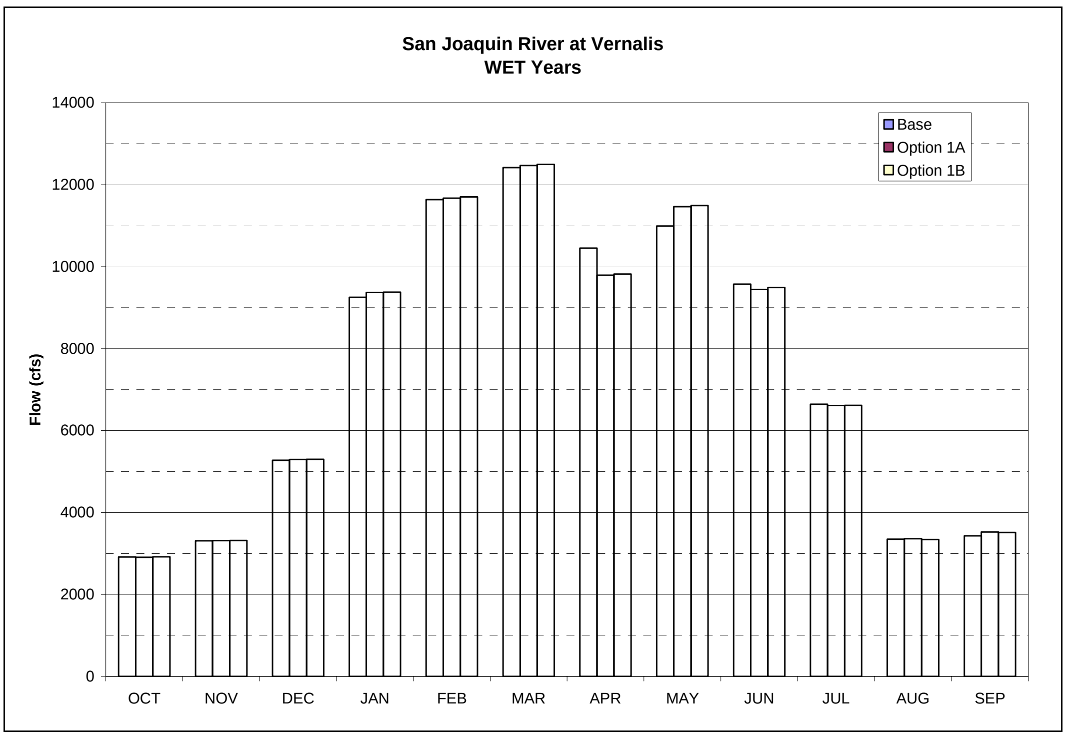


Figure D-2a. San Joaquin River at Vernalis Wet Year Average Flows

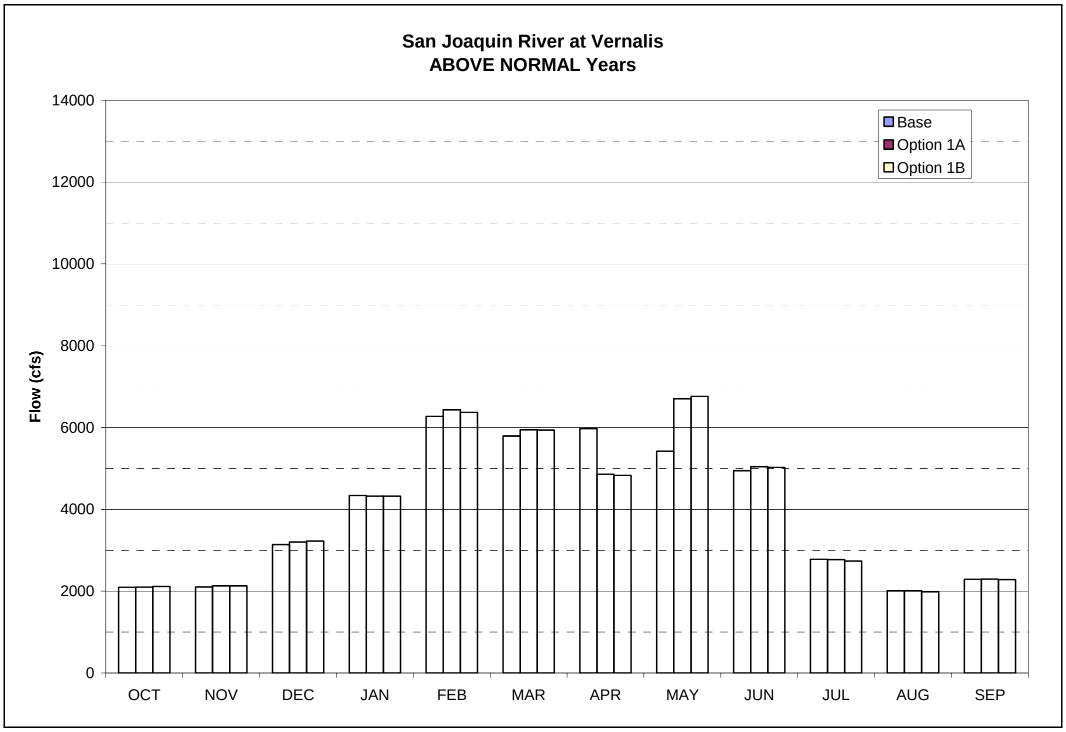


Figure D-2b. San Joaquin River at Vernalis Above Normal Year Average Flows

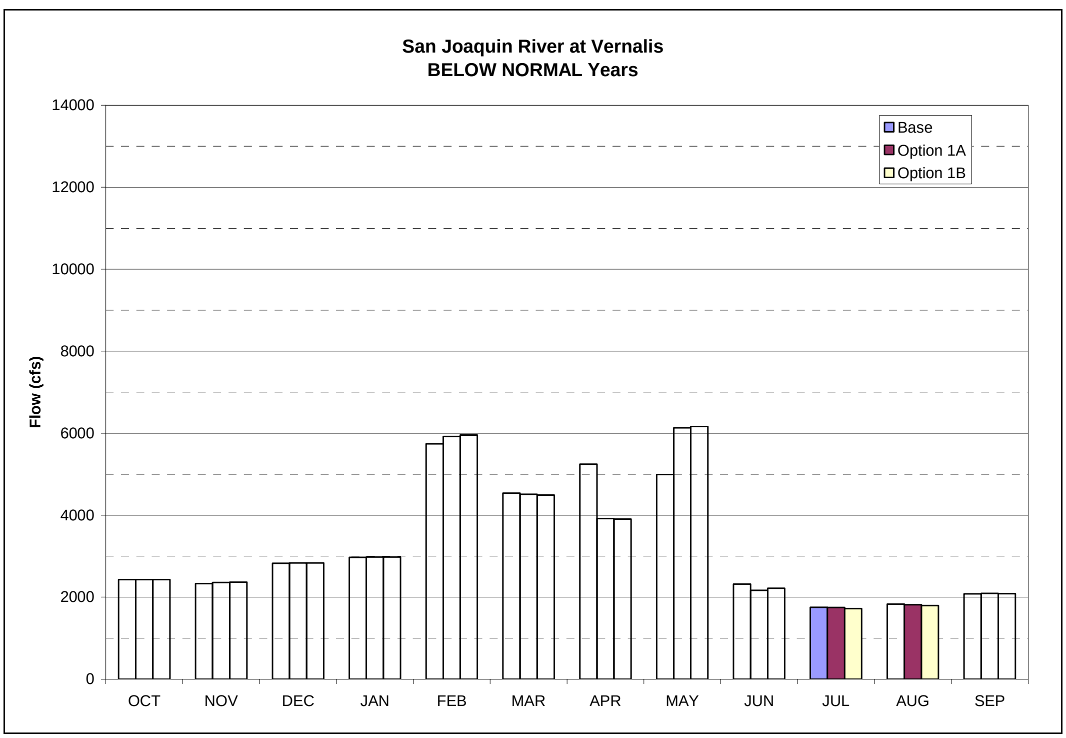


Figure D-2c. San Joaquin River at Vernalis Below Normal Year Average Flows

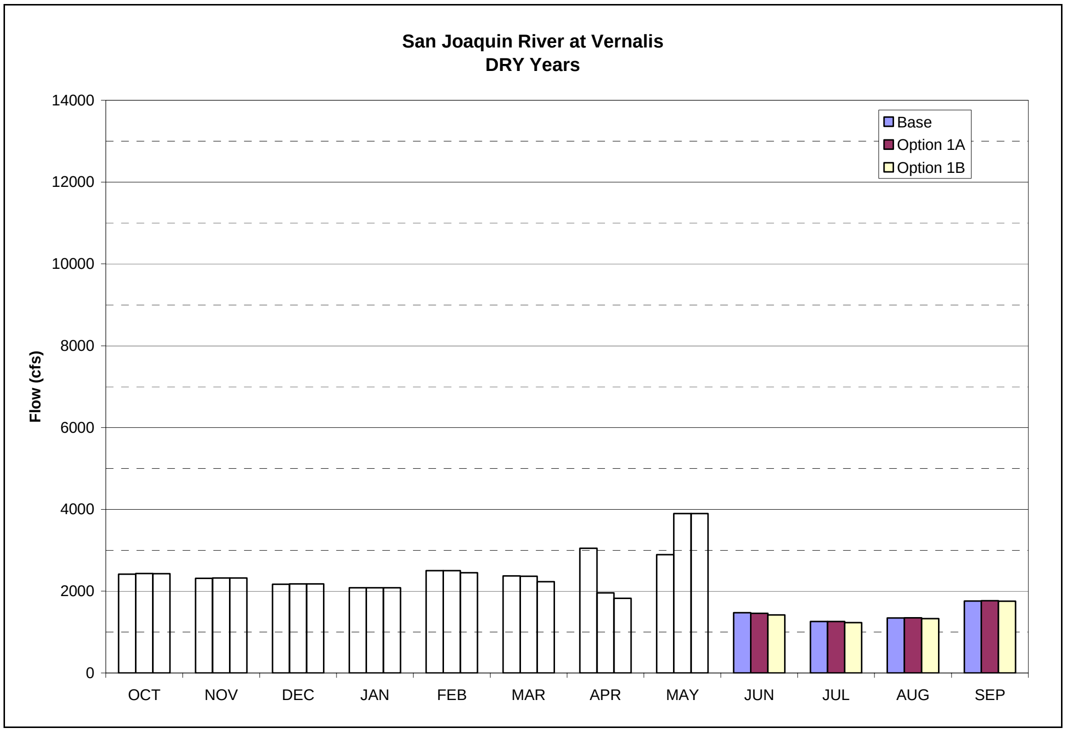


Figure D-2d. San Joaquin River at Vernalis Dry Year Average Flows

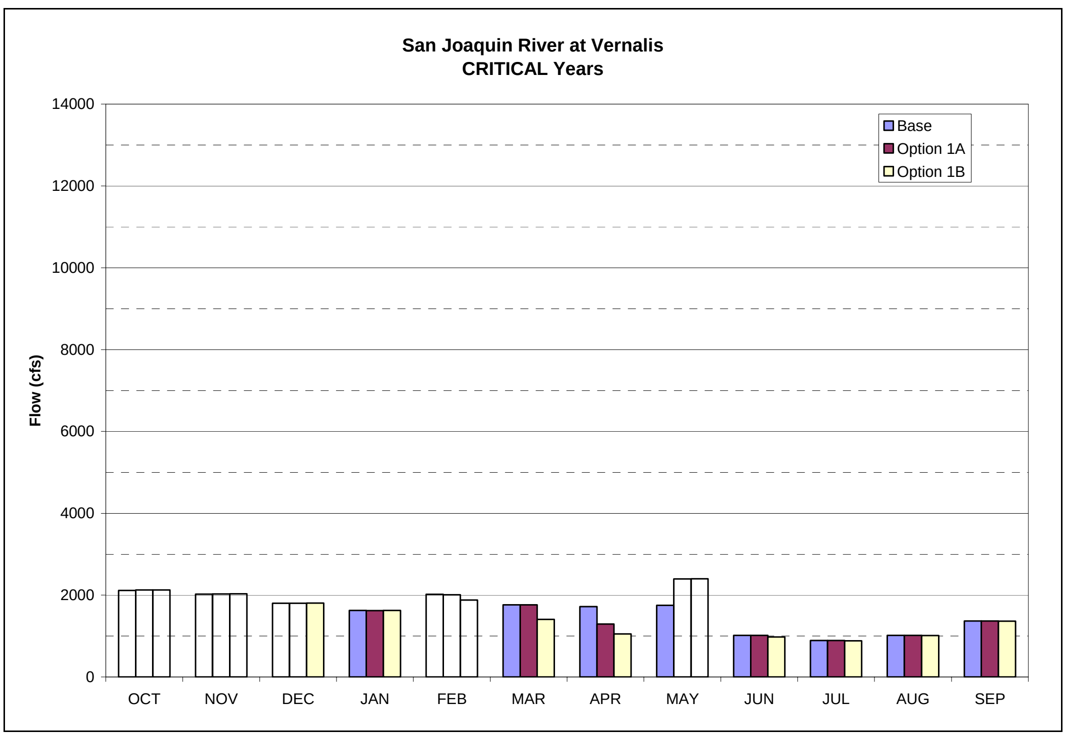


Figure D-2e. San Joaquin River at Vernalis Critical Year Average Flows

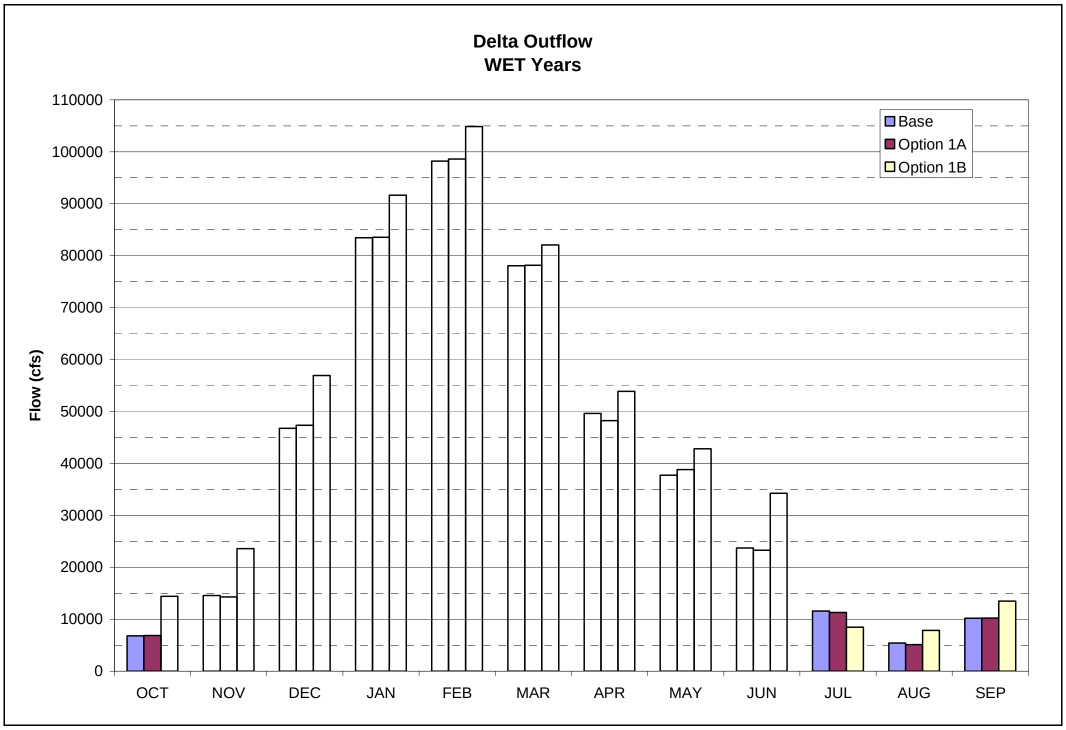


Figure D-3a. Delta Outflow Wet Year Average Flows

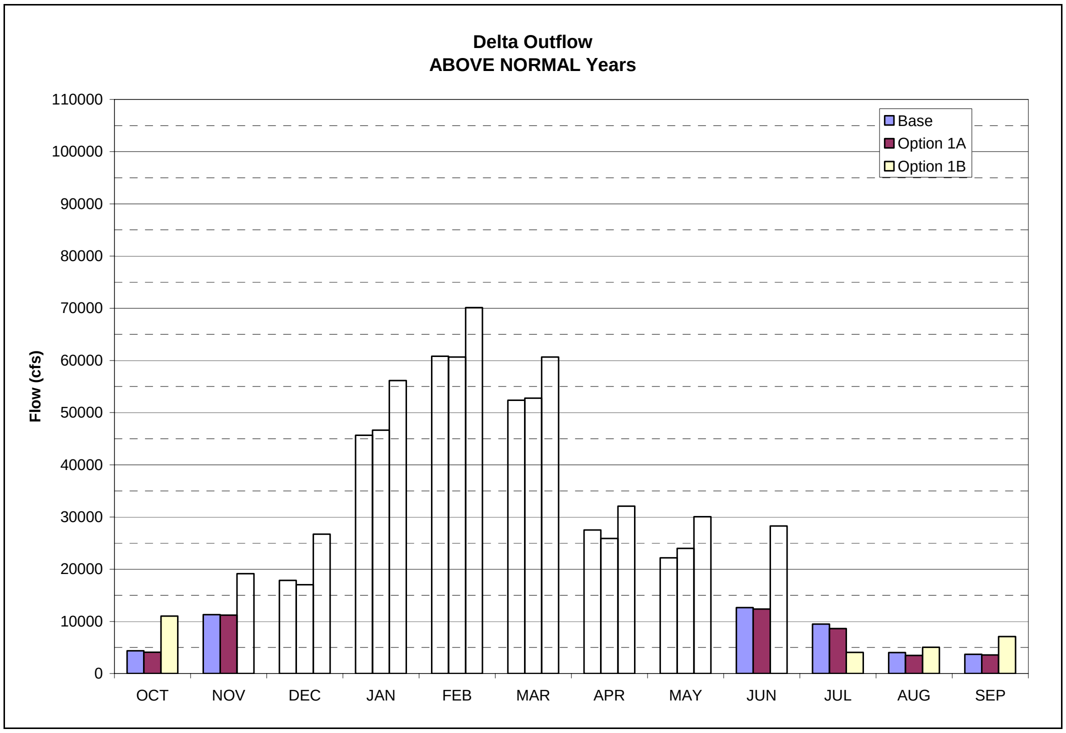


Figure D-3b. Delta Outflow Above Normal Year Average Flows

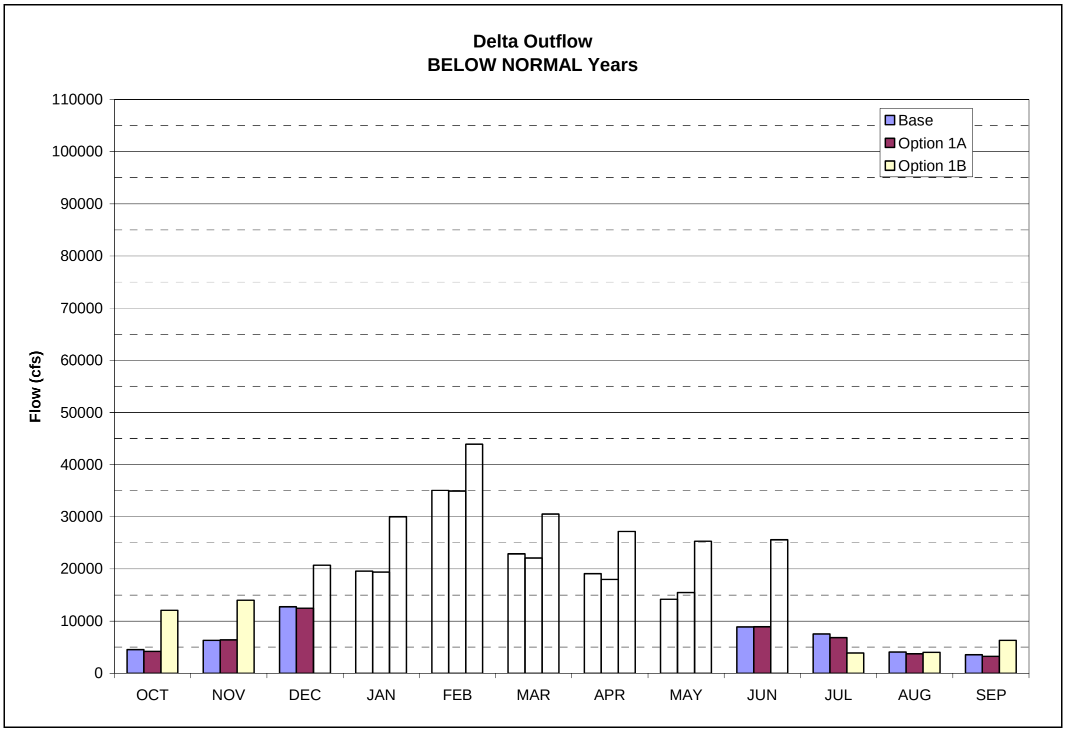


Figure D-3c. Delta Outflow Below Normal Year Average Flows

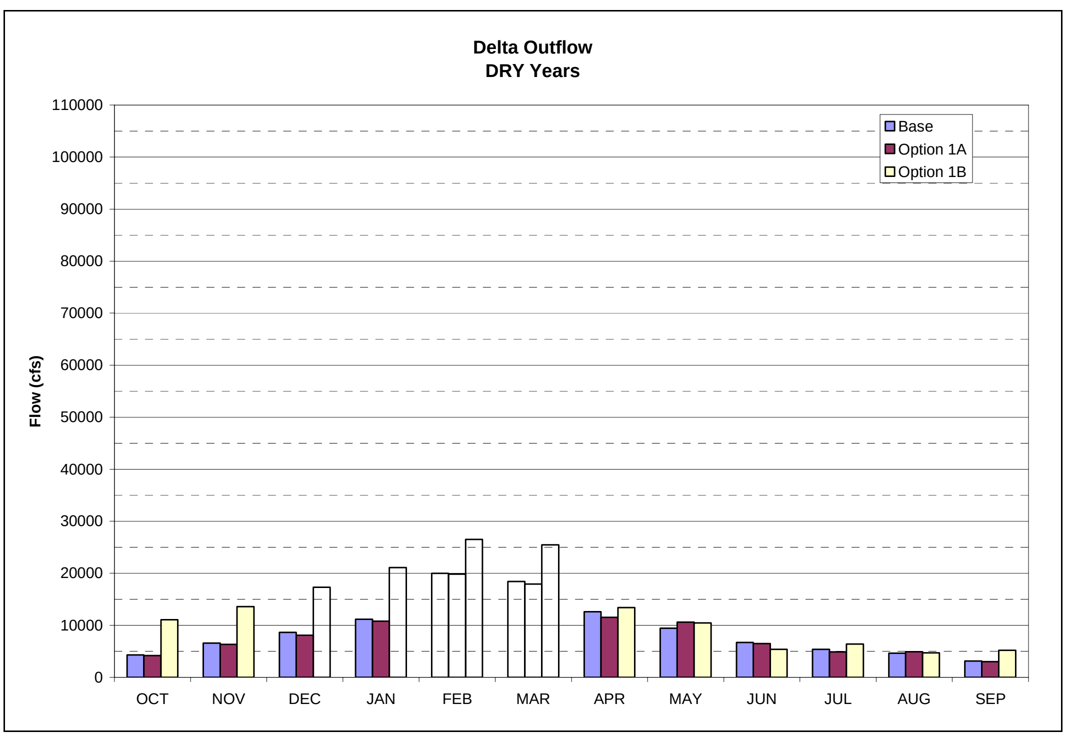


Figure D-3d. Delta Outflow Dry Year Average Flows

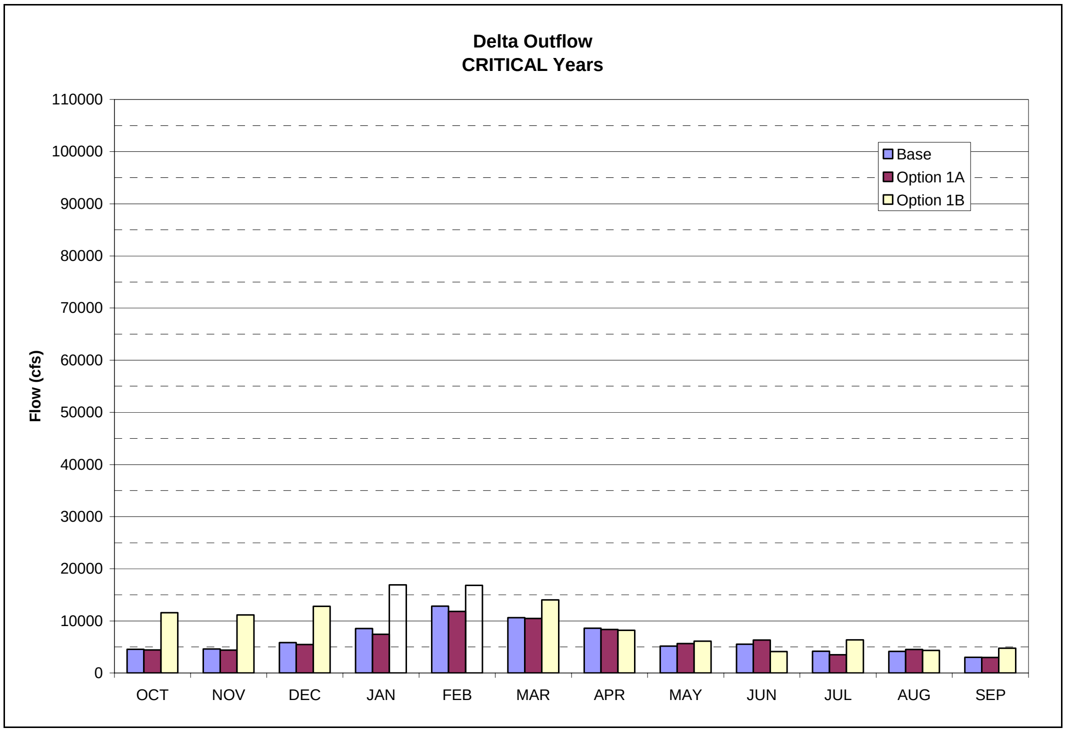


Figure D-3e. Delta Outflow Critical Year Average Flows

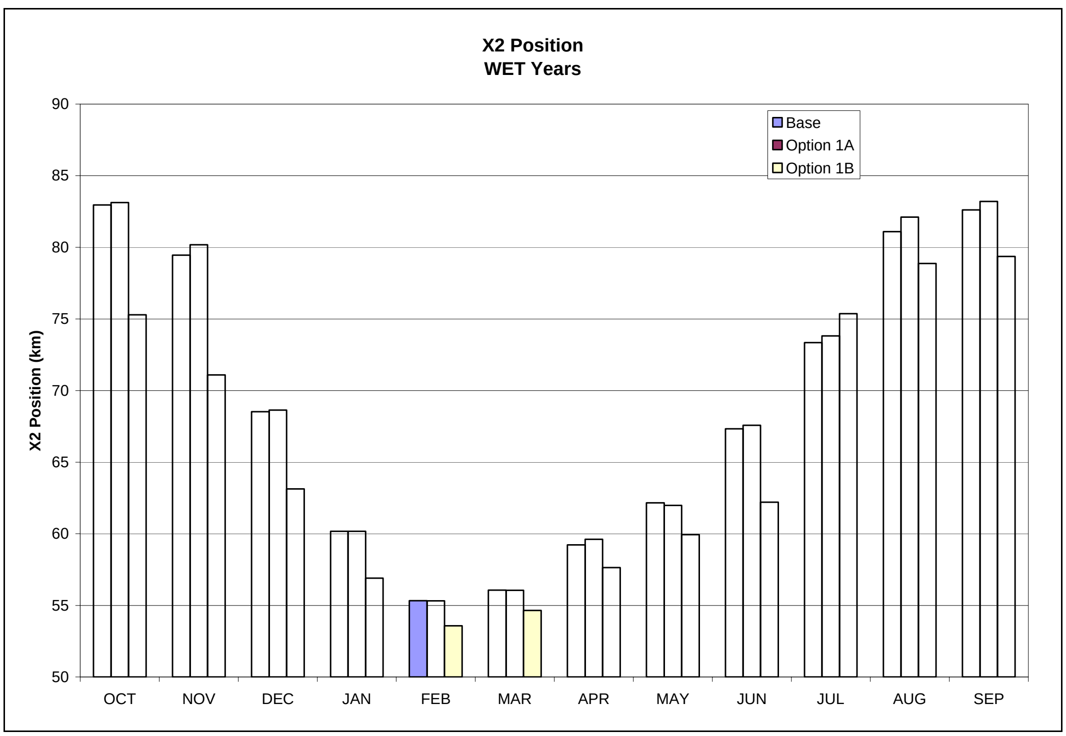


Figure D-4a. X2 Wet Year Average Distance

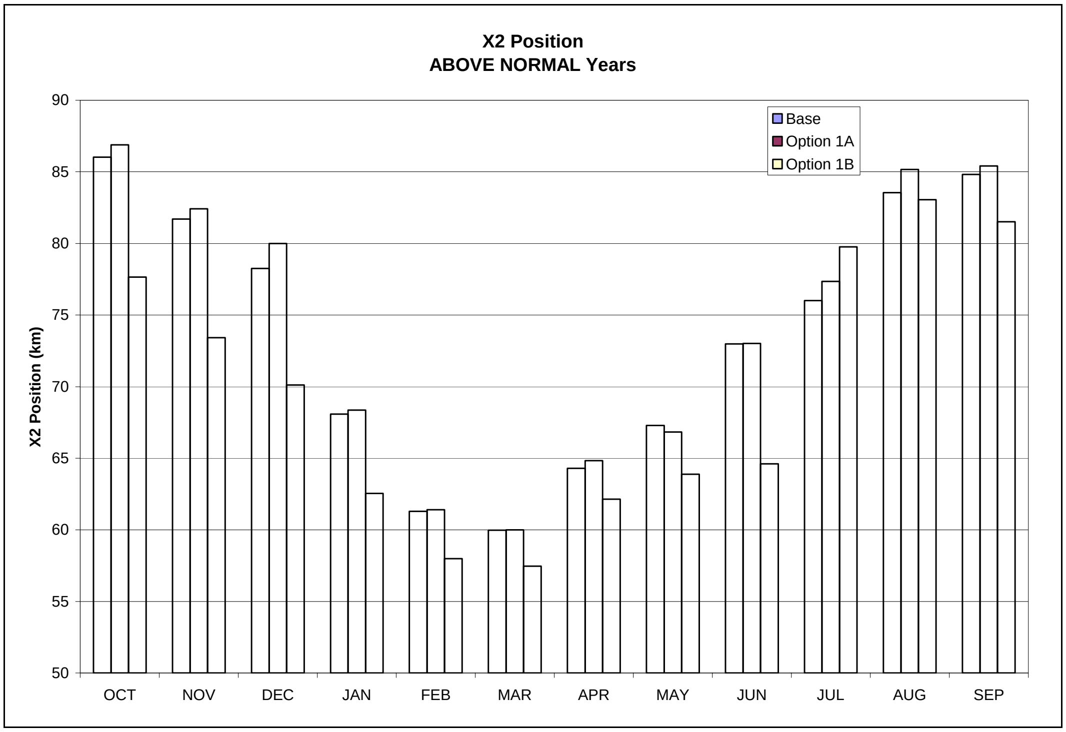


Figure D-4b. X2 Above Normal Year Average Distance

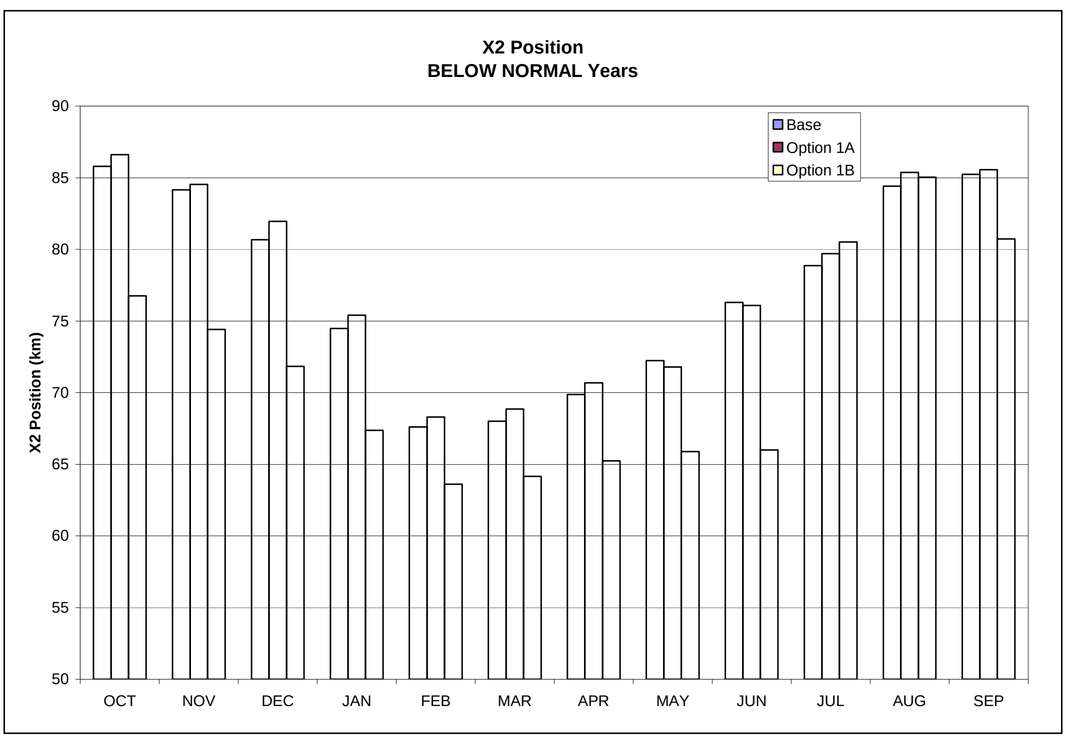


Figure D-4c. X2 Below Normal Year Average Distance

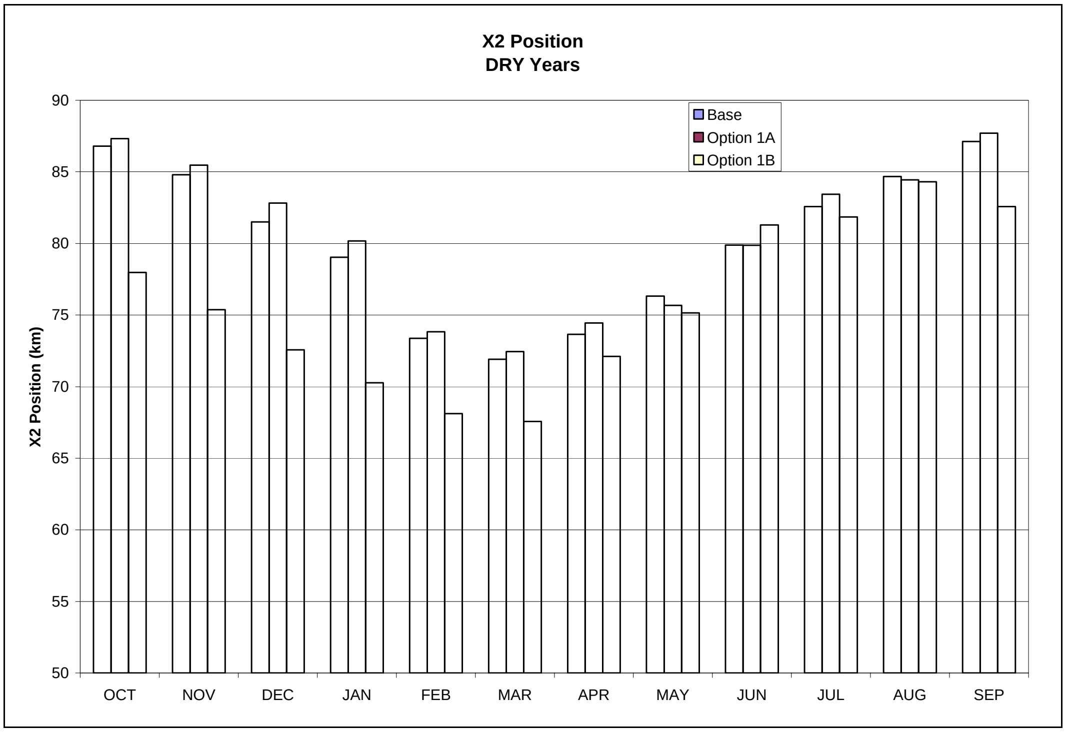


Figure D-4d. X2 Dry Year Average Distance

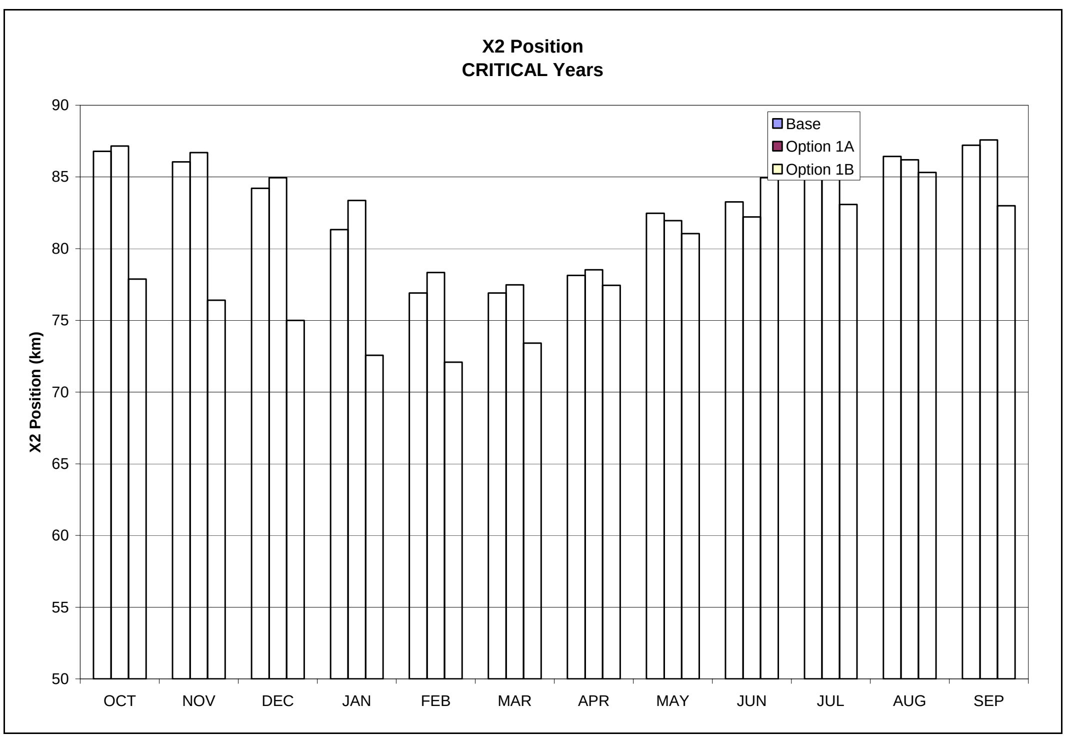


Figure D-4e. X2 Critical Year Average Distance

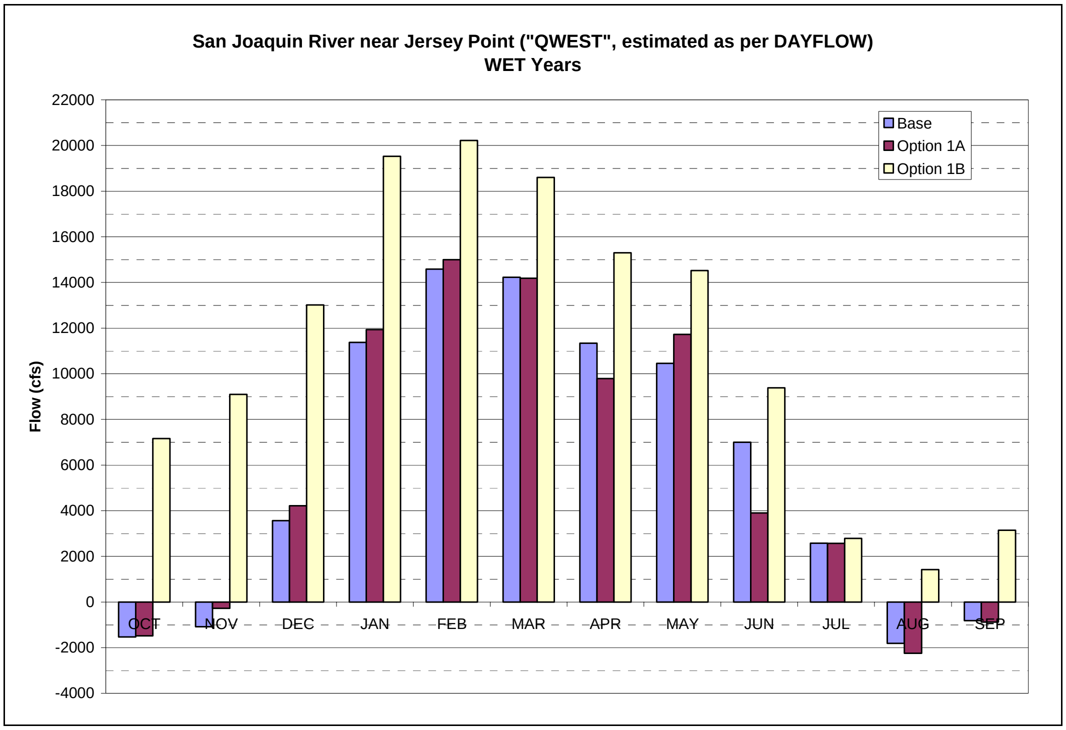


Figure D-5a. QWEST Wet Year Average Flows

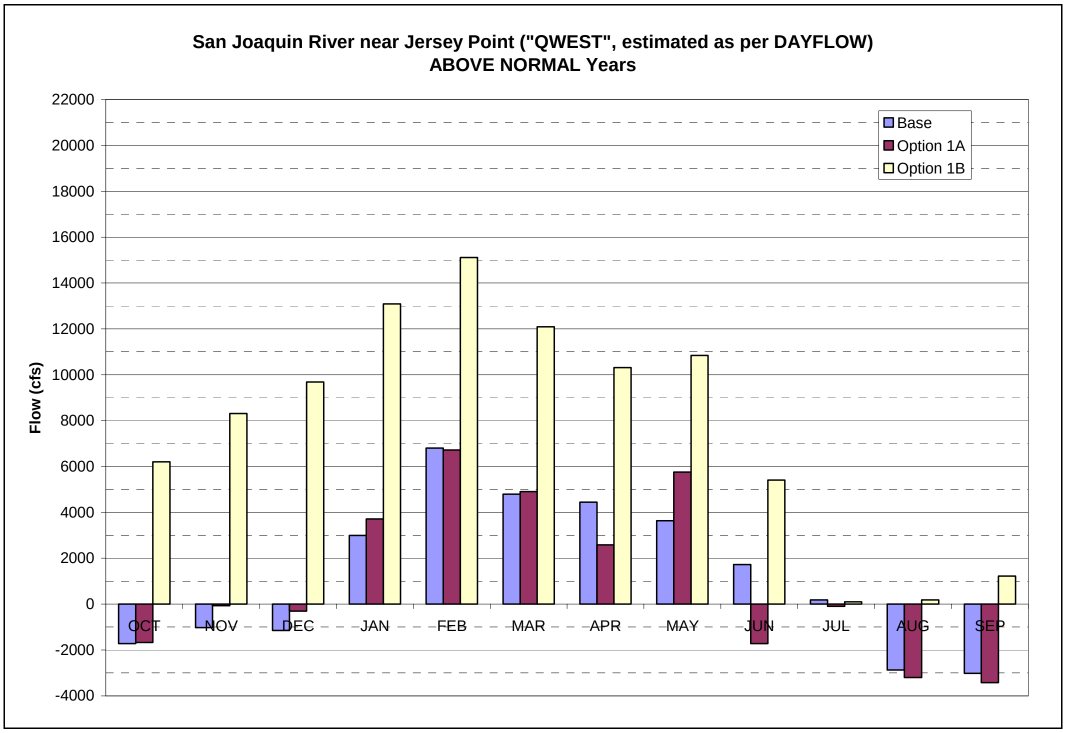


Figure D-5b. QWEST Above Normal Year Average Flows

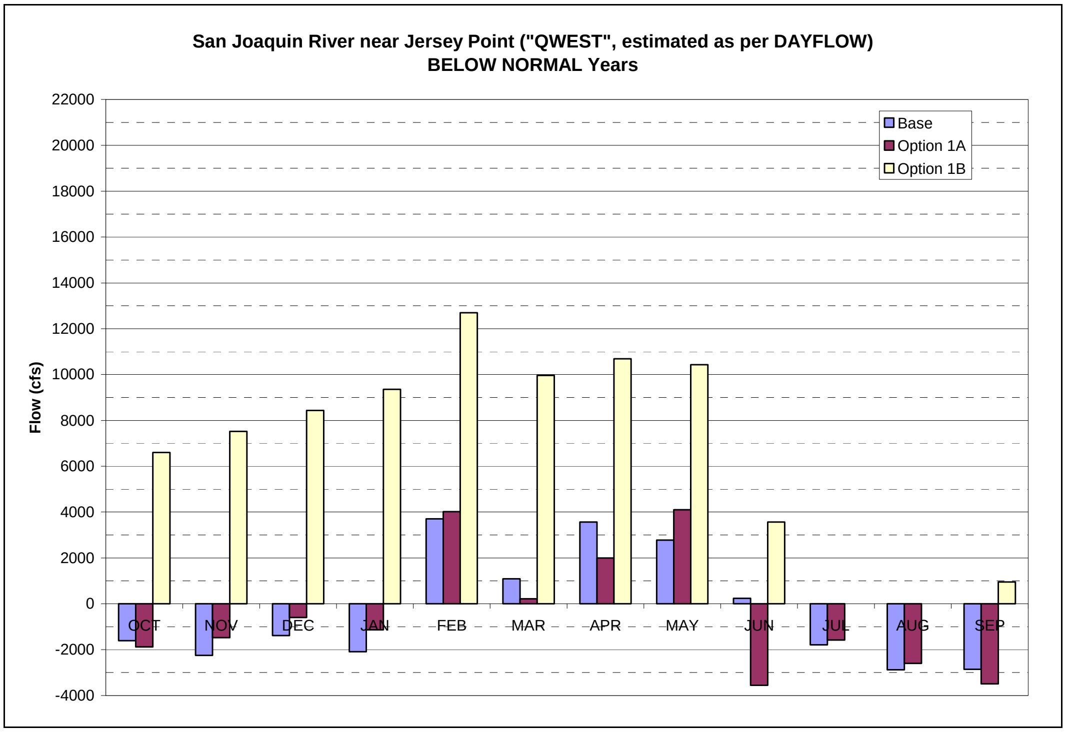


Figure D-5c. QWEST Below Normal Year Average Flows

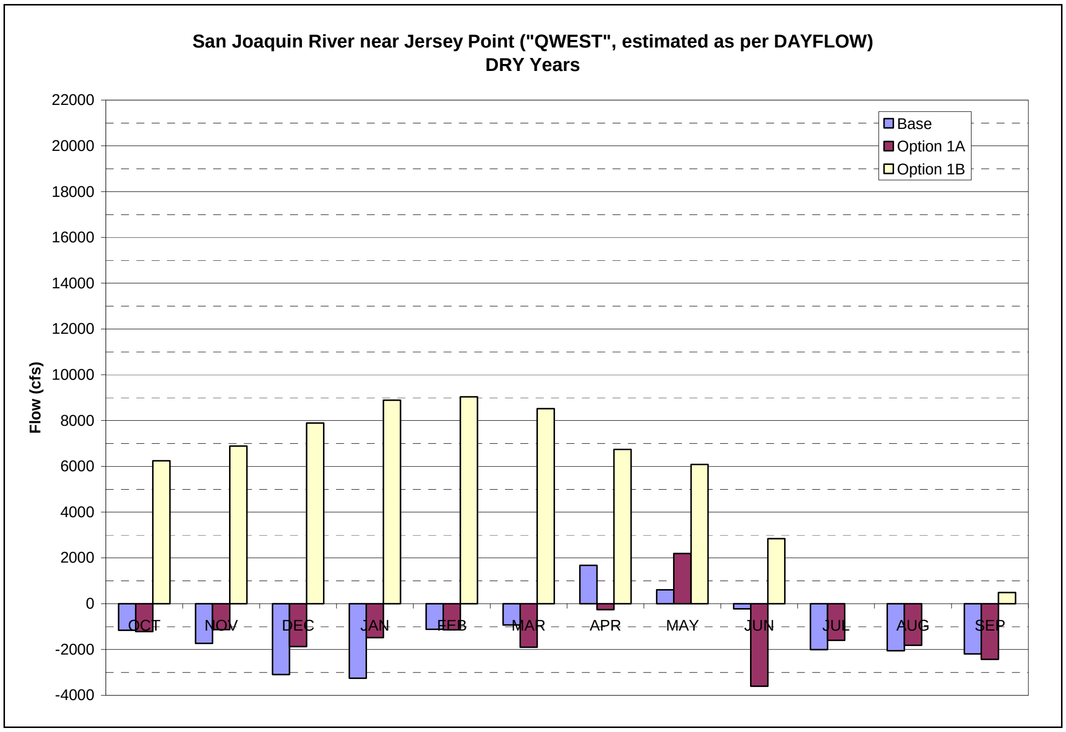


Figure D-5d. QWEST Dry Year Average Flows

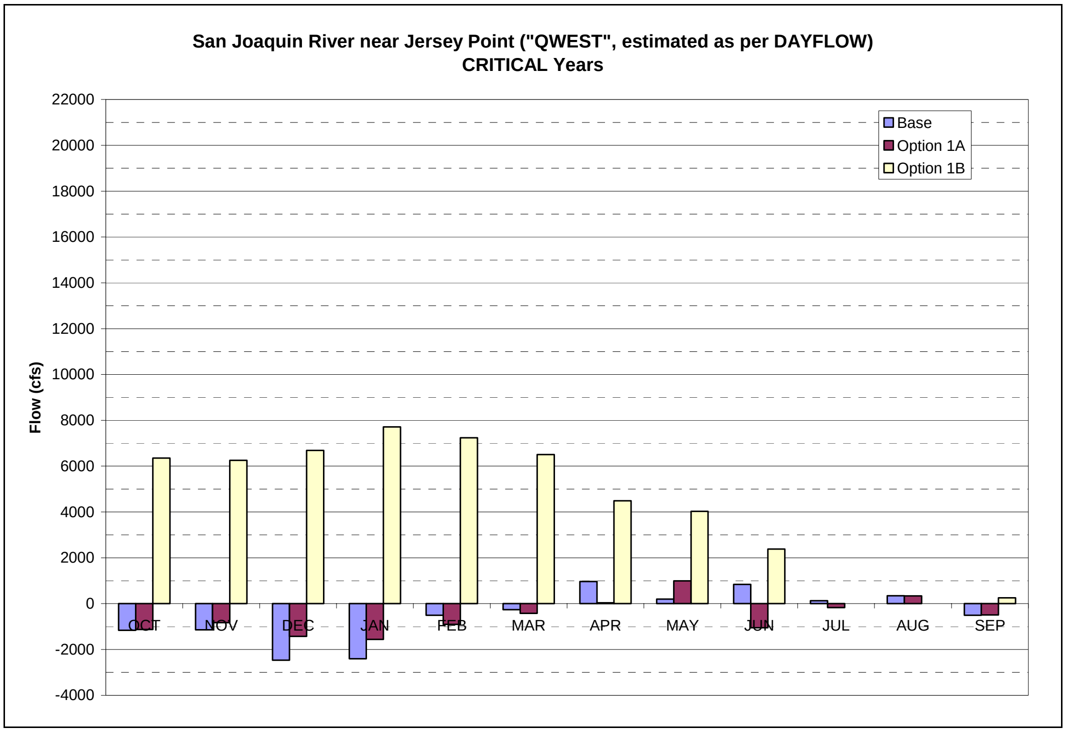


Figure D-5e. QWEST Critical Year Average Flows

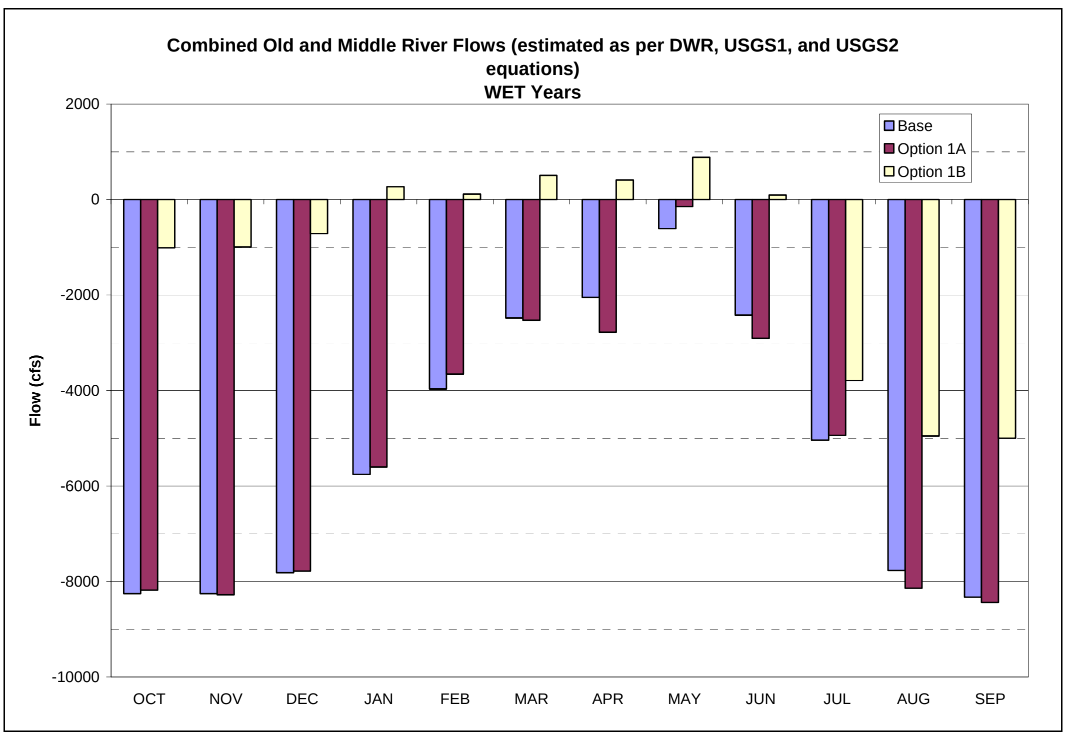


Figure D-6a. Combined Old and Middle River Wet Year Average Flows

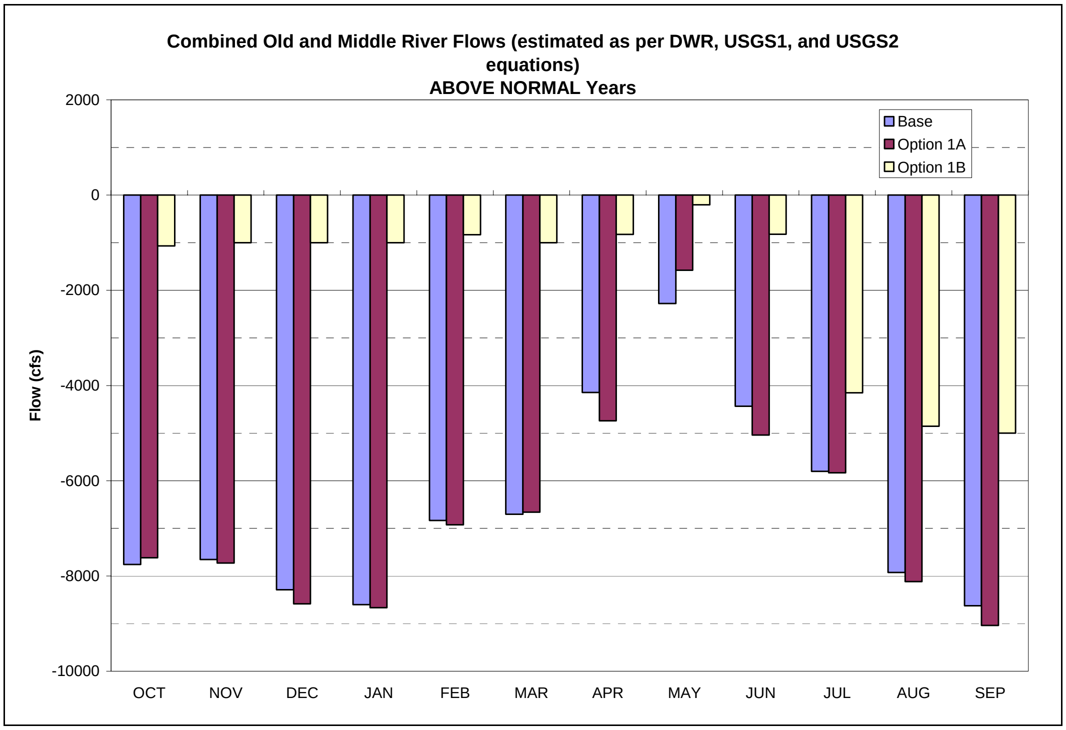


Figure D-6b. Combined Old and Middle River Above Normal Year Average Flows

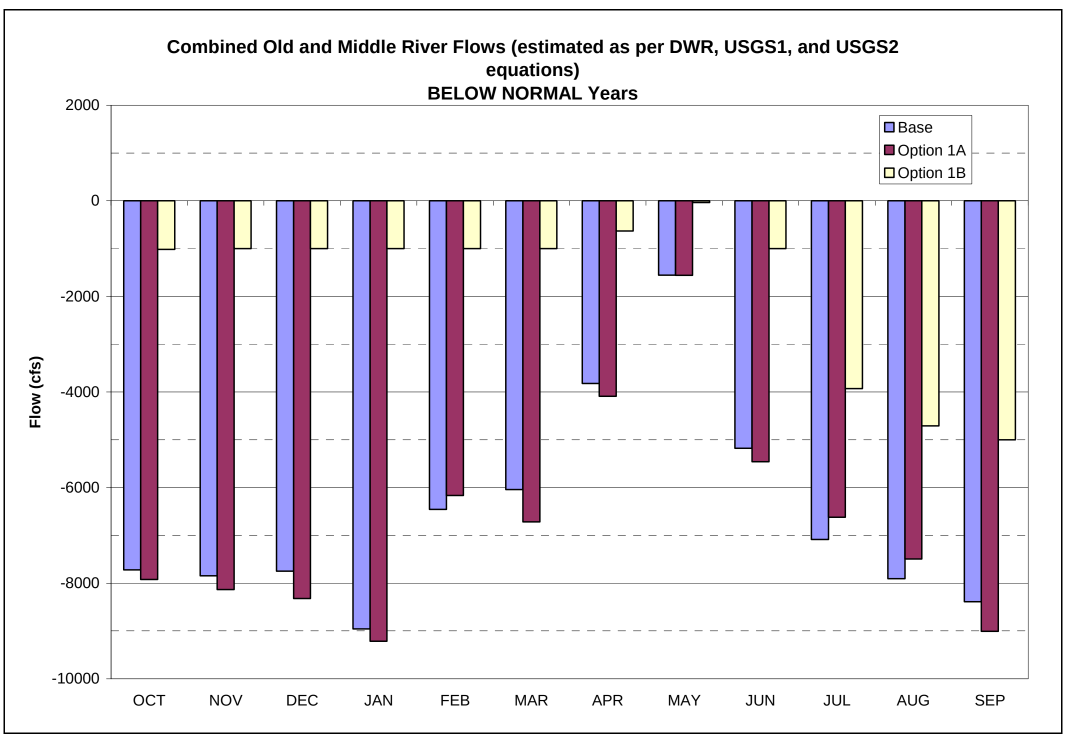


Figure D-6c. Combined Old and Middle River Below Normal Year Average Flows

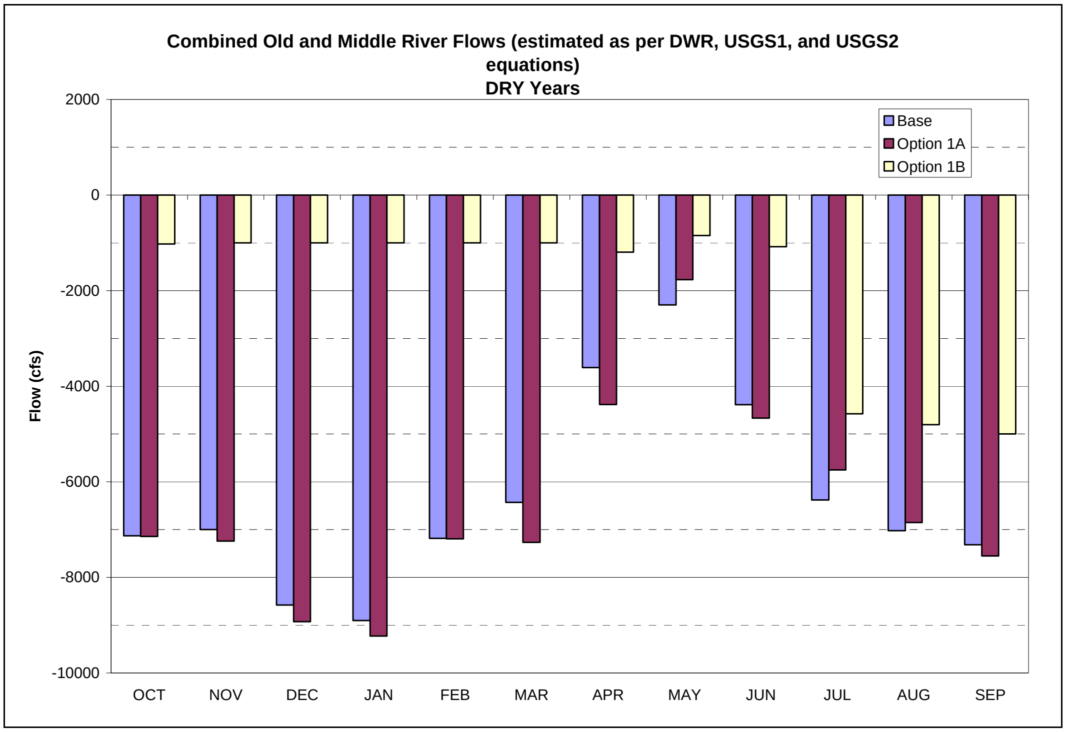


Figure D-6d. Combined Old and Middle River Dry Year Average Flows

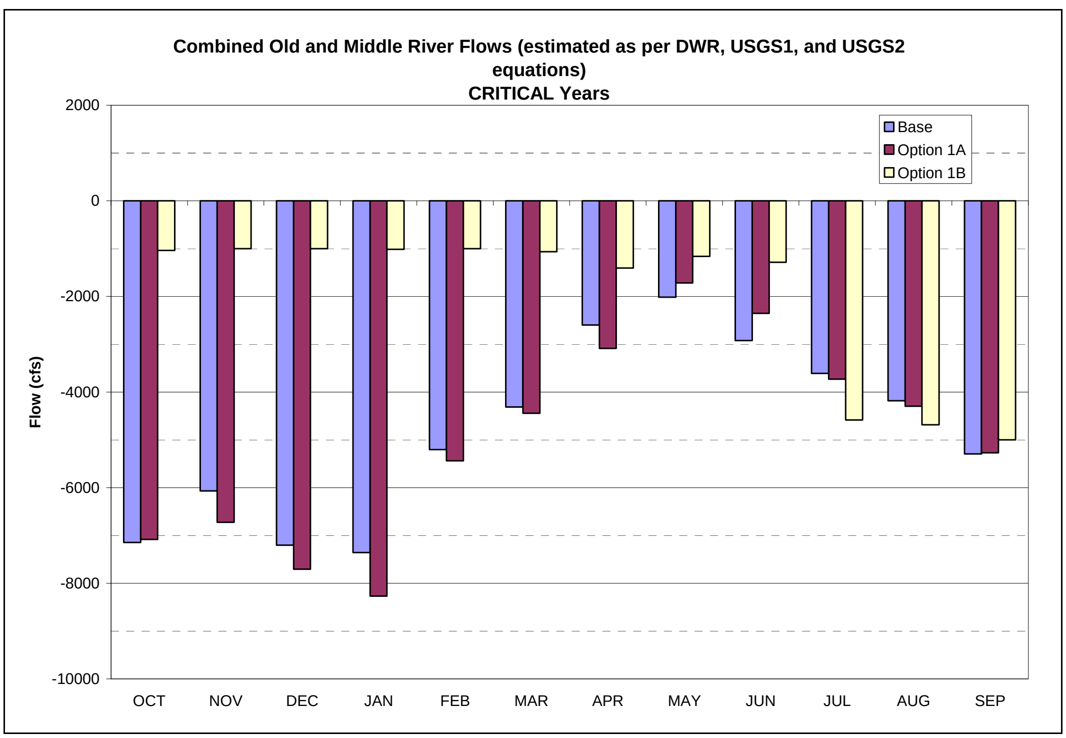


Figure D-6e. Combined Old and Middle River Critical Year Average Flows

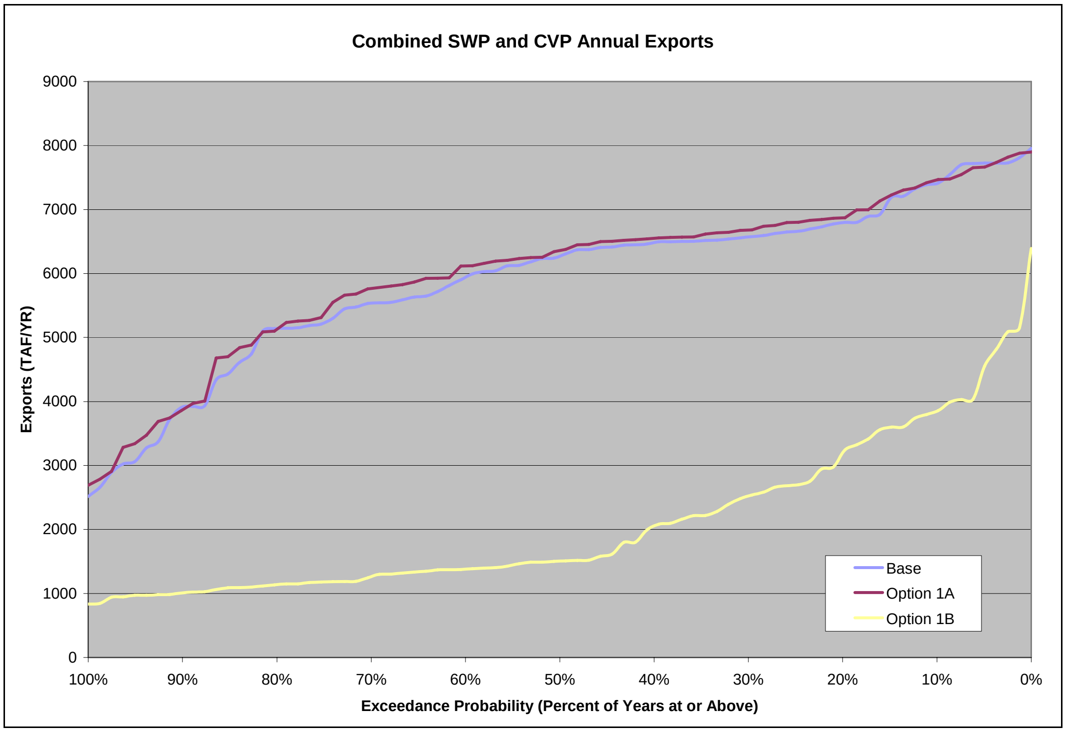


Figure D-7. Water Supply Frequency: Combined SWP and CVP Annual Delta Exports

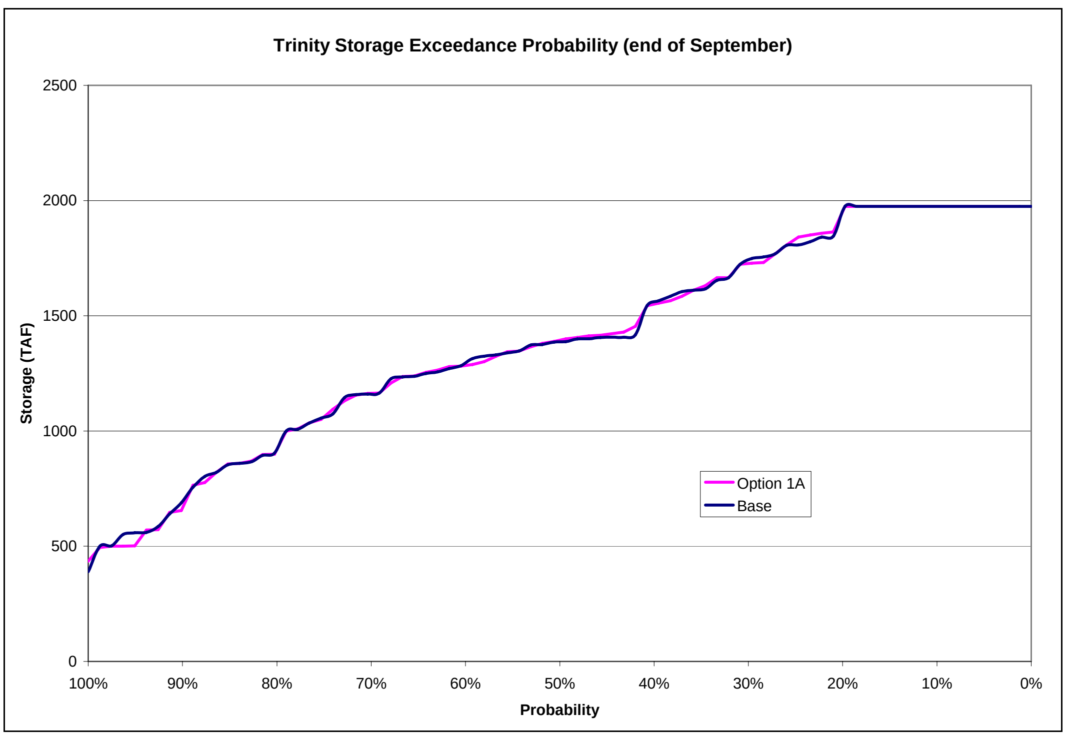


Figure D-8a. Option 1A CVP Northern Delta Storage Frequency: Trinity

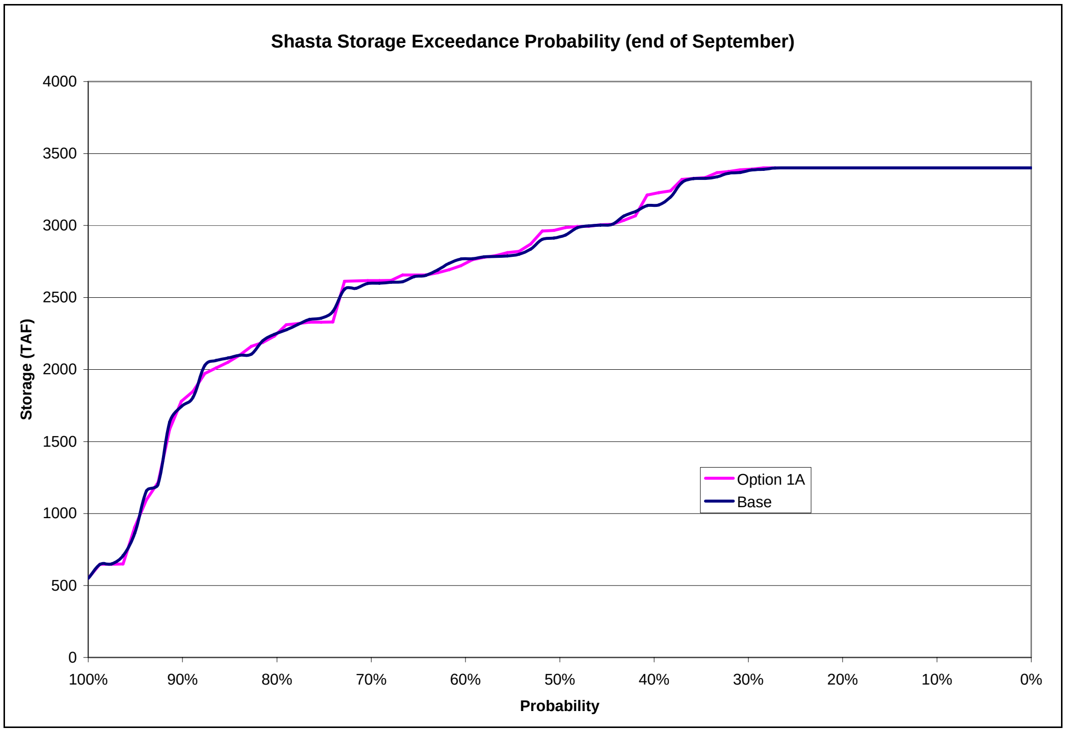


Figure D-8b. Option 1A CVP Northern Delta Storage Frequency: Shasta

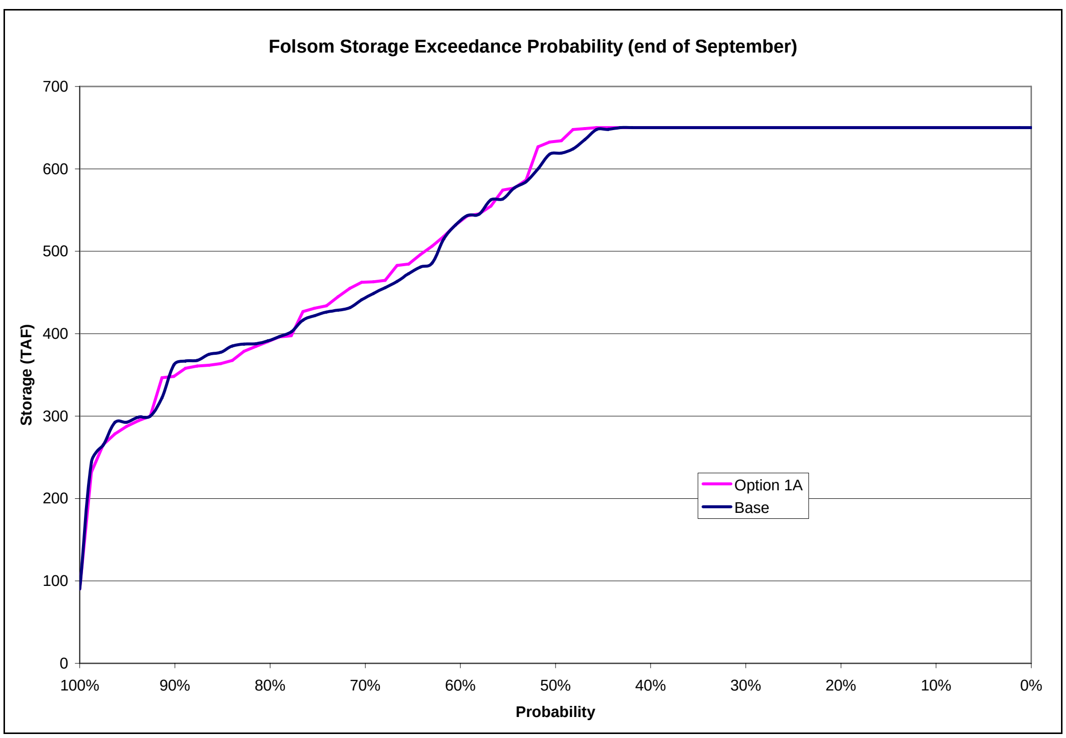


Figure D-8c. Option 1A CVP Northern Delta Storage Frequency: Folsom

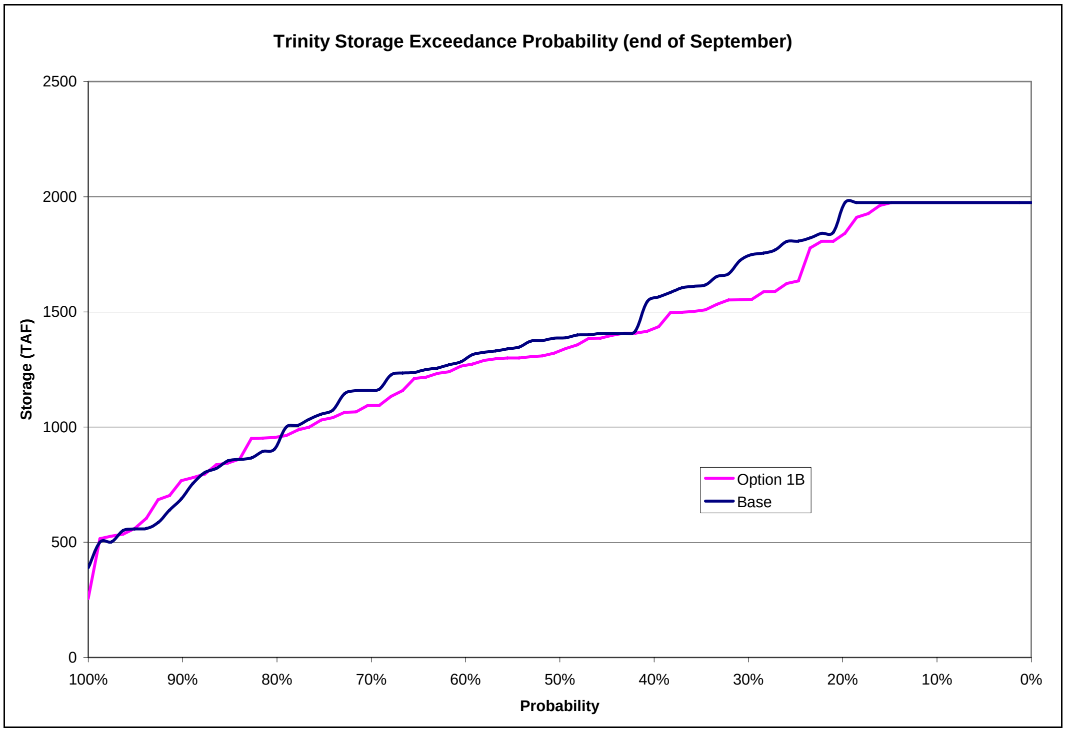


Figure D-9a. Option 1B CVP Northern Delta Storage Frequency: Trinity

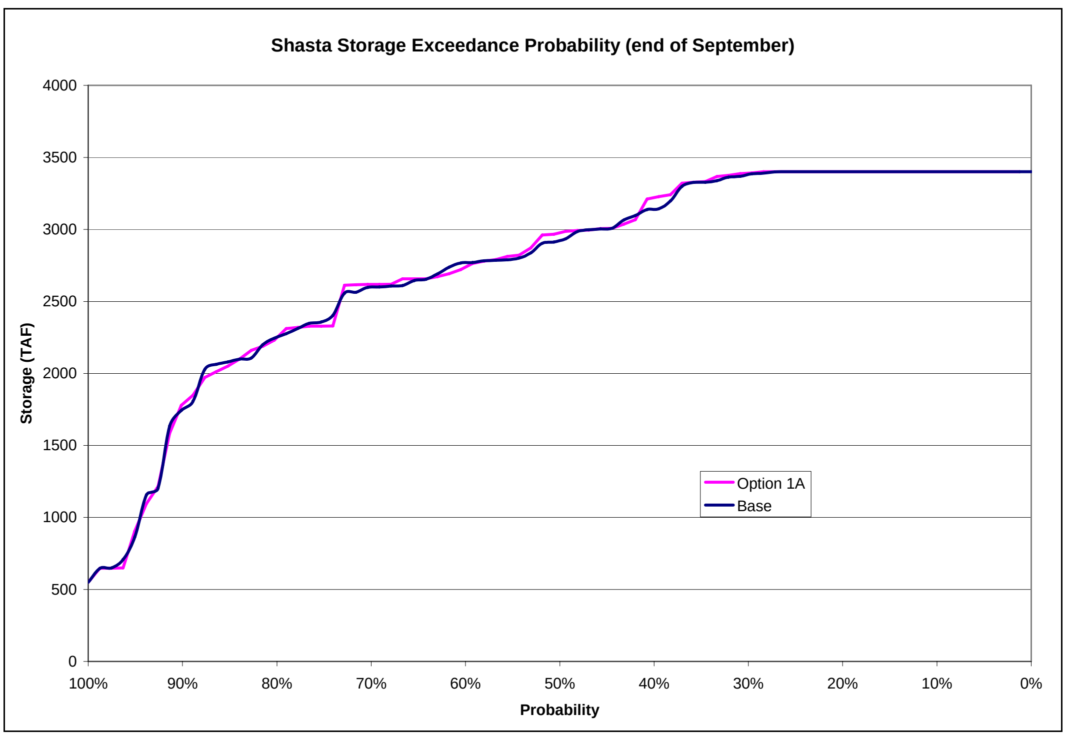


Figure D-9b. Option 1B CVP Northern Delta Storage Frequency: Shasta

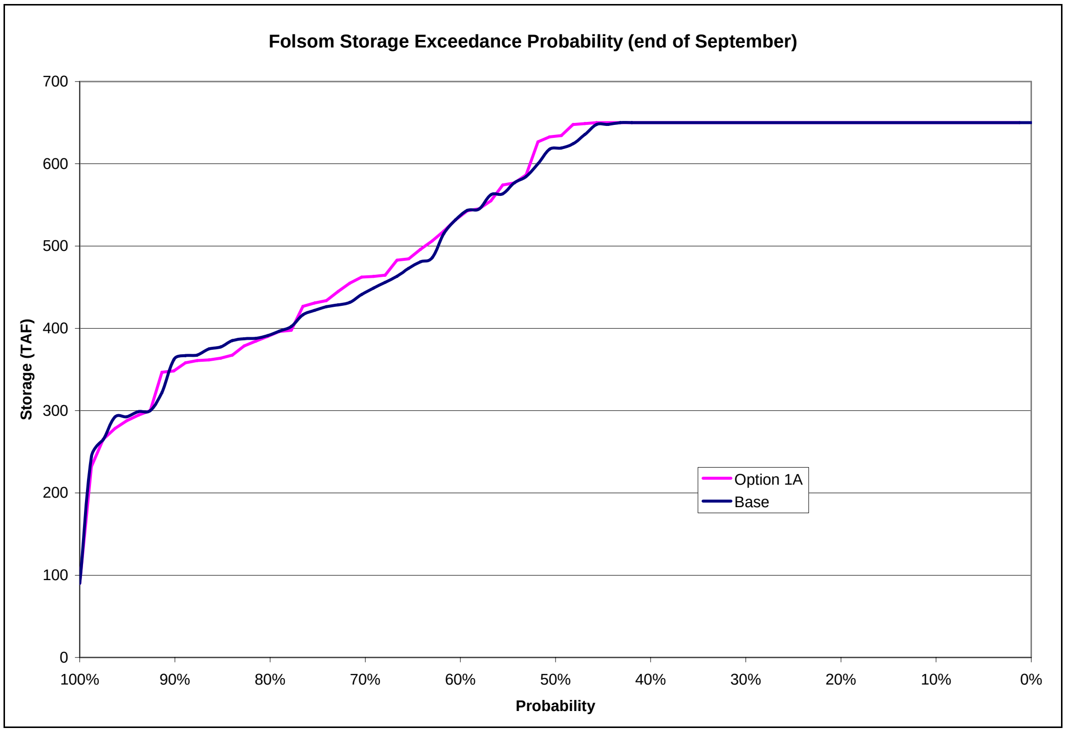


Figure D-9c. Option 1B CVP Northern Delta Storage Frequency: Folsom

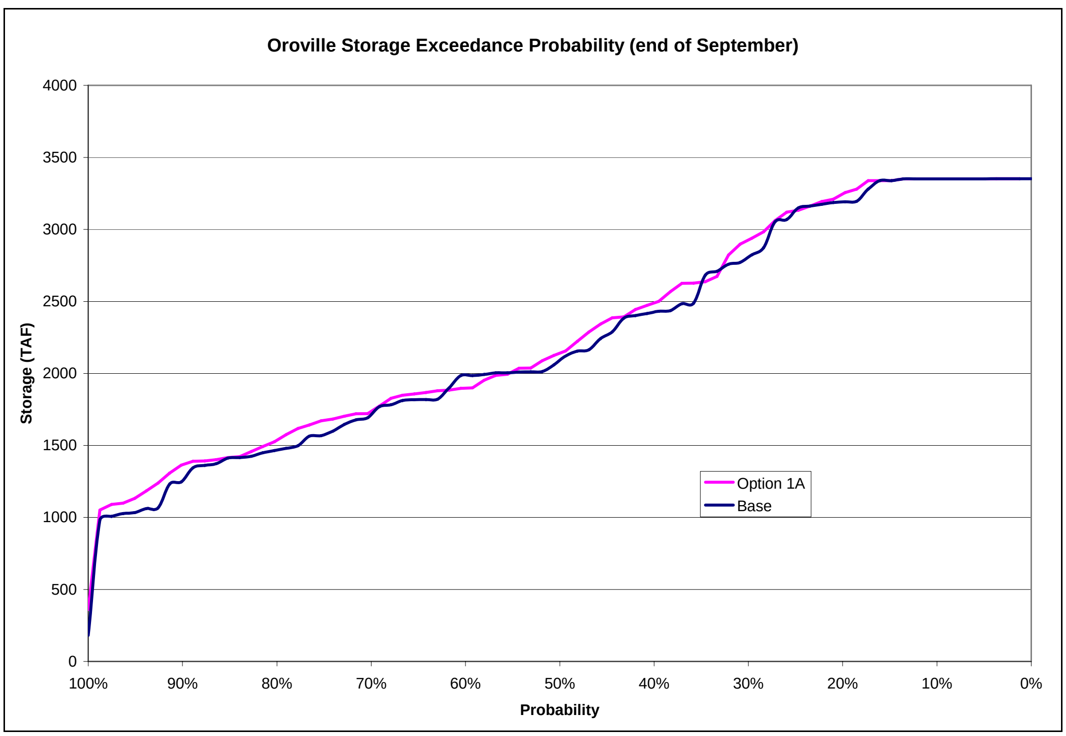


Figure D-10. Option 1A SWP Northern Delta Storage Frequency: Oroville

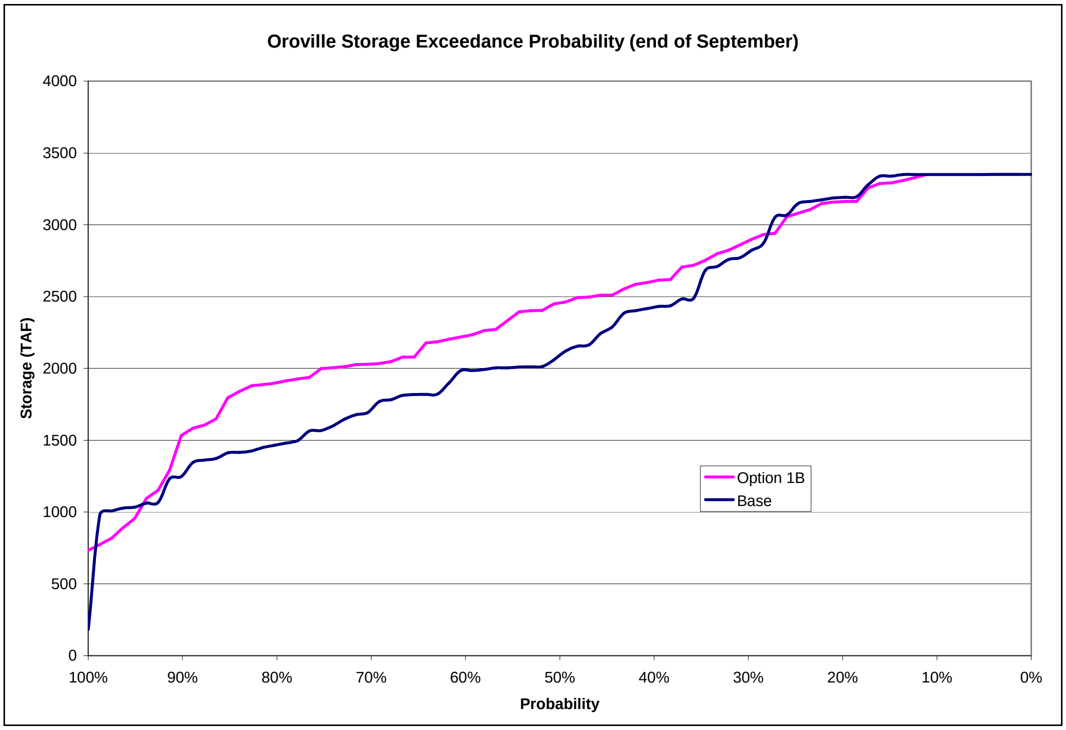


Figure D-11. Option 1B SWP Northern Delta Storage Frequency: Oroville

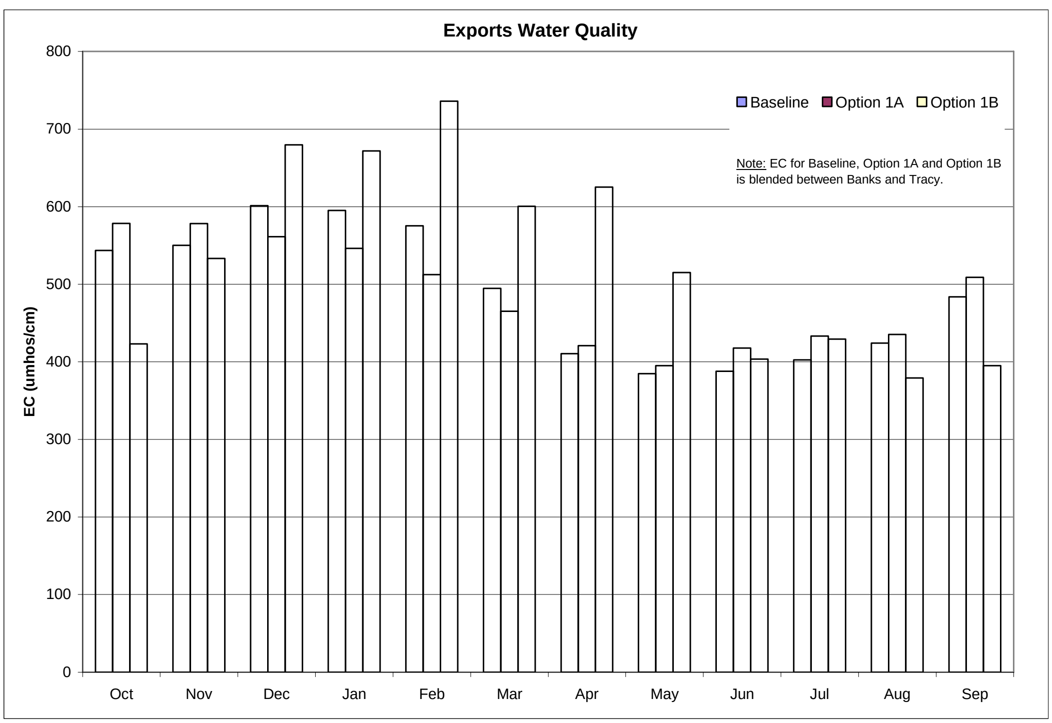


Figure D-12. Export Water Quality Annual Average, 1975-1991

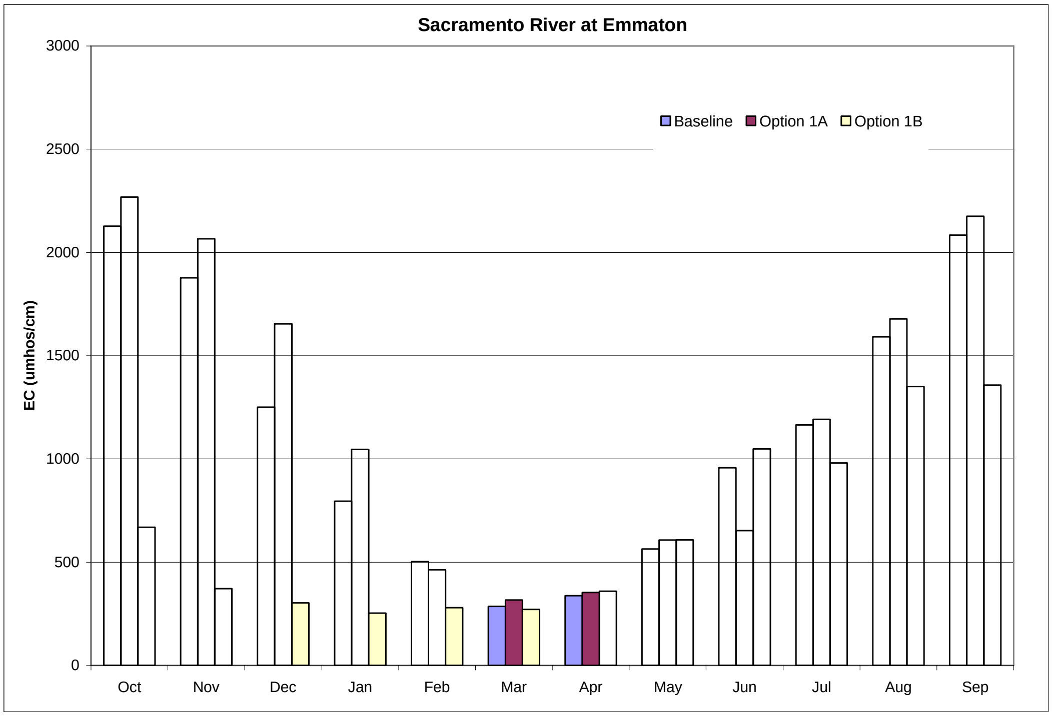


Figure D-13. In Delta Water Quality Annual Average, 1975-1991: Sacramento River at Emmaton

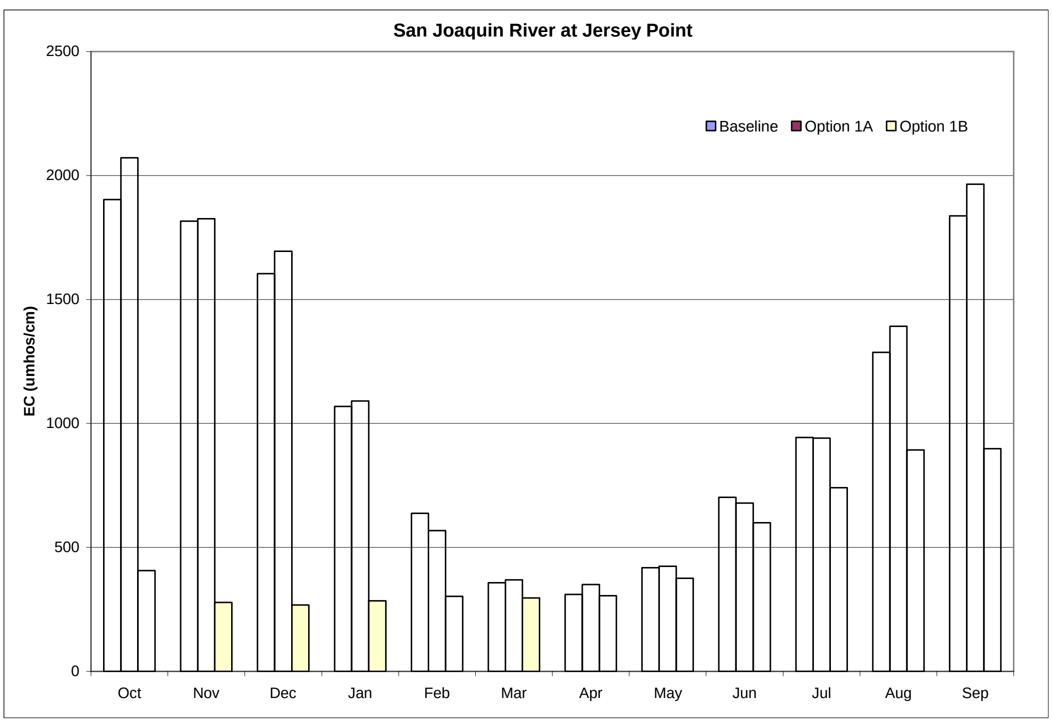


Figure D-14. In Delta Water Quality Annual Average, 1975-1991: San Joaquin River at Jersey Point

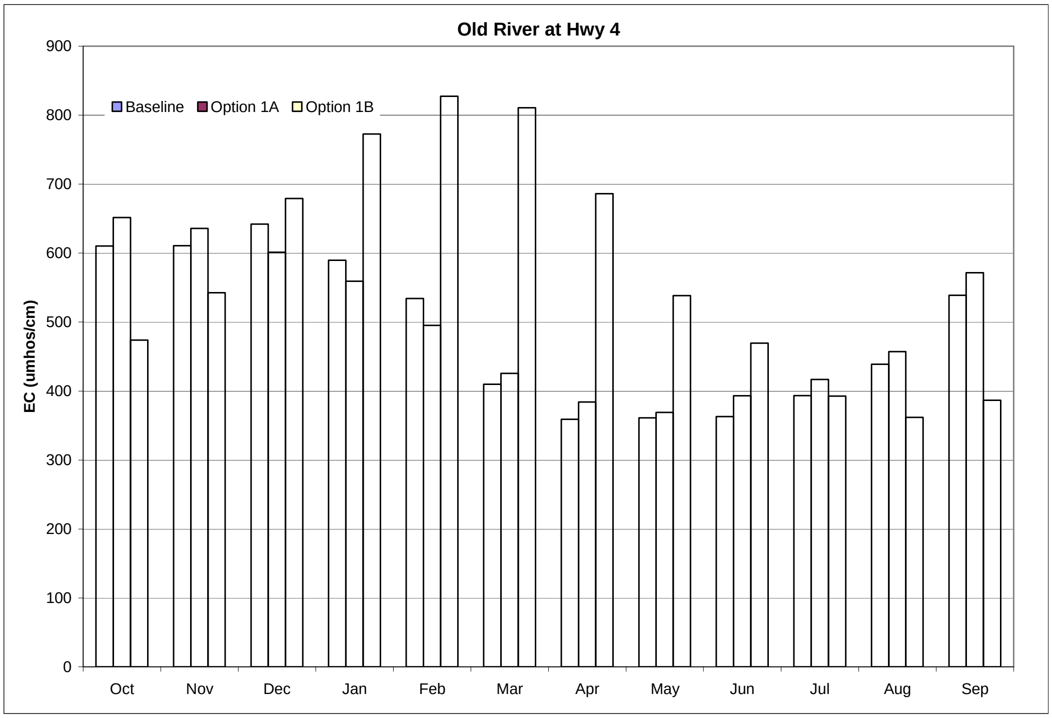


Figure D-15. In Delta Water Quality Annual Average, 1975-1991: Old River at Hwy 4

Table D-2. Option 1A Cumulative Particle Fate – September 1977

	Old River Sep 1977 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 1A	Base	Option 1A	Base	Option 1A	Base	Option 1A	Base	Option 1A
DIVERSION_AG	1.7	1.8	4.0	3.2	5.0	3.8	5.6	4.1	6.7	5.1
EXPORT_CVP	39.8	46.2	44.2	49.8	45.9	51.9	47.4	53.8	49.1	54.8
EXPORT_SWP	13.3	13.4	23.3	22.0	29.4	27.2	32.5	29.6	35.2	31.4
PAST_CHIPPS	0.0	0.1	0.0	0.0	0.1	0.1	0.3	0.4	1.7	0.7
TO_SUISUN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CENTRAL	45.2	38.5	28.5	25.0	19.6	17.0	14.2	12.1	7.3	8.0
	Middle River Sep 1977 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 1A	Base	Option 1A	Base	Option 1A	Base	Option 1A	Base	Option 1A
DIVERSION_AG	0.4	0.4	1.2	2.0	1.7	3.1	2.8	4.4	3.4	5.8
EXPORT_CVP	27.1	28.7	45.9	45.8	53.8	52.1	56.6	55.1	57.8	56.2
EXPORT_SWP	5.2	5.9	17.6	17.5	27.0	25.2	31.9	29.1	35.5	31.9
PAST_CHIPPS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TO_SUISUN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CENTRAL	67.3	65.0	35.3	34.7	17.5	19.6	8.7	11.4	3.3	6.1
	San Joaquin River d/s of Dutch Slough Sep 1977 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 1A	Base	Option 1A	Base	Option 1A	Base	Option 1A	Base	Option 1A
DIVERSION_AG	0.0	0.2	0.1	0.2	0.1	0.2	0.3	0.2	0.7	0.8
EXPORT_CVP	0.0	0.1	0.3	0.3	1.5	1.4	3.3	3.2	7.6	6.9
EXPORT_SWP	0.0	0.0	0.2	0.2	0.6	0.3	1.2	1.0	3.4	2.4
PAST_CHIPPS	17.0	19.1	17.9	18.0	37.4	36.4	34.8	36.3	48.9	50.4
TO_SUISUN	0.1	0.3	0.0	0.0	0.3	0.0	0.0	0.3	0.2	0.3
CENTRAL	82.9	80.3	81.5	81.3	60.1	61.7	60.4	59.0	39.2	39.2
	Sacramento River Sep 1977 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 1A	Base	Option 1A	Base	Option 1A	Base	Option 1A	Base	Option 1A
DIVERSION_AG	0.1	0.0	0.2	0.3	0.3	0.3	0.7	0.6	1.2	1.2
EXPORT_CVP	0.0	0.0	0.7	0.6	3.6	2.6	6.7	6.3	13.9	15.2
EXPORT_SWP	0.0	0.1	0.2	0.3	1.0	1.0	2.9	2.6	6.3	5.6
PAST_CHIPPS	0.3	0.3	1.1	1.4	9.0	9.8	10.0	9.5	20.6	23.5
TO_SUISUN	0.0	0.1	0.0	0.0	0.3	0.1	0.0	0.1	0.3	0.1
CENTRAL	99.6	99.5	97.8	97.4	85.8	86.2	79.7	80.9	57.7	54.4

Table D-2. Option 1A Cumulative Particle Fate – September 1977 (continued)

	San Joaquin River u/s of HOR Sep 1977 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 1A	Base	Option 1A	Base	Option 1A	Base	Option 1A	Base	Option 1A
DIVERSION_AG	7.1	4.2	7.9	5.2	9.8	6.5	11.2	8.2	13.6	9.1
EXPORT_CVP	30.3	0.0	32.4	4.5	33.3	27.7	43.9	37.0	57.5	48.5
EXPORT_SWP	0.0	0.0	0.0	0.6	0.2	7.5	2.6	15.3	9.6	23.1
PAST_CHIPPS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TO_SUISUN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CENTRAL	62.6	95.8	59.7	89.7	56.7	58.3	42.3	39.5	19.3	19.3

Table D-3. Option 1A Cumulative Particle Fate – January 1981

	Old River Jan 1981 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 1A	Base	Option 1A	Base	Option 1A	Base	Option 1A	Base	Option 1A
DIVERSION_AG	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.2	0.2	0.3
EXPORT_CVP	24.1	36.8	25.1	38.5	25.6	39.6	25.6	39.8	25.7	40.1
EXPORT_SWP	66.3	54.6	70.0	57.3	72.0	58.1	72.4	58.7	73.0	59.0
PAST_CHIPPS	0.2	0.0	0.2	0.0	0.2	0.1	0.3	0.2	0.3	0.2
TO_SUISUN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CENTRAL	9.4	8.6	4.7	4.2	2.2	2.2	1.5	1.1	0.8	0.4
	Middle River Jan 1981 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 1A	Base	Option 1A	Base	Option 1A	Base	Option 1A	Base	Option 1A
DIVERSION_AG	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
EXPORT_CVP	25.4	34.8	28.3	38.2	28.7	39.3	28.7	39.5	28.8	40.1
EXPORT_SWP	56.8	48.2	68.9	57.0	71.0	57.7	71.1	57.8	71.1	57.9
PAST_CHIPPS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TO_SUISUN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CENTRAL	17.8	17.0	2.8	4.8	0.3	3.0	0.2	2.7	0.1	1.9
	San Joaquin River d/s of Dutch Slough Jan 1981 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 1A	Base	Option 1A	Base	Option 1A	Base	Option 1A	Base	Option 1A
DIVERSION_AG	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EXPORT_CVP	0.5	0.5	2.5	3.7	5.1	7.0	6.8	9.4	8.3	10.8
EXPORT_SWP	1.2	0.6	6.0	3.4	11.6	7.4	16.4	9.7	20.5	12.1
PAST_CHIPPS	35.1	41.1	51.5	59.0	54.9	62.8	57.4	65.1	58.4	65.8
TO_SUISUN	4.6	4.7	6.6	6.3	7.1	7.2	7.3	7.2	7.6	7.4
CENTRAL	58.6	53.1	33.4	27.6	21.3	15.6	12.1	8.6	5.2	3.9

Table D-3. Option 1A Cumulative Particle Fate – January 1981 (continued)

	Sacramento River Jan 1981 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 1A	Base	Option 1A	Base	Option 1A	Base	Option 1A	Base	Option 1A
DIVERSION_AG	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EXPORT_CVP	1.0	0.8	4.0	3.2	5.4	5.5	6.4	7.5	8.0	8.9
EXPORT_SWP	1.4	1.1	6.2	5.3	11.5	9.1	15.8	11.2	19.0	12.6
PAST_CHIPPS	46.1	51.0	57.4	63.2	60.4	65.2	62.4	67.1	62.6	67.6
TO_SUISUN	4.8	6.2	6.3	7.2	6.6	7.5	6.9	7.6	6.9	7.6
CENTRAL	46.7	40.9	26.1	21.1	16.1	12.7	8.5	6.6	3.5	3.3
	San Joaquin River u/s of HOR Jan 1981 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 1A	Base	Option 1A	Base	Option 1A	Base	Option 1A	Base	Option 1A
DIVERSION_AG	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EXPORT_CVP	56.7	13.8	59.2	31.2	63.8	36.5	65.6	37.4	66.0	39.3
EXPORT_SWP	8.4	14.7	11.2	41.7	22.5	52.1	27.9	54.2	30.1	56.9
PAST_CHIPPS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TO_SUISUN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CENTRAL	34.9	71.5	29.6	27.1	13.7	11.4	6.5	8.4	3.9	3.8

Table D-4. Option 1A Cumulative Particle Fate – March 1990

	Old River Mar 1990 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 1A	Base	Option 1A	Base	Option 1A	Base	Option 1A	Base	Option 1A
DIVERSION_AG	0.4	0.9	0.6	1.5	1.8	3.5	2.2	4.3	3.3	5.7
EXPORT_CVP	29.9	38.5	34.7	41.8	36.7	43.5	37.9	44.4	38.8	45.1
EXPORT_SWP	23.0	31.1	37.2	39.3	43.2	42.3	46.1	42.9	46.5	43.2
PAST_CHIPPS	0.0	0.1	0.1	0.0	0.9	0.3	0.8	0.5	1.6	1.0
TO_SUISUN	0.0	0.0	0.0	0.0	0.2	0.2	0.5	0.2	0.8	0.3
CENTRAL	46.7	29.4	27.4	17.4	17.2	10.2	12.5	7.7	9.0	4.7
	Middle River Mar 1990 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 1A	Base	Option 1A	Base	Option 1A	Base	Option 1A	Base	Option 1A
DIVERSION_AG	0.2	0.3	0.6	2.2	1.2	3.3	2.0	4.2	2.6	5.2
EXPORT_CVP	15.7	29.2	31.3	39.4	35.9	42.3	38.1	43.3	39.8	43.6
EXPORT_SWP	8.9	21.3	29.7	39.1	41.7	45.3	46.9	47.8	47.6	47.9
PAST_CHIPPS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
TO_SUISUN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CENTRAL	75.2	49.2	38.4	19.3	21.2	9.1	13.0	4.7	9.9	3.3

Table D-4. Option 1A Cumulative Particle Fate – March 1990 (continued)

	San Joaquin River d/s of Dutch Slough Mar 1990 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 1A	Base	Option 1A	Base	Option 1A	Base	Option 1A	Base	Option 1A
DIVERSION_AG	0.0	0.0	0.0	0.0	0.0	0.2	0.2	0.4	0.5	1.0
EXPORT_CVP	0.0	0.2	0.2	0.9	0.8	2.5	1.5	4.2	2.3	5.6
EXPORT_SWP	0.0	0.1	0.2	0.6	0.3	2.0	1.1	3.3	1.4	3.3
PAST_CHIPPS	31.6	28.4	35.3	31.2	51.8	43.8	47.2	40.1	56.5	48.9
TO_SUISUN	6.3	6.1	9.8	10.2	12.2	13.1	13.7	14.7	15.8	16.9
CENTRAL	62.1	65.2	54.5	57.1	34.9	38.4	36.3	37.3	23.5	24.3
	Sacramento River Mar 1990 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 1A	Base	Option 1A	Base	Option 1A	Base	Option 1A	Base	Option 1A
DIVERSION_AG	0.0	0.0	0.0	0.0	0.1	0.2	0.1	0.5	0.5	1.5
EXPORT_CVP	0.0	0.2	0.9	2.3	2.3	5.9	3.7	8.9	4.4	10.6
EXPORT_SWP	0.0	0.2	0.3	1.5	1.4	4.0	3.2	6.5	3.2	6.5
PAST_CHIPPS	20.6	19.8	26.0	22.5	39.3	33.6	36.7	29.6	47.7	39.8
TO_SUISUN	4.2	3.1	7.4	6.7	10.0	9.2	11.5	11.3	14.1	13.4
CENTRAL	75.2	76.7	65.4	67.0	46.9	47.1	44.8	43.2	30.1	28.2
	San Joaquin River u/s of HOR Mar 1990 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 1A	Base	Option 1A	Base	Option 1A	Base	Option 1A	Base	Option 1A
DIVERSION_AG	14.3	2.1	19.4	2.6	20.1	3.4	20.1	4.9	22.1	8.7
EXPORT_CVP	50.5	0.2	53.7	14.8	53.9	25.6	53.9	31.3	54.2	34.2
EXPORT_SWP	0.6	0.1	0.9	11.6	1.0	26.4	1.0	33.6	1.0	34.8
PAST_CHIPPS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TO_SUISUN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CENTRAL	34.6	97.6	26.0	71.0	25.0	44.6	25.0	30.2	22.7	22.3

Table D-5. Option 1B Cumulative Particle Fate – September 1977

	Old River Sep 1977 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 1B	Base	Option 1B	Base	Option 1B	Base	Option 1B	Base	Option 1B
DIVERSION_AG	1.7	1.6	4.0	3.4	5.0	4.1	5.6	4.5	6.7	5.3
EXPORT_CVP	39.8	43.1	44.2	47.3	45.9	49.8	47.4	51.1	49.1	51.1
EXPORT_SWP	13.3	13.0	23.3	22.2	29.4	28.1	32.5	30.0	35.2	30.0
PAST_CHIPPS	0.0	0.0	0.0	0.0	0.1	1.0	0.3	1.1	1.7	3.4
TO_SUISUN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
CENTRAL	45.2	42.3	28.5	27.1	19.6	17.0	14.2	13.3	7.3	10.1

Table D-5. Option 1B Cumulative Particle Fate – September 1977 (continued)

	Middle River Sep 1977 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 1B	Base	Option 1B	Base	Option 1B	Base	Option 1B	Base	Option 1B
DIVERSION_AG	0.4	0.3	1.2	1.1	1.7	1.7	2.8	2.1	3.4	2.7
EXPORT_CVP	27.1	30.0	45.9	49.5	53.8	55.9	56.6	57.7	57.8	57.7
EXPORT_SWP	5.2	5.4	17.6	17.0	27.0	25.3	31.9	28.1	35.5	28.1
PAST_CHIPPS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
TO_SUISUN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
CENTRAL	67.3	64.3	35.3	32.4	17.5	17.1	8.7	12.1	3.3	11.2
	San Joaquin River d/s of Dutch Slough Sep 1977 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 1B	Base	Option 1B	Base	Option 1B	Base	Option 1B	Base	Option 1B
DIVERSION_AG	0.0	0.0	0.1	0.0	0.1	0.0	0.3	0.0	0.7	0.2
EXPORT_CVP	0.0	0.1	0.3	0.5	1.5	1.3	3.3	2.3	7.6	2.3
EXPORT_SWP	0.0	0.0	0.2	0.0	0.6	0.2	1.2	0.2	3.4	0.2
PAST_CHIPPS	17.0	24.3	17.9	25.6	37.4	49.5	34.8	51.1	48.9	77.4
TO_SUISUN	0.1	0.3	0.0	0.0	0.3	0.2	0.0	0.1	0.2	0.1
CENTRAL	82.9	75.3	81.5	73.9	60.1	48.8	60.4	46.3	39.2	19.8
	Sacramento River Sep 1977 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 1B	Base	Option 1B	Base	Option 1B	Base	Option 1B	Base	Option 1B
DIVERSION_AG	0.1	0.0	0.2	0.2	0.3	0.3	0.7	0.4	1.2	0.6
EXPORT_CVP	0.0	0.0	0.7	1.1	3.6	3.2	6.7	5.0	13.9	5.0
EXPORT_SWP	0.0	0.0	0.2	0.2	1.0	0.6	2.9	1.2	6.3	1.2
PAST_CHIPPS	0.3	1.2	1.1	5.6	9.0	21.4	10.0	24.7	20.6	53.4
TO_SUISUN	0.0	0.1	0.0	0.0	0.3	0.2	0.0	0.0	0.3	0.2
CENTRAL	99.6	98.7	97.8	92.9	85.8	74.3	79.7	68.7	57.7	39.6
	San Joaquin River u/s of HOR Sep 1977 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 1B	Base	Option 1B	Base	Option 1B	Base	Option 1B	Base	Option 1B
DIVERSION_AG	7.1	7.4	7.9	8.7	9.8	10.4	11.2	10.8	13.6	12.0
EXPORT_CVP	30.3	31.5	32.4	33.2	33.3	34.2	43.9	37.9	57.5	37.9
EXPORT_SWP	0.0	0.0	0.0	0.0	0.2	0.2	2.6	0.5	9.6	0.5
PAST_CHIPPS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TO_SUISUN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CENTRAL	62.6	61.1	59.7	58.1	56.7	55.2	42.3	50.8	19.3	49.6

Table D-6. Option 1B Cumulative Particle Fate – January 1981

	Old River Jan 1981 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 1B	Base	Option 1B	Base	Option 1B	Base	Option 1B	Base	Option 1B
DIVERSION_AG	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.2	0.2
EXPORT_CVP	24.1	0.0	25.1	0.0	25.6	0.0	25.6	0.0	25.7	0.0
EXPORT_SWP	66.3	0.0	70.0	0.0	72.0	0.0	72.4	0.0	73.0	0.0
PAST_CHIPPS	0.2	6.0	0.2	31.8	0.2	52.8	0.3	69.1	0.3	78.7
TO_SUISUN	0.0	0.6	0.0	3.3	0.0	4.8	0.0	6.0	0.0	6.8
CENTRAL	9.4	93.4	4.7	64.9	2.2	42.4	1.5	24.9	0.8	14.3
	Middle River Jan 1981 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 1B	Base	Option 1B	Base	Option 1B	Base	Option 1B	Base	Option 1B
DIVERSION_AG	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EXPORT_CVP	25.4	0.0	28.3	0.0	28.7	0.0	28.7	0.0	28.8	0.0
EXPORT_SWP	56.8	0.0	68.9	0.0	71.0	0.0	71.1	0.0	71.1	0.0
PAST_CHIPPS	0.0	0.3	0.0	7.6	0.0	18.5	0.0	38.0	0.0	52.1
TO_SUISUN	0.0	0.0	0.0	0.4	0.0	1.0	0.0	2.4	0.0	3.3
CENTRAL	17.8	99.7	2.8	92.0	0.3	80.5	0.2	59.6	0.1	44.6
	San Joaquin River d/s of Dutch Slough Jan 1981 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 1B	Base	Option 1B	Base	Option 1B	Base	Option 1B	Base	Option 1B
DIVERSION_AG	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EXPORT_CVP	0.5	0.0	2.5	0.0	5.1	0.0	6.8	0.0	8.3	0.0
EXPORT_SWP	1.2	0.0	6.0	0.0	11.6	0.0	16.4	0.0	20.5	0.0
PAST_CHIPPS	35.1	81.2	51.5	91.4	54.9	91.6	57.4	91.5	58.4	91.5
TO_SUISUN	4.6	7.8	6.6	8.2	7.1	8.4	7.3	8.5	7.6	8.5
CENTRAL	58.6	11.0	33.4	0.4	21.3	0.0	12.1	0.0	5.2	0.0
	Sacramento River Jan 1981 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 1B	Base	Option 1B	Base	Option 1B	Base	Option 1B	Base	Option 1B
DIVERSION_AG	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EXPORT_CVP	1.0	0.0	4.0	0.0	5.4	0.0	6.4	0.0	8.0	0.0
EXPORT_SWP	1.4	0.0	6.2	0.0	11.5	0.0	15.8	0.0	19.0	0.0
PAST_CHIPPS	46.1	65.0	57.4	89.0	60.4	91.0	62.4	91.4	62.6	91.8
TO_SUISUN	4.8	5.9	6.3	7.6	6.6	7.9	6.9	8.0	6.9	8.0
CENTRAL	46.7	29.1	26.1	3.4	16.1	1.1	8.5	0.6	3.5	0.2

Table D-6. Option 1B Cumulative Particle Fate – January 1981 (continued)

	San Joaquin River u/s of HOR Jan 1981 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 1B	Base	Option 1B	Base	Option 1B	Base	Option 1B	Base	Option 1B
DIVERSION_AG	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EXPORT_CVP	56.7	30.0	59.2	31.4	63.8	31.4	65.6	31.4	66.0	31.4
EXPORT_SWP	8.4	0.0	11.2	0.0	22.5	0.0	27.9	0.0	30.1	0.0
PAST_CHIPPS	0.0	0.0	0.0	0.0	0.0	0.5	0.0	6.6	0.0	16.8
TO_SUISUN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.8
CENTRAL	34.9	70.0	29.6	68.6	13.7	68.1	6.5	61.8	3.9	51.0

Table D-7. Option 1B Cumulative Particle Fate – March 1990

	Old River Mar 1990 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 1B	Base	Option 1B	Base	Option 1B	Base	Option 1B	Base	Option 1B
DIVERSION_AG	0.4	0.3	0.6	0.5	1.8	0.6	2.2	0.8	3.3	1.9
EXPORT_CVP	29.9	0.0	34.7	0.0	36.7	0.0	37.9	0.0	38.8	0.8
EXPORT_SWP	23.0	0.0	37.2	0.0	43.2	0.0	46.1	0.0	46.5	0.0
PAST_CHIPPS	0.0	2.5	0.1	7.0	0.9	28.5	0.8	32.2	1.6	43.5
TO_SUISUN	0.0	0.1	0.0	1.4	0.2	3.5	0.5	7.5	0.8	11.2
CENTRAL	46.7	97.1	27.4	91.1	17.2	67.4	12.5	59.5	9.0	42.6
	Middle River Mar 1990 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 1B	Base	Option 1B	Base	Option 1B	Base	Option 1B	Base	Option 1B
DIVERSION_AG	0.2	0.1	0.6	0.1	1.2	0.2	2.0	0.4	2.6	2.8
EXPORT_CVP	15.7	0.0	31.3	0.0	35.9	0.0	38.1	0.0	39.8	4.1
EXPORT_SWP	8.9	0.0	29.7	0.0	41.7	0.0	46.9	0.0	47.6	0.0
PAST_CHIPPS	0.0	0.2	0.0	0.5	0.0	3.0	0.0	5.7	0.1	11.2
TO_SUISUN	0.0	0.0	0.0	0.1	0.0	0.5	0.0	1.0	0.0	3.5
CENTRAL	75.2	99.7	38.4	99.3	21.2	96.3	13.0	92.9	9.9	78.4
	San Joaquin River d/s of Dutch Slough Mar 1990 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 1B	Base	Option 1B	Base	Option 1B	Base	Option 1B	Base	Option 1B
DIVERSION_AG	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.5	0.0
EXPORT_CVP	0.0	0.0	0.2	0.0	0.8	0.0	1.5	0.0	2.3	0.0
EXPORT_SWP	0.0	0.0	0.2	0.0	0.3	0.0	1.1	0.0	1.4	0.0
PAST_CHIPPS	31.6	63.9	35.3	74.8	51.8	85.4	47.2	82.1	56.5	84.2
TO_SUISUN	6.3	8.3	9.8	10.5	12.2	11.5	13.7	12.4	15.8	12.9
CENTRAL	62.1	27.8	54.5	14.7	34.9	3.1	36.3	5.5	23.5	2.9

Table D-7. Option 1B Cumulative Particle Fate – March 1990 (continued)

	Sacramento River Mar 1990 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 1B	Base	Option 1B	Base	Option 1B	Base	Option 1B	Base	Option 1B
DIVERSION_AG	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.5	0.1
EXPORT_CVP	0.0	0.0	0.9	0.0	2.3	0.0	3.7	0.0	4.4	0.0
EXPORT_SWP	0.0	0.0	0.3	0.0	1.4	0.0	3.2	0.0	3.2	0.0
PAST_CHIPPS	20.6	24.6	26.0	45.6	39.3	72.9	36.7	70.4	47.7	76.1
TO_SUISUN	4.2	2.6	7.4	7.5	10.0	10.5	11.5	12.4	14.1	15.0
CENTRAL	75.2	72.8	65.4	46.9	46.9	16.6	44.8	17.2	30.1	8.8
	San Joaquin River u/s of HOR Mar 1990 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 1B	Base	Option 1B	Base	Option 1B	Base	Option 1B	Base	Option 1B
DIVERSION_AG	14.3	18.5	19.4	31.6	20.1	34.4	20.1	36.4	22.1	42.2
EXPORT_CVP	50.5	0.0	53.7	0.0	53.9	0.0	53.9	1.7	54.2	10.8
EXPORT_SWP	0.6	0.0	0.9	0.0	1.0	0.0	1.0	0.0	1.0	0.0
PAST_CHIPPS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TO_SUISUN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CENTRAL	34.6	81.5	26.0	68.4	25.0	65.6	25.0	61.9	22.7	47.0

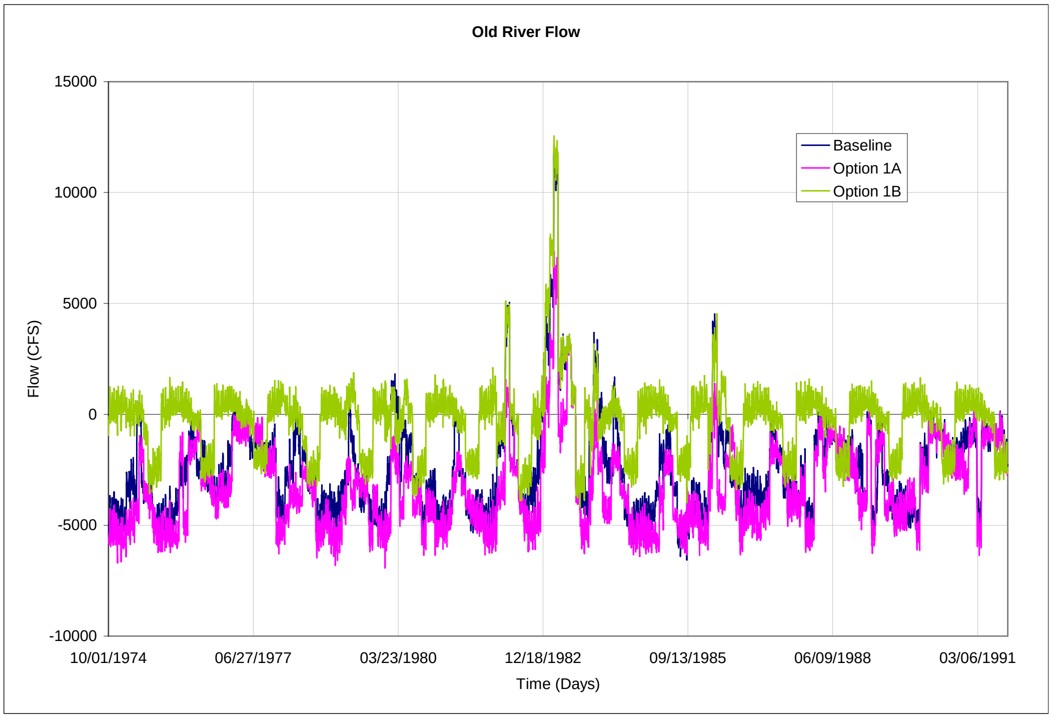


Figure D-16. DSM2 Simulated Daily Averaged Old River Flows

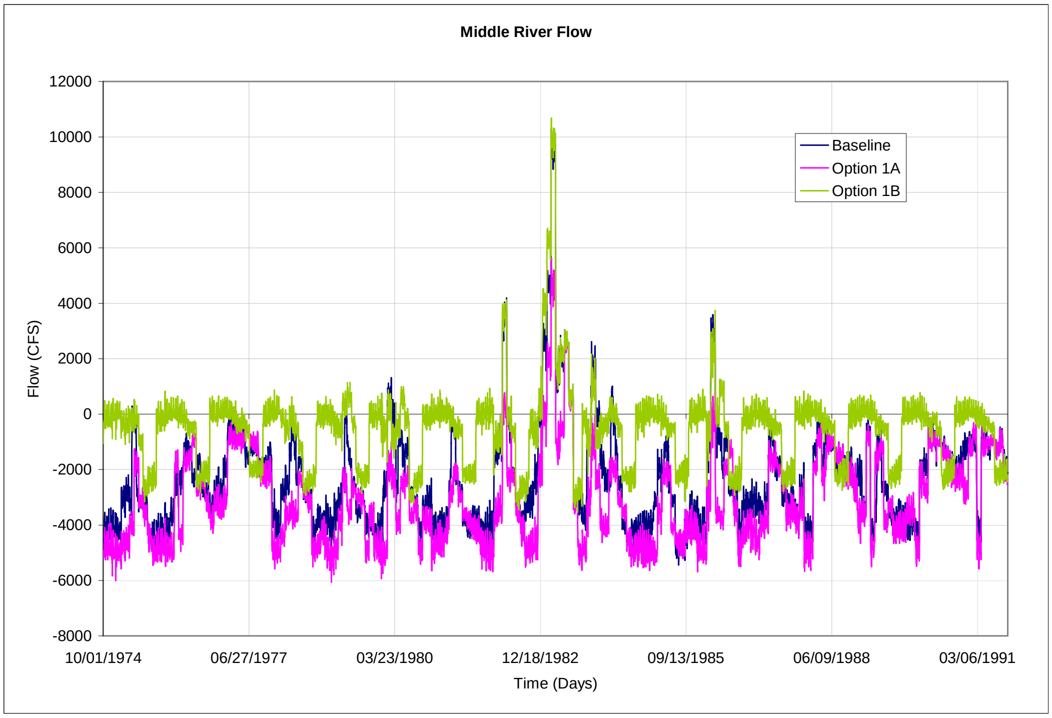


Figure D-17. DSM2 Simulated Daily Averaged Middle River Flows

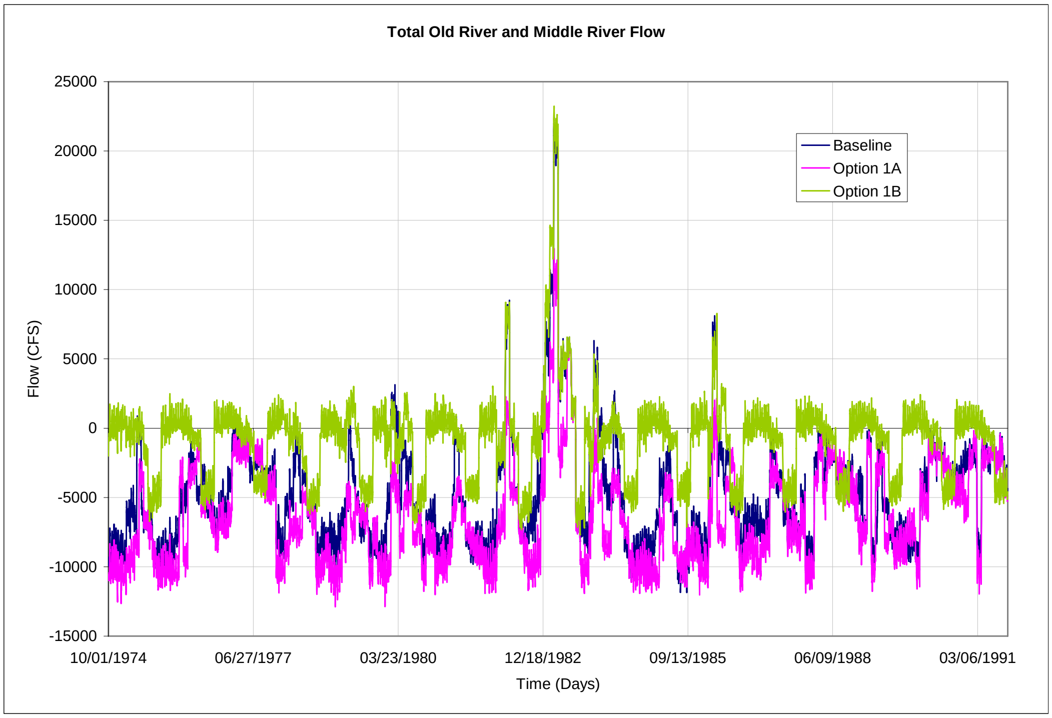


Figure D-18. DSM2 Simulated Daily Averaged Combined Old and Middle River Flows

APPENDIX E. OPTION 2 HYDROLOGIC/HYDRODYNAMIC MODEL RESULTS

Table E-1. Summary Output for the Implementation of Conservation Strategy: Option 2

	Base		Option 2A				Option 2B			
Delta flows[1]	**Annual Average**[2] **(1)**	**Dry period**[3] **(2)**	**Annual Average**[2] **(3)**	**Dry period**[3] **(4)**	**Change (3)-(1)**	**Change (4)-(2)**	**Annual Average**[2] **(5)**	**Dry period**[3] **(6)**	**Change (5)-(1)**	**Change (6)-(2)**
Sacramento River @ Hood	16,229	8,269	16,109	8,454	-120	185	16,200	8,243	-29	-27
San Joaquin River @ Vernalis	3,027	1,362	3,033	1,371	6	9	3,027	1,335	1	-26
Sacramento River @ Rio Vista	13,812	5,164	13,889	5,160	78	-4	13,383	4,111	-428	-1,054
Delta Outflow	14,991	5,154	17,783	6,163	2,791	1,010	18,404	6,266	3,413	1,113
SWP/CVP Exports	5,902	3,572	3,135	2,761	-2,767	-812	2,548	2,417	-3,354	-1,156
QWEST (cfs)	1,620	-12	5,386	1,386	3,767	1,398	6,968	3,005	5,348	3,017
Old and Middle River (cfs)	-5,842	-4,635	-2,793	-3,735	3,049	900	-2,161	-3,403	3,681	1,232
Water quality[4]	Annual Average[5] (1)	Dry period[3] (2)	Annual Average[5] (3)	Dry period[3] (4)	Change (3)-(1)	Change (4)-(2)	Annual Average[5] (5)	Dry period[3] (6)	Change (5)-(1)	Change (6)-(2)
X2 (km)	76	82	73	81	-3	-1	72	80	-4	-2
EC Exports[6]	488		304		-183		298		-190	
EC at Emmaton	1,128		852		-276		964		-164	
EC at Jersey Point	1,074		695		-378		750		-323	
EC at Collinsville	3,816		2,825		-991		2,992		-824	
EC at Old River, Hwy 4	488		630		143		677		189	
Particle Transport and Fate[7]	Average[8] (1)		Average[8] (2)		Change (2)-(1)		Average[8] (3)		Change (3)-(1)	
Insertion on Old River @ Quimby Island	57		4		-53		1		-55	
Insertion on Middle River @ Mildred Island	59		99		40		99		40	
Insertion on San Joaquin River near Big Break	9		1		-8		0		-9	
Insertion on Sacramento River near Cache Slough	13		3		-10		1		-12	
Insertion on San Joaquin River near Head of Old River	47		20		-27		22		-25	

Table E-1. Summary Output for the Implementation of Conservation Strategy: Option 2

NOTES:

1. Units in TAF unless mentioned otherwise

2. Annual average, 1921-2003

3. Dry period, 1928-1934

4. Units in EC, µMHOS/cm unless mentioned otherwise

5. For EC parameter values represent 16-year monthly Period Averaged; for X2 values represent annual average, 1921-2003

6. Base: EC is blended between EC at Banks and EC at Tracy; Options 2A and 2B: EC at the Victoria Canal siphon

7. Percentage of particles entering SWP and CVP pumping stations in Baseline and entering the Victoria Canal siphon in Option 2

8. Average of 1977, 1981 and 1990 releases of % cumulative particles ended up in exports at the end of 40 days

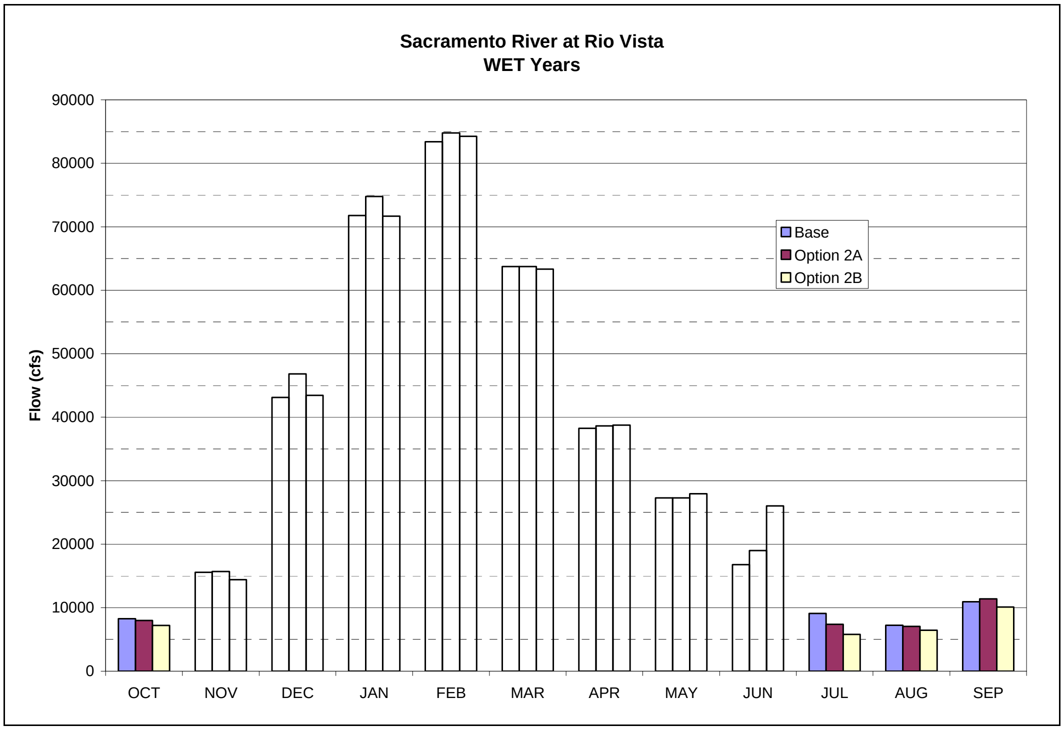


Figure E-1a. Sacramento River at Rio Vista Wet Year Average Flows

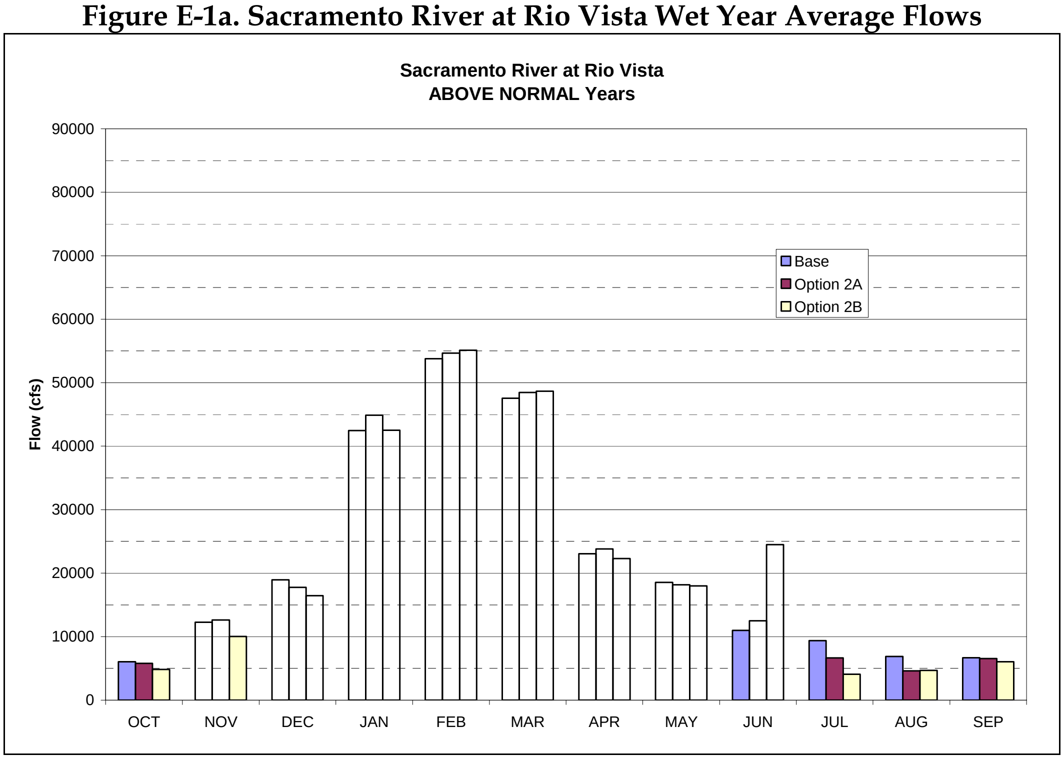


Figure E-1b. Sacramento River at Rio Vista Above Normal Year Average Flows

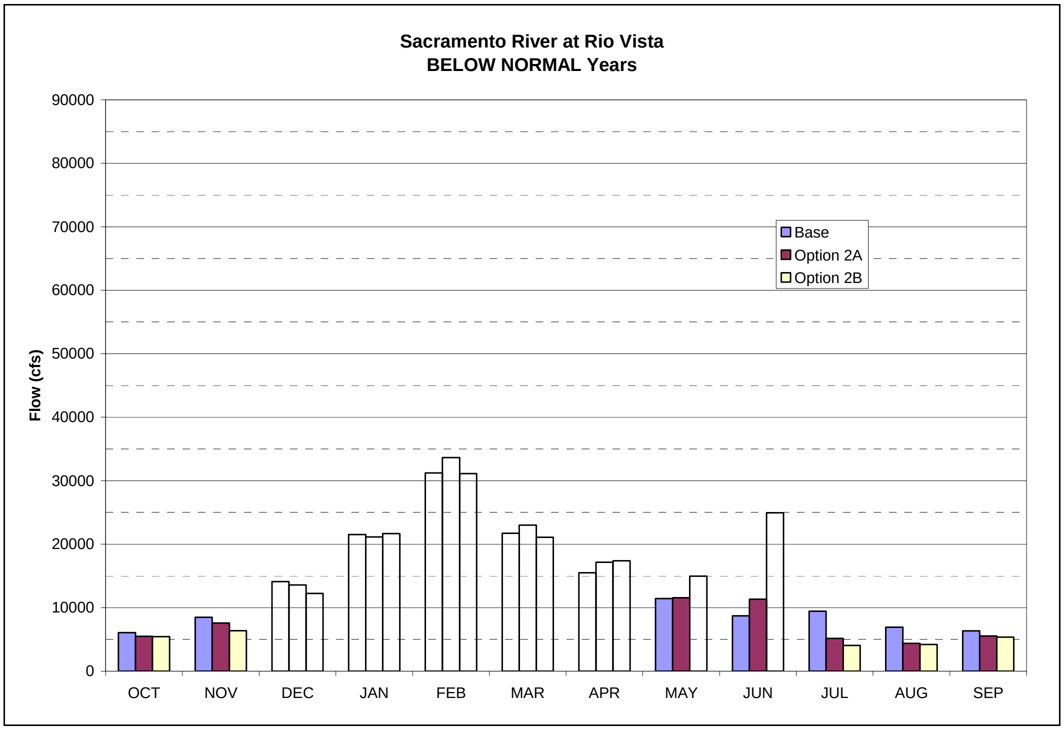


Figure E-1c. Sacramento River at Rio Vista Below Normal Year Average Flows

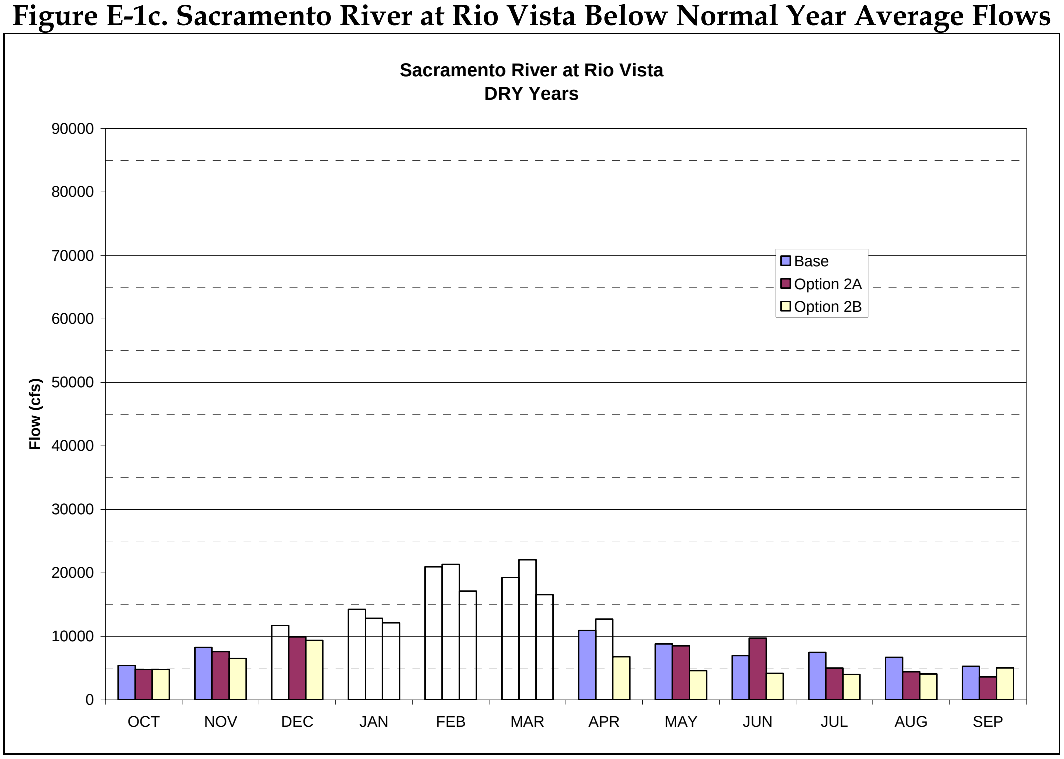


Figure E-1d. Sacramento River at Rio Vista Dry Year Average Flows

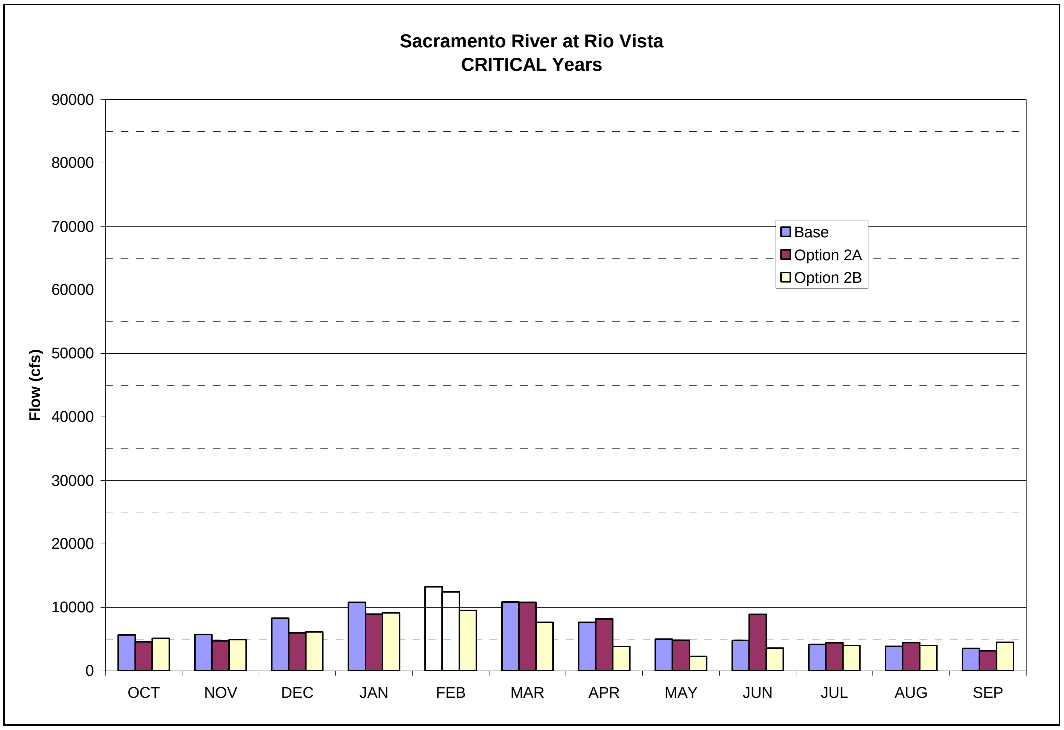


Figure E-1e. Sacramento River at Rio Vista Critical Year Average Flows

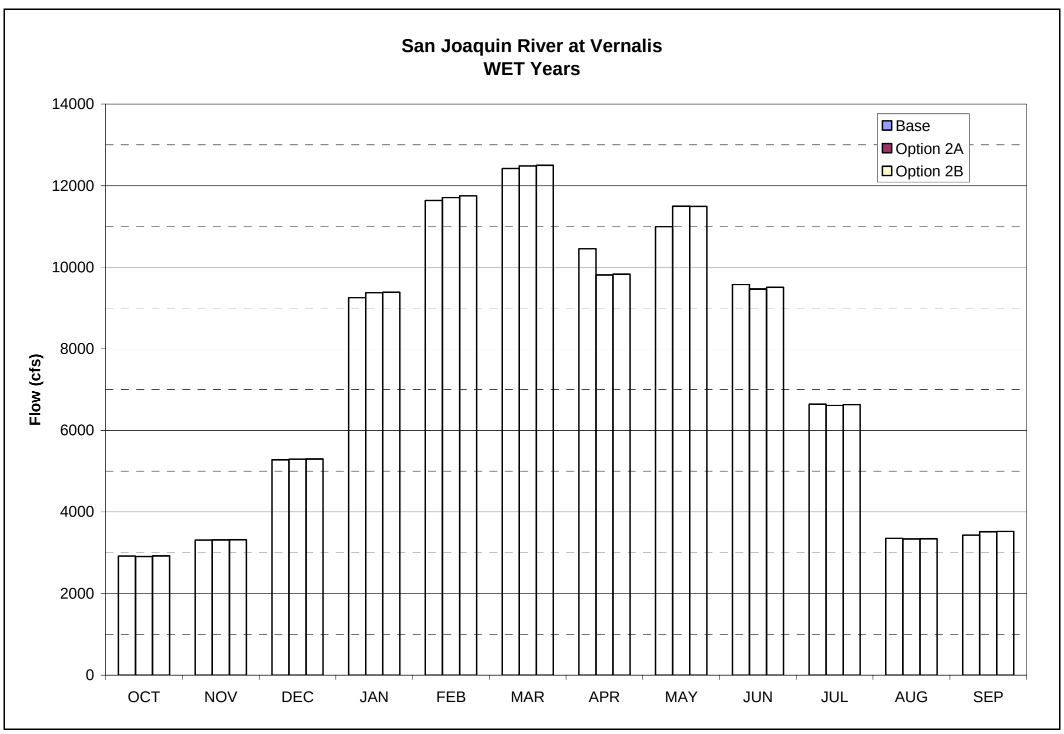


Figure E-2a. San Joaquin River at Vernalis Wet Year Average Flows

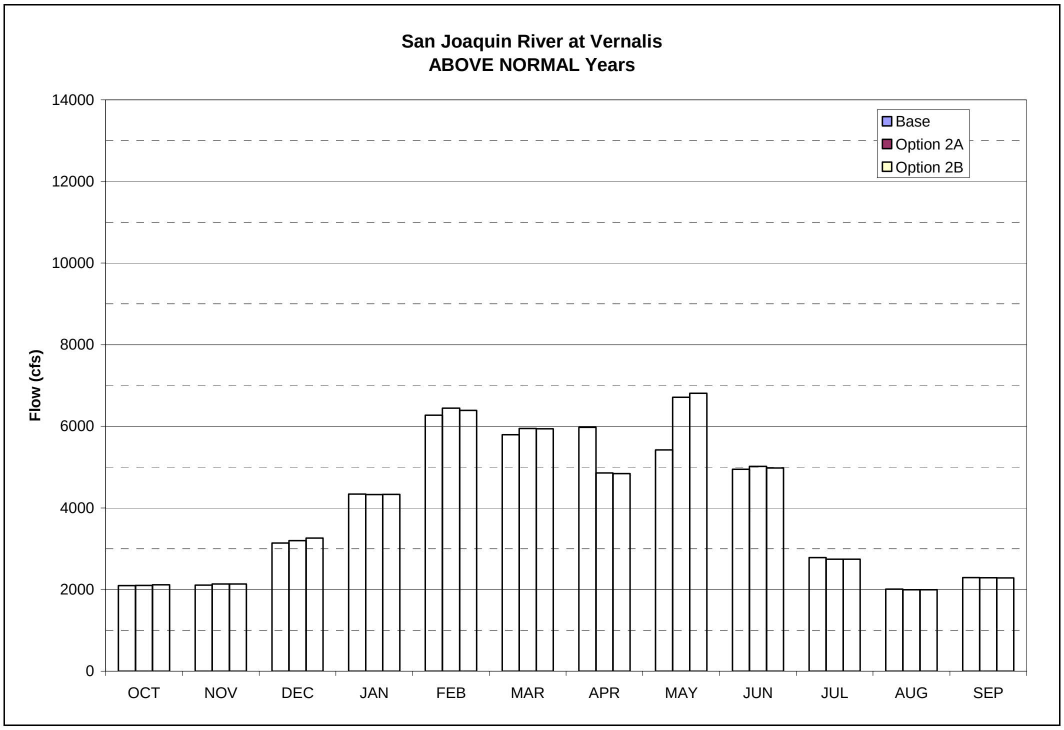


Figure E-2b. San Joaquin River at Vernalis Above Normal Year Average Flows

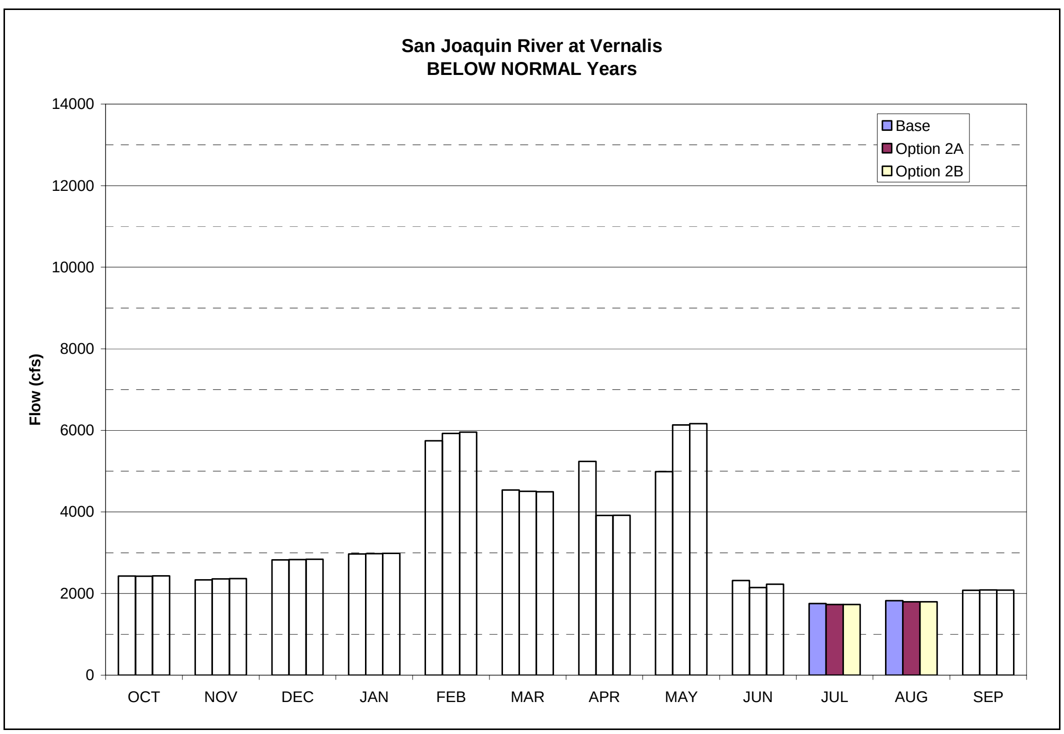


Figure E-2c. San Joaquin River at Vernalis Below Normal Year Average Flows

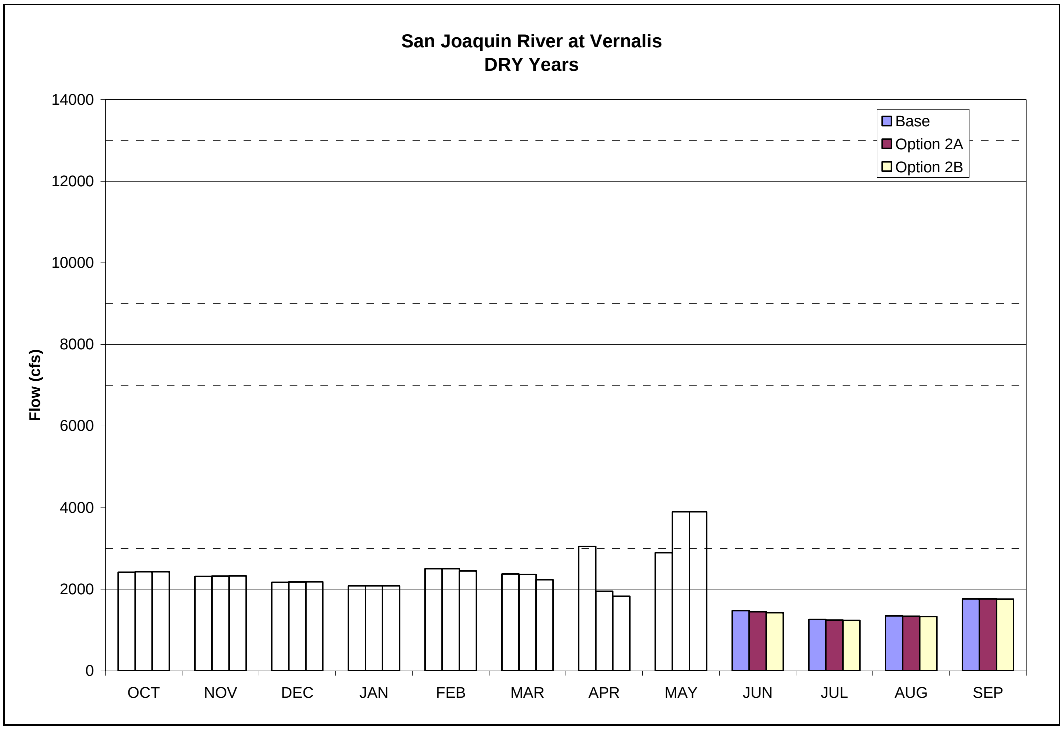


Figure E-2d. San Joaquin River at Vernalis Dry Year Average Flows

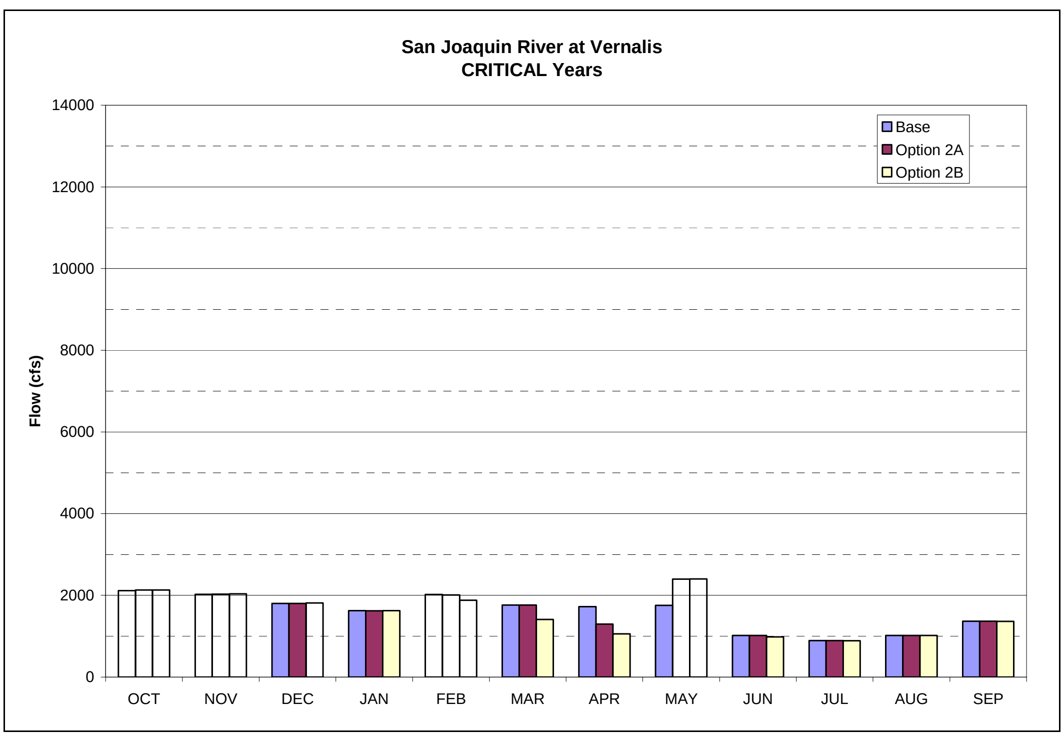


Figure E-2e. San Joaquin River at Vernalis Critical Year Average Flows

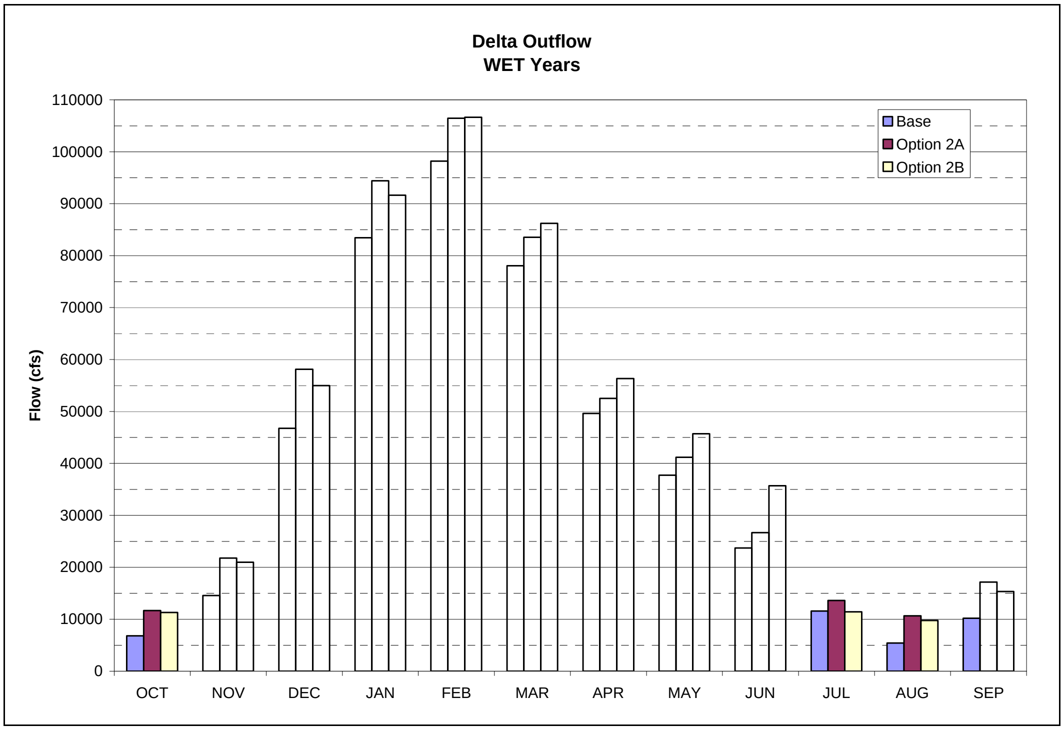


Figure E-3a. Delta Outflow Wet Year Average Flows

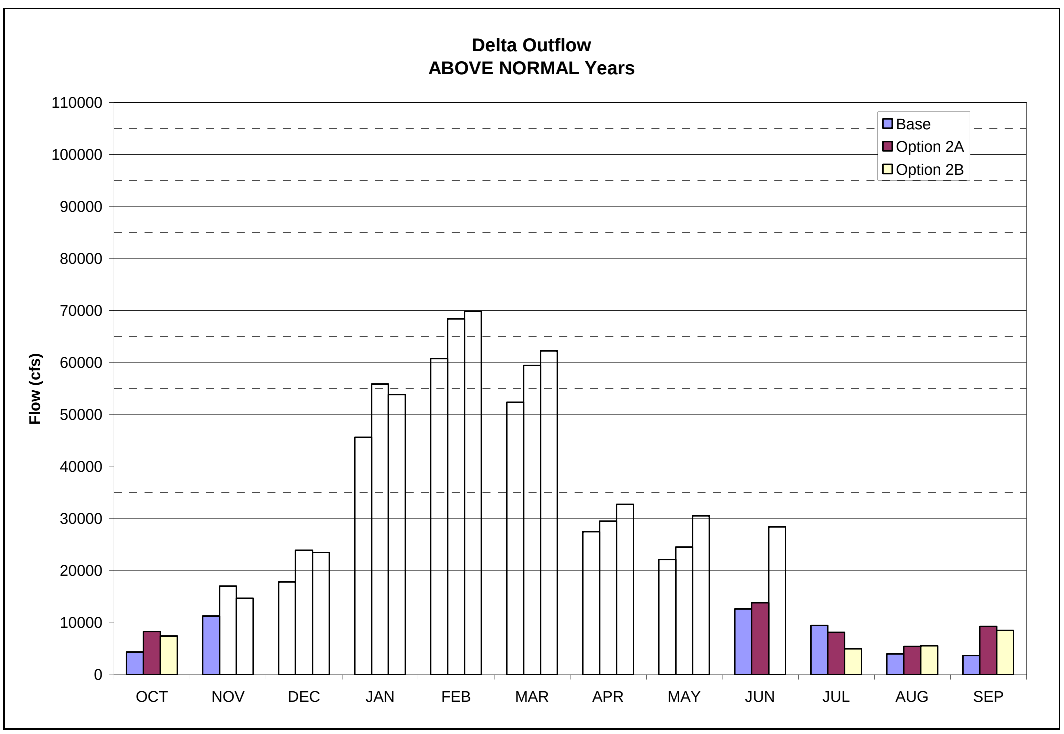


Figure E-3b. Delta Outflow Above Normal Year Average Flows

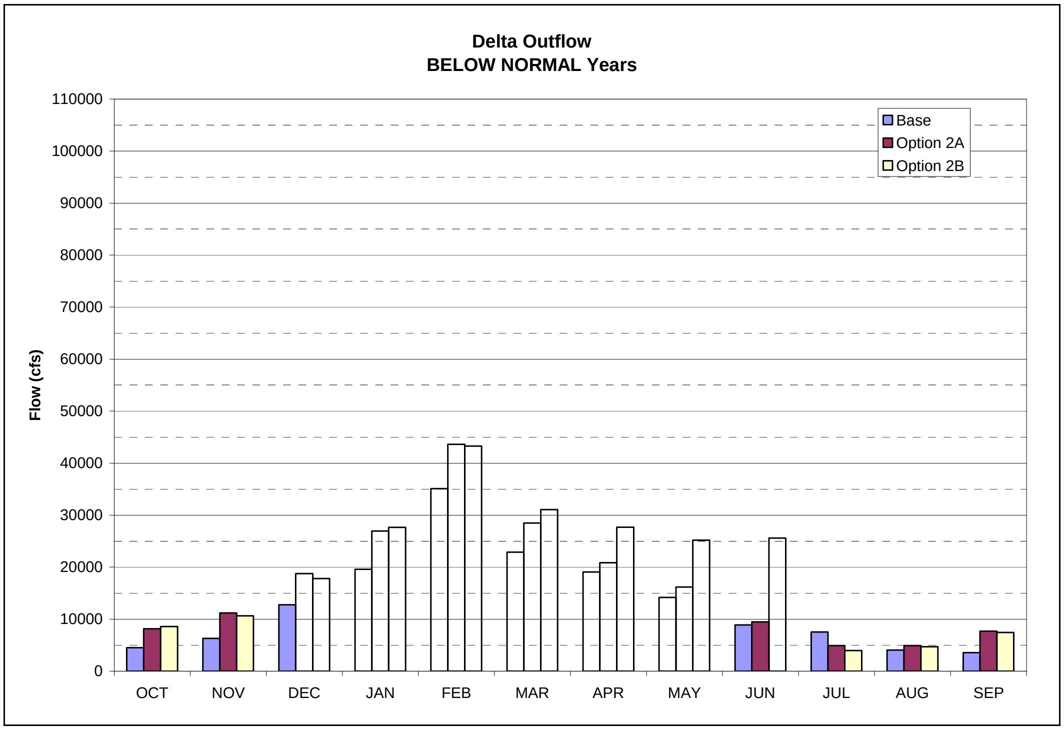


Figure E-3c. Delta Outflow Below Normal Year Average Flows

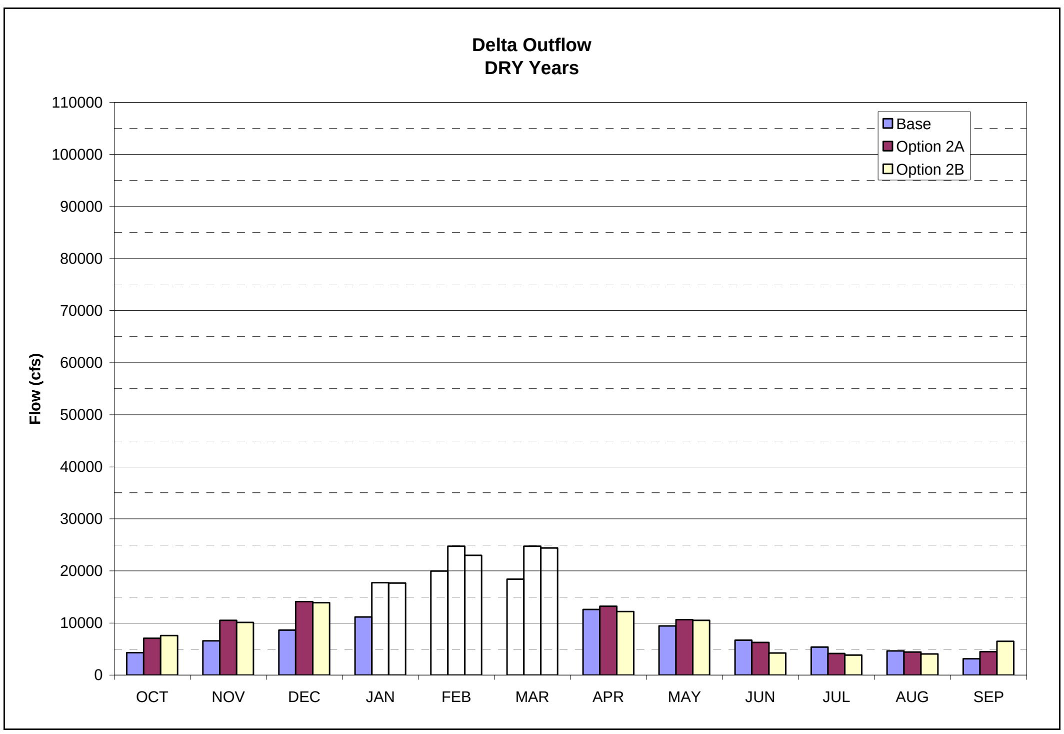


Figure E-3d. Delta Outflow Dry Year Average Flows

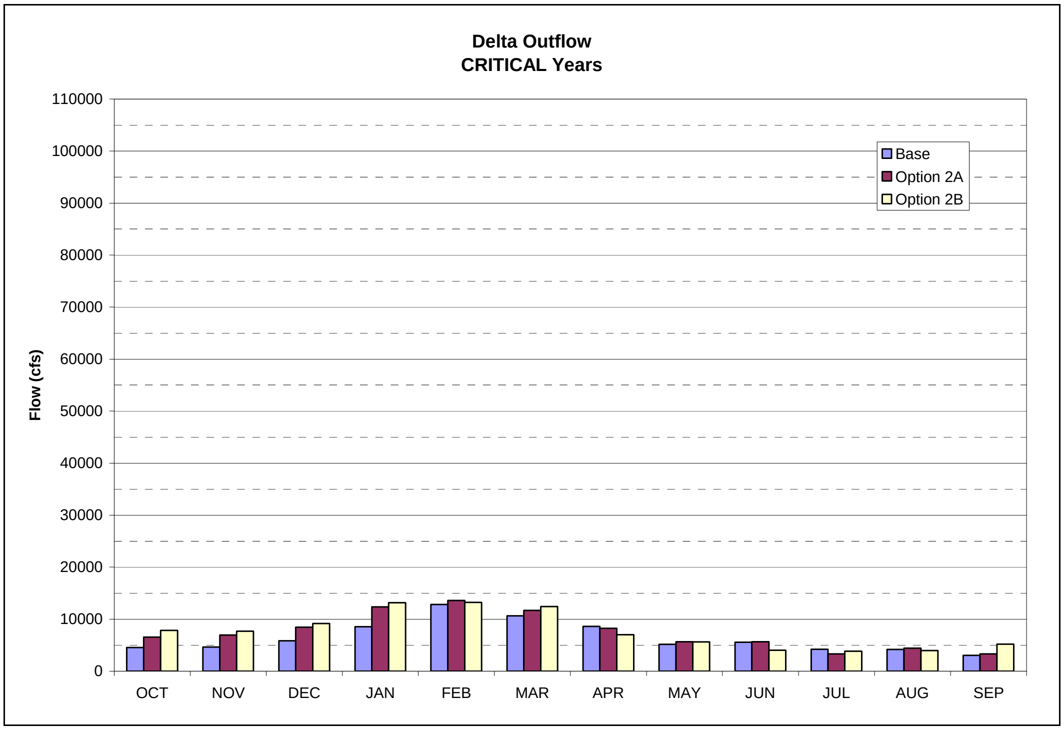


Figure E-3e. Delta Outflow Critical Year Average Flows

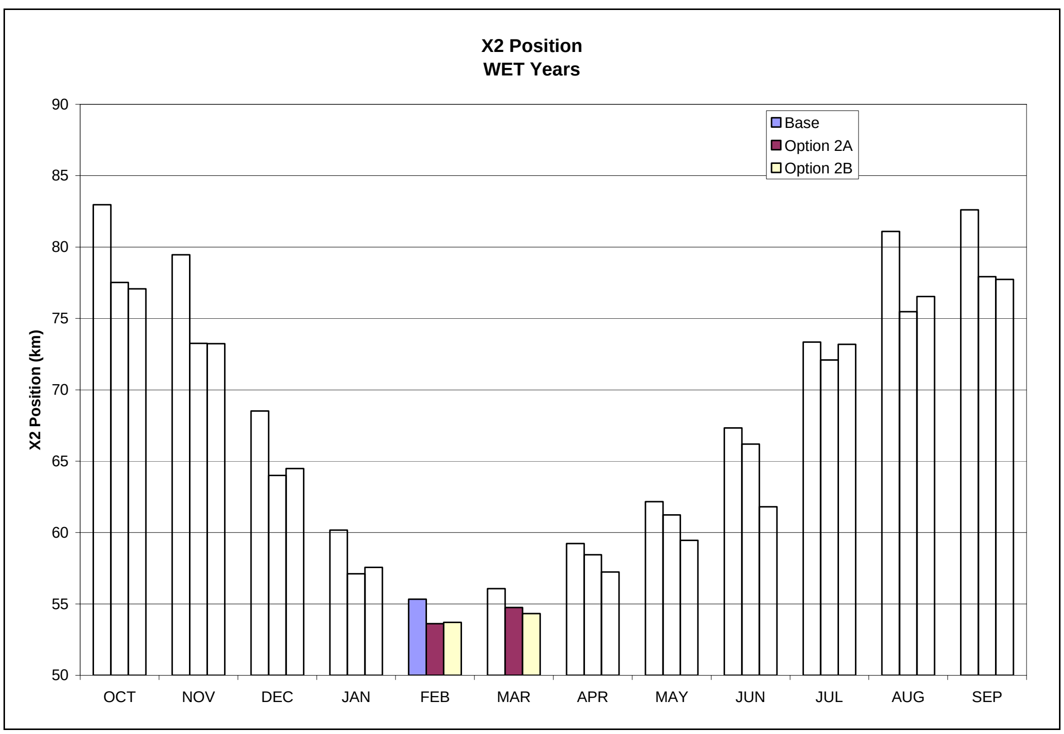


Figure E-4a. X2 Wet Year Average Distance

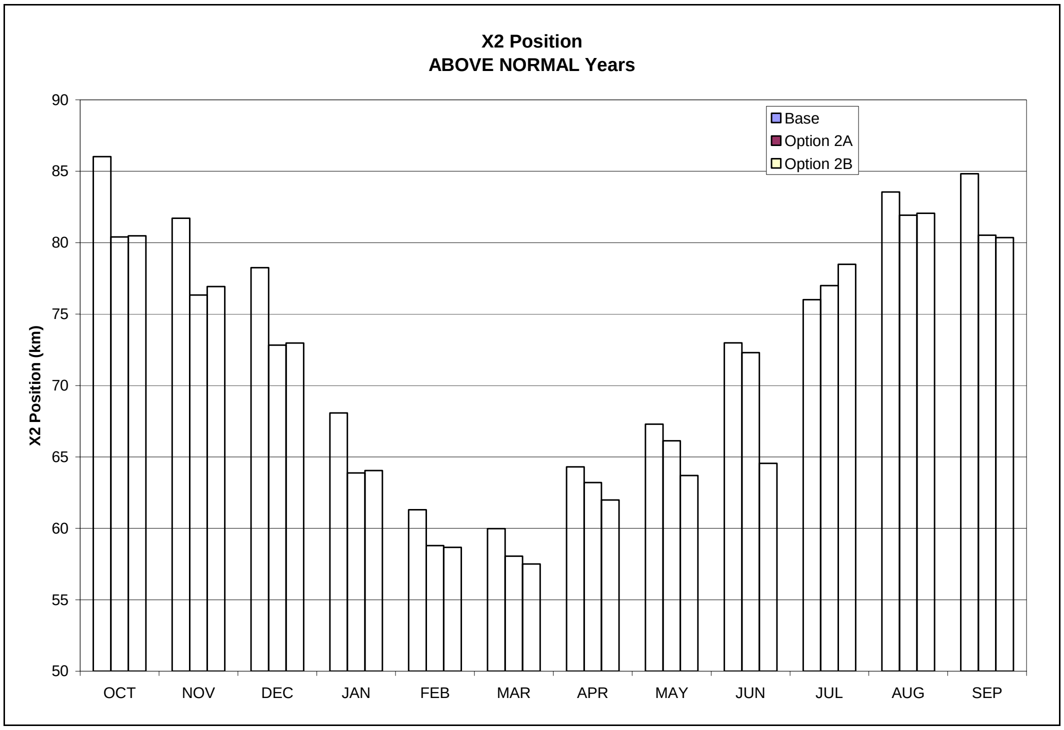


Figure E-4b. X2 Above Normal Year Average Distance

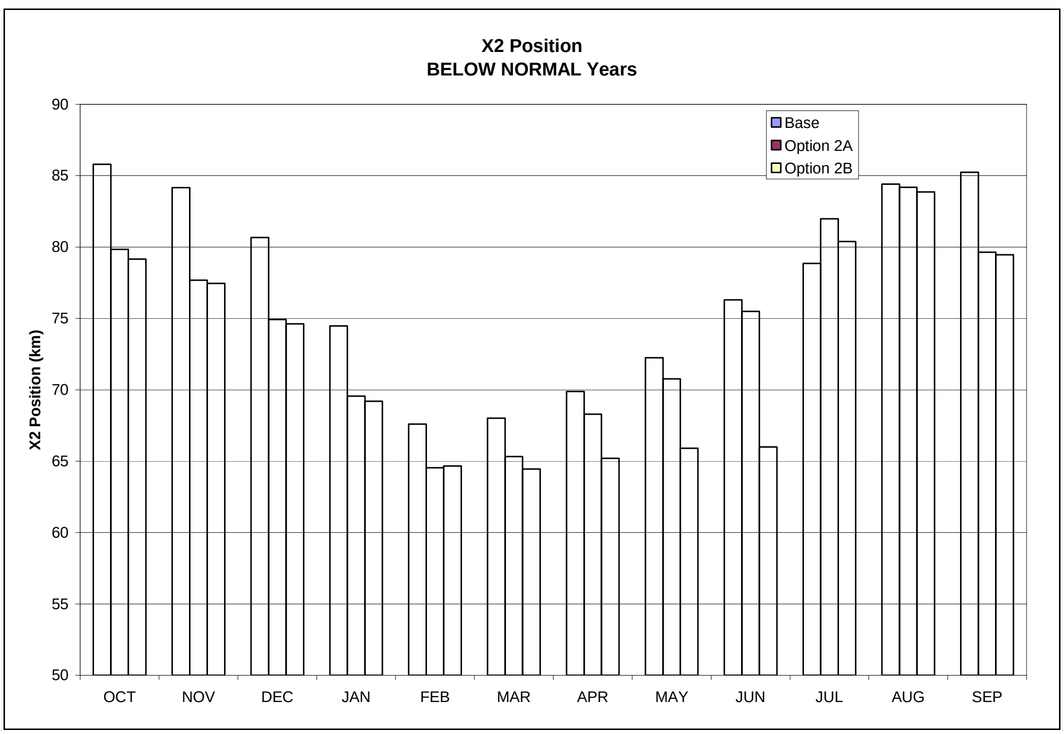


Figure E-4c. X2 Below Normal Year Average Distance

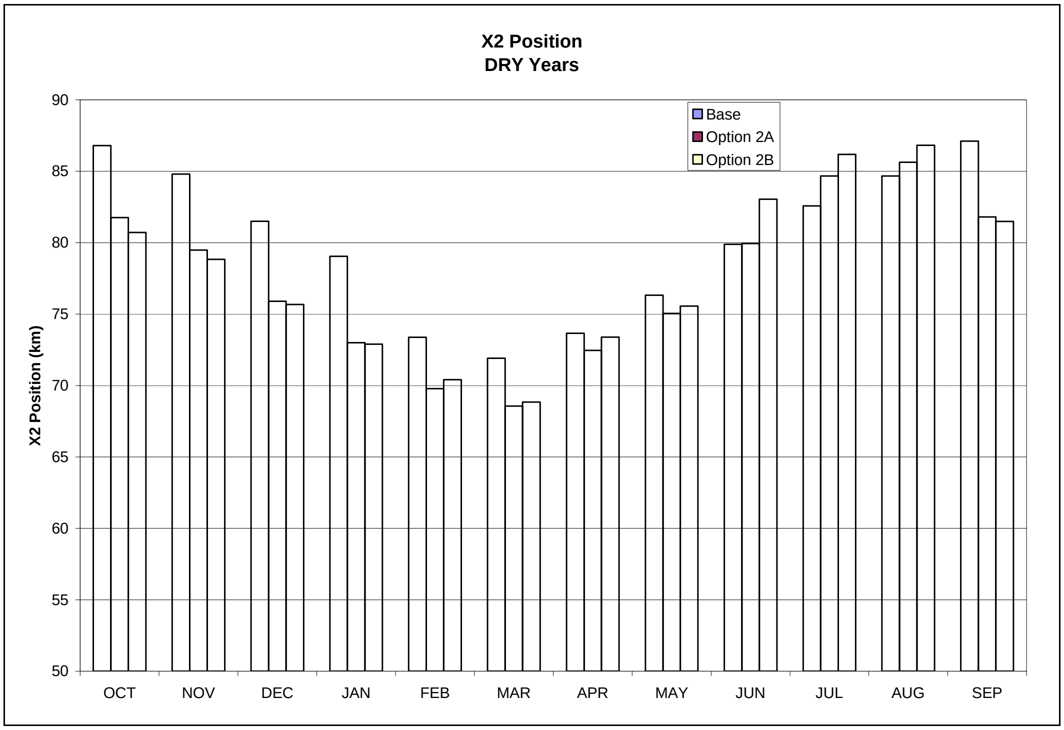


Figure E-4d. X2 Dry Year Average Distance

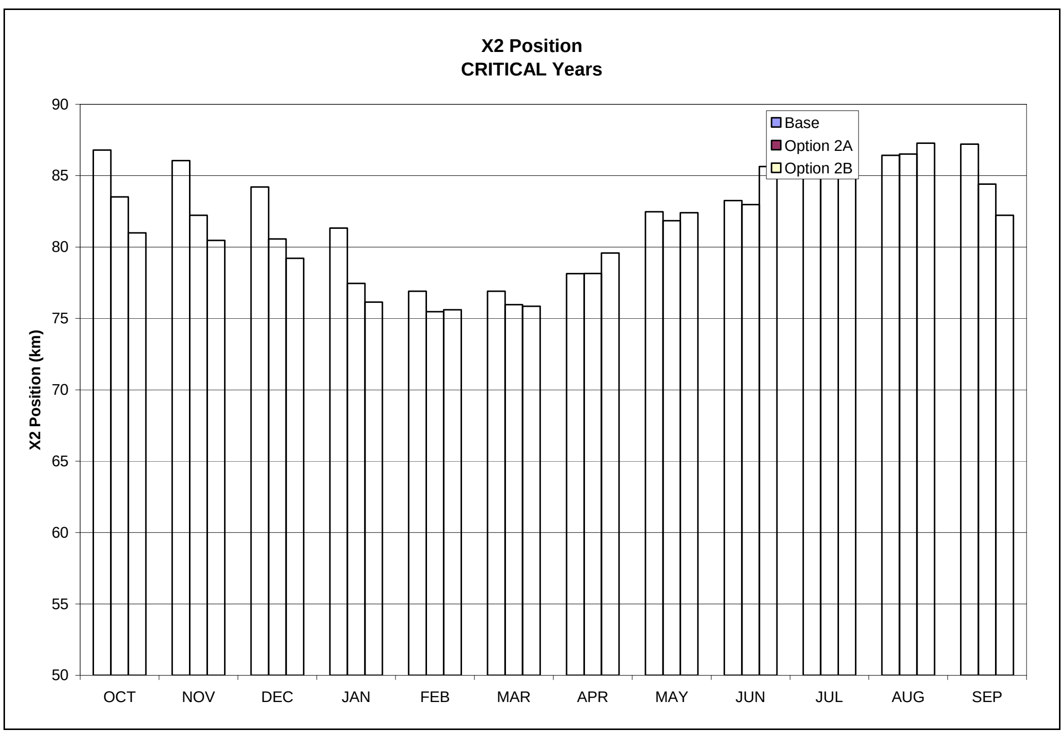


Figure E-4e. X2 Critical Year Average Distance

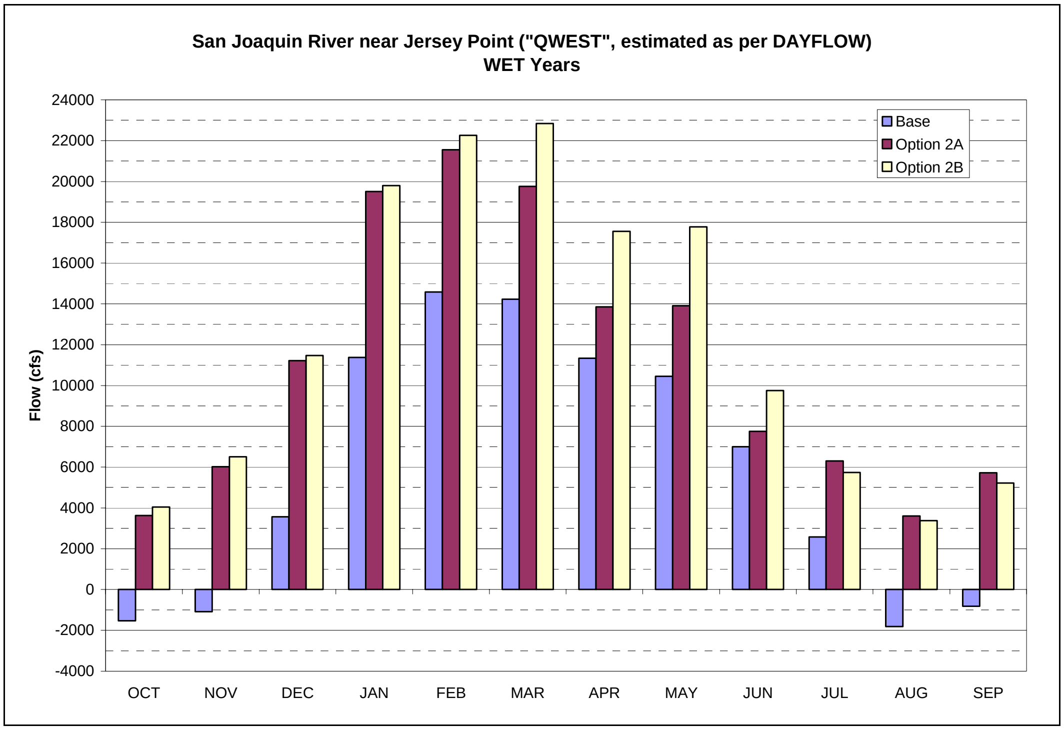


Figure E-5a. QWEST Wet Year Average Flows

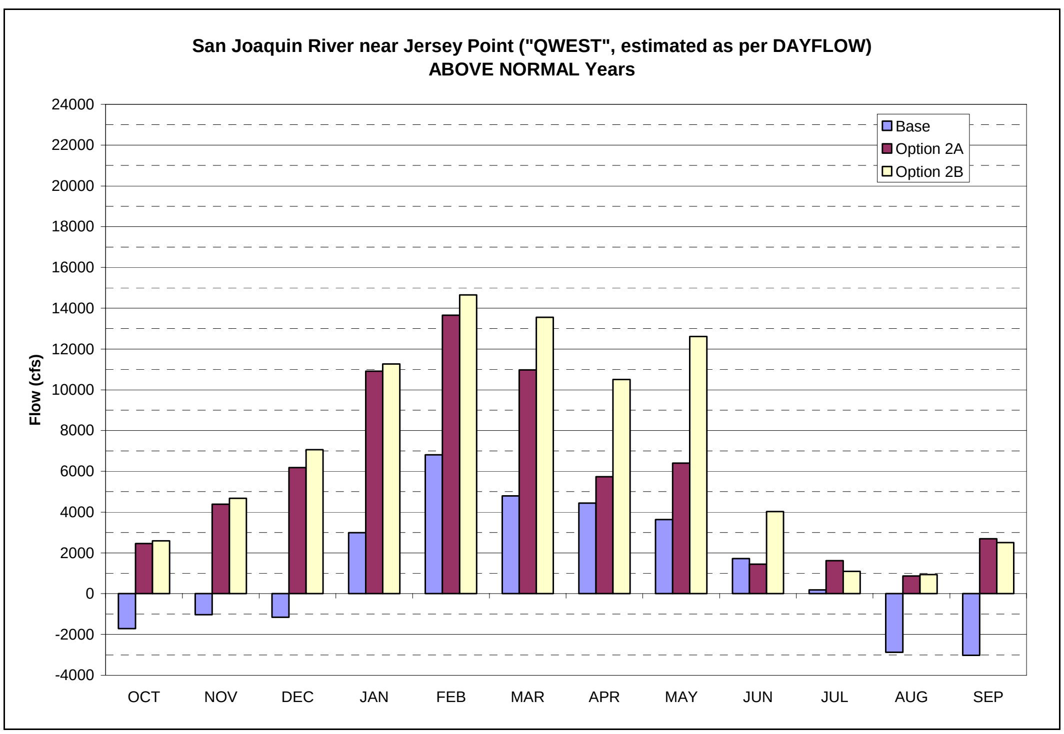


Figure E-5b. QWEST Above Normal Year Average Flows

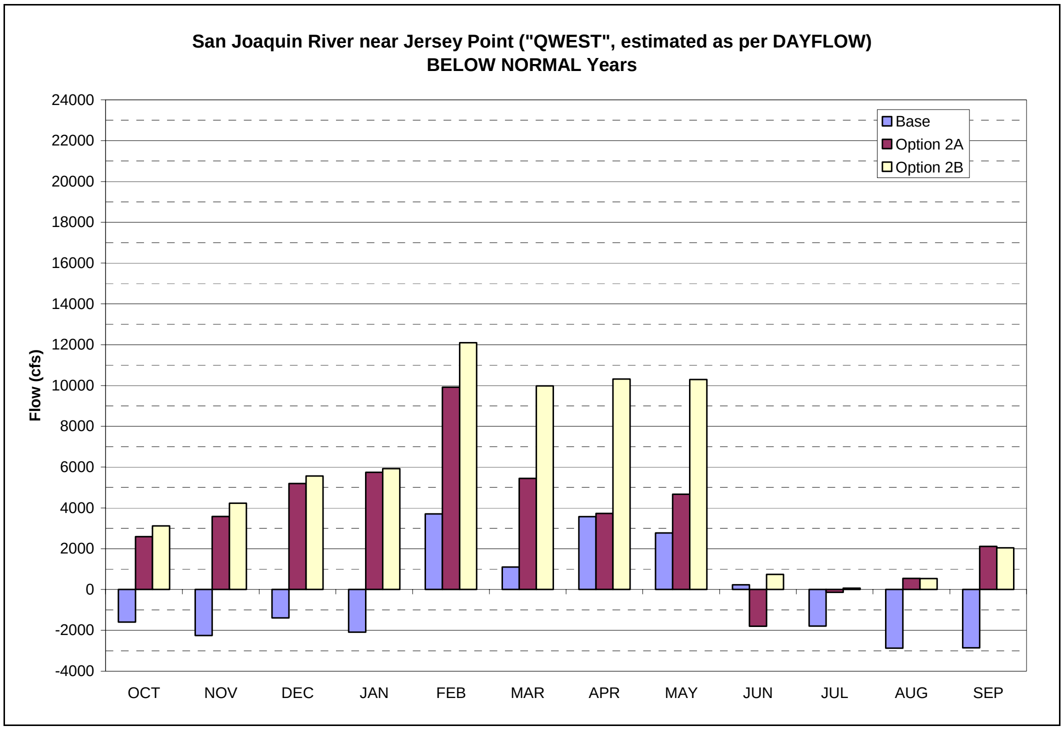


Figure E-5c. QWEST Below Normal Year Average Flows

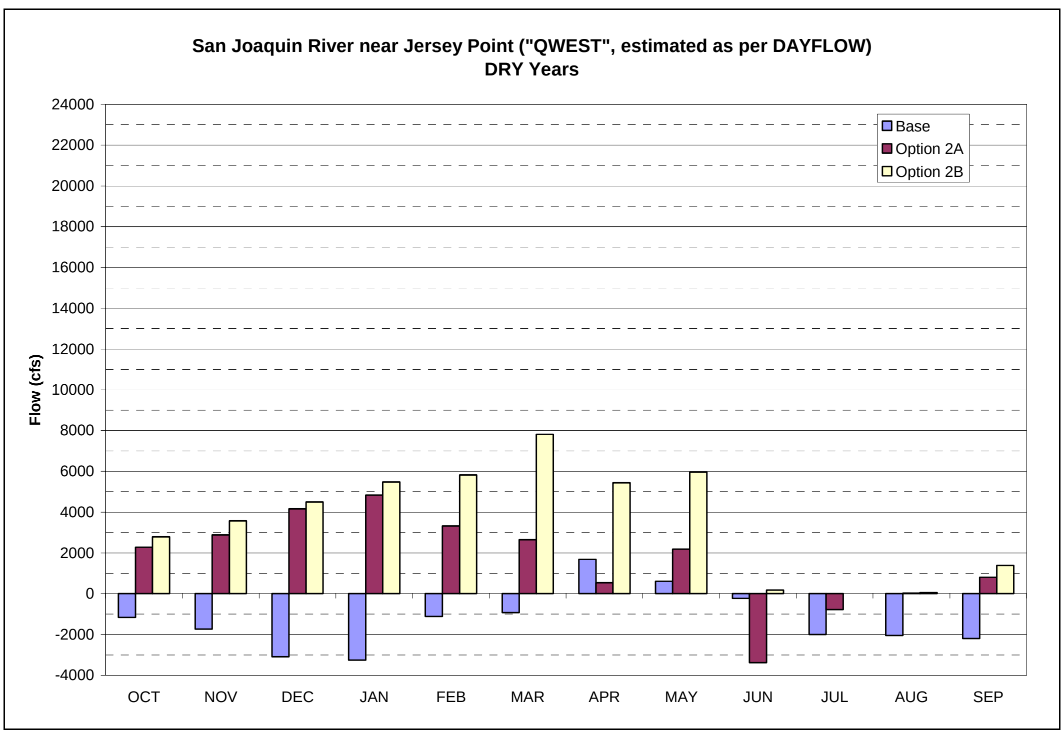


Figure E-5d. QWEST Dry Year Average Flows

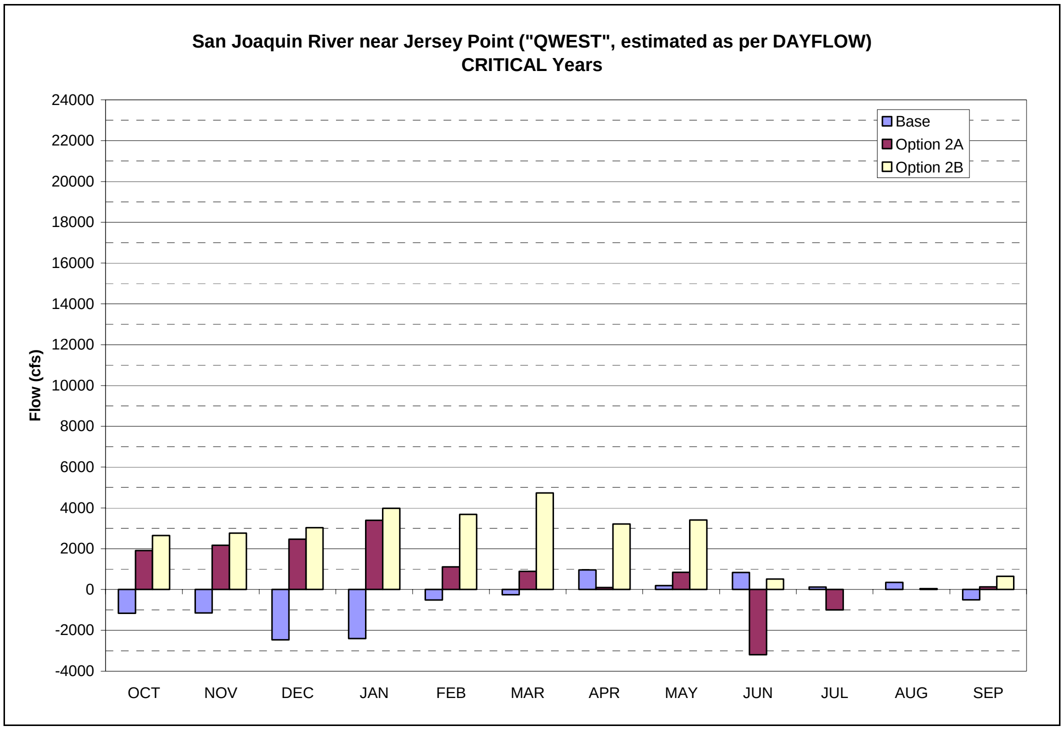


Figure E-5e. QWEST Critical Year Average Flows

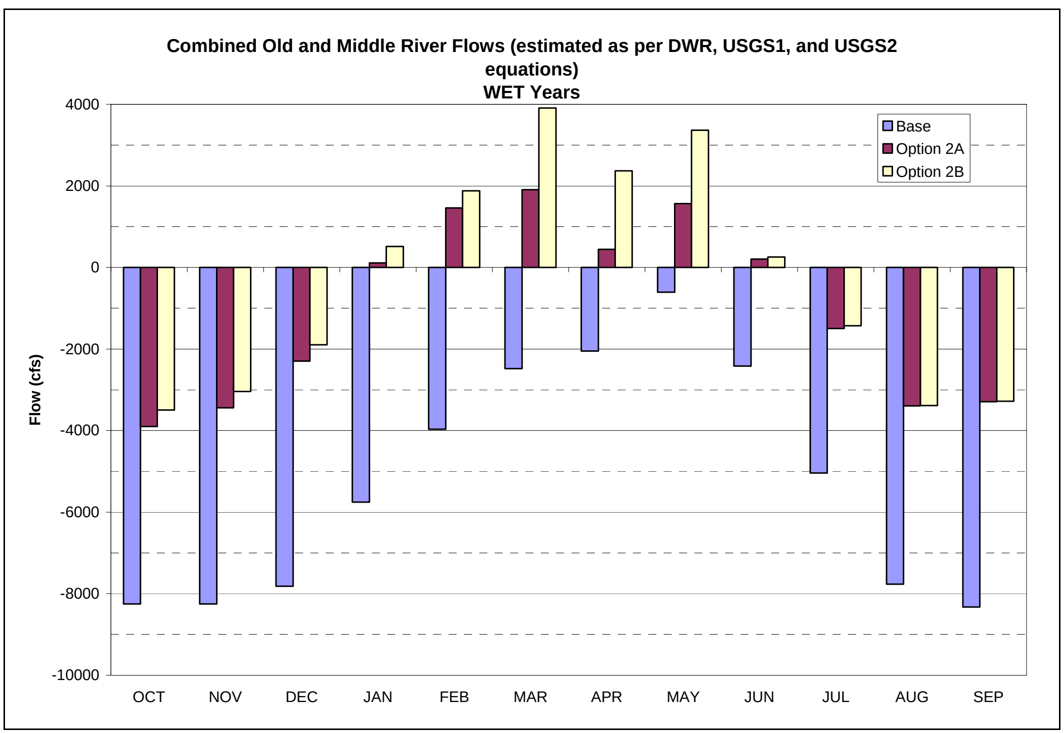


Figure E-6a. Combined Old and Middle River Wet Year Average Flows

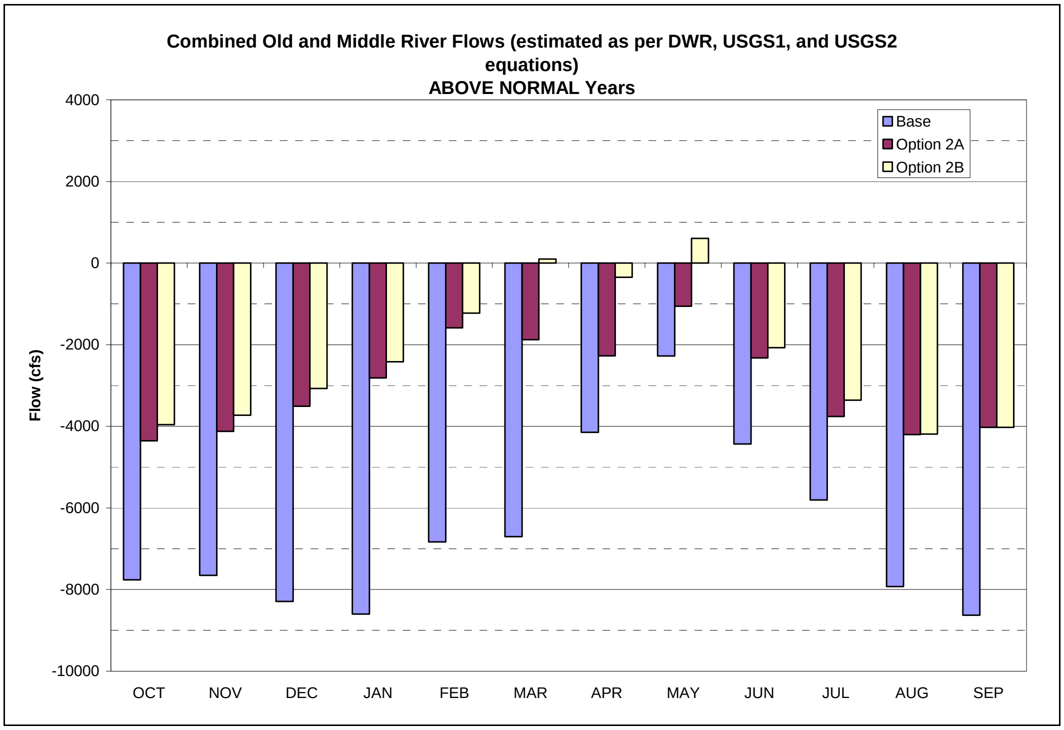


Figure E-6b. Combined Old and Middle River Above Normal Year Average Flows

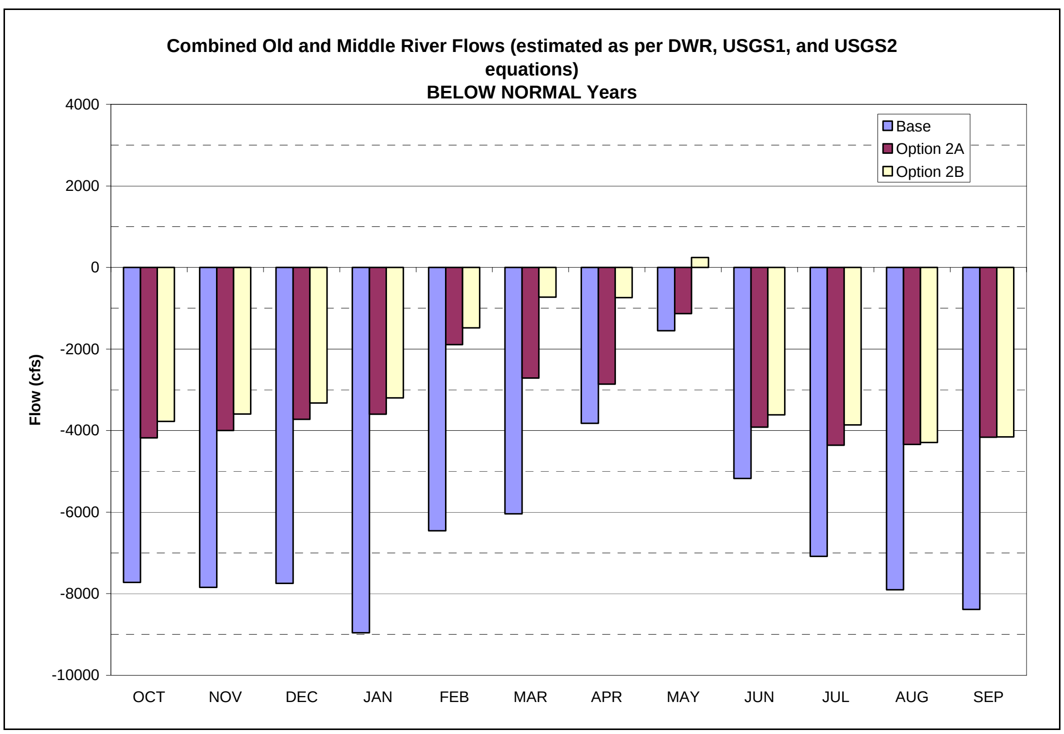


Figure E-6c. Combined Old and Middle River Below Normal Year Average Flows

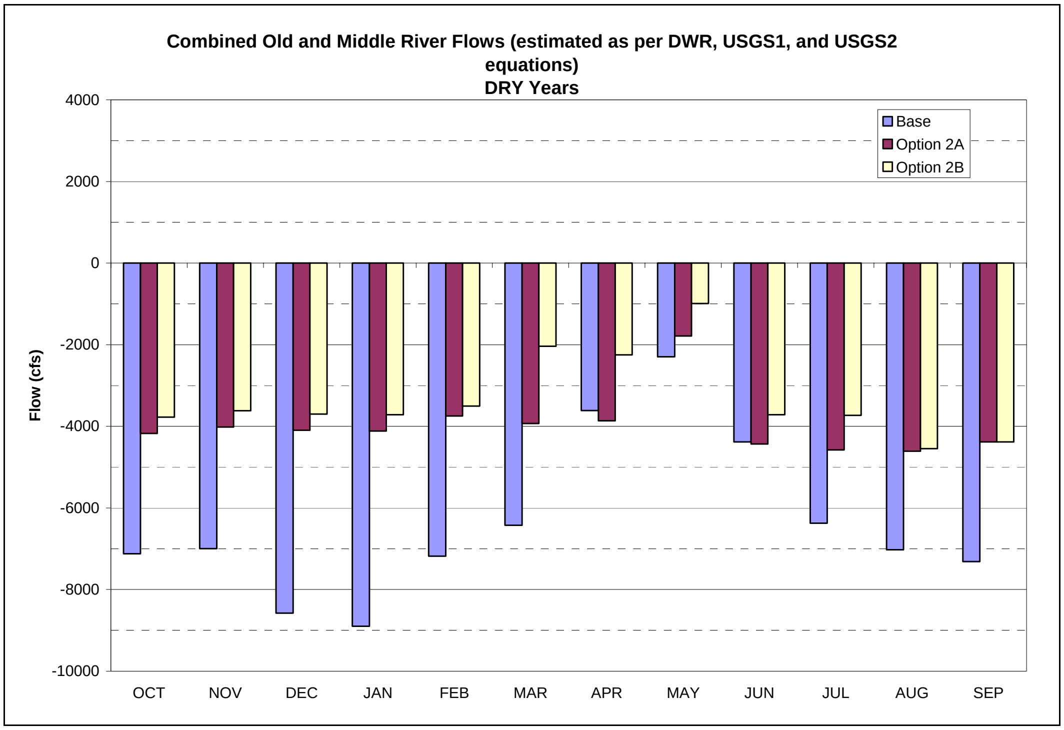


Figure E-6d. Combined Old and Middle River Dry Year Average Flows

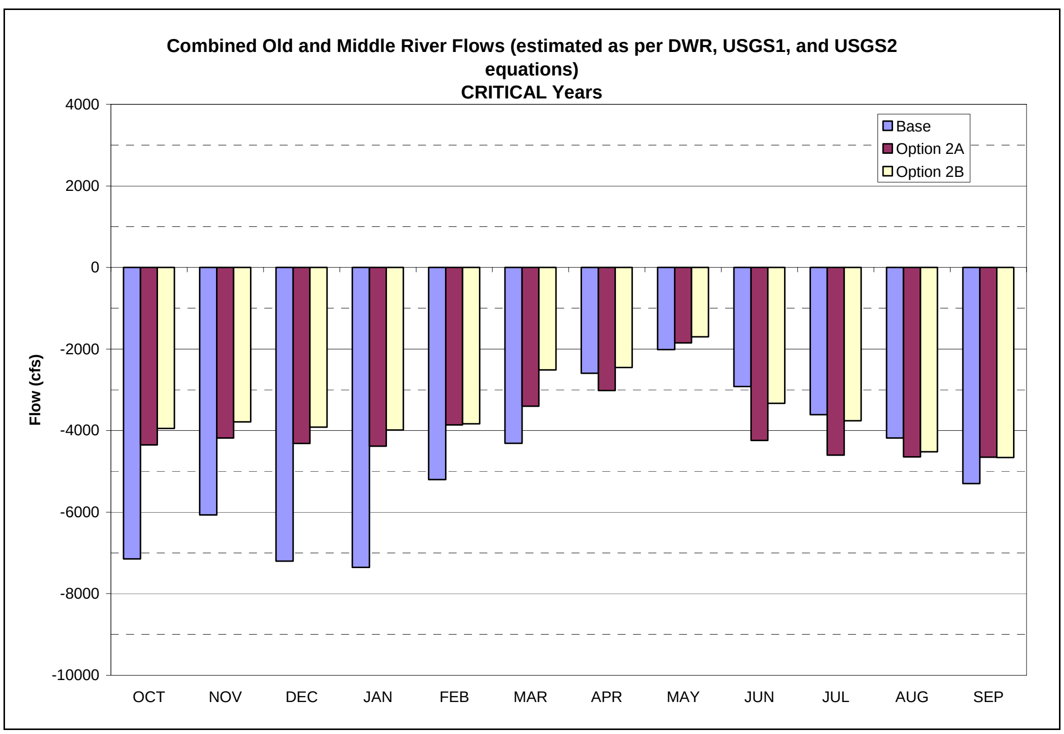


Figure E-6e. Combined Old and Middle River Critical Year Average Flows

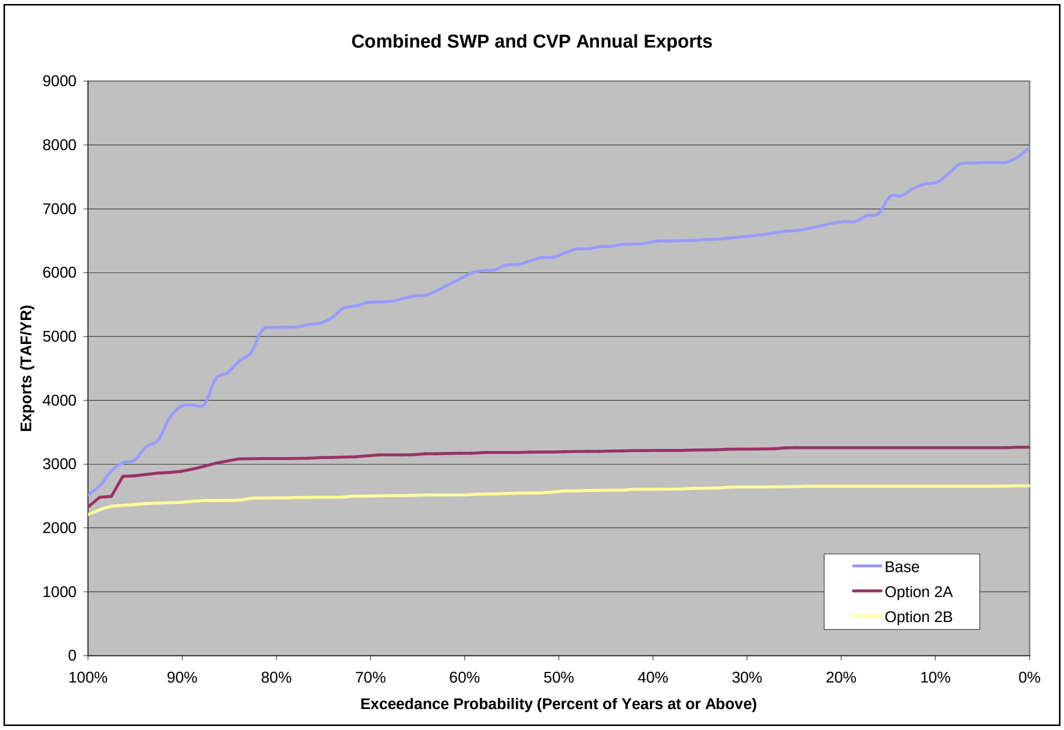


Figure E-7. Water Supply Frequency: Combined SWP and CVP Annual Delta Exports

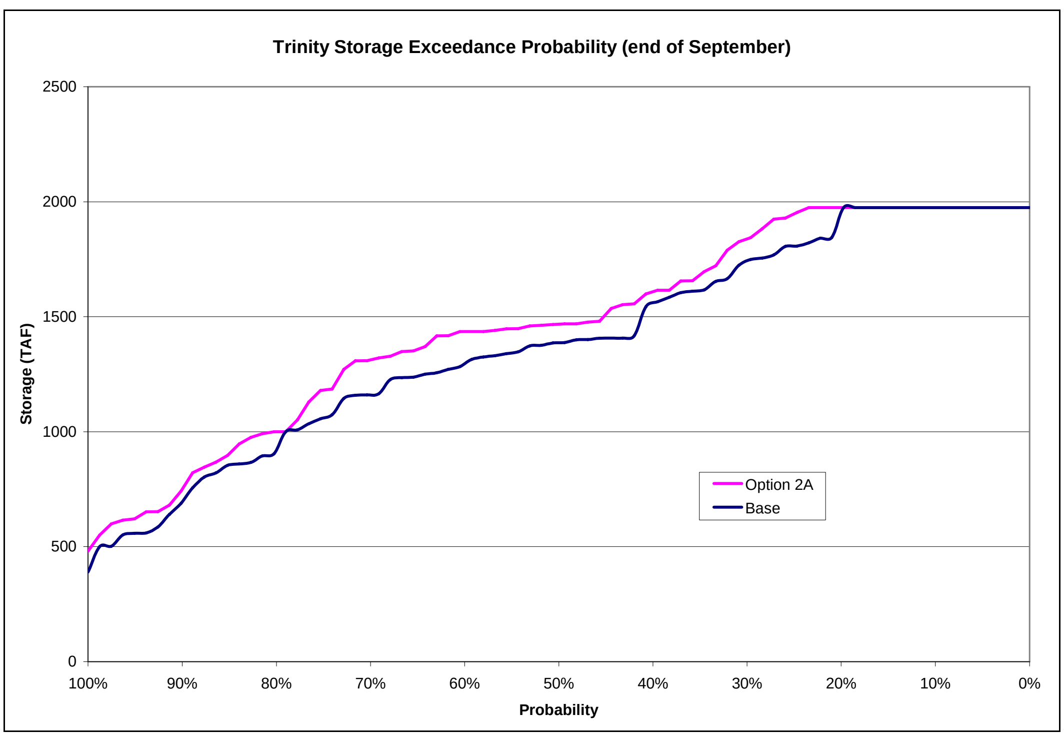


Figure E-8a. Option 2A CVP Northern Delta Storage Frequency: Trinity

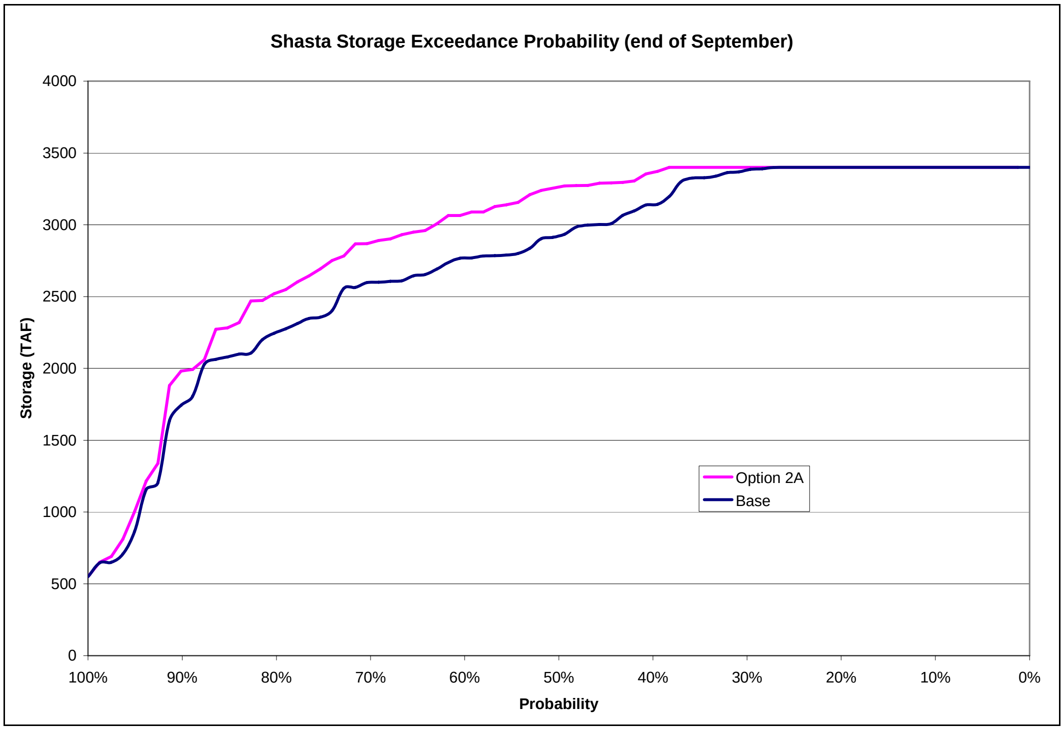


Figure E-8b. Option 2A CVP Northern Delta Storage Frequency: Shasta

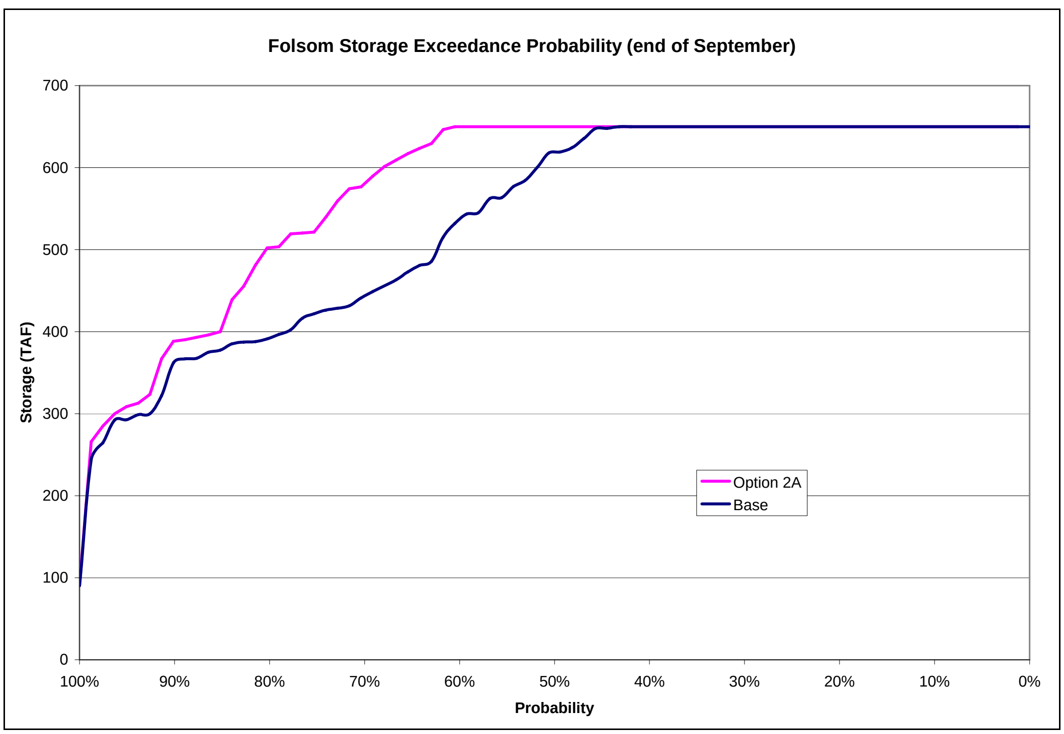


Figure E-8c. Option 2A CVP Northern Delta Storage Frequency: Folsom

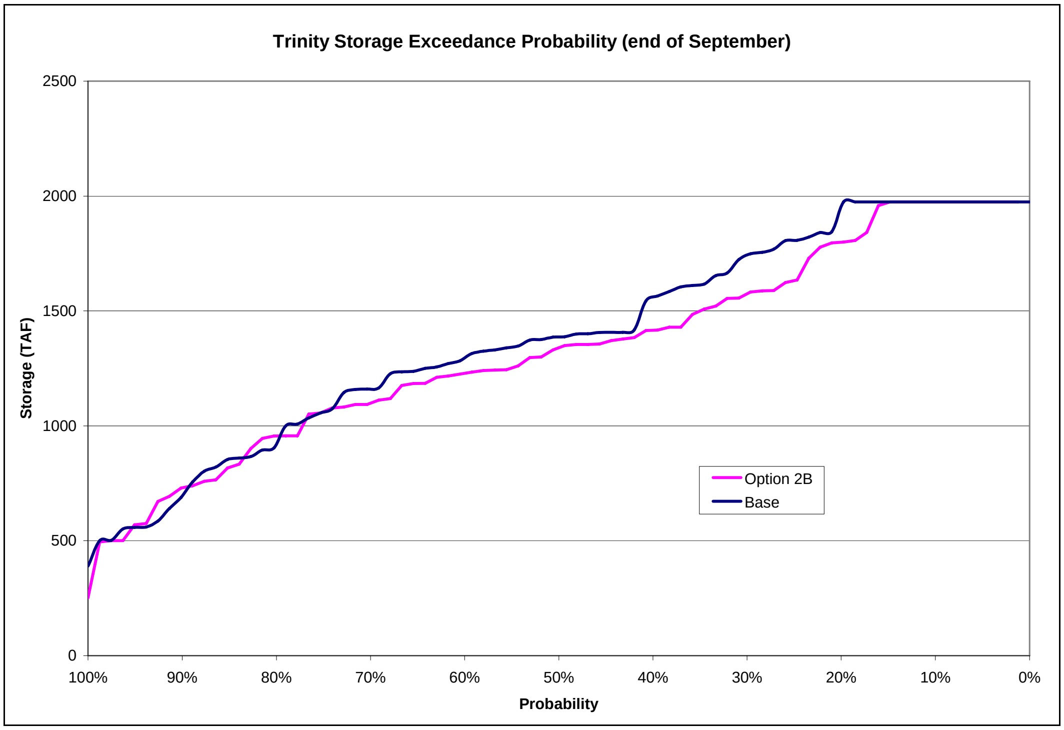


Figure E-9a. Option 2B CVP Northern Delta Storage Frequency: Trinity

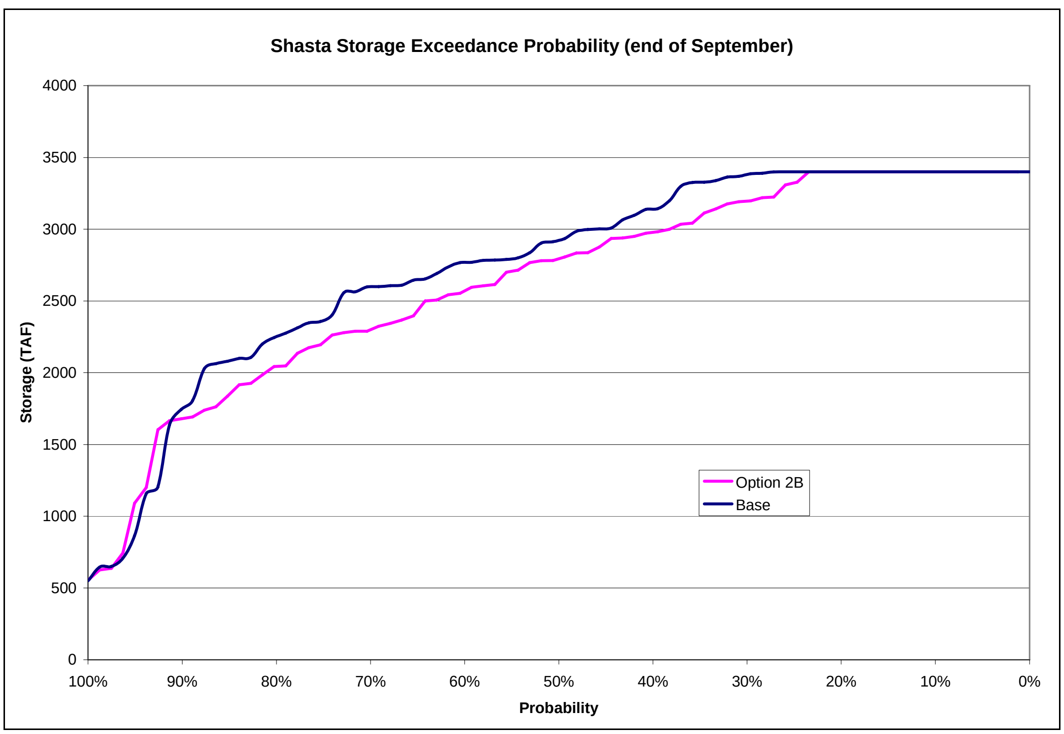


Figure E-9b. Option 2B CVP Northern Delta Storage Frequency: Shasta

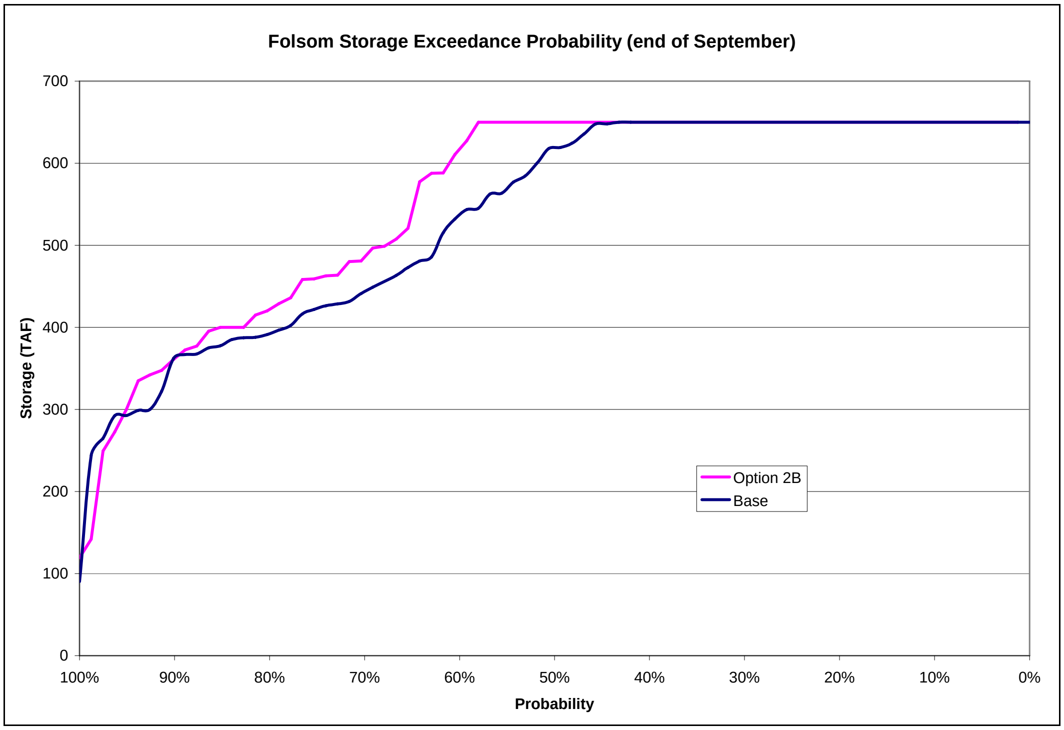


Figure E-9c. Option 2B CVP Northern Delta Storage Frequency: Folsom

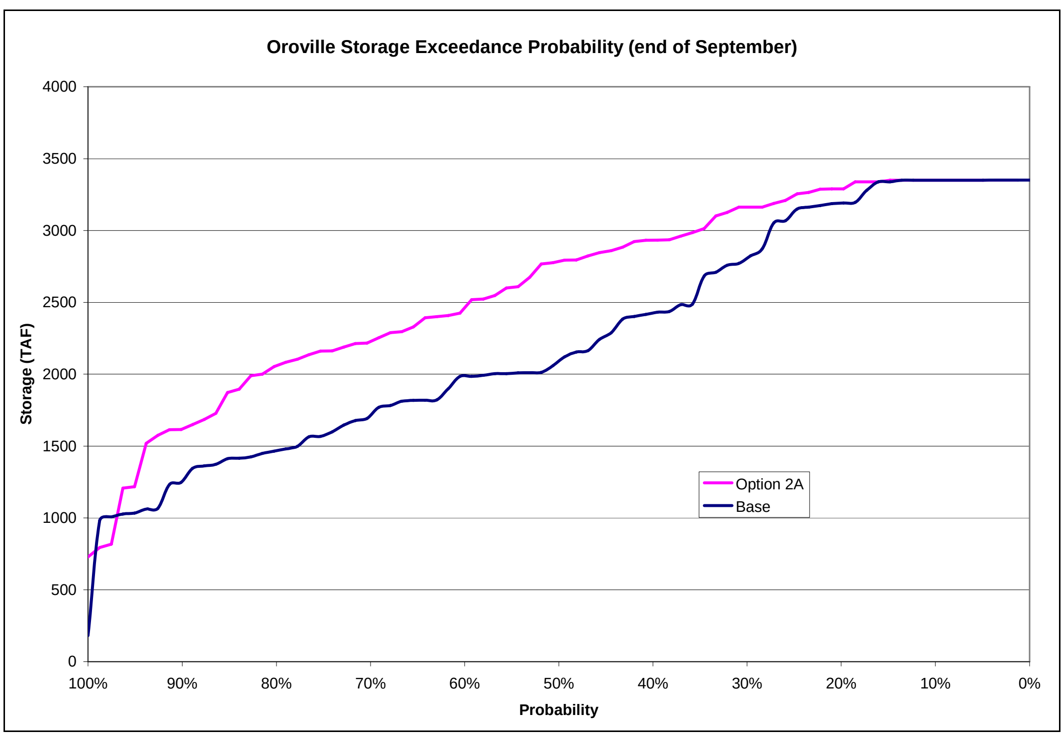


Figure E-10. Option 2A SWP Northern Delta Storage Frequency: Oroville

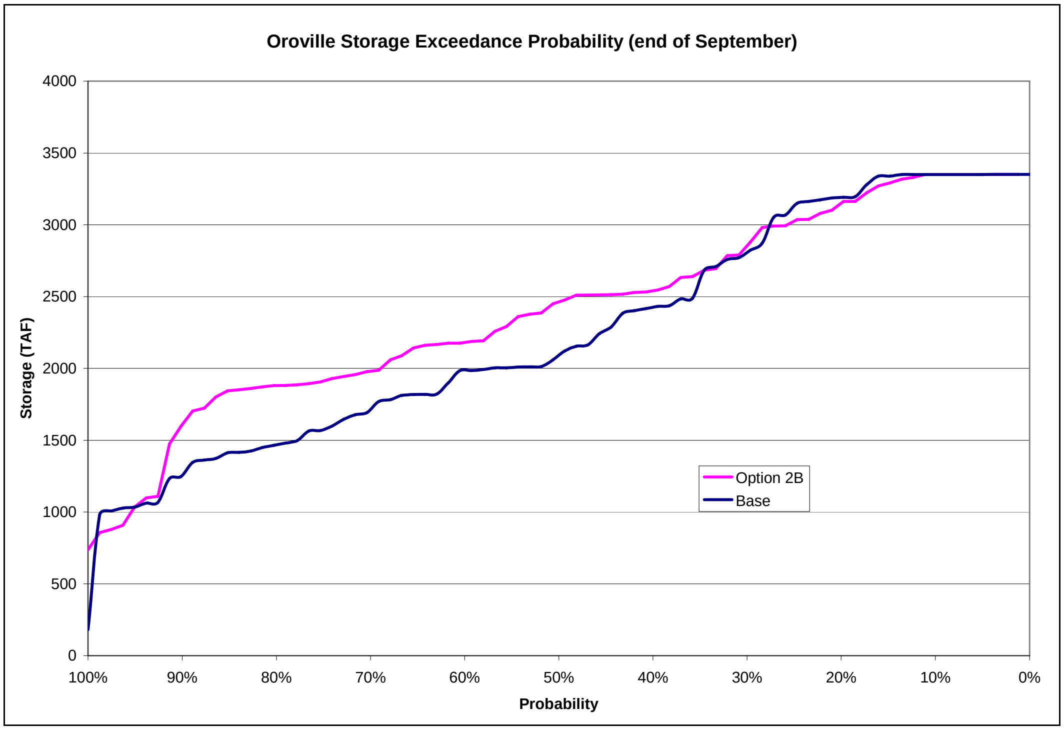


Figure E-11. Option 2B SWP Northern Delta Storage Frequency: Oroville

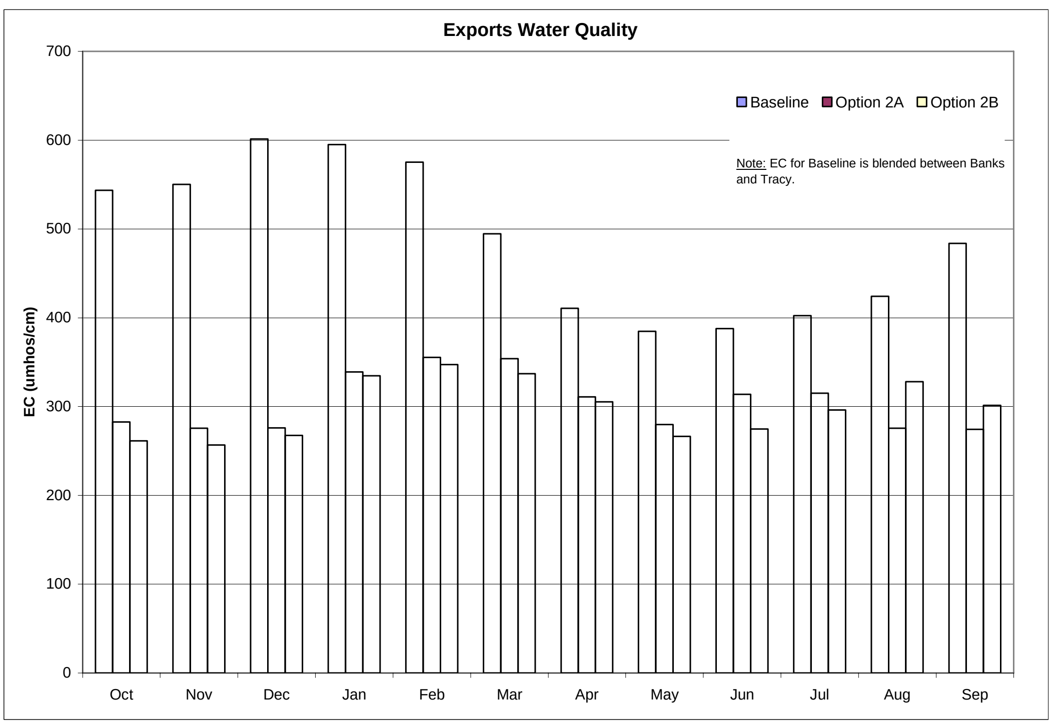


Figure E-12. Export Water Quality Annual Average, 1975-1991

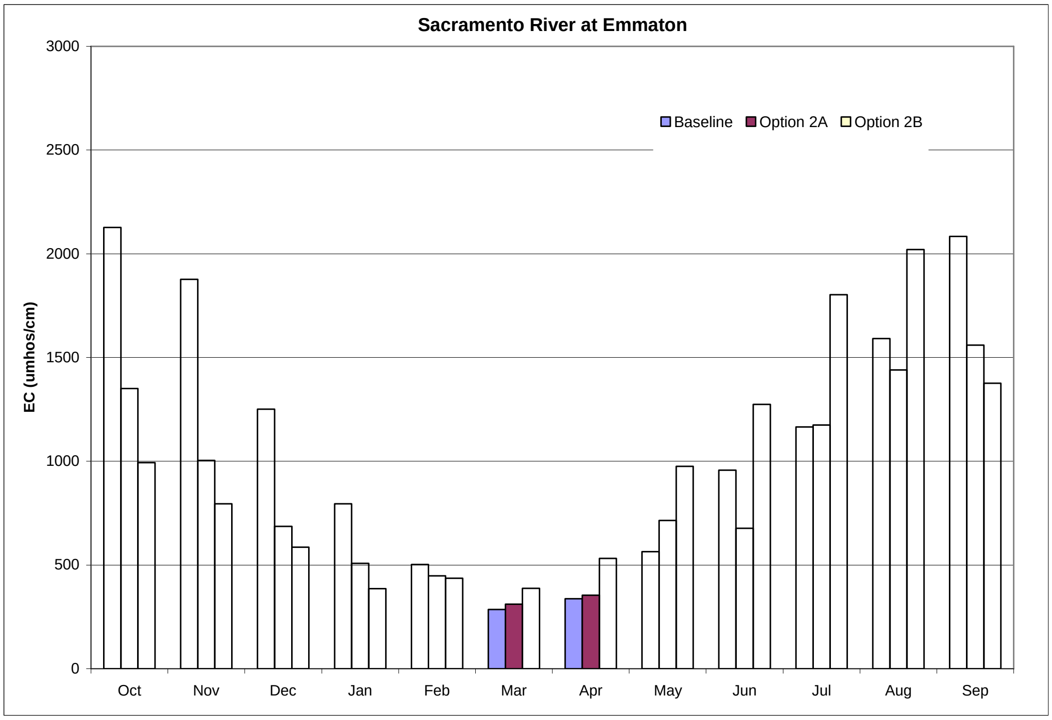


Figure E-13. In Delta Water Quality Annual Average, 1975-1991: Sacramento River at Emmaton

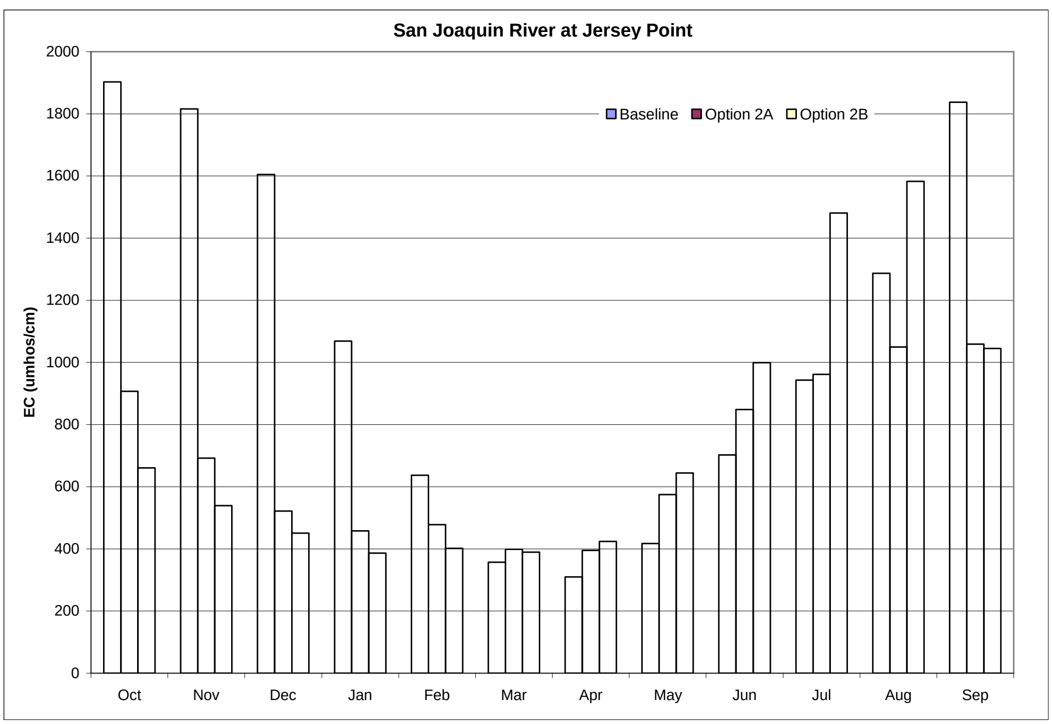


Figure E-14. In Delta Water Quality Annual Average, 1975-1991: San Joaquin River at Jersey Point

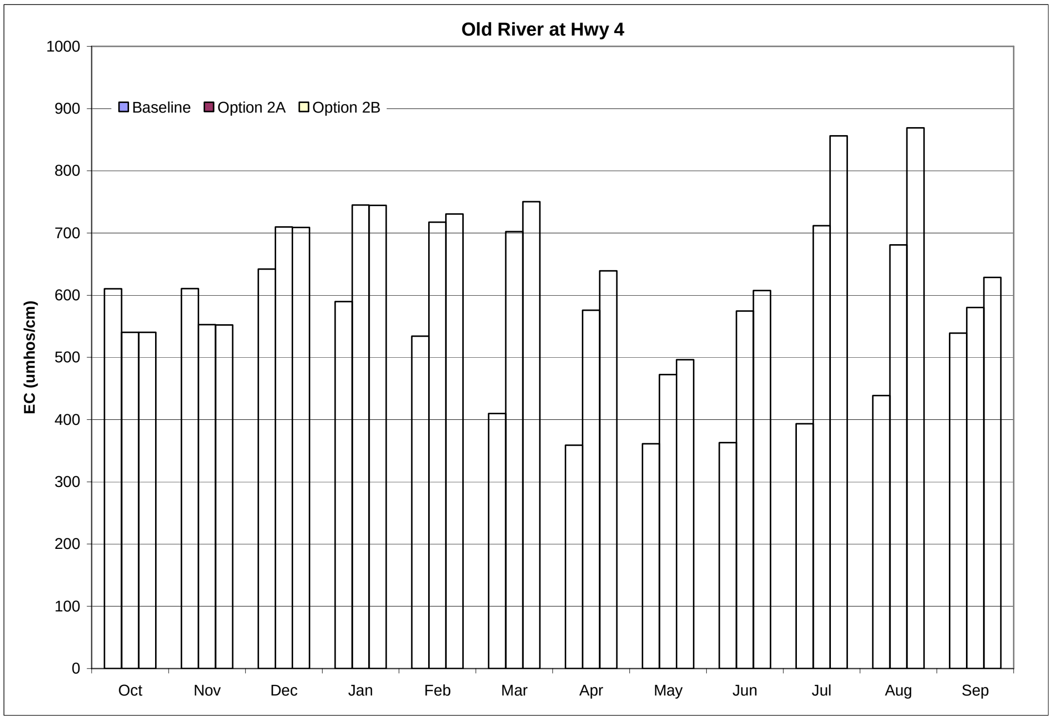


Figure E-15. In Delta Water Quality Annual Average, 1975-1991: Old River at Hwy 4

Table E-2. Option 2A Cumulative Particle Fate – September 1977

	Old River Sep 1977 Release - Cumulative particles (%)									
	7 Days		**14 Days**		**21 Days**		**28 Days**		**40 Days**	
	Base	**Option 2A**	**Base**	**Option 2A**	**Base**	**Option 2A**	**Base**	**Option 2A**	**Base**	**Option 2A**
DIVERSION_AG	1.7	0.4	4.0	0.9	5.0	1.4	5.6	2.0	6.7	3.0
PAST_CHIPPS	0.0	0.0	0.0	0.2	0.1	3.2	0.3	4.3	1.7	15.0
TO_SUISUN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
EXPORTS*	53.1	0.0	67.5	0.0	75.3	0.0	79.9	0.0	84.3	4.9
CENTRAL	45.2	99.6	28.5	98.9	19.6	95.4	14.2	93.7	7.3	77.0
	Middle River Sep 1977 Release - Cumulative particles (%)									
	7 Days		**14 Days**		**21 Days**		**28 Days**		**40 Days**	
	Base	**Option 2A**	**Base**	**Option 2A**	**Base**	**Option 2A**	**Base**	**Option 2A**	**Base**	**Option 2A**
DIVERSION_AG	0.4	0.2	1.2	0.6	1.7	0.8	2.8	0.8	3.4	0.8
PAST_CHIPPS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TO_SUISUN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EXPORTS*	32.3	0.0	63.5	35.1	80.8	87.7	88.5	92.7	93.3	98.8
CENTRAL	67.3	99.8	35.3	64.3	17.5	11.5	8.7	6.5	3.3	0.4
	San Joaquin River d/s of Dutch Slough Sep 1977 Release - Cumulative particles (%)									
	7 Days		**14 Days**		**21 Days**		**28 Days**		**40 Days**	
	Base	**Option 2A**	**Base**	**Option 2A**	**Base**	**Option 2A**	**Base**	**Option 2A**	**Base**	**Option 2A**
DIVERSION_AG	0.0	0.0	0.1	0.0	0.1	0.0	0.3	0.2	0.7	0.6
PAST_CHIPPS	17.0	22.6	17.9	19.7	37.4	39.0	34.8	36.9	48.9	53.9
TO_SUISUN	0.1	0.2	0.0	0.1	0.3	0.2	0.0	0.2	0.2	0.3
EXPORTS*	0.0	0.0	0.5	0.0	2.1	0.0	4.5	0.0	11.0	2.6
CENTRAL	82.9	77.2	81.5	80.2	60.1	60.8	60.4	62.7	39.2	42.6
	Sacramento River Sep 1977 Release - Cumulative particles (%)									
	7 Days		**14 Days**		**21 Days**		**28 Days**		**40 Days**	
	Base	**Option 2A**	**Base**	**Option 2B**	**Base**	**Option 2A**	**Base**	**Option 2B**	**Base**	**Option 2A**
DIVERSION_AG	0.1	0.0	0.2	0.1	0.3	0.2	0.7	0.4	1.2	0.7
PAST_CHIPPS	0.3	1.1	1.1	2.9	9.0	14.2	10.0	16.4	20.6	34.7
TO_SUISUN	0.0	0.1	0.0	0.0	0.3	0.0	0.0	0.0	0.3	0.1
EXPORTS*	0.0	0.0	0.9	0.0	4.6	0.0	9.6	0.0	20.2	5.7
CENTRAL	99.6	98.8	97.8	97.0	85.8	85.6	79.7	83.2	57.7	58.8
	San Joaquin River u/s of HOR Sep 1977 Release - Cumulative particles (%)									
	7 Days		**14 Days**		**21 Days**		**28 Days**		**40 Days**	
	Base	**Option 2A**	**Base**	**Option 2A**	**Base**	**Option 2A**	**Base**	**Option 2A**	**Base**	**Option 2A**
DIVERSION_AG	7.1	4.0	7.9	7.4	9.8	10.7	11.2	13.9	13.6	18.1
PAST_CHIPPS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TO_SUISUN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EXPORTS*	30.3	0.0	32.4	0.0	33.5	0.0	46.5	0.0	67.1	25.7
CENTRAL	62.6	96.0	59.7	92.6	56.7	89.3	42.3	86.1	19.3	56.2

* In Baseline Exports is the sum of particles entering SWP and CVP. In the Option 2 it is the particles entering Siphon.

Table E-3. Option 2A Cumulative Particle Fate – January 1981

	Old River Sep 1981 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 2A	Base	Option 2A	Base	Option 2A	Base	Option 2A	Base	Option 2A
DIVERSION_AG	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.2	0.0
PAST_CHIPPS	0.2	3.8	0.2	26.8	0.2	42.0	0.3	64.2	0.3	75.8
TO_SUISUN	0.0	0.9	0.0	2.5	0.0	4.0	0.0	4.8	0.0	6.4
EXPORTS*	90.4	0.0	95.1	0.0	97.6	0.0	98.0	0.0	98.7	3.4
CENTRAL	9.4	95.3	4.7	70.7	2.2	54.0	1.5	31.0	0.8	14.4
	Middle River Sep 1981 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 2A	Base	Option 2A	Base	Option 2A	Base	Option 2A	Base	Option 2A
DIVERSION_AG	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PAST_CHIPPS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TO_SUISUN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EXPORTS*	82.2	0.0	97.2	45.7	99.7	86.3	99.8	94.1	99.9	100.0
CENTRAL	17.8	100.0	2.8	54.3	0.3	13.7	0.2	5.9	0.1	0.0
	San Joaquin River d/s of Dutch Slough Sep 1981 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 2A	Base	Option 2A	Base	Option 2A	Base	Option 2A	Base	Option 2A
DIVERSION_AG	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PAST_CHIPPS	35.1	70.1	51.5	86.8	54.9	89.6	57.4	91.4	58.4	91.8
TO_SUISUN	4.6	5.4	6.6	6.7	7.1	7.3	7.3	7.4	7.6	7.5
EXPORTS*	1.7	0.0	8.5	0.0	16.7	0.0	23.2	0.0	28.8	0.1
CENTRAL	58.6	24.5	33.4	6.5	21.3	3.1	12.1	1.2	5.2	0.6
	Sacramento River Sep 1981 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 2A	Base	Option 2A	Base	Option 2A	Base	Option 2A	Base	Option 2A
DIVERSION_AG	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PAST_CHIPPS	46.1	71.6	57.4	85.4	60.4	88.1	62.4	90.5	62.6	91.1
TO_SUISUN	4.8	6.1	6.3	6.6	6.6	6.7	6.9	6.9	6.9	7.2
EXPORTS*	2.4	0.0	10.2	0.0	16.9	0.0	22.2	0.0	27.0	0.8
CENTRAL	46.7	22.3	26.1	8.0	16.1	5.2	8.5	2.6	3.5	0.9
	San Joaquin River u/s of HOR Sep 1981 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 2A	Base	Option 2A	Base	Option 2A	Base	Option 2A	Base	Option 2A
DIVERSION_AG	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
PAST_CHIPPS	0.0	0.0	0.0	2.9	0.0	10.8	0.0	29.1	0.0	45.9
TO_SUISUN	0.0	0.0	0.0	0.2	0.0	1.0	0.0	2.3	0.0	3.7
EXPORTS*	65.1	0.0	70.4	2.5	86.3	6.2	93.5	6.2	96.1	21.0
CENTRAL	34.9	100.0	29.6	94.4	13.7	82.0	6.5	62.4	3.9	29.2

*In Baseline Exports is the sum of particles entering SWP and CVP. In the Option 2 it is the particles entering Siphon.

Table E-4. Option 2A Cumulative Particle Fate – March 1990

	Old River Sep 1990 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 2A	Base	Option 2A	Base	Option 2A	Base	Option 2A	Base	Option 2A
DIVERSION_AG	0.4	0.4	0.6	0.4	1.8	0.5	2.2	0.7	3.3	1.1
PAST_CHIPPS	0.0	0.5	0.1	2.0	0.9	12.6	0.8	15.0	1.6	25.4
TO_SUISUN	0.0	0.1	0.0	0.6	0.2	2.5	0.5	4.8	0.8	8.1
EXPORTS*	52.9	0.0	71.9	0.0	79.9	0.0	84.0	0.0	85.3	3.1
CENTRAL	46.7	99.0	27.4	97.0	17.2	84.4	12.5	79.5	9.0	62.3
	Middle River Sep 1990 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 2A	Base	Option 2A	Base	Option 2A	Base	Option 2A	Base	Option 2A
DIVERSION_AG	0.2	0.1	0.6	0.1	1.2	0.2	2.0	0.7	2.6	1.1
PAST_CHIPPS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
TO_SUISUN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EXPORTS*	24.6	0.0	61.0	36.2	77.6	81.5	85.0	87.3	87.4	98.5
CENTRAL	75.2	99.9	38.4	63.7	21.2	18.3	13.0	12.0	9.9	0.4
	San Joaquin River d/s of Dutch Slough Sep 1990 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 2A	Base	Option 2A	Base	Option 2A	Base	Option 2A	Base	Option 2A
DIVERSION_AG	0.0	0.1	0.0	0.1	0.0	0.1	0.2	0.2	0.5	0.2
PAST_CHIPPS	31.6	39.0	35.3	46.6	51.8	64.0	47.2	59.1	56.5	65.4
TO_SUISUN	6.3	5.6	9.8	9.6	12.2	12.3	13.7	14.3	15.8	16.4
EXPORTS*	0.0	0.0	0.4	0.0	1.1	0.0	2.6	0.0	3.7	1.3
CENTRAL	62.1	55.3	54.5	43.7	34.9	23.6	36.3	26.4	23.5	16.7
	Sacramento River Sep 1990 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 2A	Base	Option 2A	Base	Option 2A	Base	Option 2A	Base	Option 2A
DIVERSION_AG	0.0	0.1	0.0	0.1	0.1	0.1	0.1	0.1	0.5	0.2
PAST_CHIPPS	20.6	25.9	26.0	34.2	39.3	52.7	36.7	49.3	47.7	56.0
TO_SUISUN	4.2	3.9	7.4	7.9	10.0	10.9	11.5	13.7	14.1	16.7
EXPORTS*	0.0	0.0	1.2	0.0	3.7	0.0	6.9	0.0	7.6	2.4
CENTRAL	75.2	70.1	65.4	57.8	46.9	36.3	44.8	36.9	30.1	24.7
	San Joaquin River u/s of HOR Sep 1990 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 2A	Base	Option 2A	Base	Option 2A	Base	Option 2A	Base	Option 2A
DIVERSION_AG	14.3	9.5	19.4	14.9	20.1	16.7	20.1	18.5	22.1	21.5
PAST_CHIPPS	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.3	0.0	2.0
TO_SUISUN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8
EXPORTS*	51.1	0.0	54.6	0.0	54.9	0.0	54.9	0.0	55.2	13.6
CENTRAL	34.6	90.5	26.0	85.1	25.0	83.0	25.0	81.2	22.7	62.1

* In Baseline Exports is the sum of particles entering SWP and CVP. In the Option 2 it is the particles entering Siphon.

Table E-5. Option 2B Cumulative Particle Fate – September 1977

	Old River Sep 1977 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 2B	Base	Option 2B	Base	Option 2B	Base	Option 2B	Base	Option 2B
DIVERSION_AG	1.7	0.5	4.0	0.8	5.0	1.1	5.6	2.2	6.7	3.5
PAST_CHIPPS	0.0	0.1	0.0	0.5	0.1	5.9	0.3	7.8	1.7	23.4
TO_SUISUN	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0
EXPORTS*	53.1	0.0	67.5	0.0	75.3	0.0	79.9	0.0	84.3	3.1
CENTRAL	45.2	99.4	28.5	98.7	19.6	92.9	14.2	90.0	7.3	70.0
	Middle River Sep 1977 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 2B	Base	Option 2B	Base	Option 2B	Base	Option 2B	Base	Option 2B
DIVERSION_AG	0.4	0.5	1.2	0.9	1.7	1.0	2.8	1.0	3.4	1.2
PAST_CHIPPS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TO_SUISUN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EXPORTS*	32.3	0.0	63.5	36.2	80.8	86.3	88.5	92.0	93.3	98.1
CENTRAL	67.3	99.5	35.3	62.9	17.5	12.7	8.7	7.0	3.3	0.7
	San Joaquin River d/s of Dutch Slough Sep 1977 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 2B	Base	Option 2B	Base	Option 2B	Base	Option 2B	Base	Option 2B
DIVERSION_AG	0.0	0.2	0.1	0.3	0.1	0.3	0.3	0.3	0.7	0.5
PAST_CHIPPS	17.0	28.5	17.9	29.9	37.4	55.1	34.8	56.8	48.9	73.5
TO_SUISUN	0.1	0.2	0.0	0.0	0.3	0.3	0.0	0.0	0.2	0.2
EXPORTS*	0.0	0.0	0.5	0.0	2.1	0.0	4.5	0.0	11.0	0.6
CENTRAL	82.9	71.1	81.5	69.8	60.1	44.3	60.4	42.9	39.2	25.2
	Sacramento River Sep 1977 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 2B	Base	Option 2B	Base	Option 2B	Base	Option 2B	Base	Option 2B
DIVERSION_AG	0.1	0.1	0.2	0.1	0.3	0.1	0.7	0.3	1.2	0.4
PAST_CHIPPS	0.3	2.2	1.1	7.7	9.0	26.4	10.0	28.2	20.6	49.6
TO_SUISUN	0.0	0.1	0.0	0.0	0.3	0.2	0.0	0.3	0.3	0.5
EXPORTS*	0.0	0.0	0.9	0.0	4.6	0.0	9.6	0.0	20.2	2.9
CENTRAL	99.6	97.6	97.8	92.2	85.8	73.3	79.7	71.2	57.7	46.6
	San Joaquin River u/s of HOR Sep 1977 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 2B	Base	Option 2B	Base	Option 2B	Base	Option 2B	Base	Option 2B
DIVERSION_AG	7.1	4.2	7.9	8.3	9.8	11.5	11.2	14.8	13.6	19.2
PAST_CHIPPS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TO_SUISUN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EXPORTS*	30.3	0.0	32.4	0.0	33.5	0.0	46.5	0.0	67.1	24.8
CENTRAL	62.6	95.8	59.7	91.7	56.7	88.5	42.3	85.2	19.3	56.0

* In Baseline Exports is the sum of particles entering SWP and CVP. In the Option 2 it is the particles entering Siphon.

Table E-6. Option 2B Cumulative Particle Fate – January 1981

	Old River Sep 1981 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 2B	Base	Option 2B	Base	Option 2B	Base	Option 2B	Base	Option 2B
DIVERSION_AG	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.2	0.0
PAST_CHIPPS	0.2	3.8	0.2	30.3	0.2	48.2	0.3	72.0	0.3	82.2
TO_SUISUN	0.0	0.7	0.0	2.9	0.0	5.1	0.0	6.7	0.0	7.6
EXPORTS*	90.4	0.0	95.1	0.0	97.6	0.0	98.0	0.1	98.7	0.3
CENTRAL	9.4	95.5	4.7	66.8	2.2	46.7	1.5	21.2	0.8	9.9
	Middle River Sep 1981 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 2B	Base	Option 2B	Base	Option 2B	Base	Option 2B	Base	Option 2B
DIVERSION_AG	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PAST_CHIPPS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TO_SUISUN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EXPORTS*	82.2	0.0	97.2	44.7	99.7	86.5	99.8	94.2	99.9	99.8
CENTRAL	17.8	100.0	2.8	55.3	0.3	13.5	0.2	5.8	0.1	0.2
	San Joaquin River d/s of Dutch Slough Sep 1981 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 2B	Base	Option 2B	Base	Option 2B	Base	Option 2B	Base	Option 2B
DIVERSION_AG	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PAST_CHIPPS	35.1	73.6	51.5	88.1	54.9	89.8	57.4	90.3	58.4	90.2
TO_SUISUN	4.6	7.7	6.6	9.2	7.1	9.4	7.3	9.5	7.6	9.6
EXPORTS*	1.7	0.0	8.5	0.0	16.7	0.0	23.2	0.0	28.8	0.0
CENTRAL	58.6	18.7	33.4	2.7	21.3	0.8	12.1	0.2	5.2	0.2
	Sacramento River Sep 1981 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 2B	Base	Option 2B	Base	Option 2B	Base	Option 2B	Base	Option 2B
DIVERSION_AG	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PAST_CHIPPS	46.1	56.1	57.4	83.2	60.4	86.3	62.4	89.1	62.6	89.7
TO_SUISUN	4.8	5.6	6.3	8.3	6.6	8.9	6.9	8.9	6.9	9.0
EXPORTS*	2.4	0.0	10.2	0.0	16.9	0.0	22.2	0.0	27.0	0.0
CENTRAL	46.7	38.3	26.1	8.5	16.1	4.8	8.5	2.0	3.5	1.3
	San Joaquin River u/s of HOR Sep 1981 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 2B	Base	Option 2B	Base	Option 2B	Base	Option 2B	Base	Option 2B
DIVERSION_AG	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
PAST_CHIPPS	0.0	0.0	0.0	2.8	0.0	13.7	0.0	39.3	0.0	52.5
TO_SUISUN	0.0	0.0	0.0	0.5	0.0	1.8	0.0	3.2	0.0	4.4
EXPORTS*	65.1	0.0	70.4	2.0	86.3	5.9	93.5	5.9	96.1	19.3
CENTRAL	34.9	100.0	29.6	94.7	13.7	78.6	6.5	51.6	3.9	23.5

* In Baseline Exports is the sum of particles entering SWP and CVP. In the Option 2 it is the particles entering Siphon.

Table D-7. Option 2B Cumulative Particle Fate – March 1990

	Old River Sep 1990 Release - Cumulative particles (%)									
	7 Days		**14 Days**		**21 Days**		**28 Days**		**40 Days**	
	Base	**Option 2B**	**Base**	**Option 2B**	**Base**	**Option 2B**	**Base**	**Option 2B**	**Base**	**Option 2B**
DIVERSION_AG	0.4	0.4	0.6	0.6	1.8	0.7	2.2	1.1	3.3	3.7
PAST_CHIPPS	0.0	0.8	0.1	3.6	0.9	15.6	0.8	17.0	1.6	26.2
TO_SUISUN	0.0	0.0	0.0	1.1	0.2	2.6	0.5	4.6	0.8	8.3
EXPORTS*	52.9	0.0	71.9	0.0	79.9	0.0	84.0	0.0	85.3	0.0
CENTRAL	46.7	98.8	27.4	94.7	17.2	81.1	12.5	77.3	9.0	61.8
	Middle River Sep 1990 Release - Cumulative particles (%)									
	7 Days		**14 Days**		**21 Days**		**28 Days**		**40 Days**	
	Base	**Option 2B**	**Base**	**Option 2B**	**Base**	**Option 2B**	**Base**	**Option 2B**	**Base**	**Option 2B**
DIVERSION_AG	0.2	0.1	0.6	0.8	1.2	1.3	2.0	1.5	2.6	1.5
PAST_CHIPPS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
TO_SUISUN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EXPORTS*	24.6	0.0	61.0	35.9	77.6	82.7	85.0	88.5	87.4	98.4
CENTRAL	75.2	99.9	38.4	63.3	21.2	16.0	13.0	10.0	9.9	0.1
	San Joaquin River d/s of Dutch Slough Sep 1990 Release - Cumulative particles (%)									
	7 Days		**14 Days**		**21 Days**		**28 Days**		**40 Days**	
	Base	**Option 2B**	**Base**	**Option 2B**	**Base**	**Option 2B**	**Base**	**Option 2B**	**Base**	**Option 2B**
DIVERSION_AG	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.5	0.0
PAST_CHIPPS	31.6	54.4	35.3	62.1	51.8	76.5	47.2	72.4	56.5	76.2
TO_SUISUN	6.3	6.8	9.8	11.8	12.2	13.4	13.7	14.7	15.8	16.1
EXPORTS*	0.0	0.0	0.4	0.0	1.1	0.0	2.6	0.0	3.7	0.0
CENTRAL	62.1	38.8	54.5	26.1	34.9	10.1	36.3	12.9	23.5	7.7
	Sacramento River Sep 1990 Release - Cumulative particles (%)									
	7 Days		**14 Days**		**21 Days**		**28 Days**		**40 Days**	
	Base	**Option 2B**	**Base**	**Option 2B**	**Base**	**Option 2B**	**Base**	**Option 2B**	**Base**	**Option 2B**
DIVERSION_AG	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.5	0.2
PAST_CHIPPS	20.6	25.1	26.0	43.2	39.3	65.2	36.7	62.5	47.7	66.5
TO_SUISUN	4.2	2.4	7.4	7.3	10.0	10.5	11.5	13.1	14.1	15.8
EXPORTS*	0.0	0.0	1.2	0.0	3.7	0.0	6.9	0.0	7.6	0.1
CENTRAL	75.2	72.5	65.4	49.5	46.9	24.3	44.8	24.4	30.1	17.4
	San Joaquin River u/s of HOR Sep 1990 Release - Cumulative particles (%)									
	7 Days		**14 Days**		**21 Days**		**28 Days**		**40 Days**	
	Base	**Option 2B**	**Base**	**Option 2B**	**Base**	**Option 2B**	**Base**	**Option 2B**	**Base**	**Option 2B**
DIVERSION_AG	14.3	14.4	19.4	23.6	20.1	26.9	20.1	28.7	22.1	34.4
PAST_CHIPPS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TO_SUISUN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EXPORTS*	51.1	0.0	54.6	0.0	54.9	0.0	54.9	0.0	55.2	21.8
CENTRAL	34.6	85.6	26.0	76.4	25.0	73.1	25.0	71.3	22.7	43.8

* In Baseline Exports is the sum of particles entering SWP and CVP. In the Option 2 it is the particles entering Siphon.

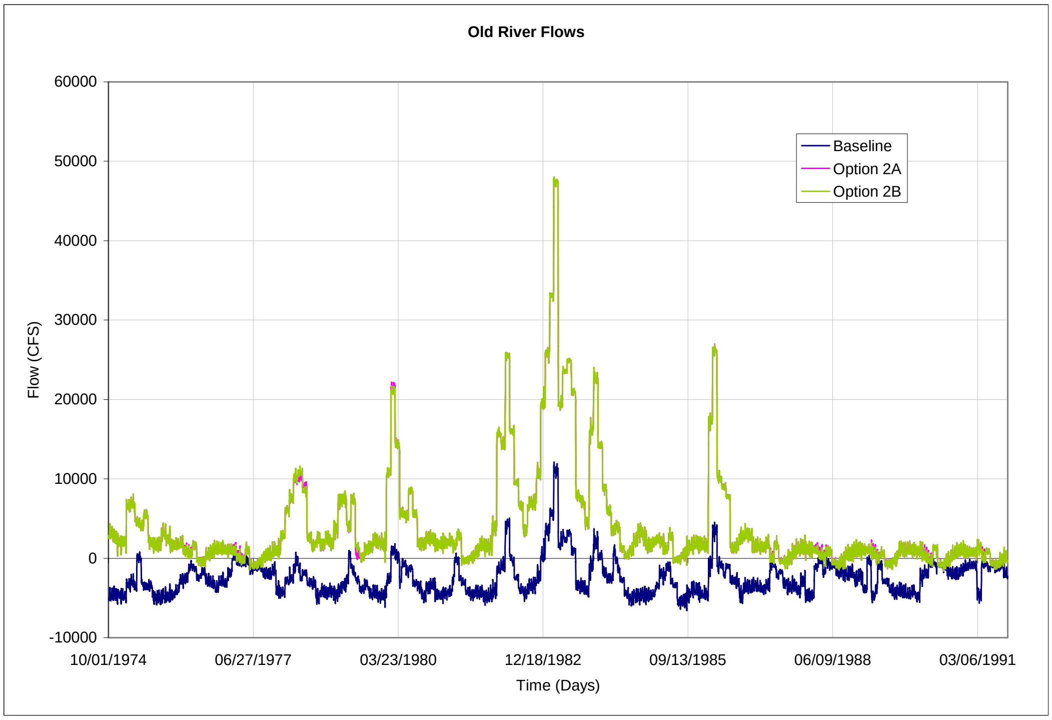


Figure E-16. DSM2 Simulated Daily Averaged Old River Flows

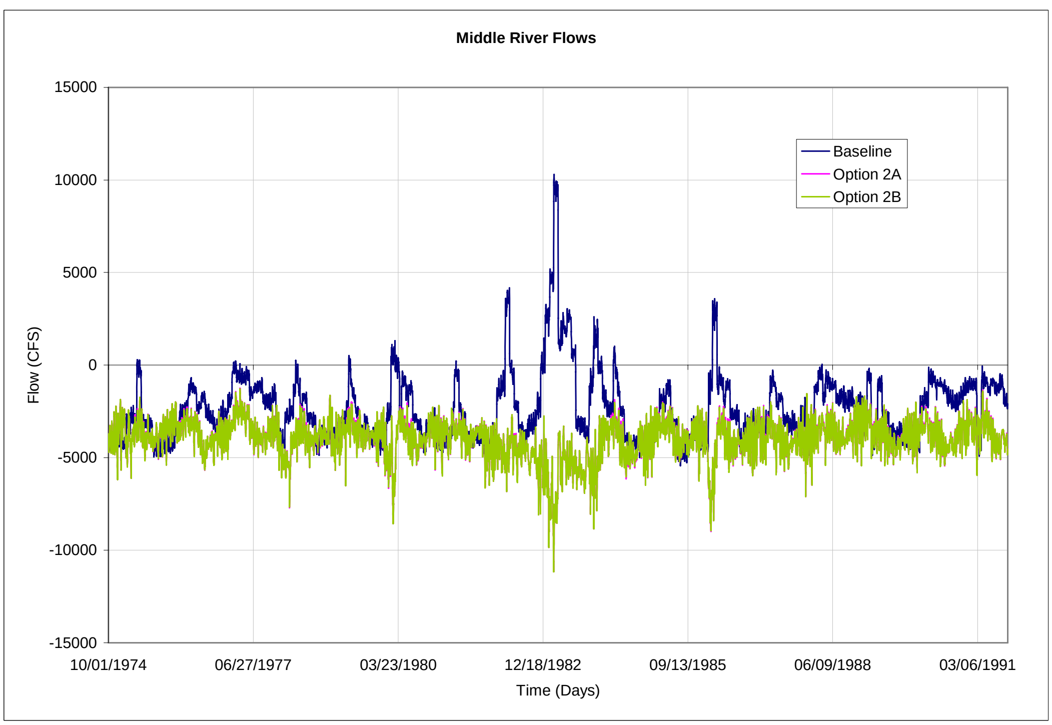


Figure E-17. DSM2 Simulated Daily Averaged Middle River Flows

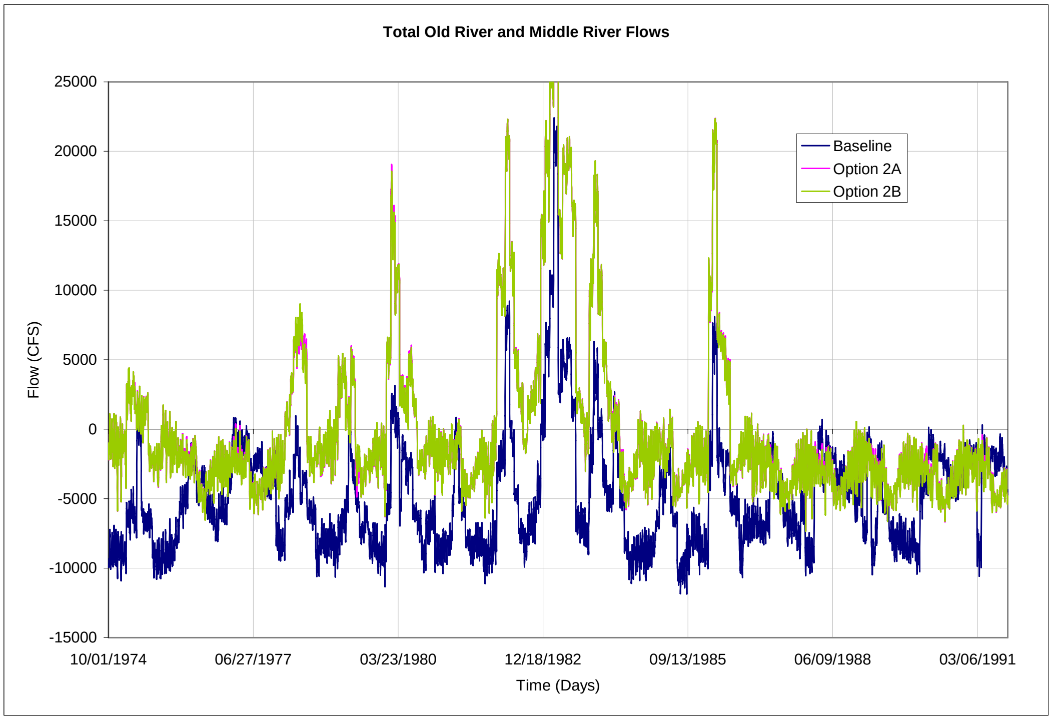


Figure E-18. DSM2 Simulated Daily Averaged Combined Old and Middle River Flows

Appendix F. Option 4 Hydrologic/Hydrodynamic Model Results

The following appendix presents hydrologic/hydrodynamic model results in the following tables and figures:

F. Option 3 Hydrologic/Hydrodynamic Model Results

Table F-1. Summary Output for the Implementation of Conservation Strategy: Option 3

	Base		**Option 3A**				**Option 3B**			
Delta flows[1]	**Annual Average[2] (1)**	**Dry period[3] (2)**	**Annual Average[2] (3)**	**Dry period[3] (4)**	**Change (3)-(1)**	**Change (4)-(2)**	**Annual Average[2] (5)**	**Dry period[3] (6)**	**Change (5)-(1)**	**Change (6)-(2)**
Sacramento River @ Hood	16,229	8,269	16,188	8,302	-41	33	16,260	7,959	31	-310
San Joaquin River @ Vernalis	3,027	1,362	3,033	1,371	6	9	3,029	1,336	2	-26
Sacramento River @ Rio Vista	13,812	5,164	10,678	3,865	-3,134	-1,299	10,950	3,388	-2,861	-1,777
Delta Outflow	14,991	5,154	14,579	4,753	-412	-401	15,043	4,227	52	-927
SWP/CVP Exports	5,902	3,572	6,309	4,007	407	435	5,878	4,159	-24	586
QWEST (cfs)	1,620	-12	5,397	1,241	3,778	1,253	5,665	1,166	4,045	1,178
Old and Middle River (cfs)	-5,842	-4,635	-865	-2,113	4,977	2,522	-718	-2,101	5,124	2,534
Water quality[4]	Annual Average[5] (1)	Dry period[3] (2)	Annual Average[5] (3)	Dry period[3] (4)	Change (3)-(1)	Change (4)-(2)	Annual Average[5] (5)	Dry period[3] (6)	Change (5)-(1)	Change (6)-(2)
X2 (km)	76	82	77	83	1	1	76	84	0	2
EC Exports[6]	488		283		-205		269		-219	
EC at Emmaton	1,128		1,573		445		1,628		500	
EC at Jersey Point	1,074		1,297		224		1,243		170	
EC at Collinsville	3,816		4,555		740		4,766		951	
EC at Old River, Hwy 4	488		625		137		646		159	
Particle Transport and Fate[7]	Average[8] (1)		Average[8] (2)		Change (2)-(1)		Average[8] (3)		Change (3)-(1)	
Insertion on Old River @ Quimby Island	57		1		-56		1		-56	
Insertion on Middle River @ Mildred Island	59		26		-33		67		8	
Insertion on San Joaquin River near Big Break	9		0		-9		1		-9	
Insertion on Sacramento River near Cache Slough	13		1		-13		1		-12	
Insertion on San Joaquin River near Head of Old River	47		5		-42		8		-39	

Table F-1. Summary Output for the Implementation of Conservation Strategy: Option 3

NOTES:
1. Units in TAF unless mentioned otherwise
2. Annual average, 1921-2003
3. Dry period, 1928-1934
4. Units in EC, µMHOS/cm unless mentioned otherwise
5. For EC parameter values represent 16-year monthly Period Averaged; for X2 values represent annual average, 1921-2003
6. EC is blended between EC at Banks and EC at Tracy
7. Percentage of particles entering SWP and CVP pumping stations
8. Average of 1977, 1981 and 1990 releases of % cumulative particles ended up in exports at the end of 40 days

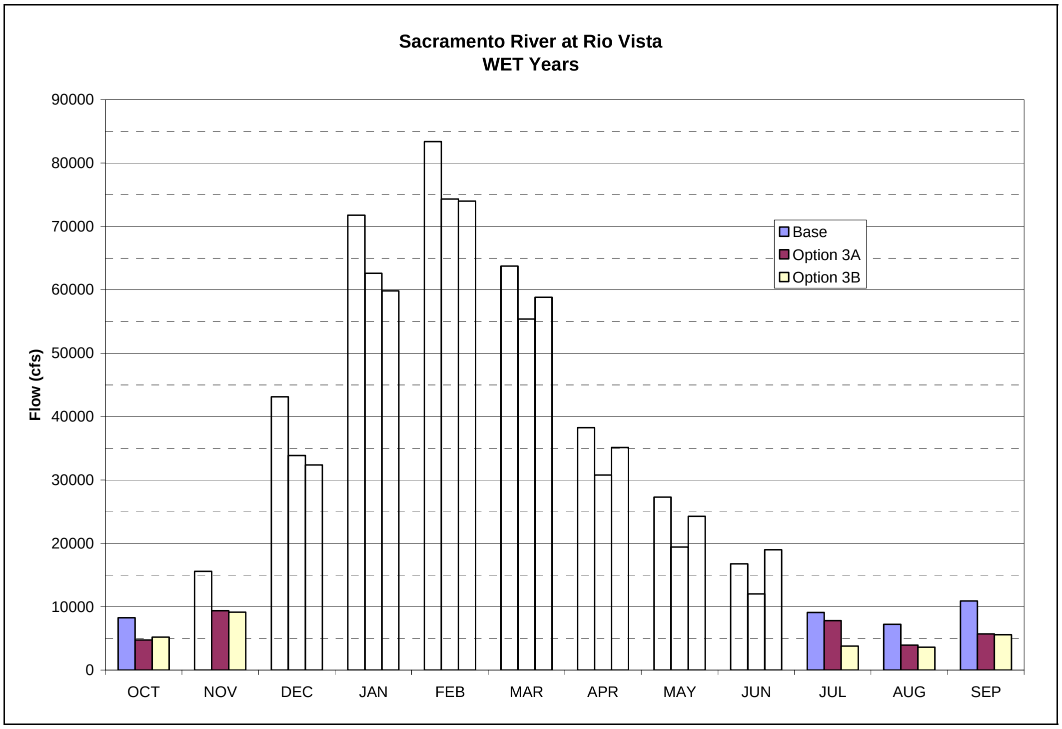


Figure F-1a. Sacramento River at Rio Vista Wet Year Average Flows

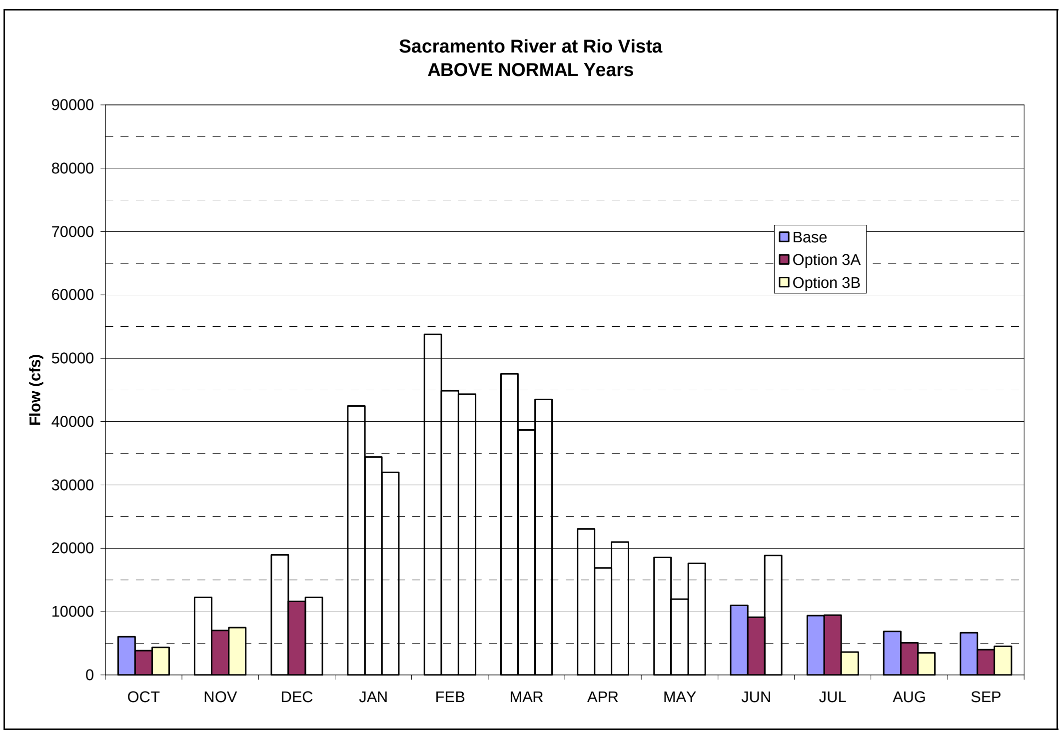


Figure F-1b. Sacramento River at Rio Vista Above Normal Year Average Flows

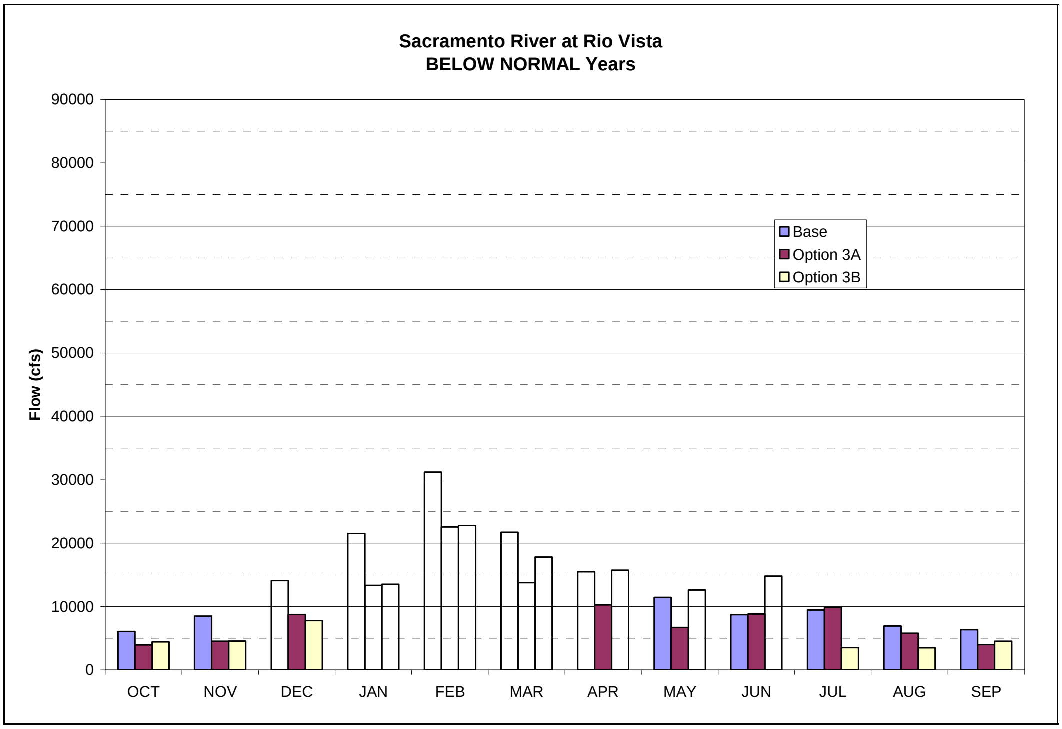


Figure F-1c. Sacramento River at Rio Vista Below Normal Year Average Flows

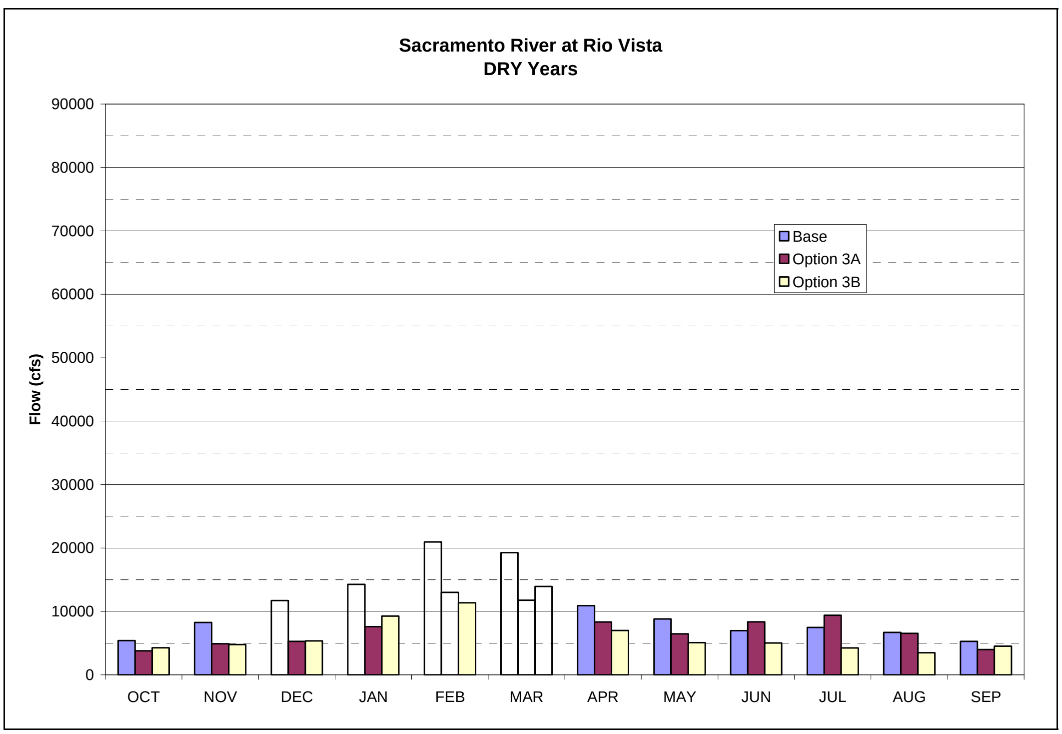


Figure F-1d. Sacramento River at Rio Vista Dry Year Average Flows

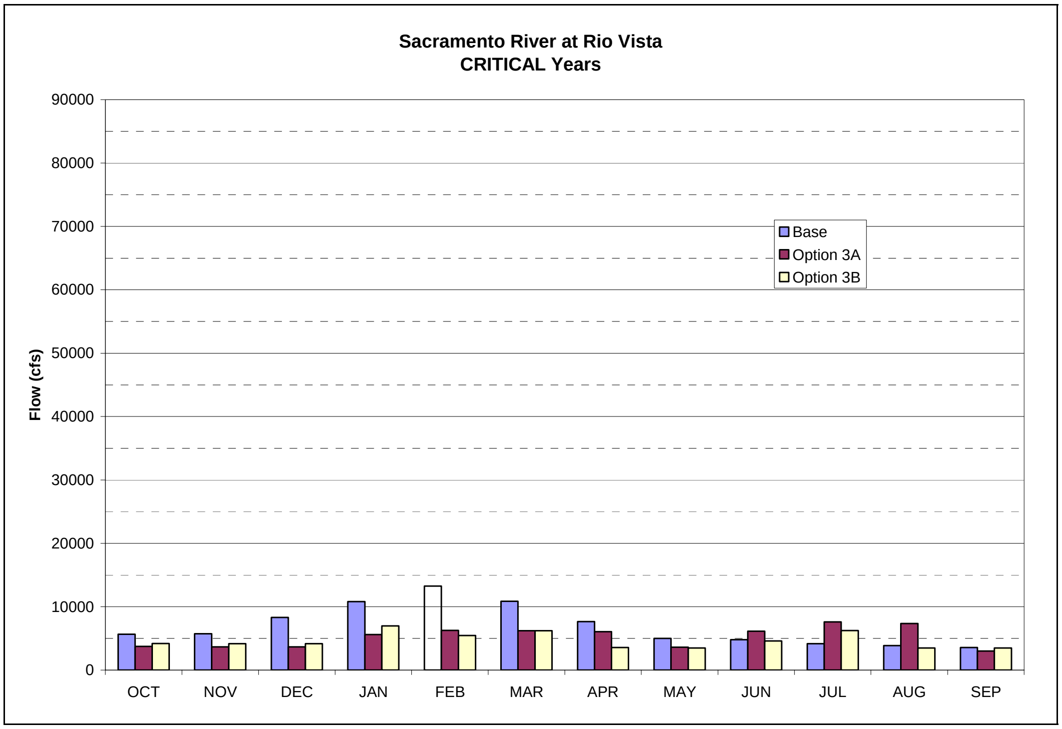


Figure F-1e. Sacramento River at Rio Vista Critical Year Average Flows

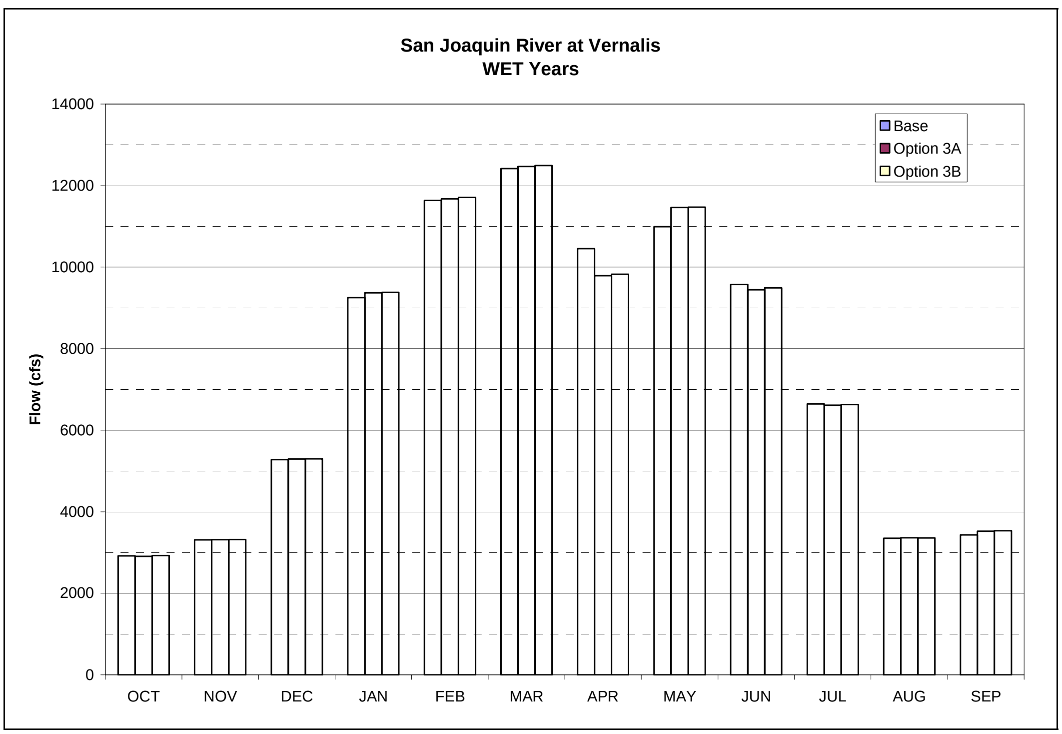


Figure F-2a. San Joaquin River at Vernalis Wet Year Average Flows

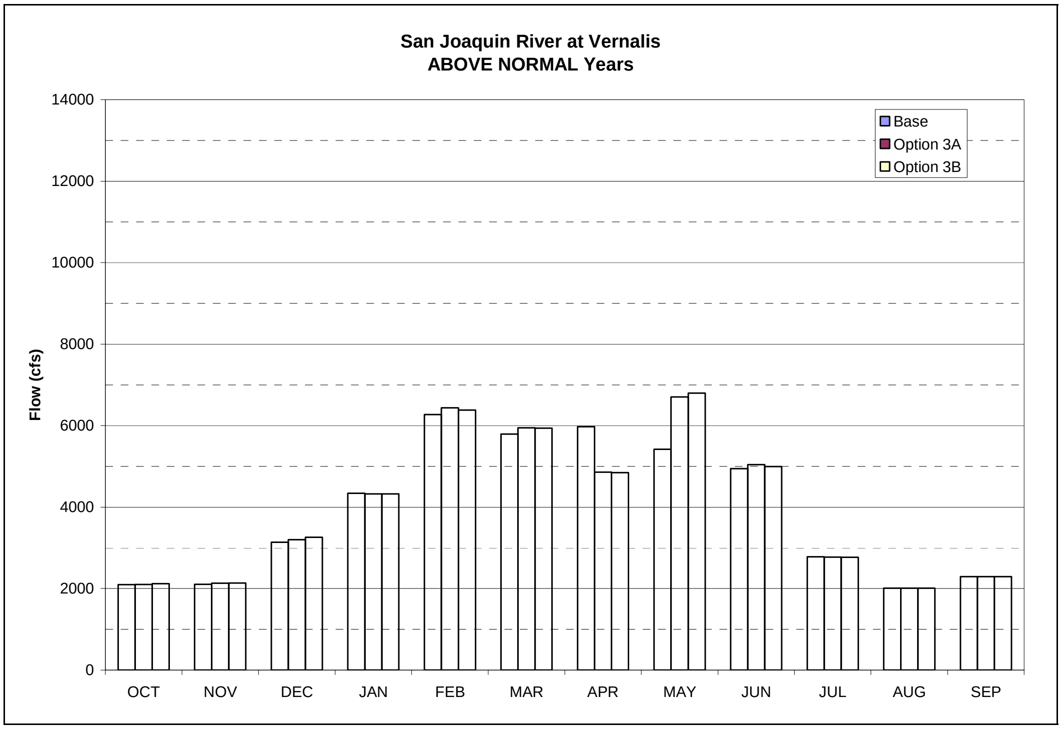


Figure F-2b. San Joaquin River at Vernalis Above Normal Year Average Flows

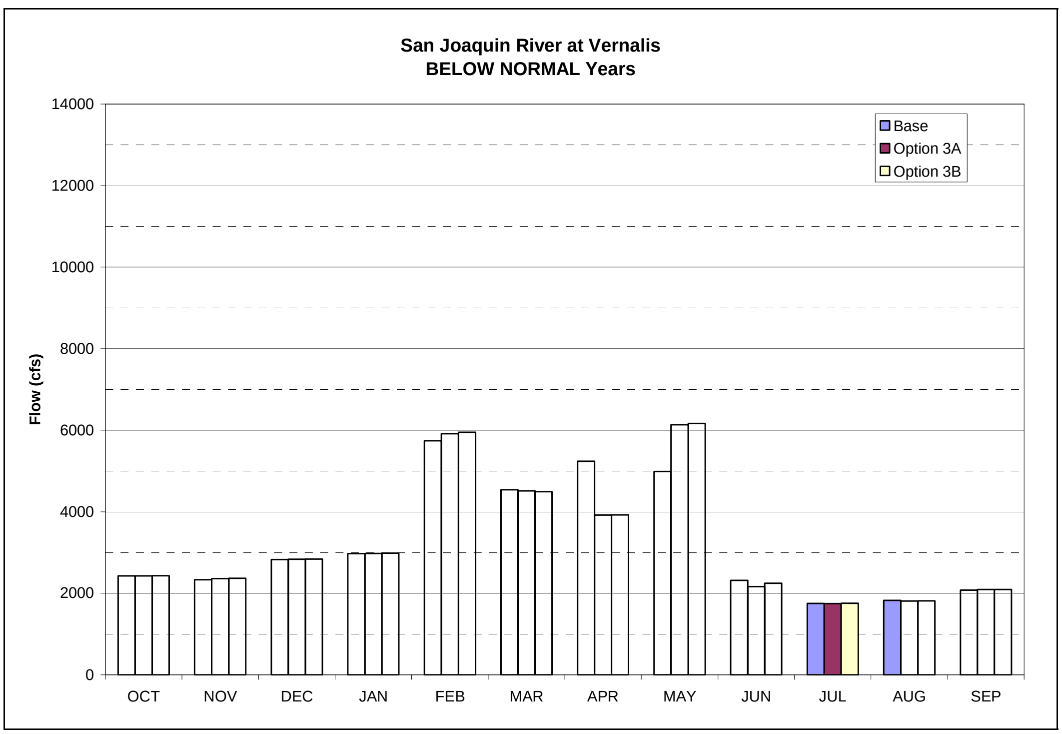


Figure F-2c. San Joaquin River at Vernalis Below Normal Year Average Flows

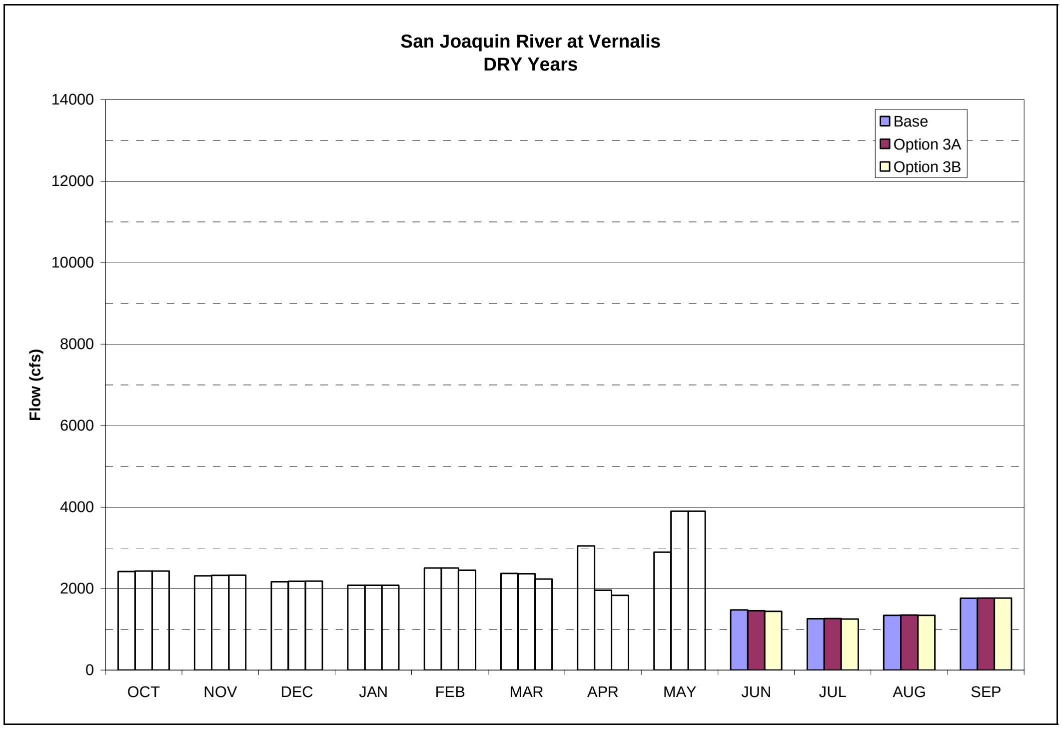


Figure F-2d. San Joaquin River at Vernalis Dry Year Average Flows

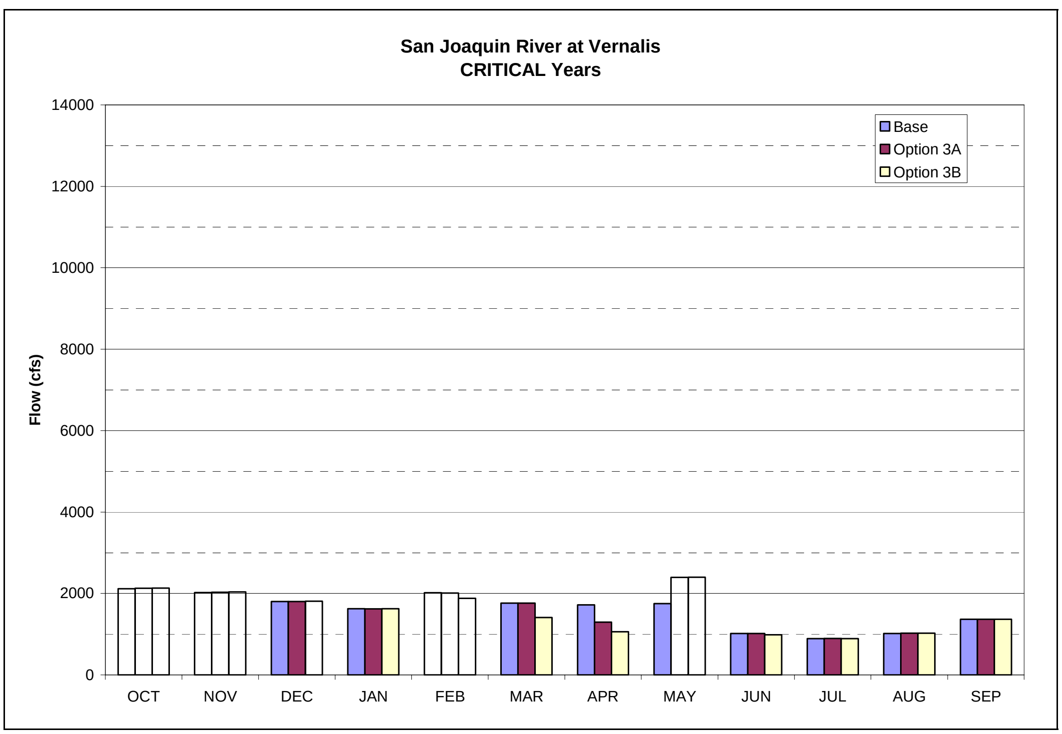
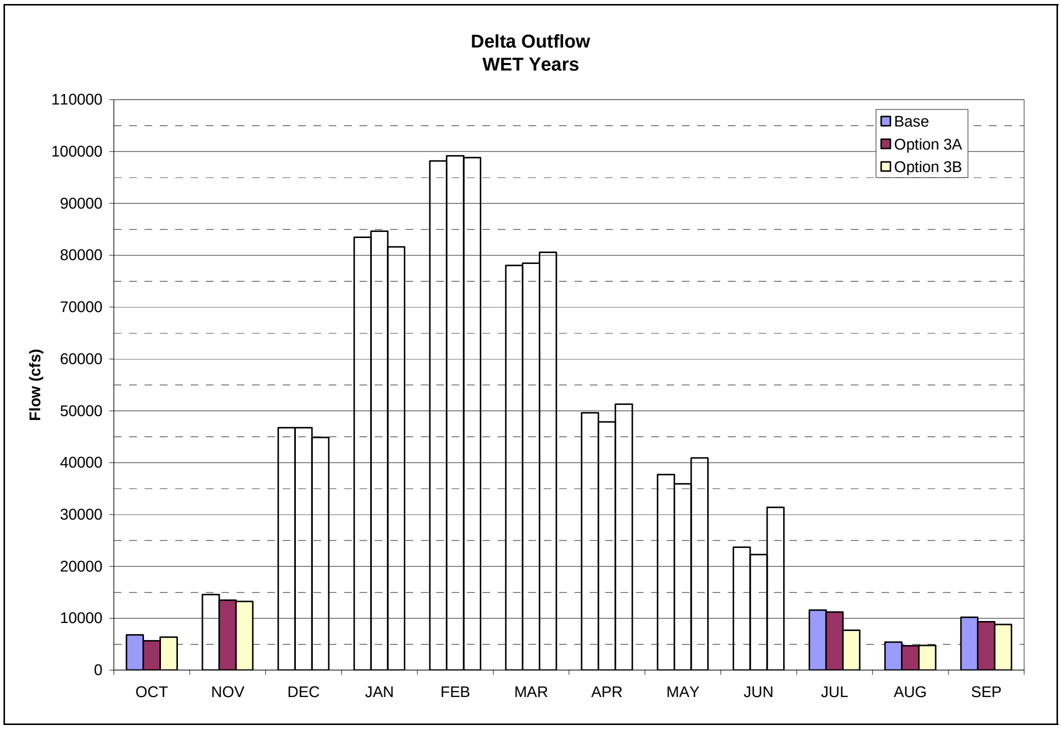


Figure F-2e. San Joaquin River at Vernalis Critical Year Average Flows

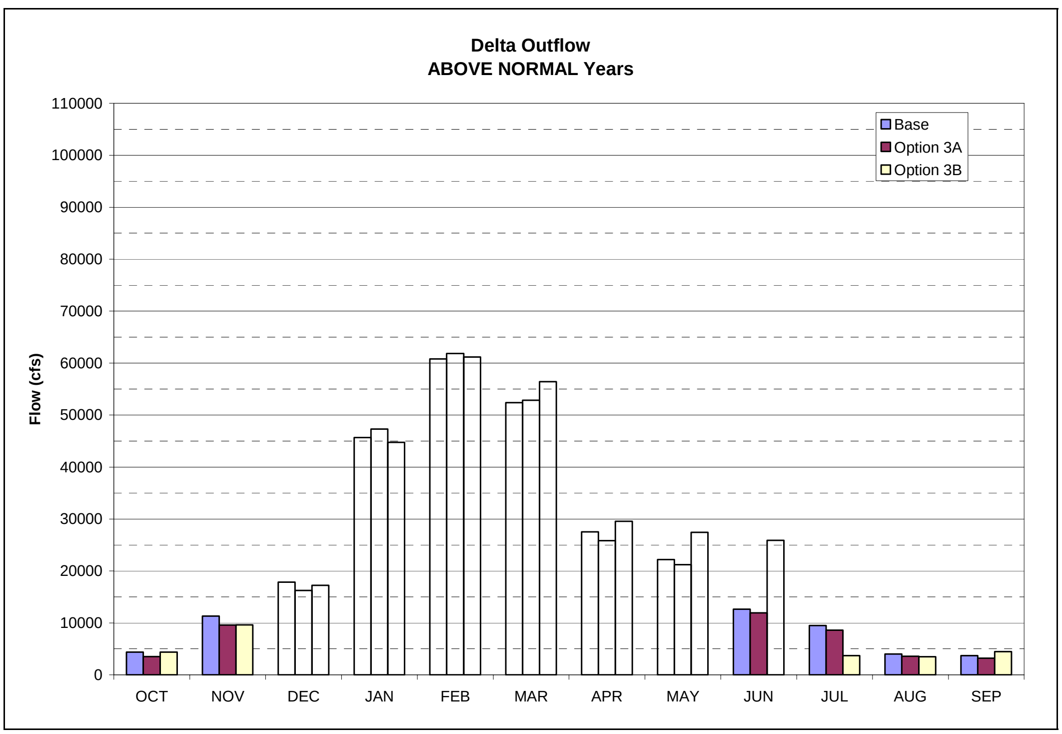
1



2 **Figure F-3a. Delta Outflow Wet Year Average Flows**

3

4



5 **Figure F-3b. Delta Outflow Above Normal Year Average Flows**

6

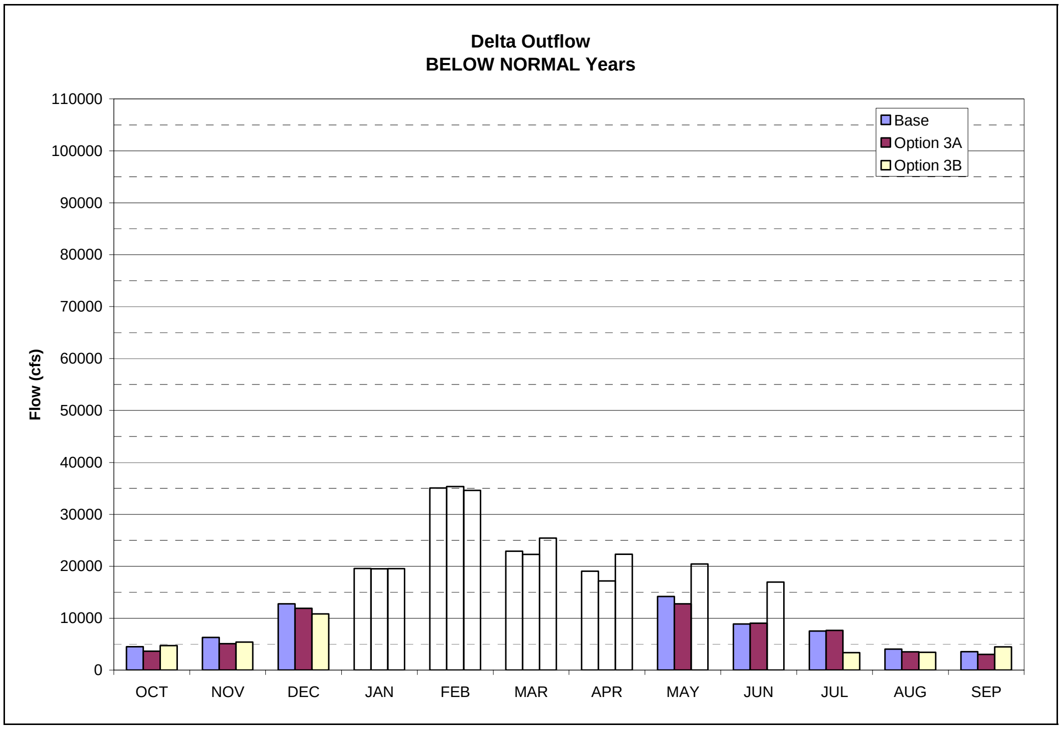


Figure F-3c. Delta Outflow Below Normal Year Average Flows

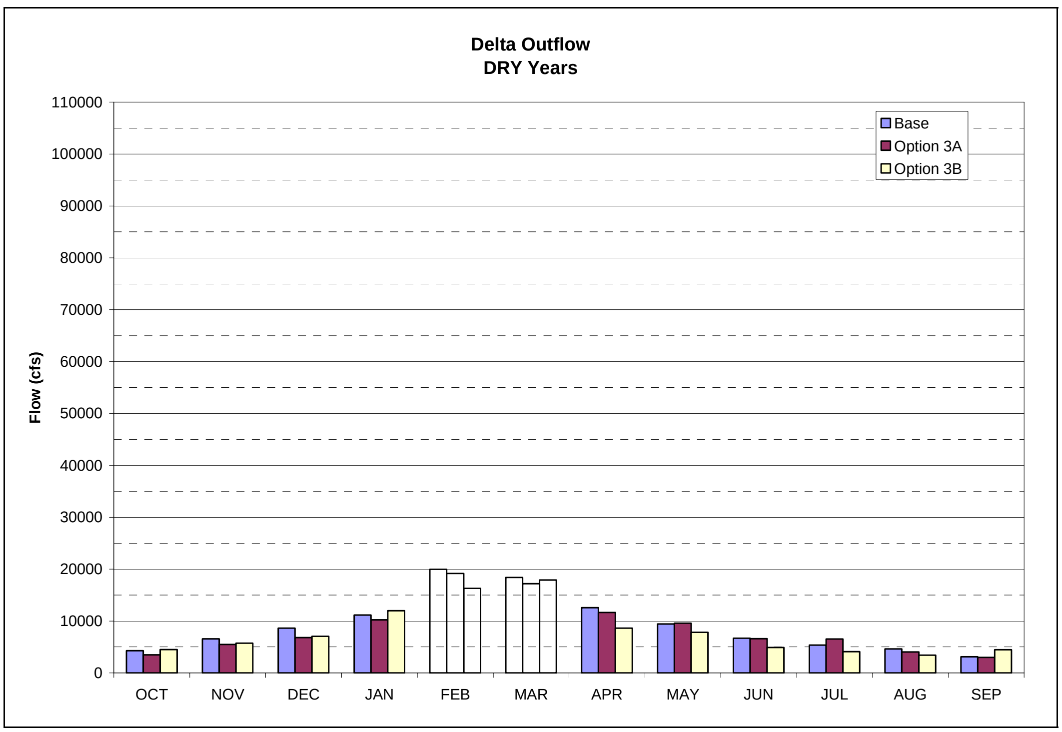


Figure F-3d. Delta Outflow Dry Year Average Flows

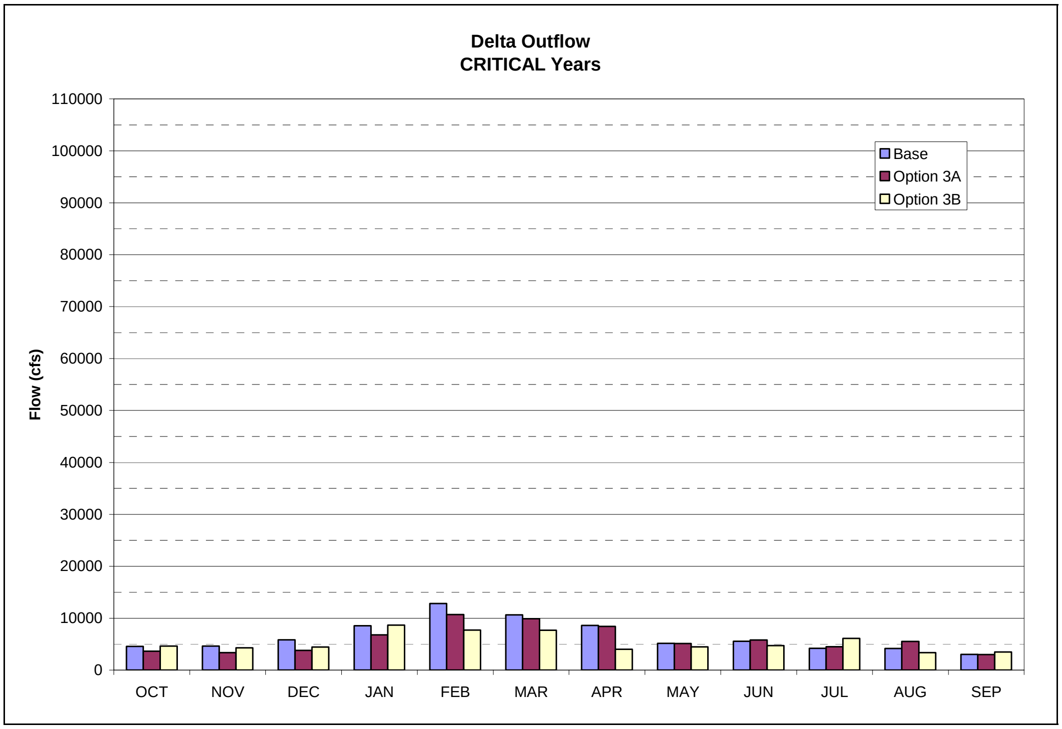


Figure F-3e. Delta Outflow Critical Year Average Flows

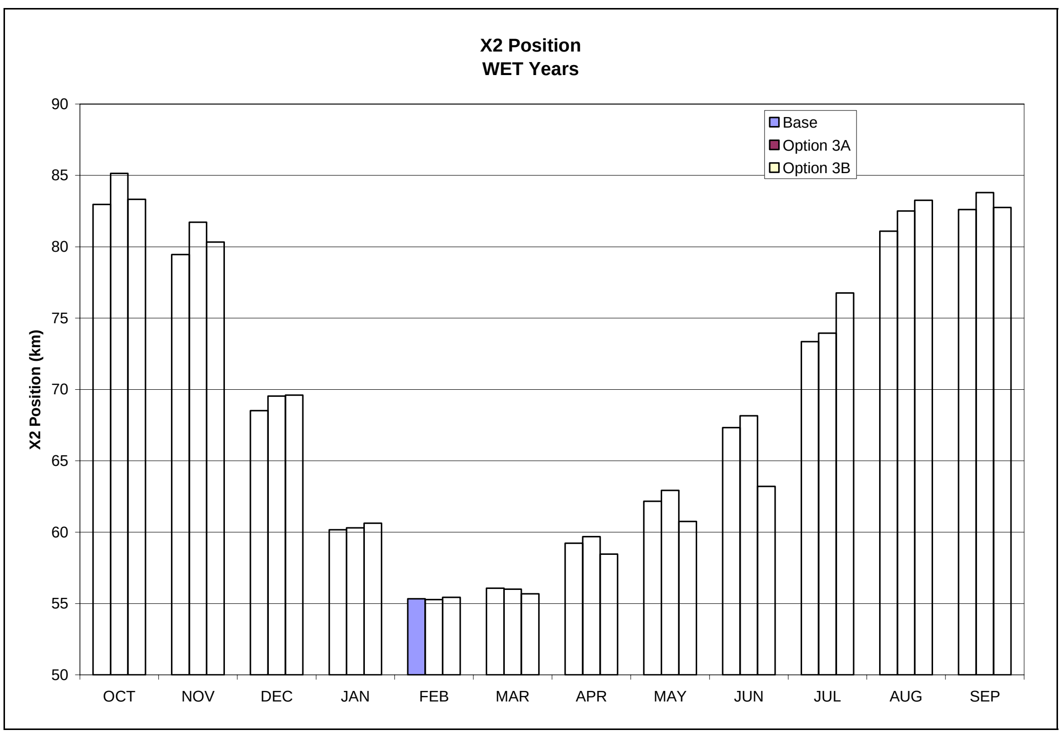


Figure F-4a. X2 Wet Year Average Distance

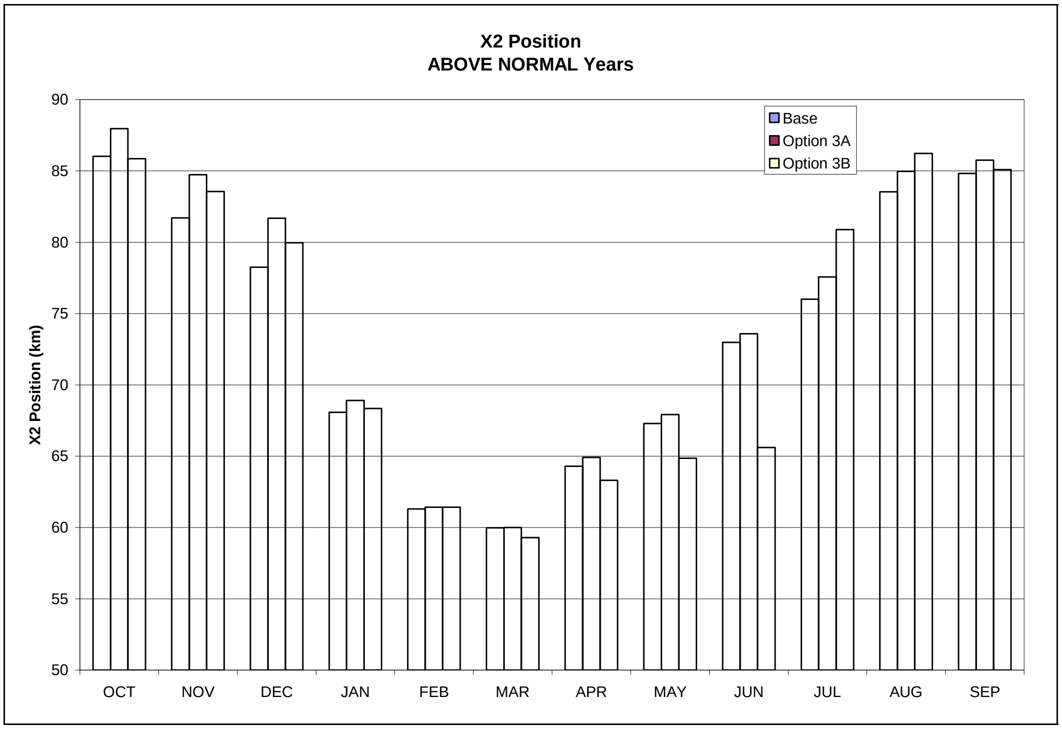


Figure F-4b. X2 Above Normal Year Average Distance

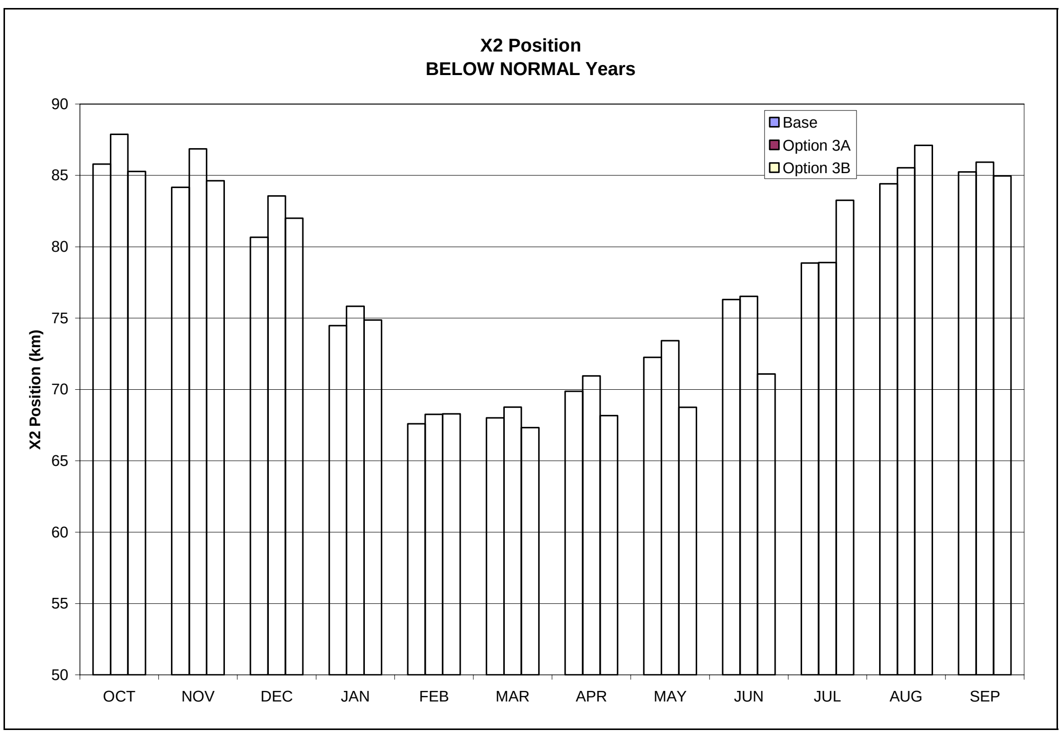


Figure F-4c. X2 Below Normal Year Average Distance

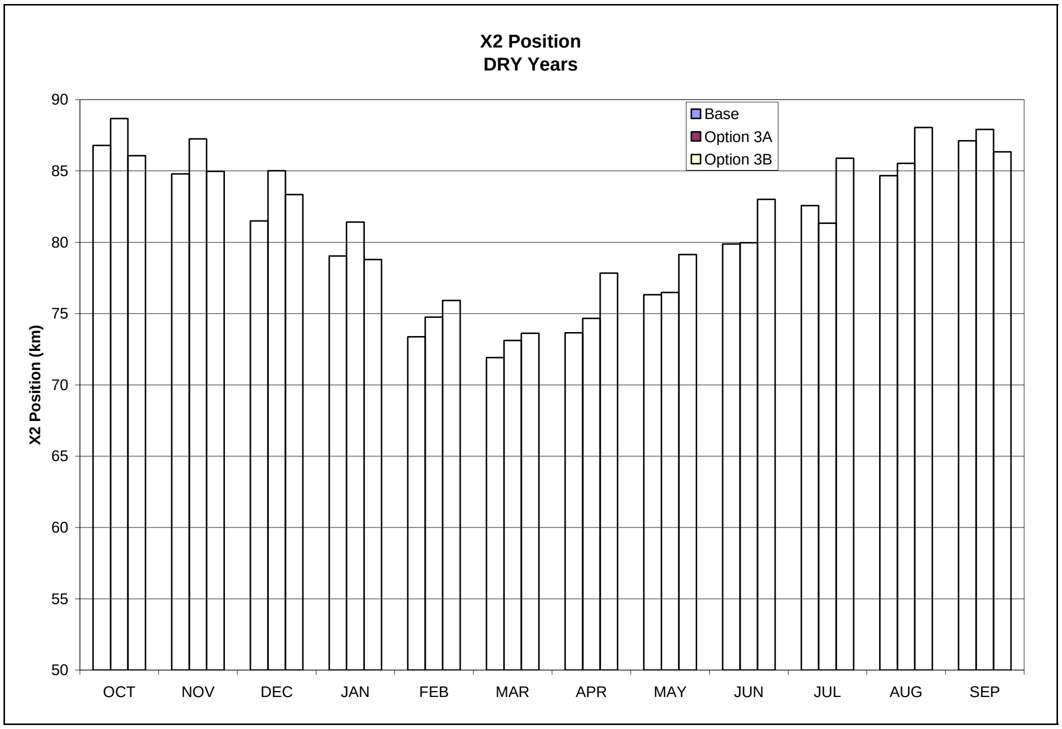


Figure F-4d. X2 Dry Year Average Distance

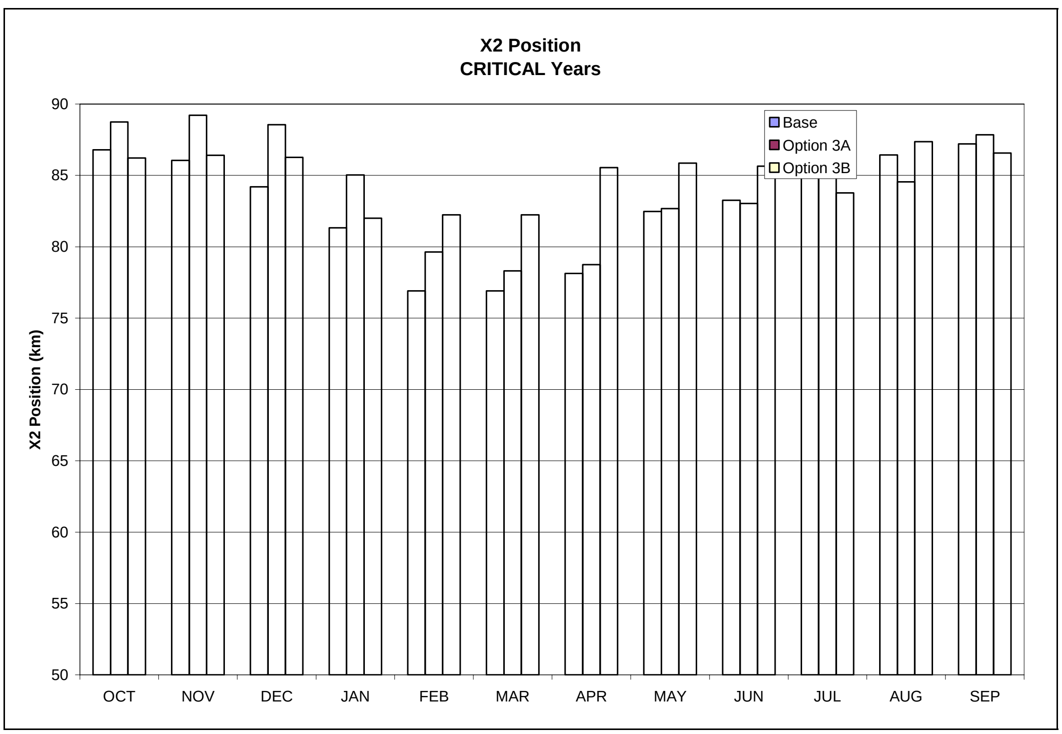


Figure F-4e. X2 Critical Year Average Distance

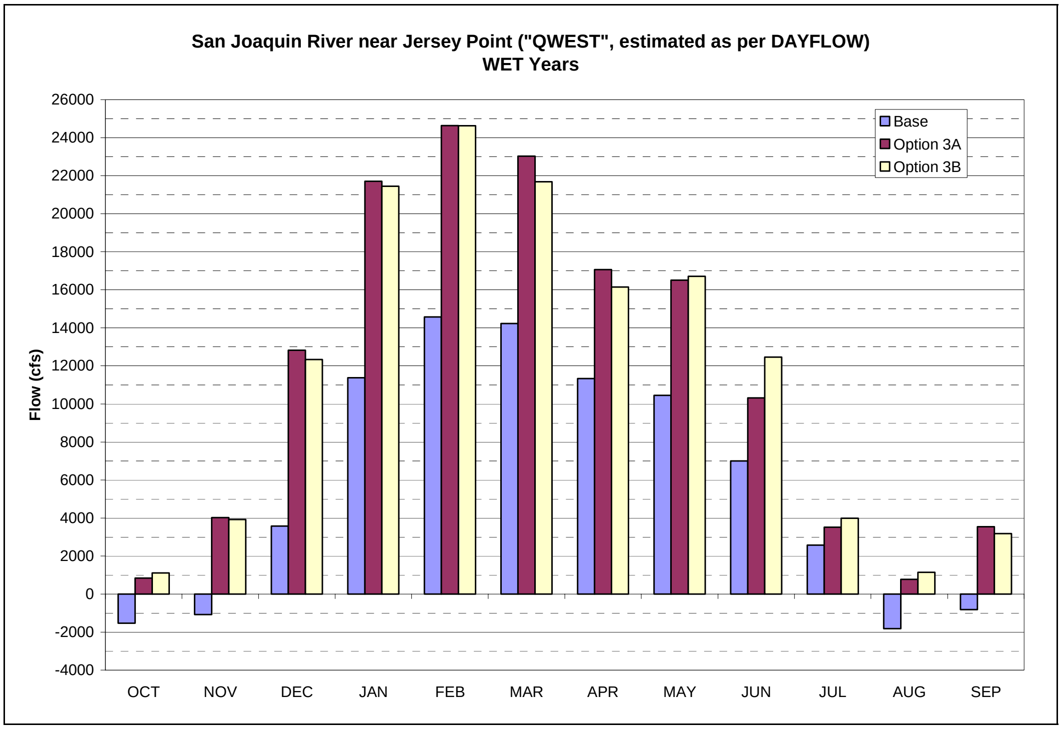


Figure F-5a. QWEST Wet Year Average Flows

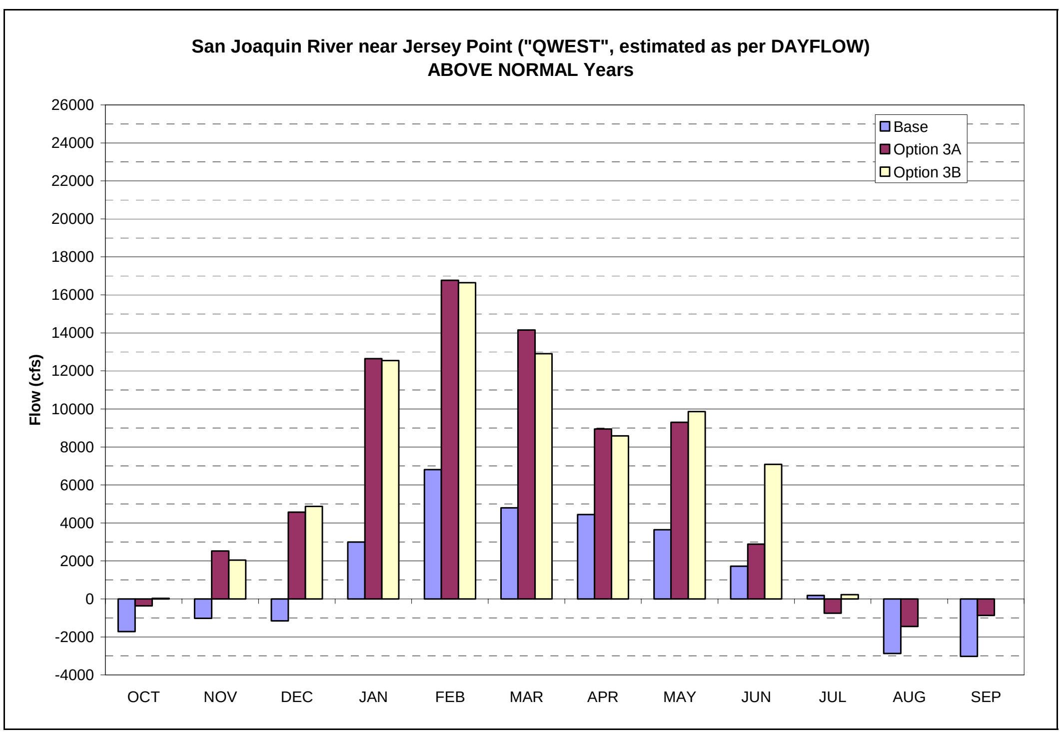


Figure F-5b. QWEST Above Normal Year Average Flows

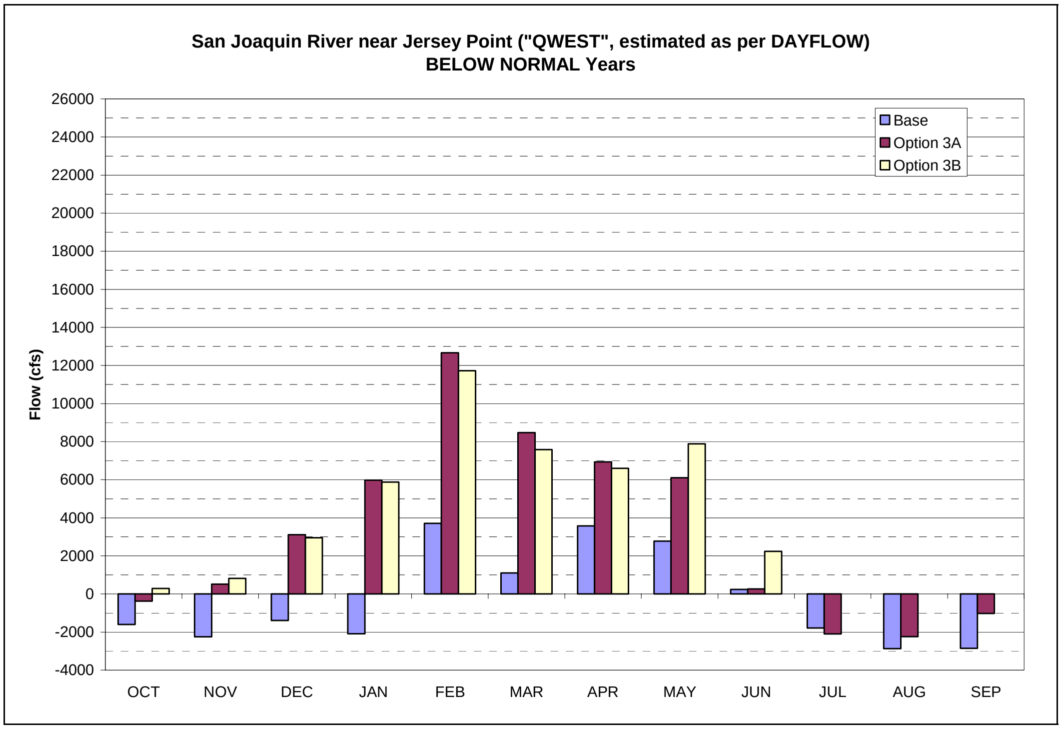


Figure F-5c. QWEST Below Normal Year Average Flows

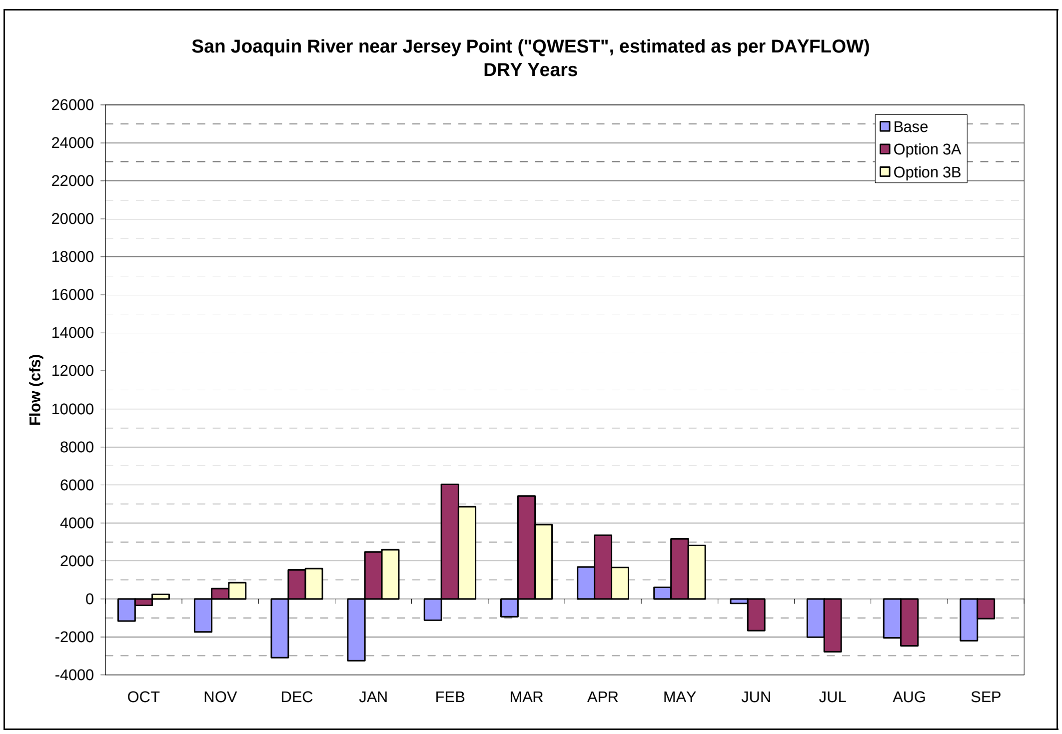


Figure F-5d. QWEST Dry Year Average Flows

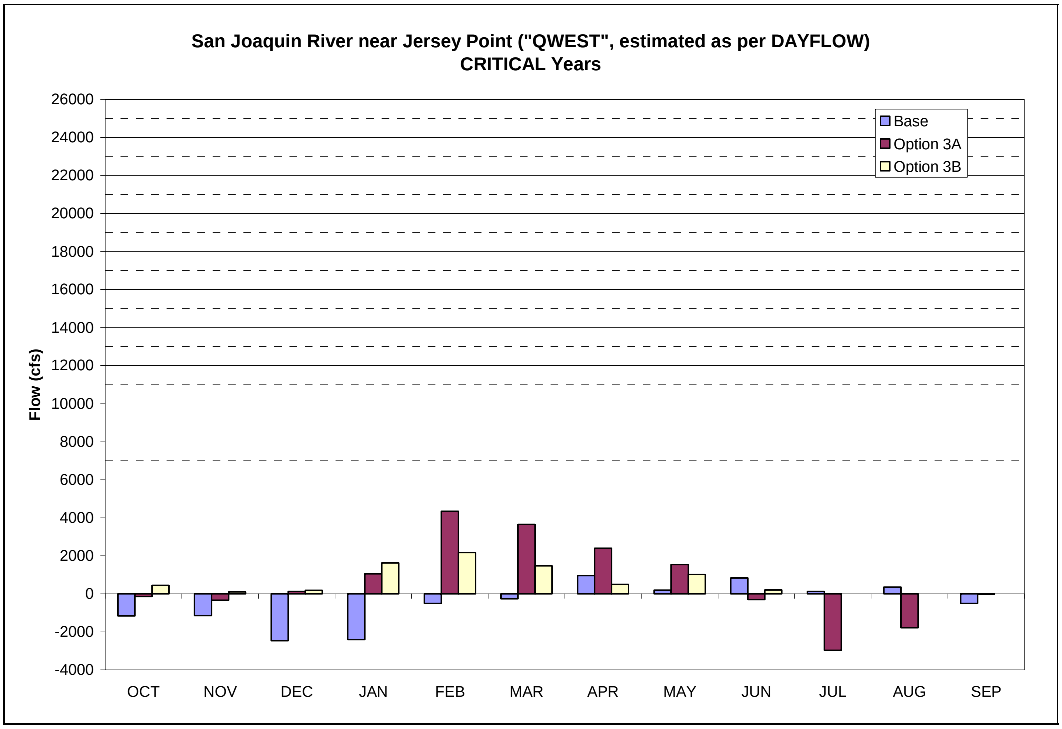


Figure F-5e. QWEST Critical Year Average Flows

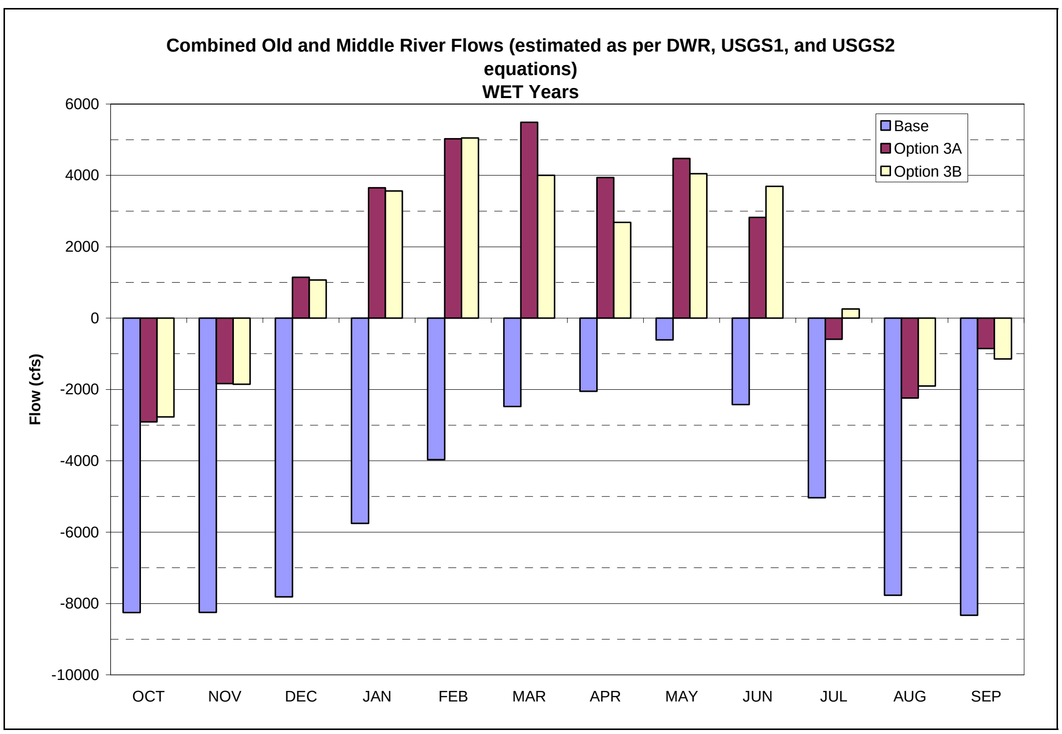


Figure F-6a. Combined Old and Middle River Wet Year Average Flows

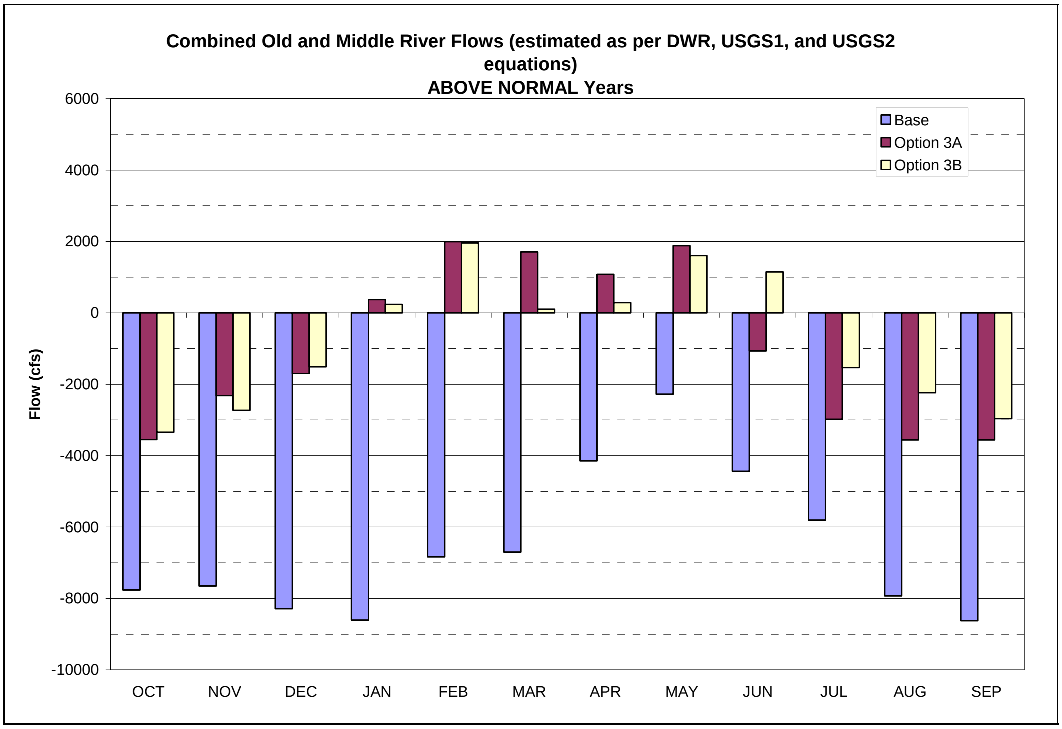


Figure F-6b. Combined Old and Middle River Above Normal Year Average Flows

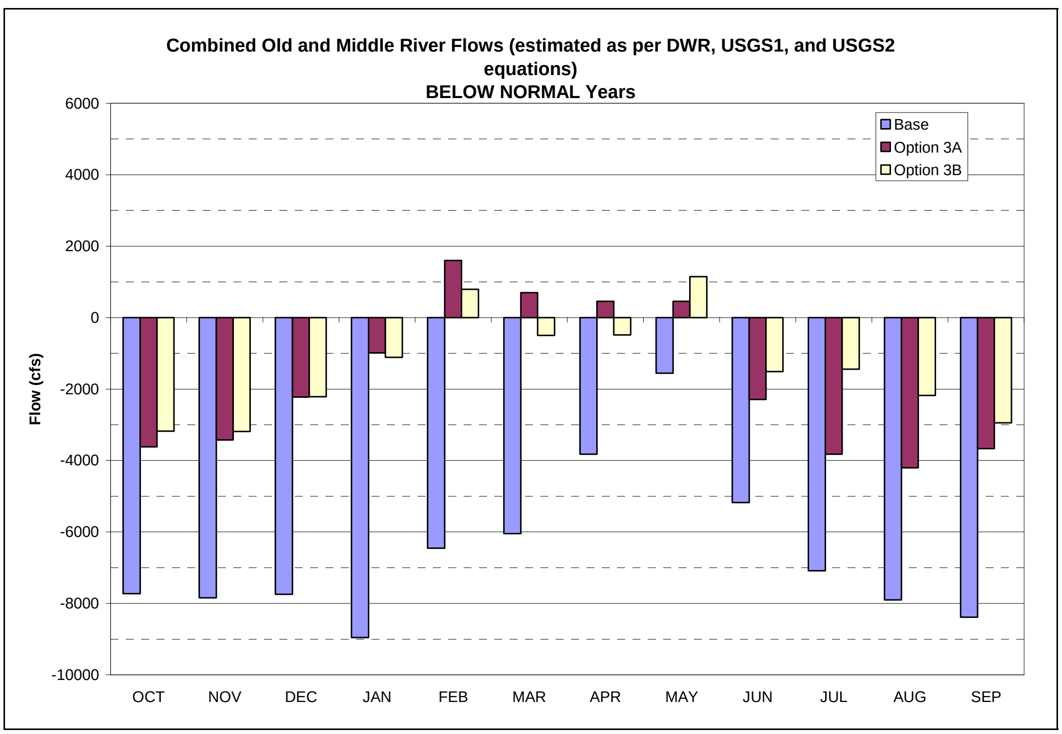


Figure F-6c. Combined Old and Middle River Below Normal Year Average Flows

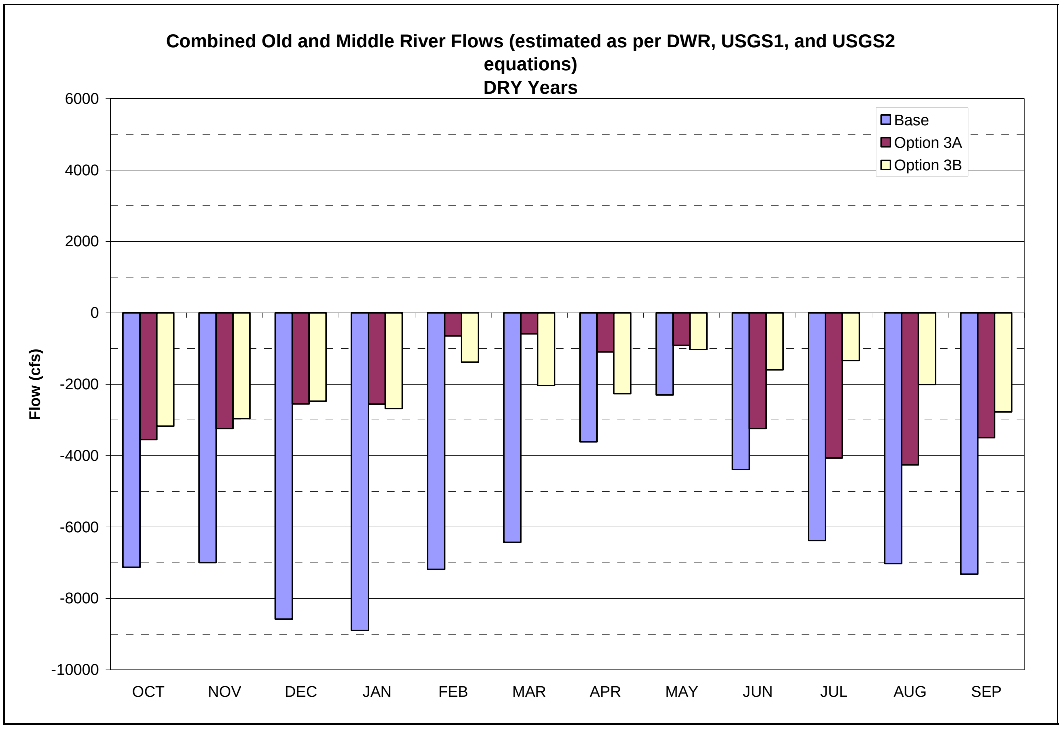


Figure F-6d. Combined Old and Middle River Dry Year Average Flows

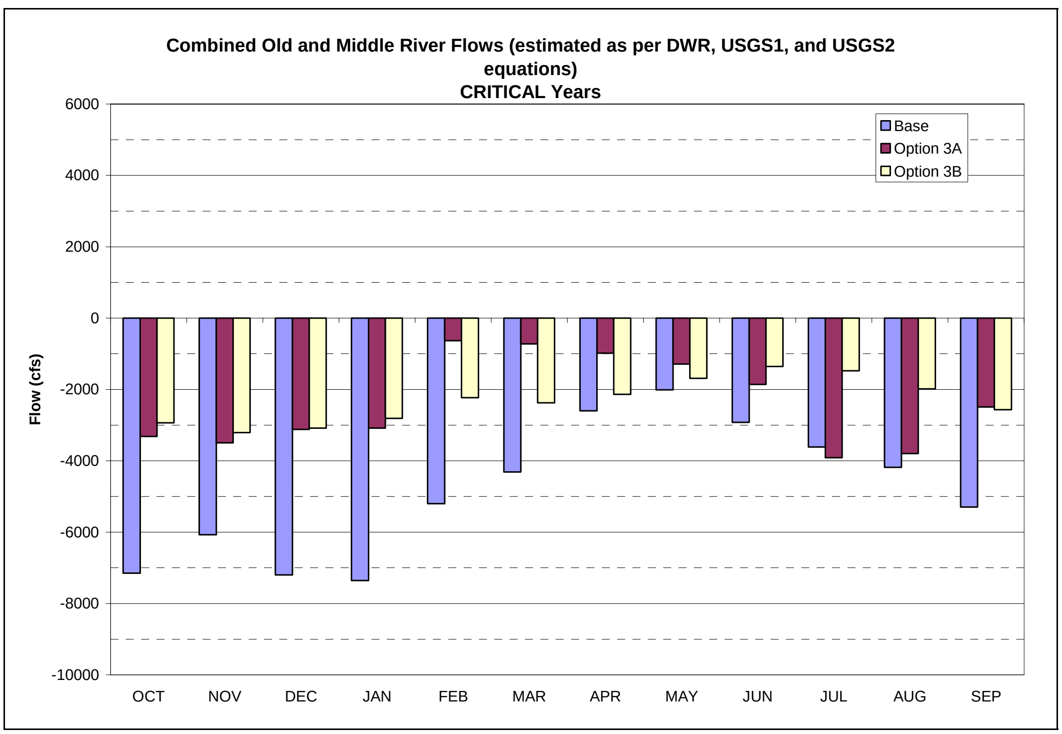


Figure F-6e. Combined Old and Middle River Critical Year Average Flows

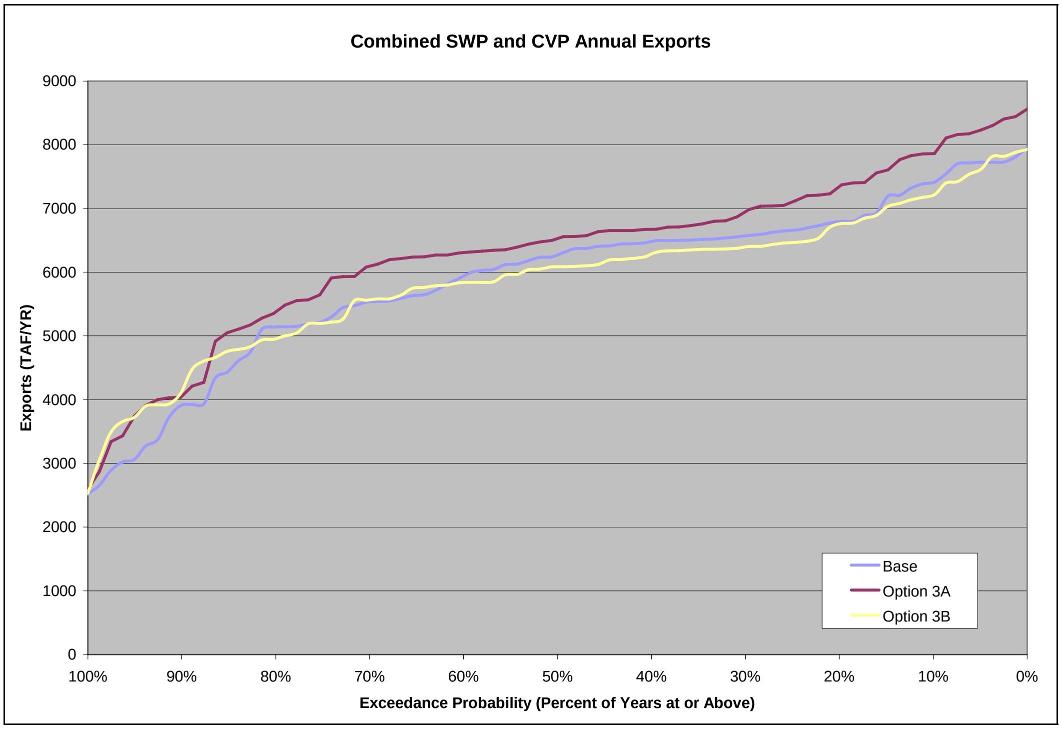


Figure F-7. Water Supply Frequency: Combined SWP and CVP Annual Delta Exports

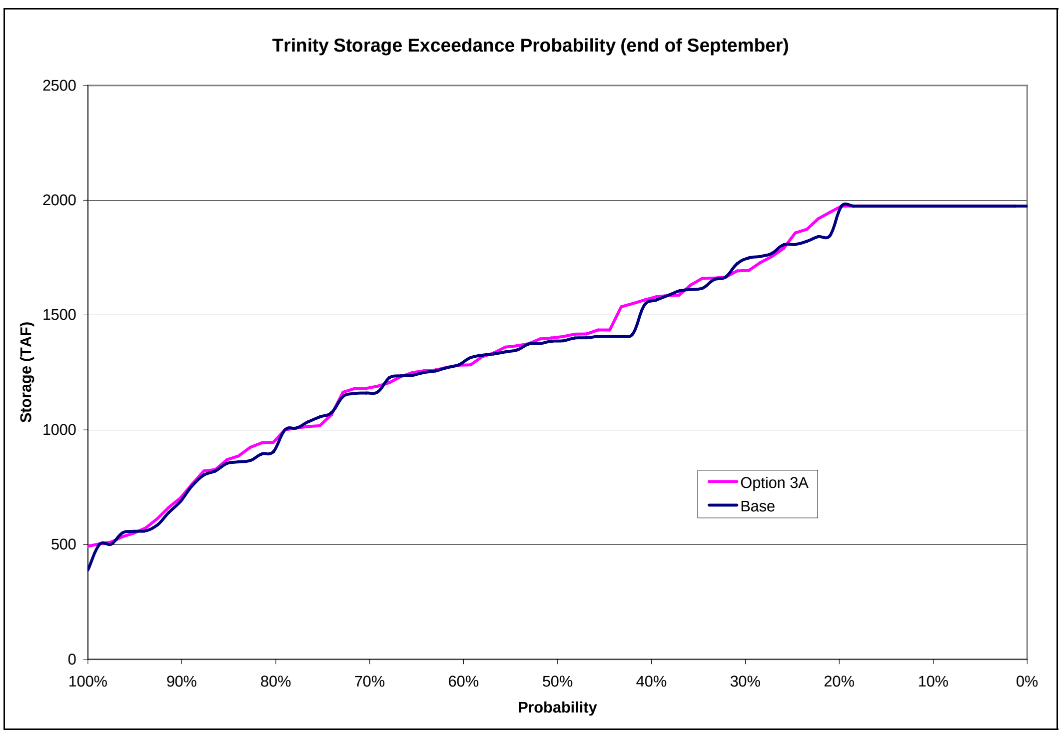


Figure F-8a. Option 3A CVP Northern Delta Storage Frequency: Trinity

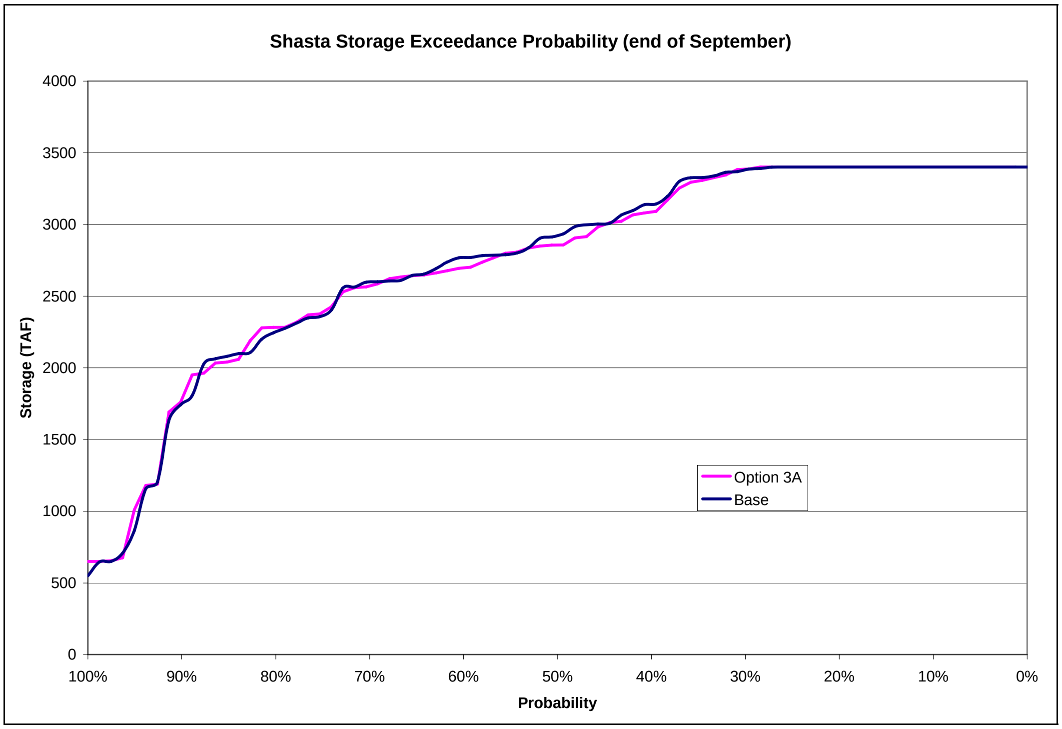


Figure F-8b. Option 3A CVP Northern Delta Storage Frequency: Shasta

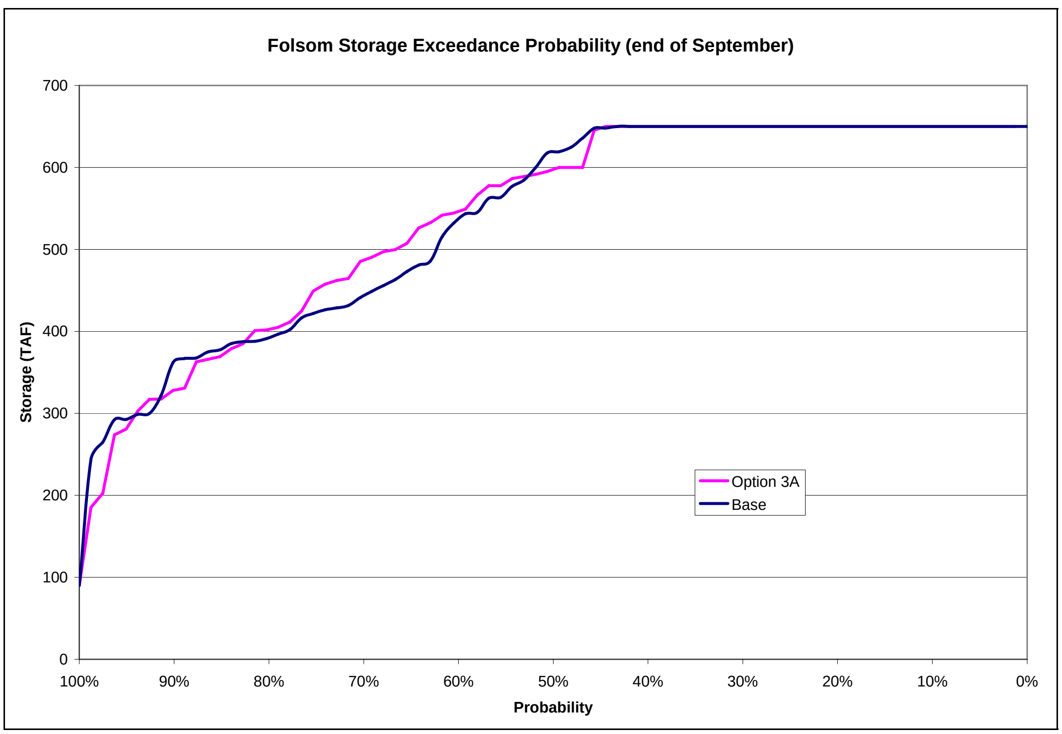


Figure F-8c. Option 3A CVP Northern Delta Storage Frequency: Folsom

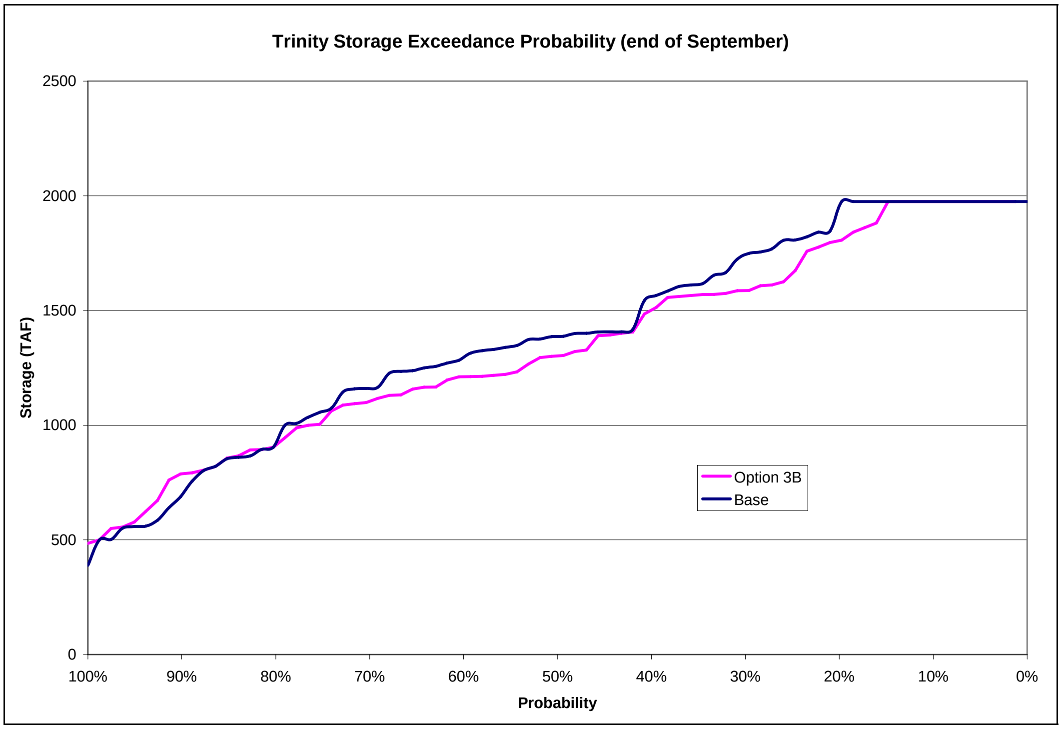


Figure F-9a. Option 3B CVP Northern Delta Storage Frequency: Trinity

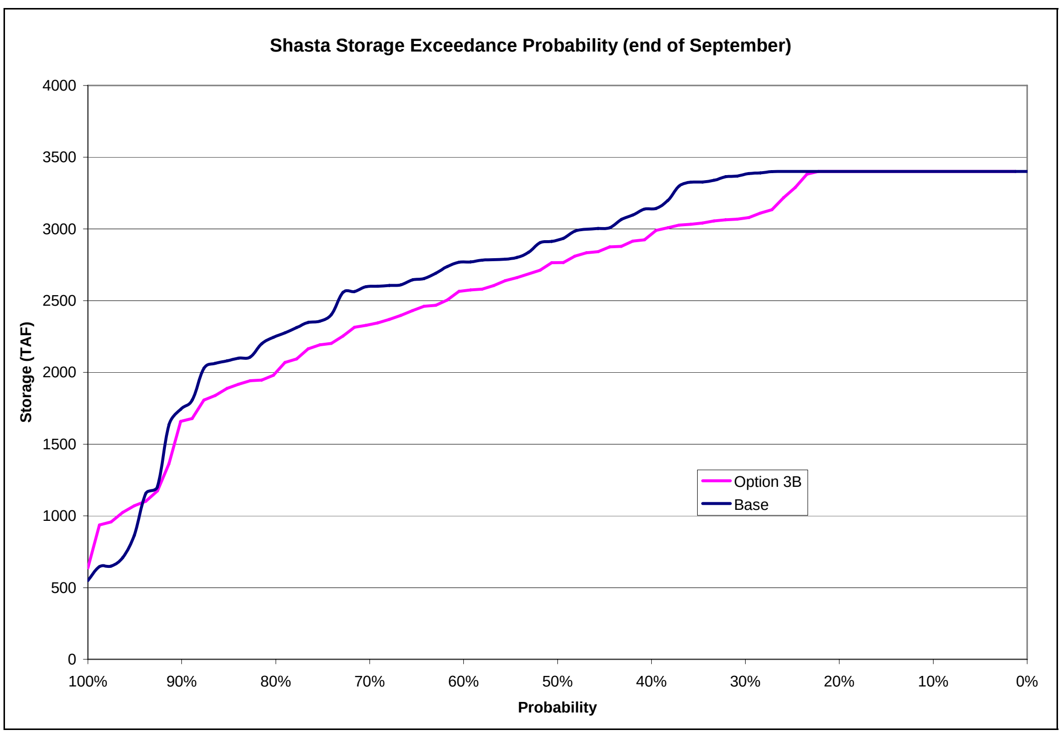


Figure F-9b. Option 3B CVP Northern Delta Storage Frequency: Shasta

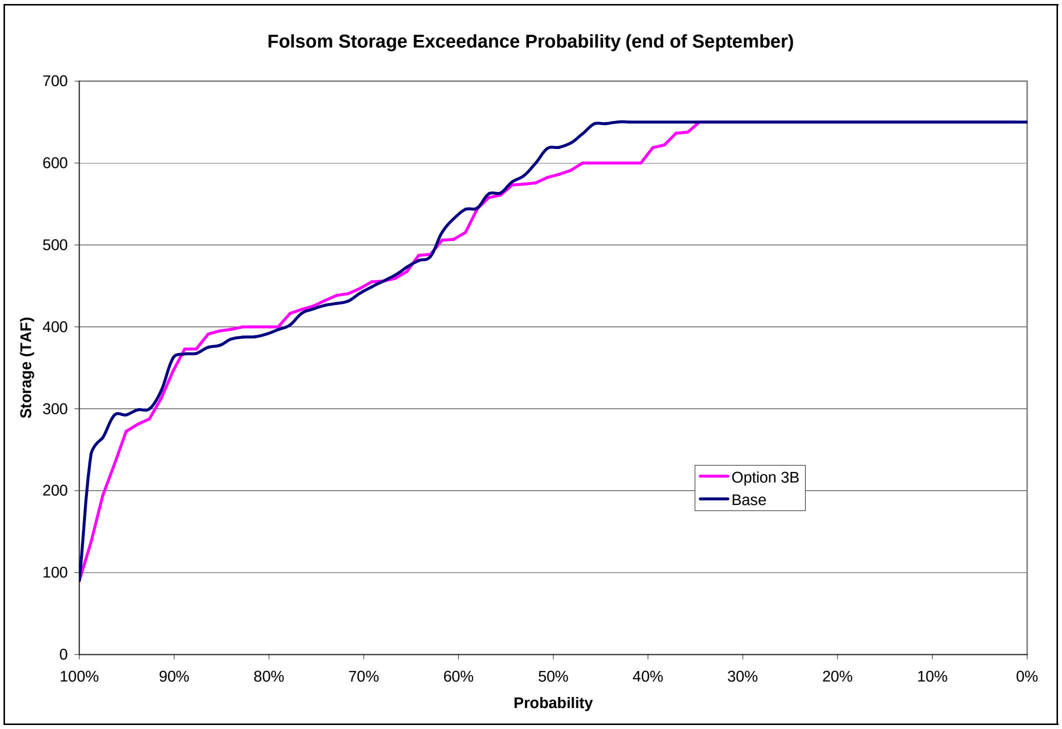


Figure F-9c. Option 3B CVP Northern Delta Storage Frequency: Folsom

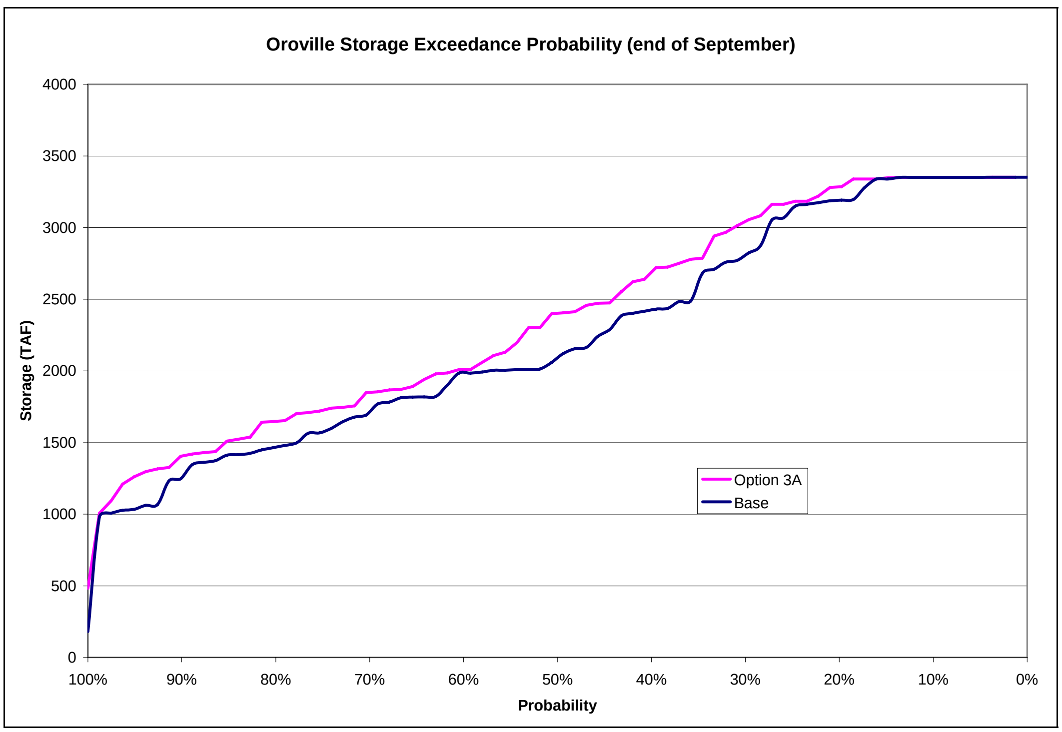


Figure F-10. Option 3A SWP Northern Delta Storage Frequency: Oroville

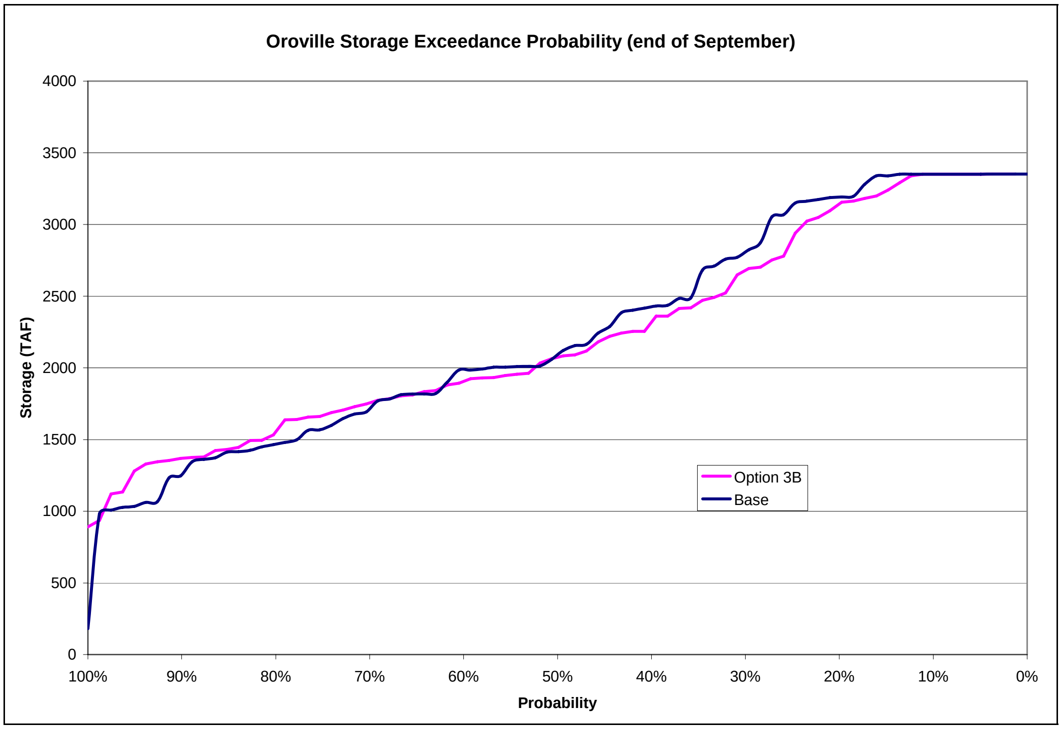


Figure F-11. Option 3B SWP Northern Delta Storage Frequency: Oroville

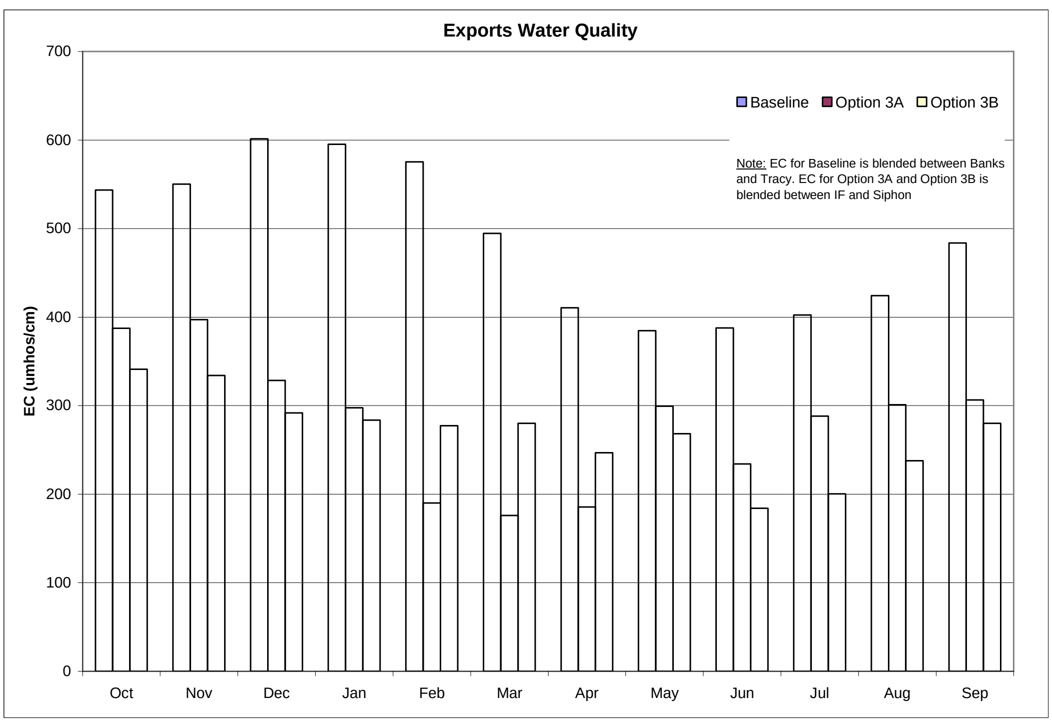


Figure F-12. Export Water Quality Annual Average, 1975-1991

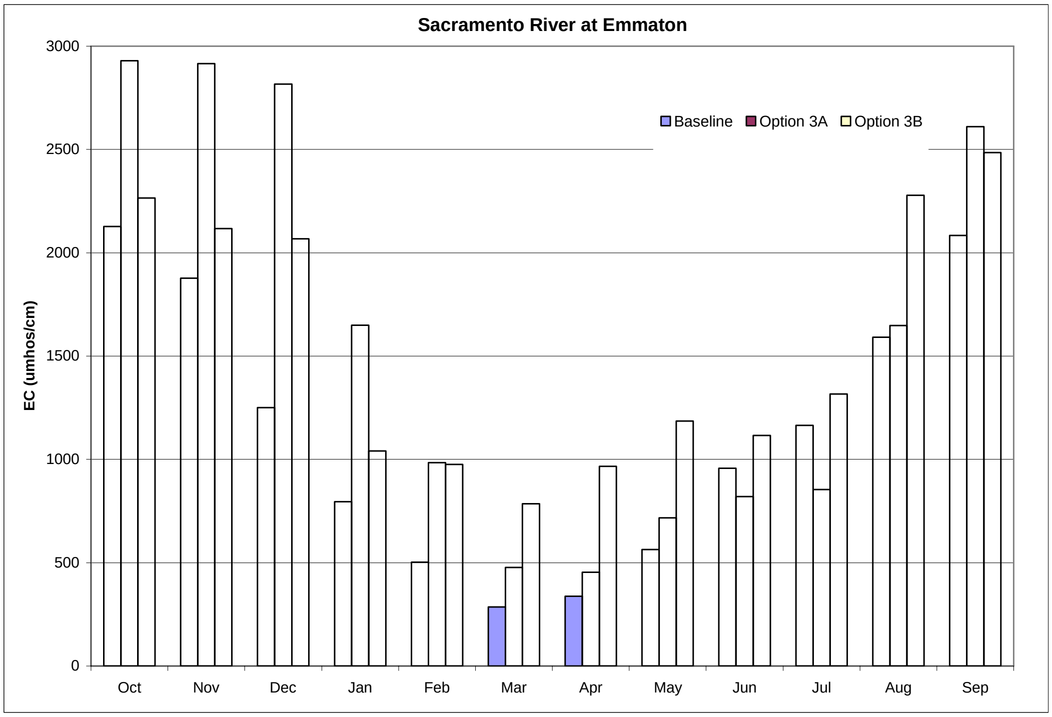


Figure F-13. In Delta Water Quality Annual Average, 1975-1991: Sacramento River at Emmaton

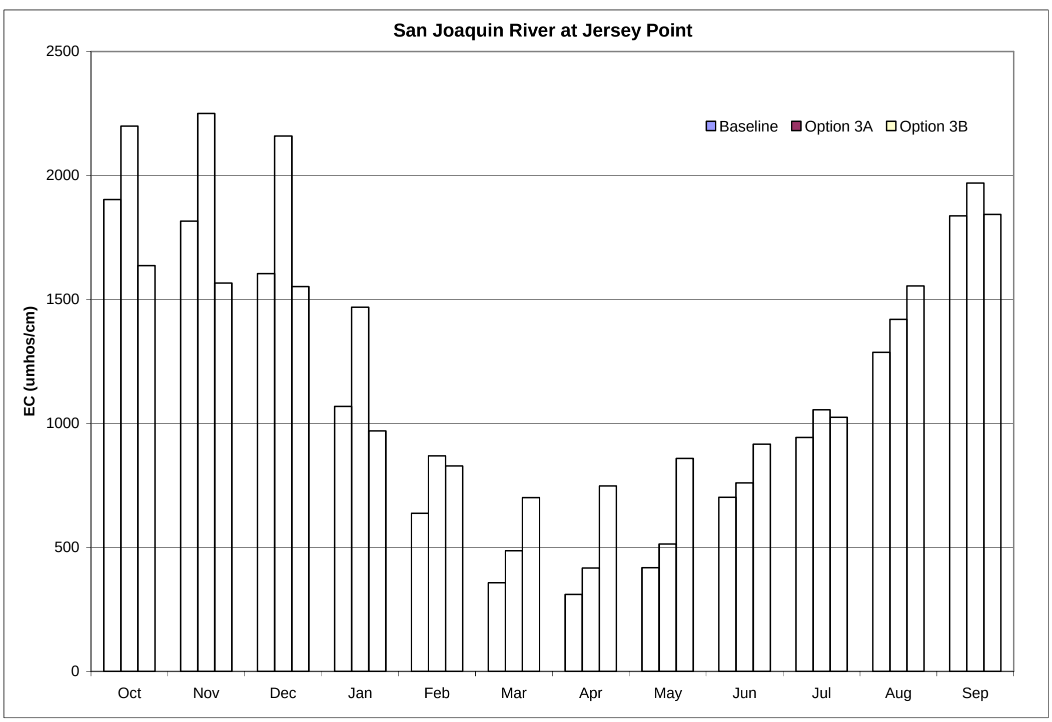


Figure F-14. In Delta Water Quality Annual Average, 1975-1991: San Joaquin River at Jersey Point

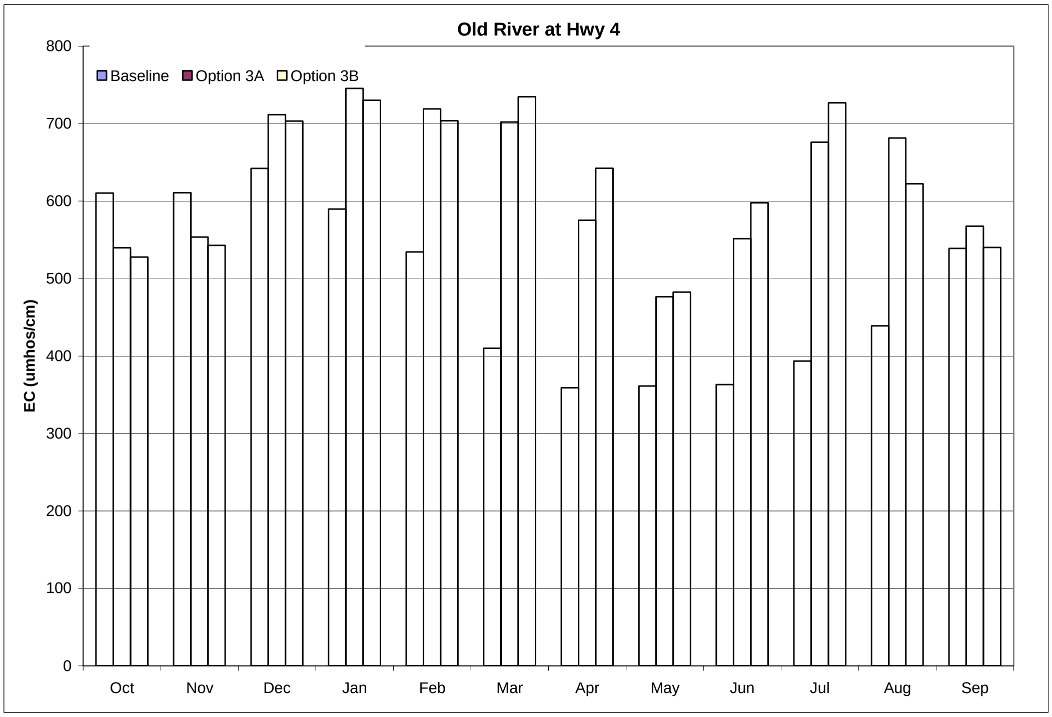


Figure F-15. In Delta Water Quality Annual Average, 1975-1991: Old River at Hwy 4

Table F-2. Option 3A Cumulative Particle Fate – September 1977

	Old River Sep 1977 Release - Cumulative particles (%)									
	7 Days		**14 Days**		**21 Days**		**28 Days**		**40 Days**	
	Base	**Option 3A**	**Base**	**Option 3A**	**Base**	**Option 3A**	**Base**	**Option 3A**	**Base**	**Option 3A**
DIVERSION_AG	1.7	0.3	4.0	0.5	5.0	0.9	5.6	1.4	6.7	2.6
PAST_CHIPPS	0.0	0.0	0.0	0.1	0.1	1.8	0.3	3.4	1.7	11.8
TO_SUISUN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EXPORTS*	53.1	0.0	67.5	0.0	75.3	0.0	79.9	0.0	84.3	2.5
CENTRAL	45.2	99.7	28.5	99.4	19.6	97.3	14.2	95.2	7.3	83.1

	Middle River Sep 1977 Release - Cumulative particles (%)									
	7 Days		**14 Days**		**21 Days**		**28 Days**		**40 Days**	
	Base	**Option 3A**	**Base**	**Option 3A**	**Base**	**Option 3A**	**Base**	**Option 3A**	**Base**	**Option 3A**
DIVERSION_AG	0.4	0.3	1.2	0.5	1.7	1.0	2.8	1.0	3.4	1.6
PAST_CHIPPS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TO_SUISUN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EXPORTS*	32.3	0.0	63.5	2.0	80.8	40.8	88.5	51.7	93.3	77.7
CENTRAL	67.3	99.7	35.3	97.5	17.5	58.2	8.7	47.3	3.3	20.7

	San Joaquin River d/s of Dutch Slough Sep 1977 Release - Cumulative particles (%)									
	7 Days		**14 Days**		**21 Days**		**28 Days**		**40 Days**	
	Base	**Option 3A**	**Base**	**Option 3A**	**Base**	**Option 3A**	**Base**	**Option 3A**	**Base**	**Option 3A**
DIVERSION_AG	0.0	0.0	0.1	0.0	0.1	0.0	0.3	0.1	0.7	0.2
PAST_CHIPPS	17.0	18.0	17.9	16.5	37.4	35.9	34.8	32.9	48.9	49.4
TO_SUISUN	0.1	0.3	0.0	0.0	0.3	0.3	0.0	0.1	0.2	0.0
EXPORTS*	0.0	0.0	0.5	0.0	2.1	0.0	4.5	0.0	11.0	0.8
CENTRAL	82.9	81.7	81.5	83.5	60.1	63.8	60.4	66.9	39.2	49.6
	Sacramento River Sep 1977 Release - Cumulative particles (%)									
	7 Days		**14 Days**		**21 Days**		**28 Days**		**40 Days**	
	Base	**Option 3A**	**Base**	**Option 2B**	**Base**	**Option 3A**	**Base**	**Option 3A**	**Base**	**Option 3A**
DIVERSION_AG	0.1	0.1	0.2	0.1	0.3	0.3	0.7	0.6	1.2	1.1
PAST_CHIPPS	0.3	0.0	1.1	1.4	9.0	10.1	10.0	11.0	20.6	23.0
TO_SUISUN	0.0	0.1	0.0	0.0	0.3	0.1	0.0	0.0	0.3	0.1
EXPORTS*	0.0	0.0	0.9	0.0	4.6	0.0	9.6	0.1	20.2	2.1
CENTRAL	99.6	99.8	97.8	98.5	85.8	89.5	79.7	88.3	57.7	73.7
	San Joaquin River u/s of HOR Sep 1977 Release - Cumulative particles (%)									
	7 Days		**14 Days**		**21 Days**		**28 Days**		**40 Days**	
	Base	**Option 3A**	**Base**	**Option 3A**	**Base**	**Option 3A**	**Base**	**Option 3A**	**Base**	**Option 3A**
DIVERSION_AG	7.1	2.3	7.9	4.4	9.8	7.1	11.2	9.7	13.6	13.9
PAST_CHIPPS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
TO_SUISUN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EXPORTS*	30.3	0.0	32.4	0.0	33.5	0.0	46.5	0.0	67.1	14.6
CENTRAL	62.6	97.7	59.7	95.6	56.7	92.9	42.3	90.3	19.3	71.4

* In Baseline, Exports is the sum of particles entering SWP and CVP. In the Option 3, it is the sum of particles leaving through IF diversion and Victoria Canal Siphon

Table F-3. Option 3A Cumulative Particle Fate – January 1981

	Old River Jan 1981 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 3A	Base	Option 3A	Base	Option 3A	Base	Option 3A	Base	Option 3A
DIVERSION_AG	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.2	0.0
PAST_CHIPPS	0.2	3.1	0.2	28.9	0.2	50.1	0.3	72.4	0.3	81.1
TO_SUISUN	0.0	0.9	0.0	2.9	0.0	4.9	0.0	6.6	0.0	8.2
EXPORTS*	90.4	0.0	95.1	0.0	97.6	0.0	98.0	0.0	98.7	0.0
CENTRAL	9.4	96.0	4.7	68.2	2.2	45.0	1.5	21.0	0.8	10.7

	Middle River Jan 1981 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 3A	Base	Option 3A	Base	Option 3A	Base	Option 3A	Base	Option 3A
DIVERSION_AG	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
PAST_CHIPPS	0.0	0.0	0.0	0.2	0.0	1.1	0.0	6.5	0.0	13.9
TO_SUISUN	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.2	0.0	1.2
EXPORTS*	82.2	0.0	97.2	0.0	99.7	0.0	99.8	0.0	99.9	0.0
CENTRAL	17.8	100.0	2.8	99.8	0.3	98.8	0.2	93.3	0.1	84.8

	San Joaquin River d/s of Dutch Slough Jan 1981 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 3A	Base	Option 3A	Base	Option 3A	Base	Option 3A	Base	Option 3A
DIVERSION_AG	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PAST_CHIPPS	35.1	64.3	51.5	85.0	54.9	87.6	57.4	88.4	58.4	88.4
TO_SUISUN	4.6	8.6	6.6	10.6	7.1	11.0	7.3	11.1	7.6	11.1
EXPORTS*	1.7	0.0	8.5	0.0	16.7	0.0	23.2	0.0	28.8	0.0
CENTRAL	58.6	27.1	33.4	4.4	21.3	1.4	12.1	0.5	5.2	0.5

	Sacramento River Jan 1981 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 3A	Base	Option 3A	Base	Option 3A	Base	Option 3A	Base	Option 3A
DIVERSION_AG	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PAST_CHIPPS	46.1	53.7	57.4	83.0	60.4	85.7	62.4	88.2	62.6	89.4
TO_SUISUN	4.8	5.9	6.3	8.3	6.6	9.1	6.9	9.4	6.9	9.4
EXPORTS*	2.4	0.0	10.2	0.0	16.9	0.0	22.2	0.0	27.0	0.0
CENTRAL	46.7	40.4	26.1	8.7	16.1	5.2	8.5	2.4	3.5	1.2

	San Joaquin River u/s of HOR Jan 1981 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 3A	Base	Option 3A	Base	Option 3A	Base	Option 3A	Base	Option 3A
DIVERSION_AG	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
PAST_CHIPPS	0.0	0.0	0.0	4.2	0.0	13.8	0.0	37.6	0.0	51.4
TO_SUISUN	0.0	0.0	0.0	0.3	0.0	2.0	0.0	4.1	0.0	6.2
EXPORTS*	65.1	0.0	70.4	0.0	86.3	0.0	93.5	0.0	96.1	0.0
CENTRAL	34.9	100.0	29.6	95.5	13.7	84.2	6.5	58.3	3.9	42.1

* In Baseline, Exports is the sum of particles entering SWP and CVP. In the Option 3, it is the sum of particles leaving through IF diversion and Victoria Canal Siphon

Table F-4. Option 3A Cumulative Particle Fate – March 1990

	Old River Mar 1990 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 3A	Base	Option 3A	Base	Option 3A	Base	Option 3A	Base	Option 3A
DIVERSION_AG	0.4	0.2	0.6	0.5	1.8	0.6	2.2	0.9	3.3	1.5
PAST_CHIPPS	0.0	0.5	0.1	2.1	0.9	10.8	0.8	13.8	1.6	33.8
TO_SUISUN	0.0	0.1	0.0	0.8	0.2	2.4	0.5	5.1	0.8	10.5
EXPORTS*	52.9	0.0	71.9	0.0	79.9	0.0	84.0	0.0	85.3	0.0
CENTRAL	46.7	99.2	27.4	96.6	17.2	86.2	12.5	80.2	9.0	54.2

	Middle River Mar 1990 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 3A	Base	Option 3A	Base	Option 3A	Base	Option 3A	Base	Option 3A
DIVERSION_AG	0.2	0.0	0.6	0.0	1.2	0.2	2.0	0.4	2.6	3.8
PAST_CHIPPS	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.2	0.1	1.6
TO_SUISUN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5
EXPORTS*	24.6	0.0	61.0	0.0	77.6	0.0	85.0	0.0	87.4	0.0
CENTRAL	75.2	100.0	38.4	100.0	21.2	99.6	13.0	99.4	9.9	94.1

	San Joaquin River d/s of Dutch Slough Mar 1990 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 3A	Base	Option 3A	Base	Option 3A	Base	Option 3A	Base	Option 3A
DIVERSION_AG	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.5	0.2
PAST_CHIPPS	31.6	38.3	35.3	39.4	51.8	58.9	47.2	52.2	56.5	64.5
TO_SUISUN	6.3	7.0	9.8	12.5	12.2	15.4	13.7	18.1	15.8	21.0
EXPORTS*	0.0	0.0	0.4	0.0	1.1	0.0	2.6	0.0	3.7	0.0
CENTRAL	62.1	54.7	54.5	48.1	34.9	25.7	36.3	29.7	23.5	14.3

	Sacramento River Mar 1990 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 3A	Base	Option 3A	Base	Option 3A	Base	Option 3A	Base	Option 3A
DIVERSION_AG	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.5	0.6
PAST_CHIPPS	20.6	4.8	26.0	9.9	39.3	31.6	36.7	29.8	47.7	51.1
TO_SUISUN	4.2	1.5	7.4	4.4	10.0	8.9	11.5	13.1	14.1	17.2
EXPORTS*	0.0	0.0	1.2	0.0	3.7	0.0	6.9	0.0	7.6	0.0
CENTRAL	75.2	93.7	65.4	85.6	46.9	59.4	44.8	57.0	30.1	31.1

	San Joaquin River u/s of HOR Mar 1990 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 3A	Base	Option 3A	Base	Option 3A	Base	Option 3A	Base	Option 3A
DIVERSION_AG	14.3	6.3	19.4	12.6	20.1	13.6	20.1	14.7	22.1	17.9
PAST_CHIPPS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	4.8
TO_SUISUN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.4
EXPORTS*	51.1	0.0	54.6	0.0	54.9	0.0	54.9	0.0	55.2	0.0
CENTRAL	34.6	93.7	26.0	87.4	25.0	86.4	25.0	85.2	22.7	75.9

* In Baseline, Exports is the sum of particles entering SWP and CVP. In the Option 3, it is the sum of particles leaving through IF diversion and Victoria Canal Siphon

Table F-5. Option 3B Cumulative Particle Fate – September 1977

	Old River Sep 1977 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 3B	Base	Option 3B	Base	Option 3B	Base	Option 3B	Base	Option 3B
DIVERSION_AG	1.7	0.4	4.0	0.6	5.0	1.2	5.6	1.6	6.7	1.7
PAST_CHIPPS	0.0	0.0	0.0	0.1	0.1	2.1	0.3	2.8	1.7	12.2
TO_SUISUN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EXPORTS*	53.1	0.0	67.5	0.0	75.3	0.0	79.9	0.0	84.3	2.2
CENTRAL	45.2	99.6	28.5	99.3	19.6	96.7	14.2	95.6	7.3	83.9

	Middle River Sep 1977 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 3B	Base	Option 3B	Base	Option 3B	Base	Option 3B	Base	Option 3B
DIVERSION_AG	0.4	0.3	1.2	0.5	1.7	0.9	2.8	1.2	3.4	1.5
PAST_CHIPPS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TO_SUISUN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EXPORTS*	32.3	0.0	63.5	3.9	80.8	45.3	88.5	56.2	93.3	80.1
CENTRAL	67.3	99.7	35.3	95.6	17.5	53.8	8.7	42.6	3.3	18.4

	San Joaquin River d/s of Dutch Slough Sep 1977 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 3B	Base	Option 3B	Base	Option 3B	Base	Option 3B	Base	Option 3B
DIVERSION_AG	0.0	0.0	0.1	0.0	0.1	0.0	0.3	0.0	0.7	0.1
PAST_CHIPPS	17.0	17.4	17.9	18.5	37.4	38.6	34.8	37.1	48.9	54.9
TO_SUISUN	0.1	0.3	0.0	0.0	0.3	0.1	0.0	0.2	0.2	0.2
EXPORTS*	0.0	0.0	0.5	0.0	2.1	0.0	4.5	0.0	11.0	1.5
CENTRAL	82.9	82.3	81.5	81.5	60.1	61.3	60.4	62.7	39.2	43.3

	Sacramento River Sep 1977 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 3B	Base	Option 3B	Base	Option 3B	Base	Option 3B	Base	Option 3B
DIVERSION_AG	0.1	0.0	0.2	0.0	0.3	0.1	0.7	0.5	1.2	0.7
PAST_CHIPPS	0.3	0.7	1.1	1.3	9.0	11.7	10.0	12.8	20.6	27.7
TO_SUISUN	0.0	0.0	0.0	0.0	0.3	0.1	0.0	0.0	0.3	0.2
EXPORTS*	0.0	0.0	0.9	0.0	4.6	0.0	9.6	0.0	20.2	2.1
CENTRAL	99.6	99.3	97.8	98.7	85.8	88.1	79.7	86.7	57.7	69.3

	San Joaquin River u/s of HOR Sep 1977 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 3B	Base	Option 3B	Base	Option 3B	Base	Option 3B	Base	Option 3B
DIVERSION_AG	7.1	1.9	7.9	5.1	9.8	7.6	11.2	9.9	13.6	15.0
PAST_CHIPPS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
TO_SUISUN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EXPORTS*	30.3	0.0	32.4	0.0	33.5	0.0	46.5	0.0	67.1	15.2
CENTRAL	62.6	98.1	59.7	94.9	56.7	92.4	42.3	90.1	19.3	69.6

* In Baseline, Exports is the sum of particles entering SWP and CVP. In the Option 3, it is the sum of particles leaving through IF diversion and Victoria Canal Siphon

Table F-6. Option 3B Cumulative Particle Fate – January 1981

	Old River Jan 1981 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 3B	Base	Option 3B	Base	Option 3B	Base	Option 3B	Base	Option 3B
DIVERSION_AG	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.2	0.0
PAST_CHIPPS	0.2	1.1	0.2	17.0	0.2	30.2	0.3	57.9	0.3	72.6
TO_SUISUN	0.0	0.1	0.0	1.2	0.0	4.2	0.0	6.4	0.0	10.0
EXPORTS*	90.4	0.0	95.1	0.0	97.6	0.0	98.0	0.0	98.7	0.0
CENTRAL	9.4	98.8	4.7	81.8	2.2	65.6	1.5	35.7	0.8	17.4

	Middle River Jan 1981 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 3B	Base	Option 3B	Base	Option 3B	Base	Option 3B	Base	Option 3B
DIVERSION_AG	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PAST_CHIPPS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.0	2.2
TO_SUISUN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.2
EXPORTS*	82.2	0.0	97.2	0.0	99.7	5.1	99.8	12.1	99.9	39.2
CENTRAL	17.8	100.0	2.8	100.0	0.3	94.9	0.2	86.9	0.1	58.4

	San Joaquin River d/s of Dutch Slough Jan 1981 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 3B	Base	Option 3B	Base	Option 3B	Base	Option 3B	Base	Option 3B
DIVERSION_AG	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PAST_CHIPPS	35.1	48.5	51.5	76.4	54.9	78.7	57.4	84.5	58.4	85.4
TO_SUISUN	4.6	7.0	6.6	10.9	7.1	12.4	7.3	13.0	7.6	13.3
EXPORTS*	1.7	0.0	8.5	0.0	16.7	0.0	23.2	0.0	28.8	0.0
CENTRAL	58.6	44.5	33.4	12.7	21.3	8.9	12.1	2.5	5.2	1.3

	Sacramento River Jan 1981 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 3B	Base	Option 3B	Base	Option 3B	Base	Option 3B	Base	Option 3B
DIVERSION_AG	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PAST_CHIPPS	46.1	19.4	57.4	60.0	60.4	67.0	62.4	79.7	62.6	82.3
TO_SUISUN	4.8	4.5	6.3	9.9	6.6	12.2	6.9	13.0	6.9	14.0
EXPORTS*	2.4	0.0	10.2	0.0	16.9	0.0	22.2	0.0	27.0	0.0
CENTRAL	46.7	76.1	26.1	30.1	16.1	20.8	8.5	7.3	3.5	3.7

	San Joaquin River u/s of HOR Jan 1981 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 3B	Base	Option 3B	Base	Option 3B	Base	Option 3B	Base	Option 3B
DIVERSION_AG	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
PAST_CHIPPS	0.0	0.0	0.0	1.4	0.0	7.4	0.0	29.4	0.0	50.5
TO_SUISUN	0.0	0.0	0.0	0.3	0.0	1.6	0.0	3.2	0.0	6.5
EXPORTS*	65.1	0.0	70.4	0.0	86.3	0.0	93.5	0.0	96.1	0.1
CENTRAL	34.9	100.0	29.6	98.3	13.7	91.0	6.5	67.4	3.9	42.6

* In Baseline, Exports is the sum of particles entering SWP and CVP. In the Option 3, it is the sum of particles leaving through IF diversion and Victoria Canal Siphon

Table F-7. Option 3B Cumulative Particle Fate – March 1990

	Old River Mar 1990 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 3B	Base	Option 3B	Base	Option 3B	Base	Option 3B	Base	Option 3B
DIVERSION_AG	0.4	0.1	0.6	0.3	1.8	0.5	2.2	1.3	3.3	3.6
PAST_CHIPPS	0.0	0.2	0.1	0.5	0.9	3.5	0.8	3.4	1.6	7.9
TO_SUISUN	0.0	0.0	0.0	0.2	0.2	0.5	0.5	1.5	0.8	4.3
EXPORTS*	52.9	0.0	71.9	0.0	79.9	0.0	84.0	0.0	85.3	0.5
CENTRAL	46.7	99.7	27.4	99.0	17.2	95.5	12.5	93.8	9.0	83.7

	Middle River Mar 1990 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 3B	Base	Option 3B	Base	Option 3B	Base	Option 3B	Base	Option 3B
DIVERSION_AG	0.2	0.3	0.6	2.6	1.2	3.3	2.0	3.8	2.6	4.4
PAST_CHIPPS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
TO_SUISUN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EXPORTS*	24.6	0.0	61.0	7.8	77.6	56.5	85.0	65.2	87.4	82.7
CENTRAL	75.2	99.7	38.4	89.6	21.2	40.2	13.0	31.0	9.9	12.9

	San Joaquin River d/s of Dutch Slough Mar 1990 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 3B	Base	Option 3B	Base	Option 3B	Base	Option 3B	Base	Option 3B
DIVERSION_AG	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.5	0.2
PAST_CHIPPS	31.6	29.0	35.3	26.1	51.8	38.8	47.2	30.9	56.5	37.7
TO_SUISUN	6.3	5.9	9.8	9.8	12.2	14.0	13.7	17.3	15.8	22.8
EXPORTS*	0.0	0.0	0.4	0.0	1.1	0.0	2.6	0.0	3.7	0.2
CENTRAL	62.1	65.1	54.5	64.1	34.9	47.2	36.3	51.8	23.5	39.1

	Sacramento River Mar 1990 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 3B	Base	Option 3B	Base	Option 3B	Base	Option 3B	Base	Option 3B
DIVERSION_AG	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.3	0.5	0.7
PAST_CHIPPS	20.6	2.3	26.0	4.6	39.3	17.3	36.7	15.1	47.7	22.0
TO_SUISUN	4.2	0.4	7.4	1.8	10.0	4.6	11.5	7.0	14.1	11.7
EXPORTS*	0.0	0.0	1.2	0.0	3.7	0.0	6.9	0.0	7.6	0.6
CENTRAL	75.2	97.3	65.4	93.5	46.9	78.0	44.8	77.6	30.1	65.0

	San Joaquin River u/s of HOR Mar 1990 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 3B	Base	Option 3B	Base	Option 3B	Base	Option 3B	Base	Option 3B
DIVERSION_AG	14.3	8.1	19.4	18.2	20.1	21.0	20.1	23.0	22.1	28.9
PAST_CHIPPS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TO_SUISUN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EXPORTS*	51.1	0.0	54.6	0.0	54.9	0.0	54.9	0.0	55.2	8.4
CENTRAL	34.6	91.9	26.0	81.8	25.0	79.0	25.0	77.0	22.7	62.7

* In Baseline, Exports is the sum of particles entering SWP and CVP. In the Option 3, it is the sum of particles leaving through IF diversion and Victoria Canal Siphon

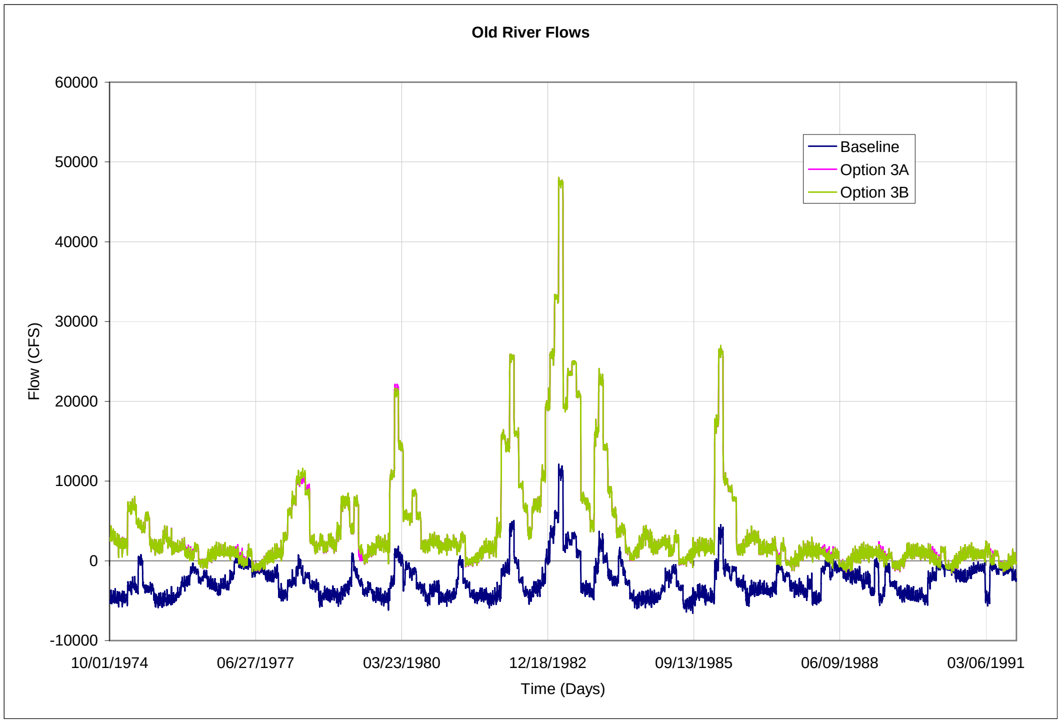


Figure F-16. DSM2 Simulated Daily Averaged Old River Flows

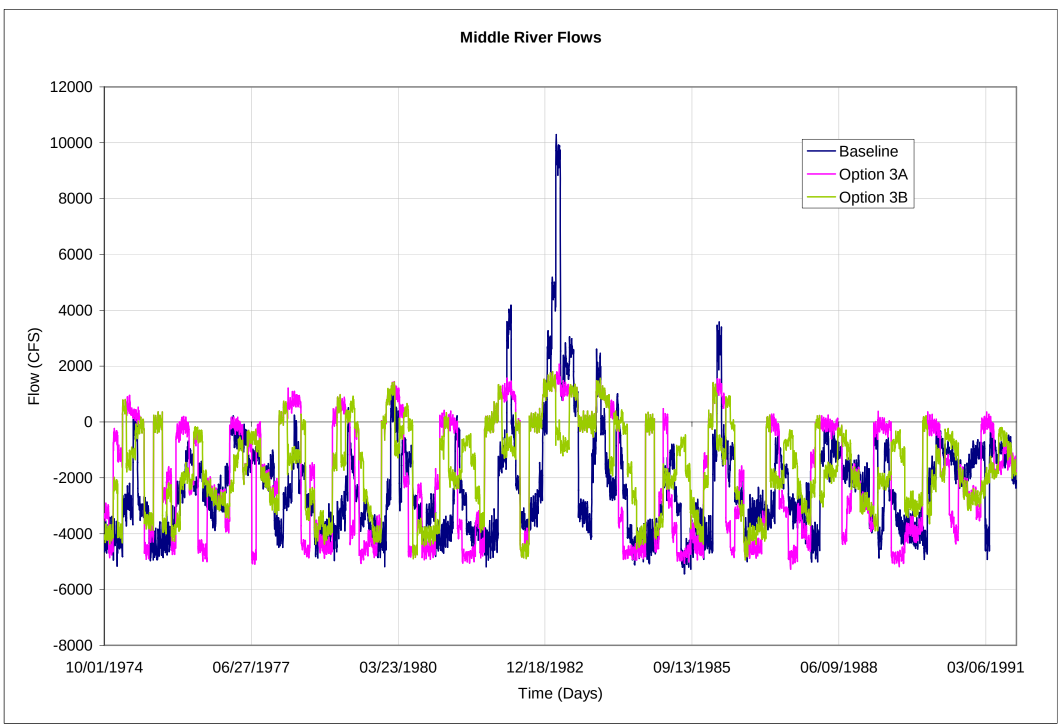


Figure F-17. DSM2 Simulated Daily Averaged Middle River Flows

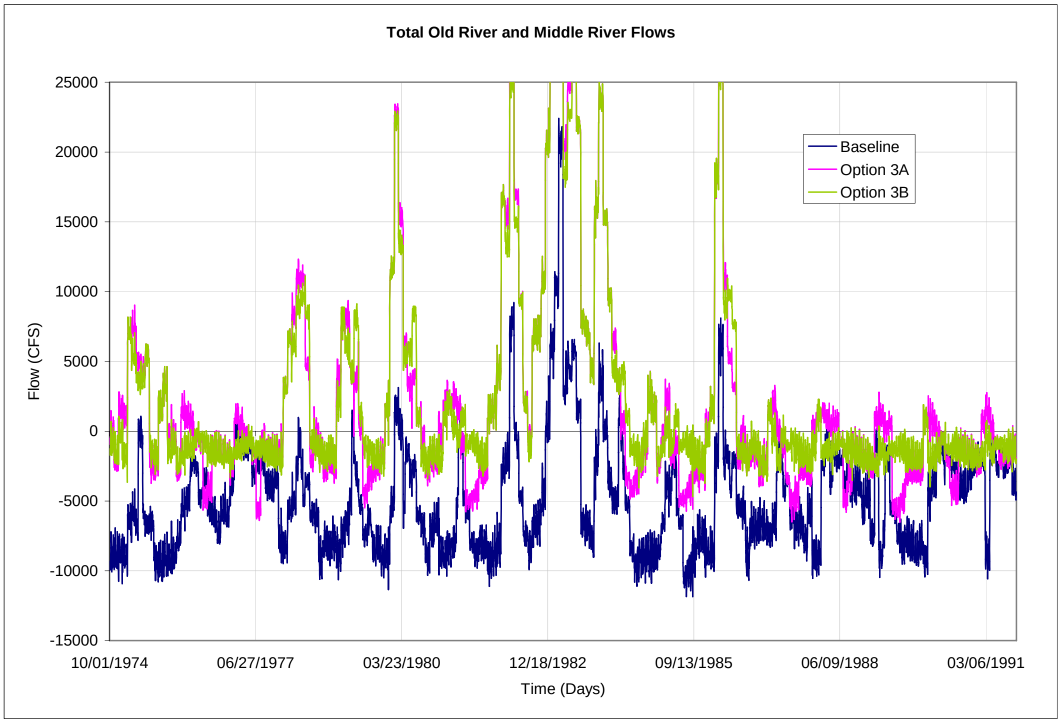


Figure F-18. DSM2 Simulated Daily Averaged Combined Old and Middle River Flows

Appendix G. Option 4 Hydrologic/Hydrodynamic Model Results

The following appendix presents hydrologic/hydrodynamic model results in the following tables and figures:

G. Option 4 Hydrologic/Hydrodynamic Model Results

Table G-1. Summary Output for the Implementation of Conservation Strategy: Option 4

	Base		Option 4A				Option 4B			
Delta flows[1]	**Annual Average[2] (1)**	**Dry period[3] (2)**	**Annual Average[2] (3)**	**Dry period[3] (4)**	**Change (3)-(1)**	**Change (4)-(2)**	**Annual Average[2] (5)**	**Dry period[3] (6)**	**Change (5)-(1)**	**Change (6)-(2)**
Sacramento River @ Hood	16,229	8,269	16,267	8,327	39	58	16,433	8,059	204	-210
San Joaquin River @ Vernalis	3,027	1,362	3,033	1,370	6	9	3,028	1,335	2	-27
Sacramento River @ Rio Vista	13,812	5,164	9,915	3,435	-3,897	-1,729	10,560	3,329	-3,252	-1,835
Delta Outflow	14,991	5,154	15,098	5,553	107	399	15,854	5,395	863	241
SWP/CVP Exports	5,902	3,572	5,824	3,243	-78	-329	5,129	3,101	-773	-472
QWEST (cfs)	1,620	-12	7,162	2,939	5,542	2,951	7,321	2,867	5,701	2,879
Old and Middle River (cfs)	-5,842	-4,635	657	-695	6,499	3,940	647	-740	6,489	3,894
Water quality[4]	**Annual Average[5] (1)**	**Dry period[3] (2)**	**Annual Average[5] (3)**	**Dry period[3] (4)**	**Change (3)-(1)**	**Change (4)-(2)**	**Annual Average[5] (5)**	**Dry period[3] (6)**	**Change (5)-(1)**	**Change (6)-(2)**
X2 (km)	76	82	74	81	-2	-1	74	81	-2	-1
EC Exports[6]	488		176		-312		176		-312	
EC at Emmaton	1,128		941		-187		904		-224	
EC at Jersey Point	1,074		638		-436		630		-444	
EC at Collinsville	3,816		3,068		-747		2,969		-846	
EC at Old River, Hwy 4	488		600		113		619		131	
Particle Transport and Fate[7]	**Average[8] (1)**		**Average[8] (2)**		**Change (2)-(1)**		**Average[8] (3)**		**Change (3)-(1)**	
Insertion on Old River @ Quimby Island	57		0		-57		0		-57	
Insertion on Middle River @ Mildred Island	59		0		-59		0		-59	
Insertion on San Joaquin River near Big Break	9		0		-9		0		-9	
Insertion on Sacramento River near Cache Slough	13		0		-13		0		-13	
Insertion on San Joaquin River near Head of Old River	47		0		-47		0		-47	

Table G-1. Summary Output for the Implementation of Conservation Strategy: Option 4

NOTES:
1. Units in TAF unless mentioned otherwise
2. Annual average, 1921-2003
3. Dry period, 1928-1934
4. Units in EC, µMHOS/cm unless mentioned otherwise
5. For EC conductivity parameter values represent 16-year monthly Period Averaged; for X2 values represent annual average, 1921-2003
6. Base: EC is blended between EC at Banks and EC at Tracy; Option 4A and 4B: EC Exports is EC at Isolated Facility diversion
7. Percentage of particles entering SWP and CVP pumping stations in Baseline and entering the isolated facility diversion in Option 4
8. Average of 1977, 1981 and 1990 releases of % cumulative particles ended up in exports at the end of 40 days

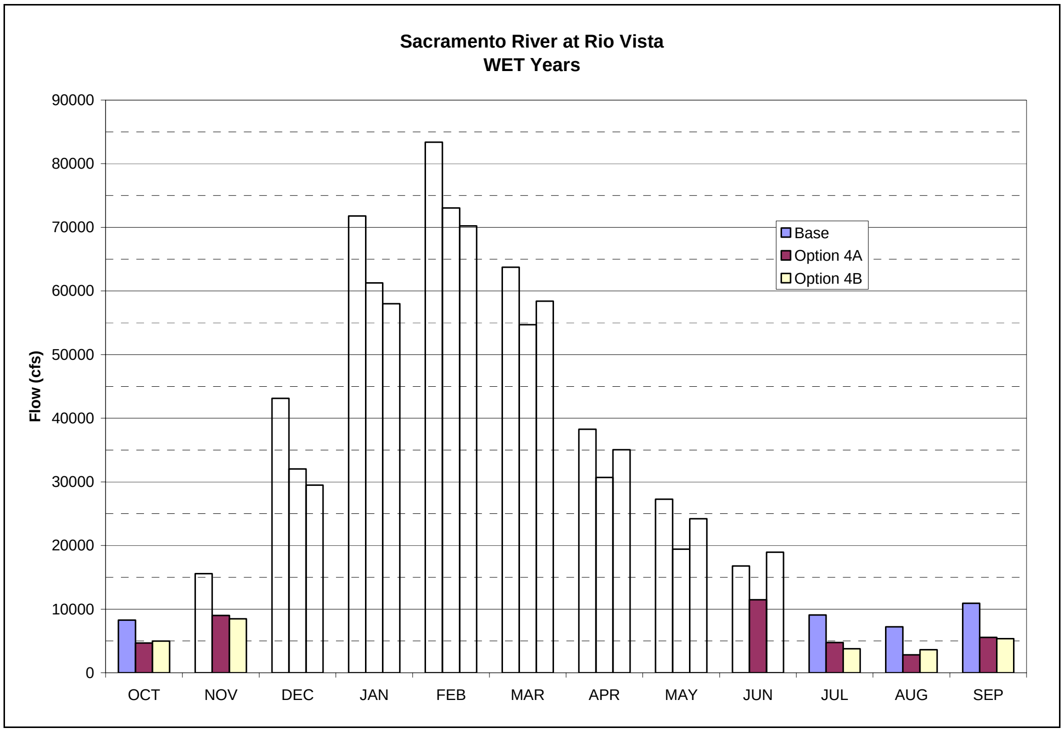


Figure G-1a. Sacramento River at Rio Vista Wet Year Average Flows

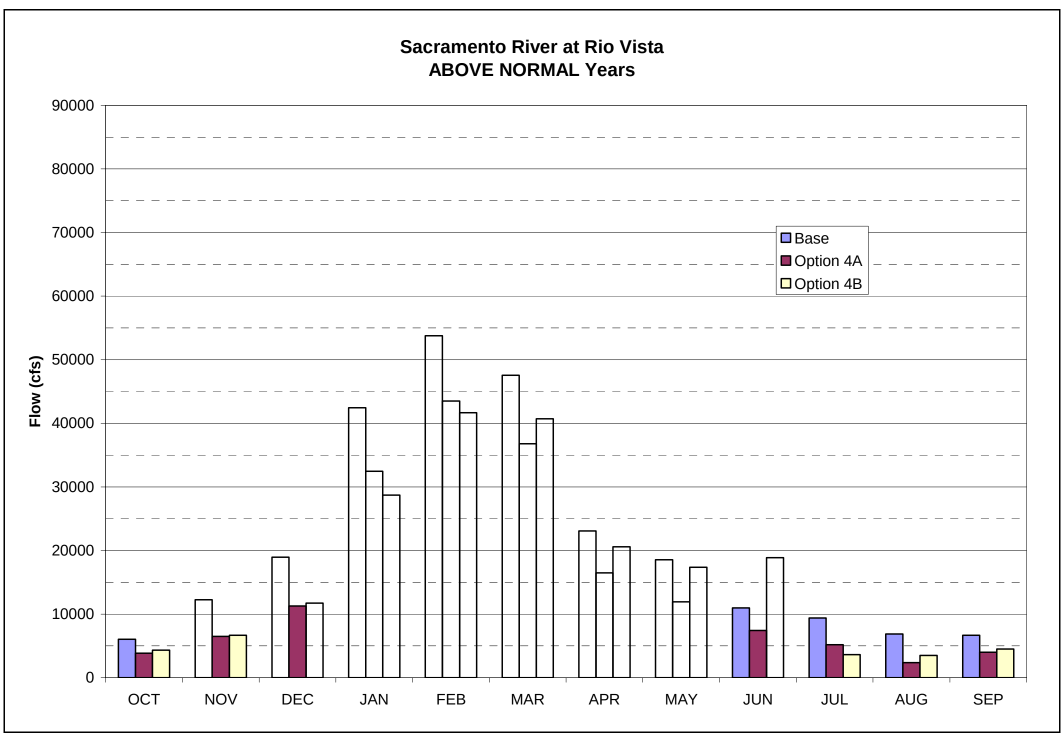


Figure G-1b. Sacramento River at Rio Vista Above Normal Year Average Flows

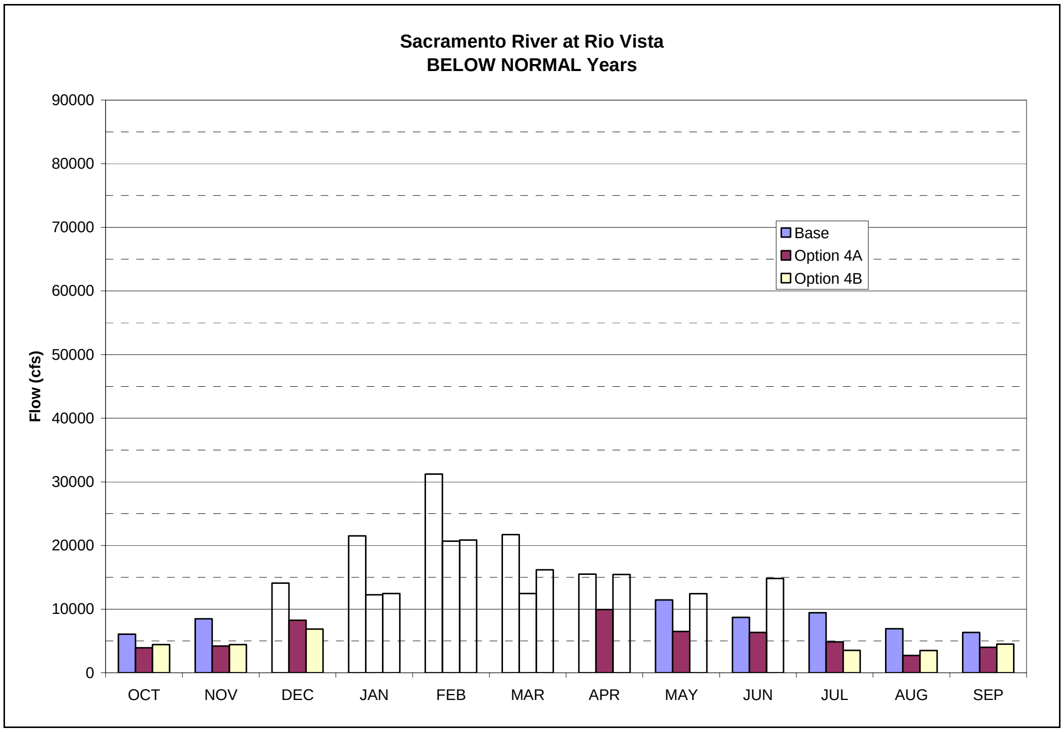


Figure G-1c. Sacramento River at Rio Vista Below Normal Year Average Flows

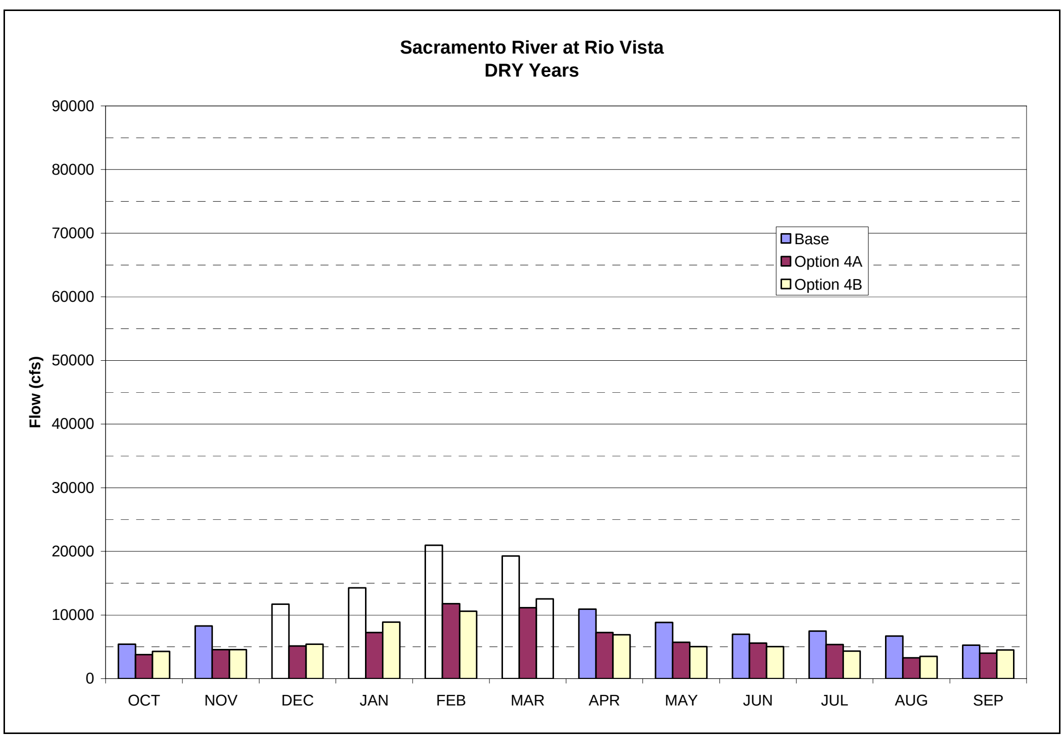


Figure G-1d. Sacramento River at Rio Vista Dry Year Average Flows

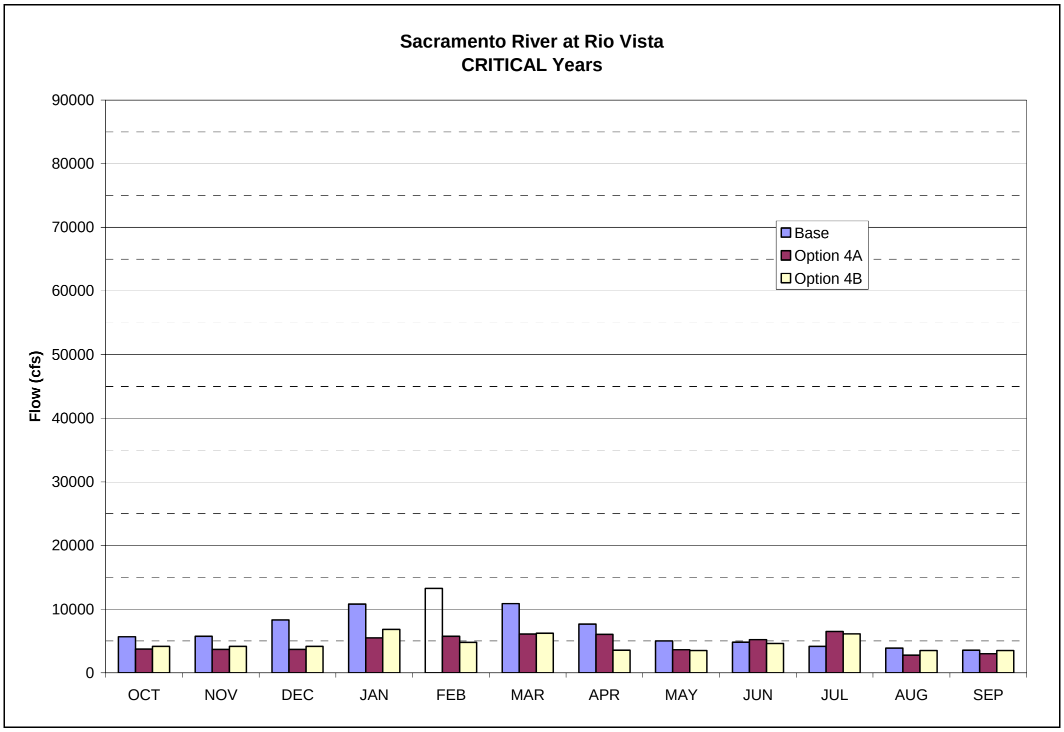


Figure G-1e. Sacramento River at Rio Vista Critical Year Average Flows

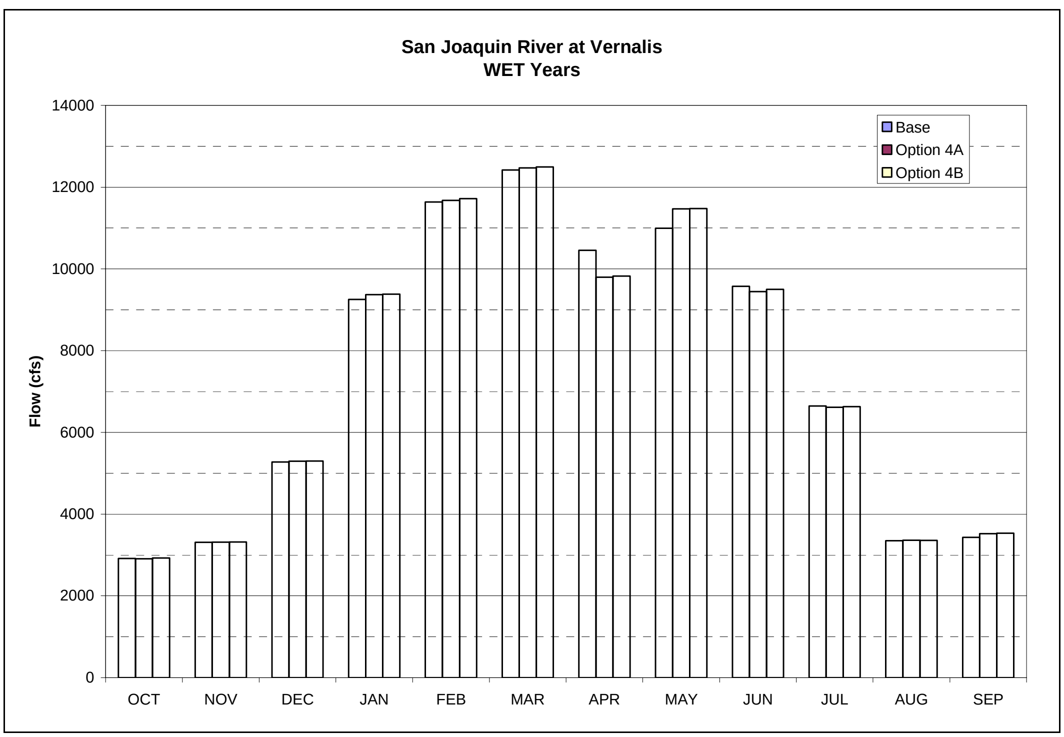


Figure G-2a. San Joaquin River at Vernalis Wet Year Average Flows

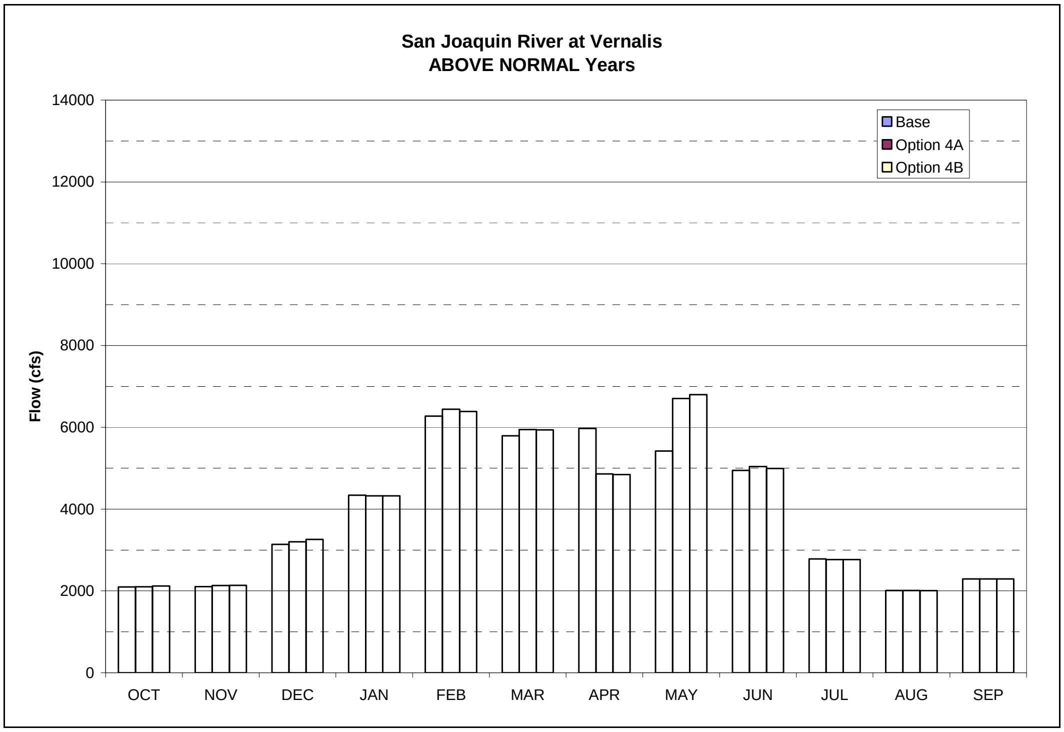


Figure G-2b. San Joaquin River at Vernalis Above Normal Year Average Flows

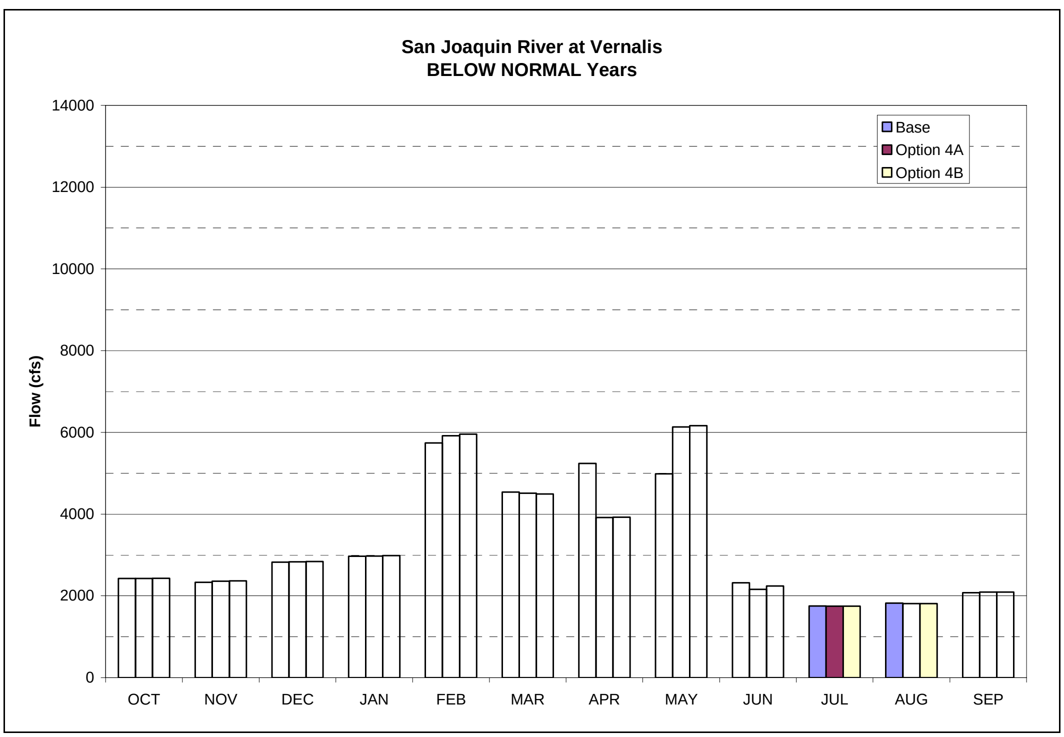


Figure G-2c. San Joaquin River at Vernalis Below Normal Year Average Flows

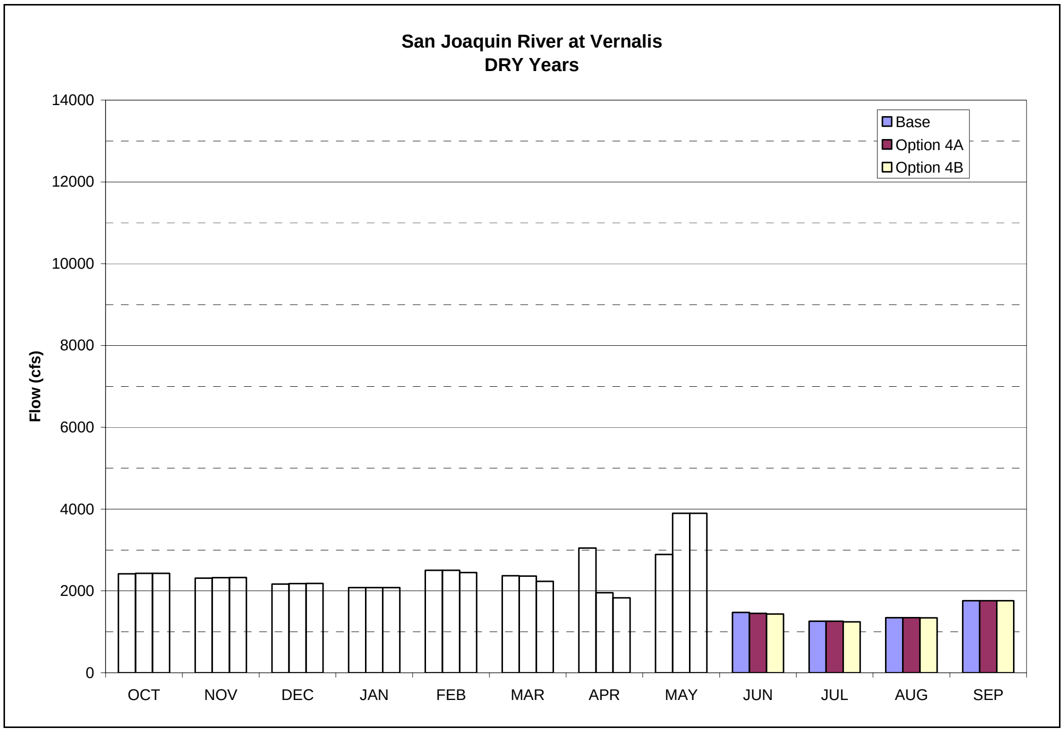


Figure G-2d. San Joaquin River at Vernalis Dry Year Average Flows

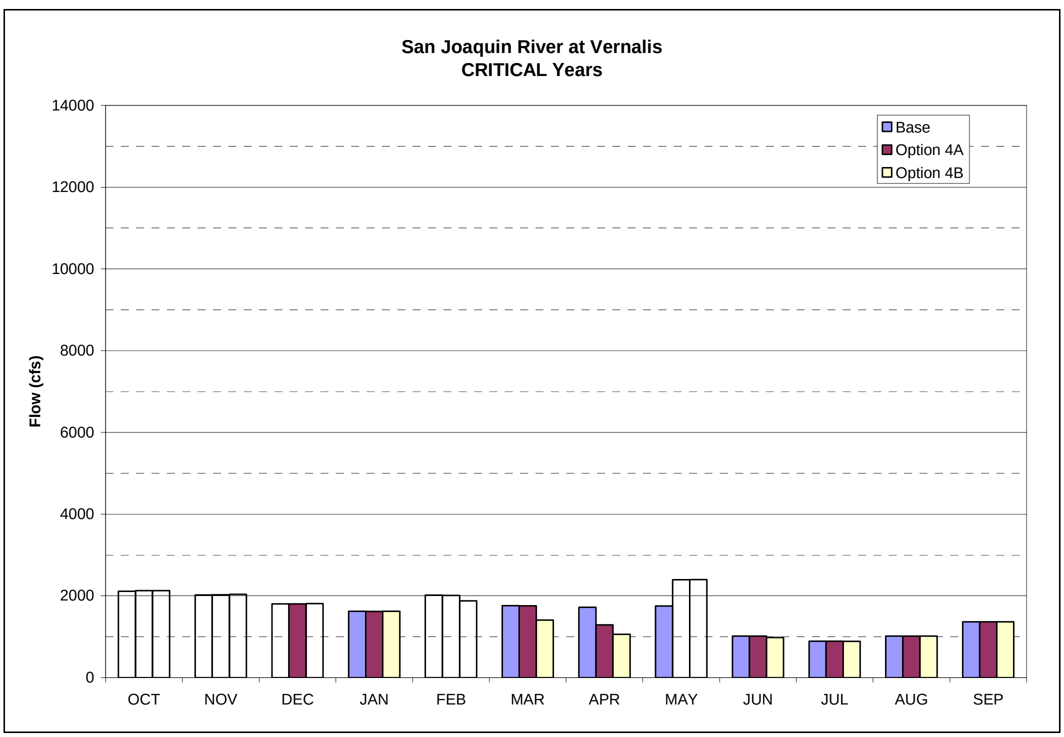


Figure G-2e. San Joaquin River at Vernalis Critical Year Average Flows

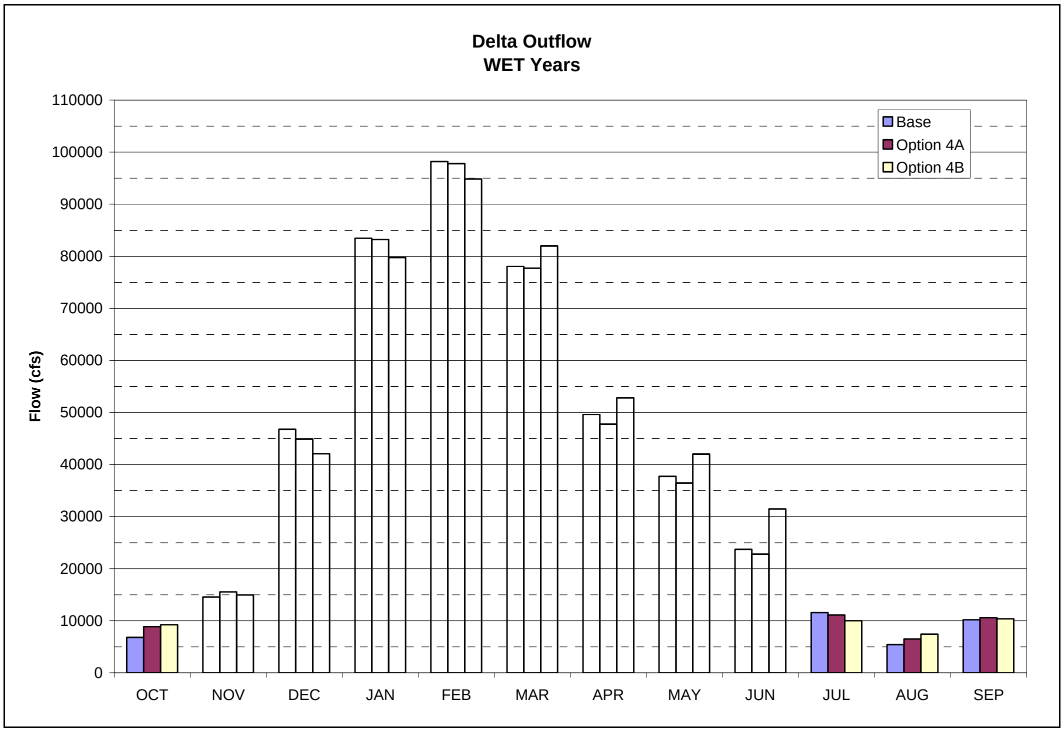


Figure G-3a. Delta Outflow Wet Year Average Flows

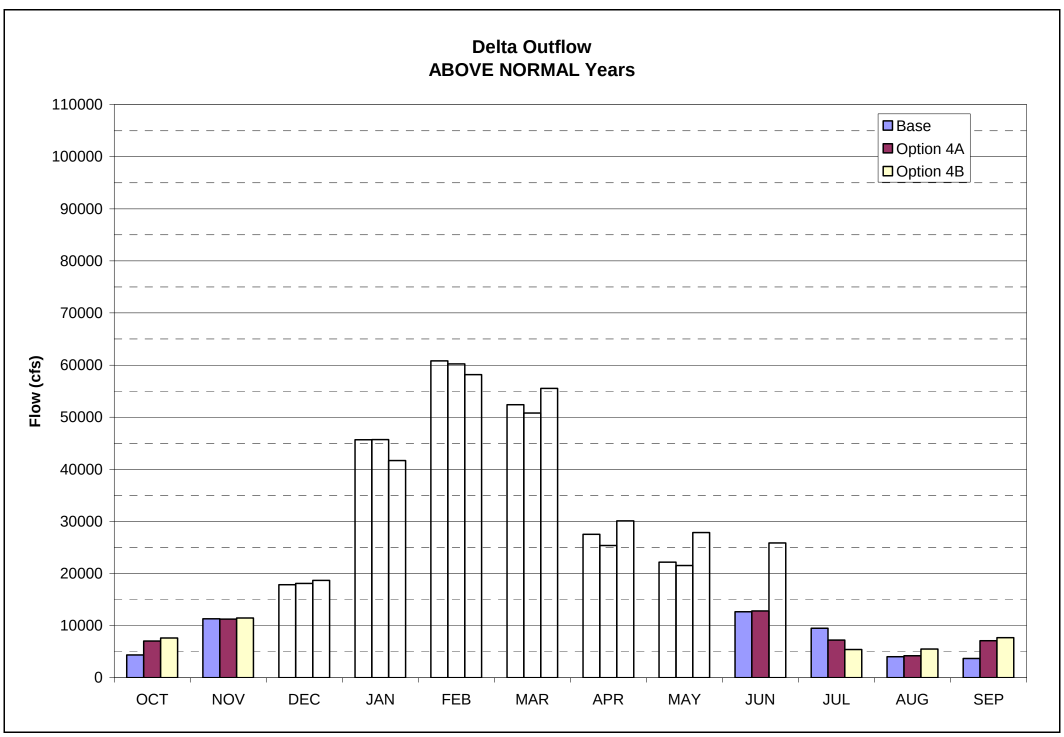


Figure G-3b. Delta Outflow Above Normal Year Average Flows

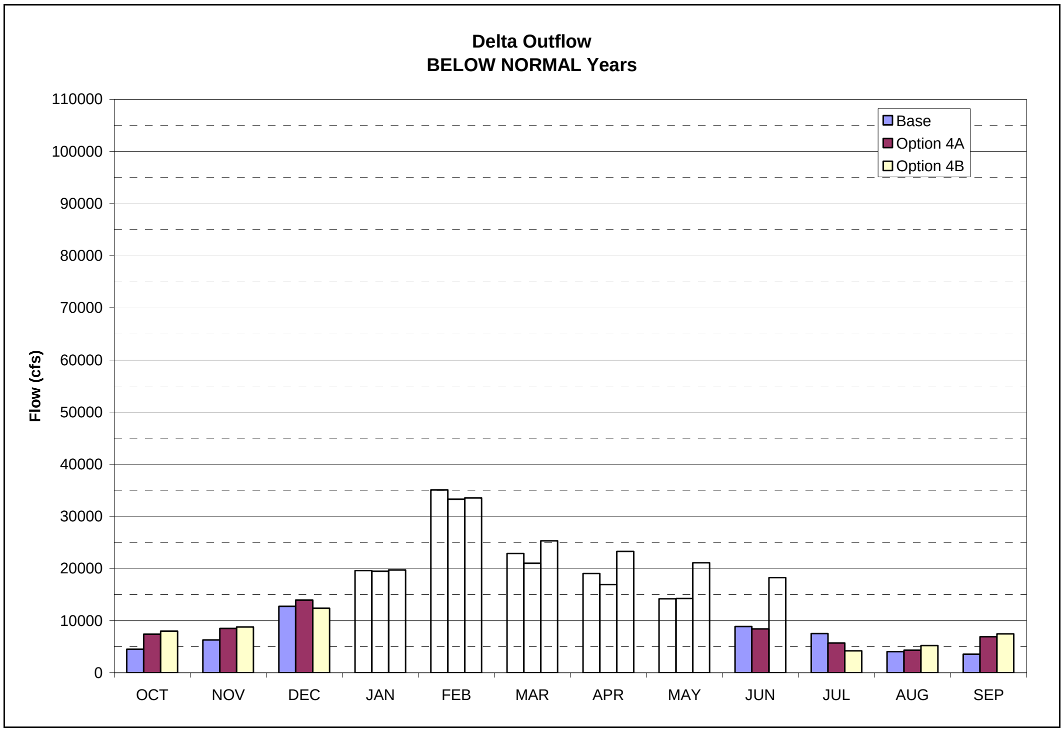


Figure G-3c. Delta Outflow Below Normal Year Average Flows

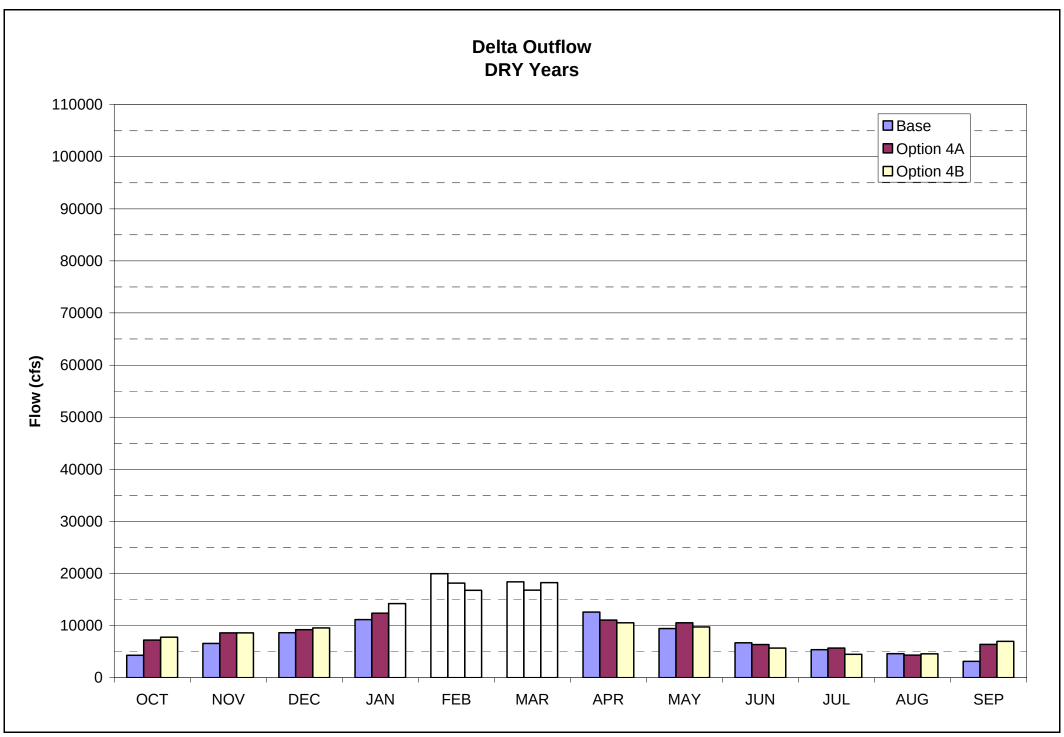


Figure G-3d. Delta Outflow Dry Year Average Flows

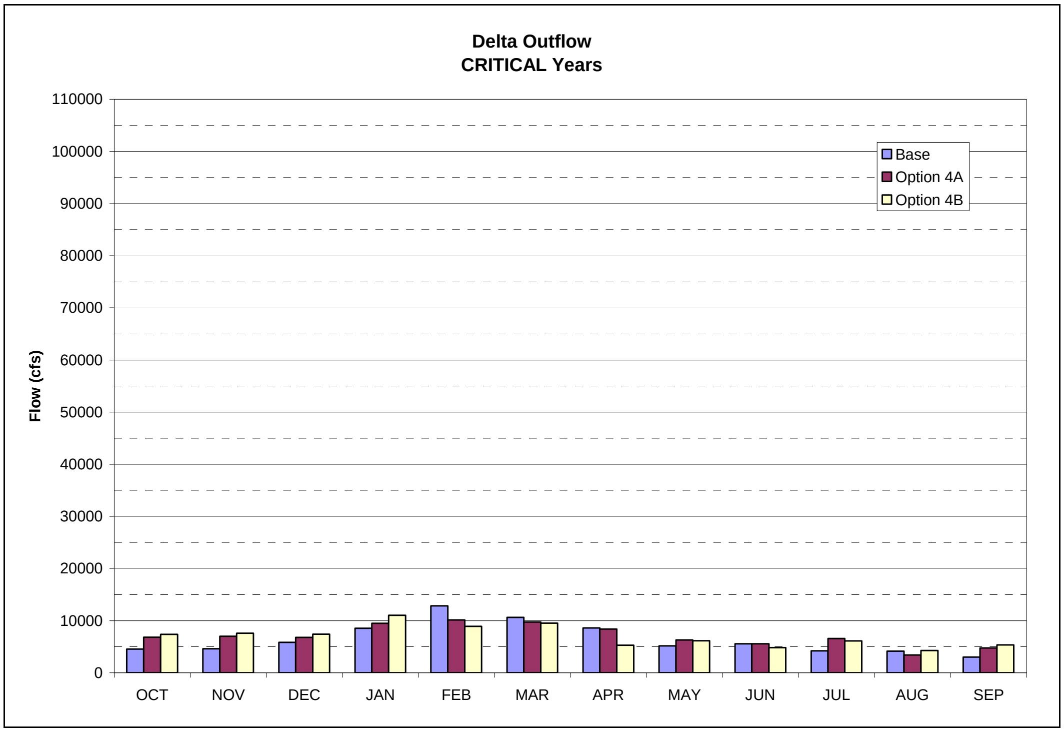


Figure G-3e. Delta Outflow Critical Year Average Flows

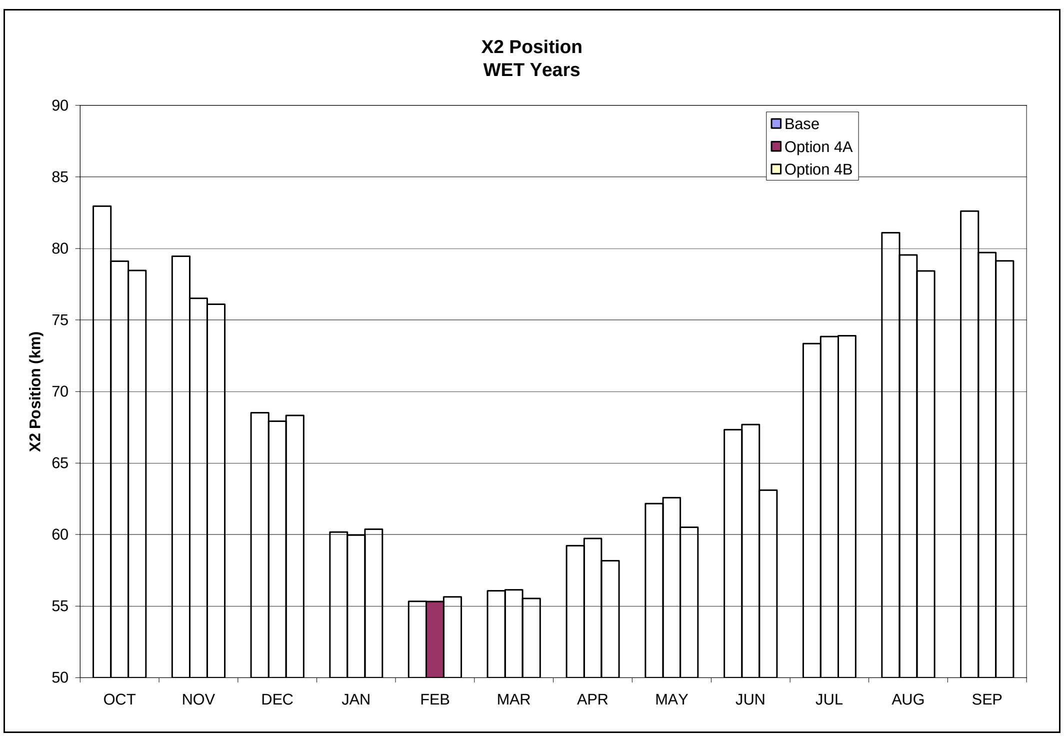


Figure G-4a. X2 Wet Year Average Distance

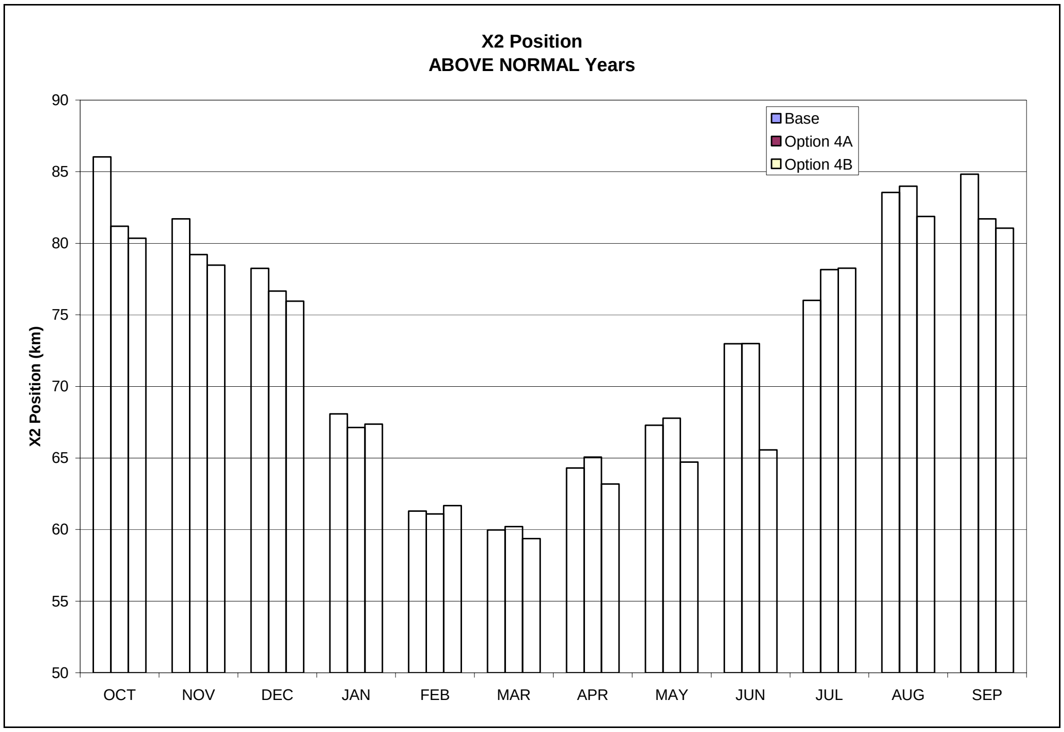


Figure G-4b. X2 Above Normal Year Average Distance

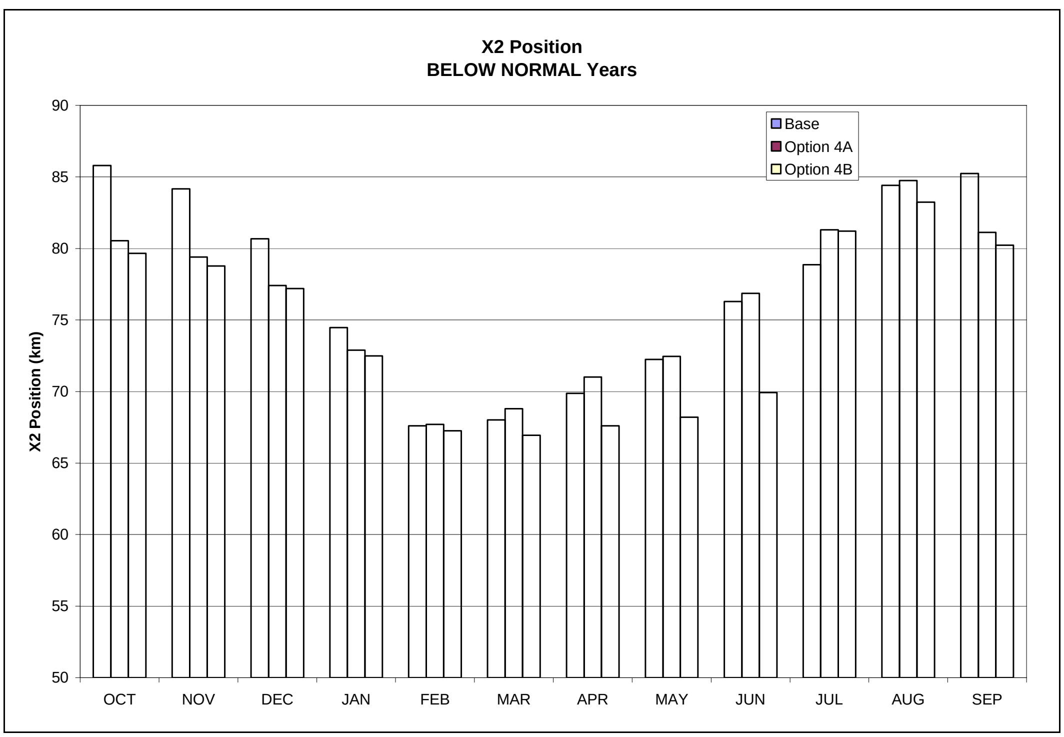


Figure G-4c. X2 Below Normal Year Average Distance

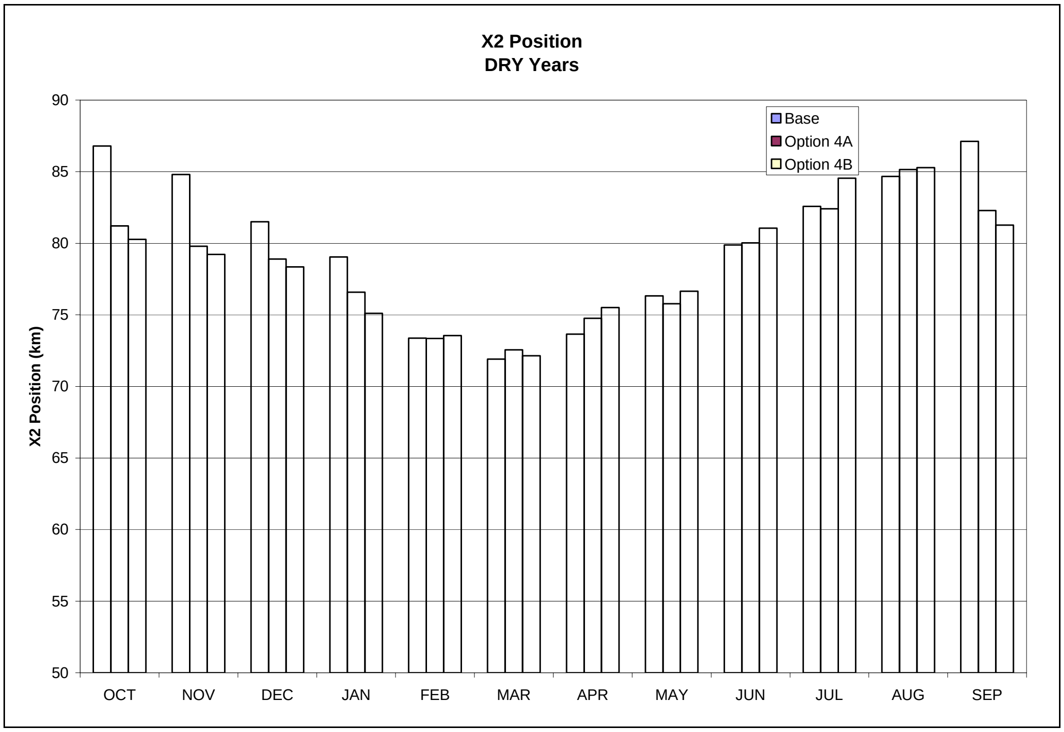


Figure G-4d. X2 Dry Year Average Distance

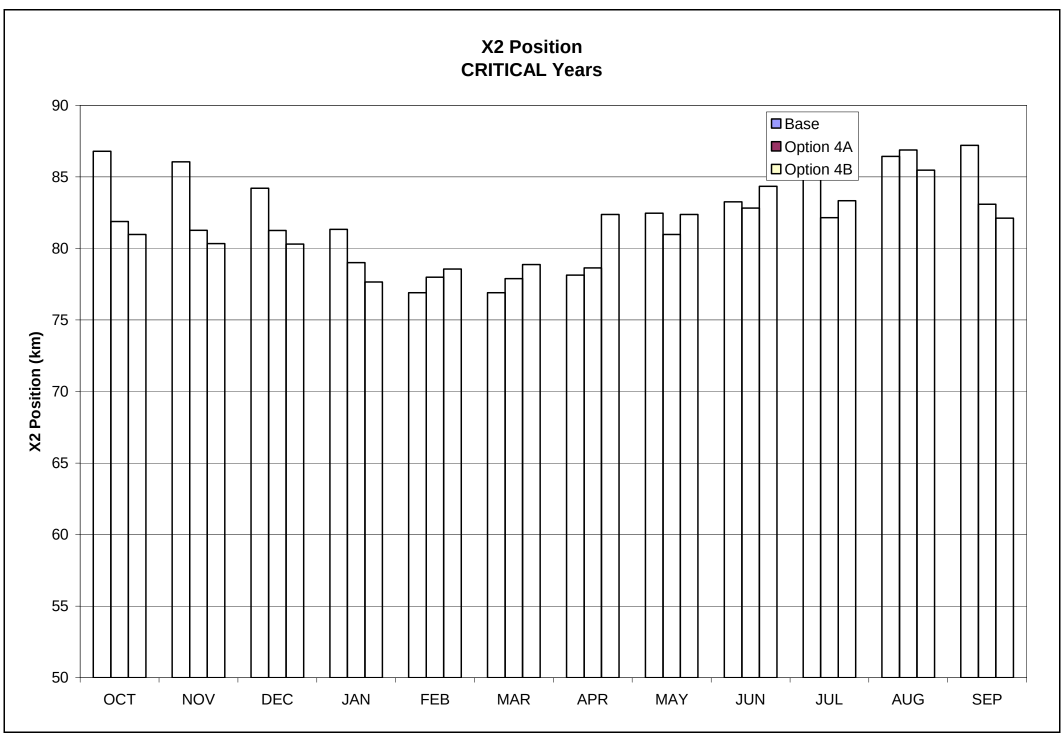


Figure G-4e. X2 Critical Year Average Distance

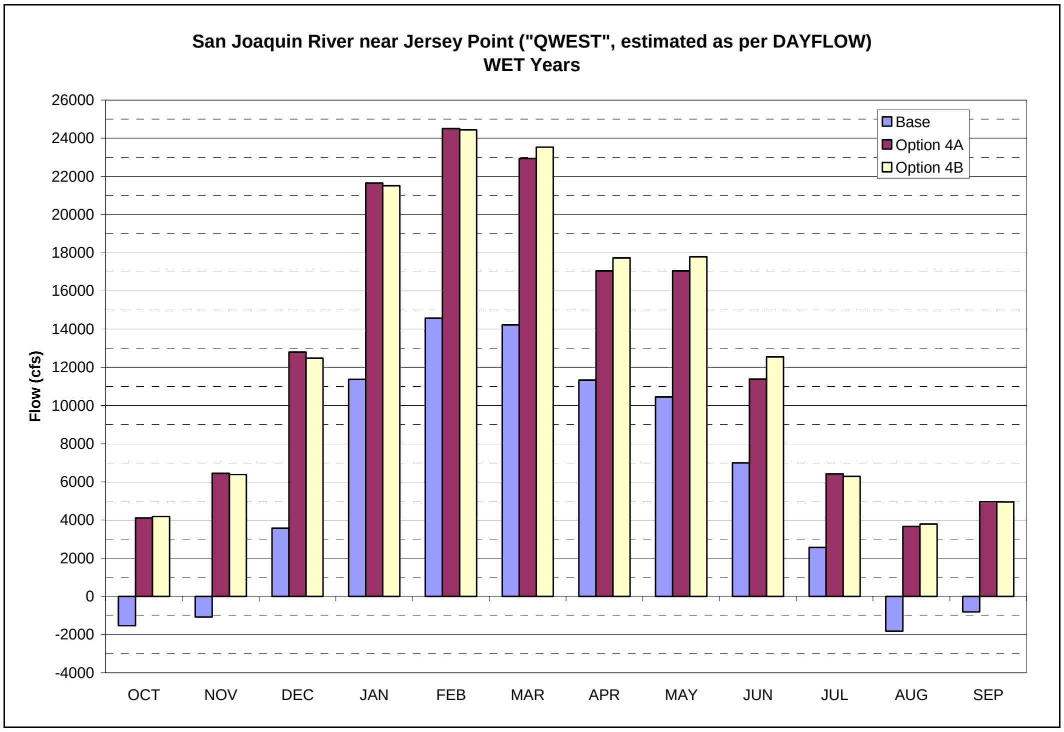


Figure G-5a. QWEST Wet Year Average Flows

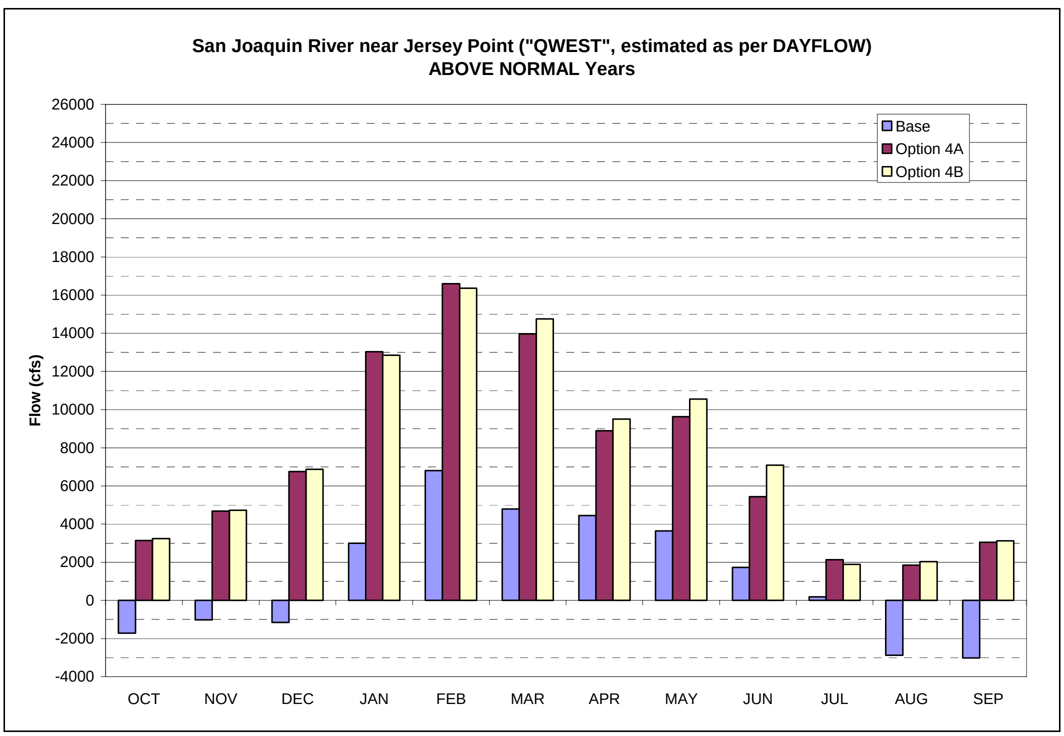


Figure G-5b. QWEST Above Normal Year Average Flows

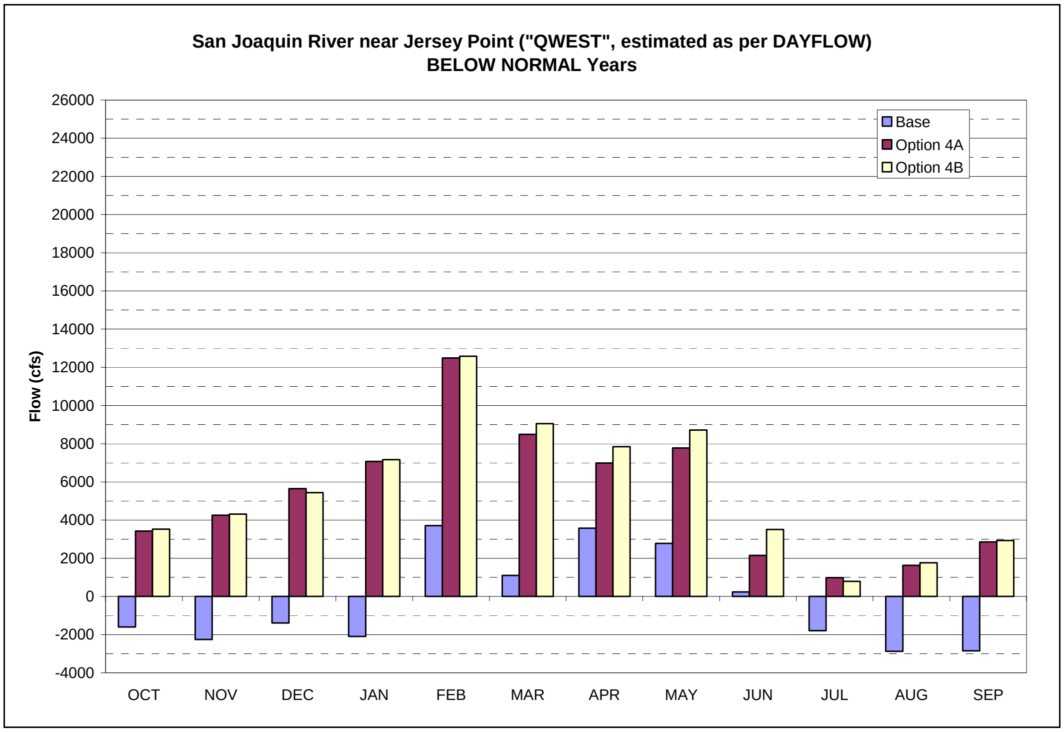


Figure G-5c. QWEST Below Normal Year Average Flows

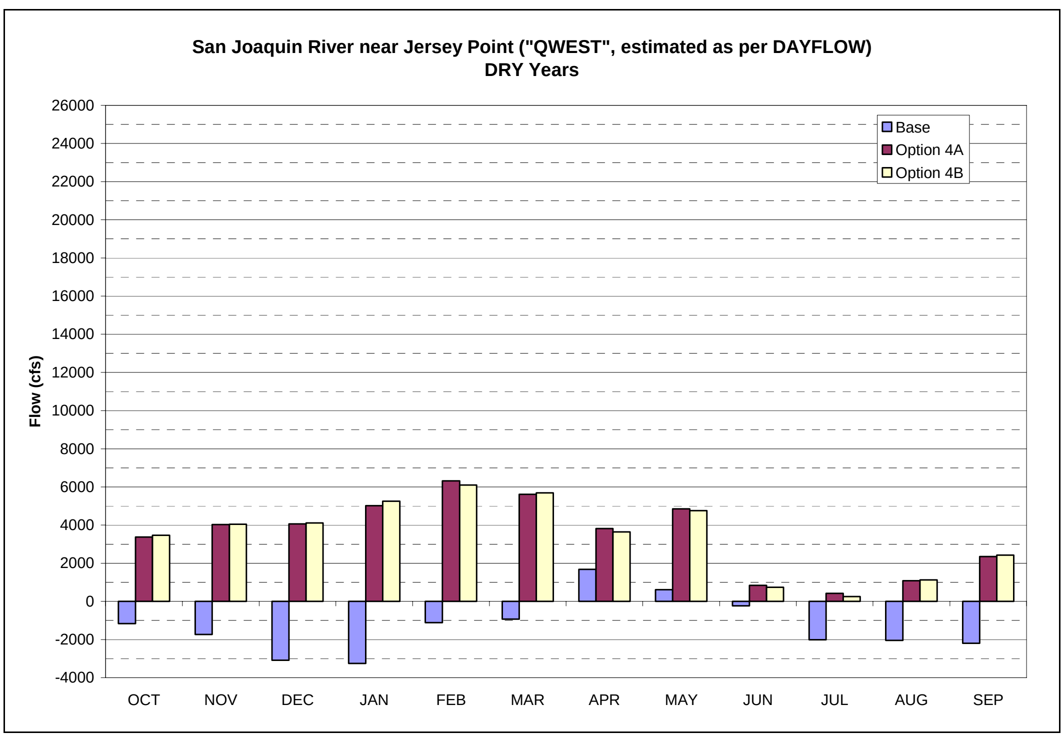


Figure G-5d. QWEST Dry Year Average Flows

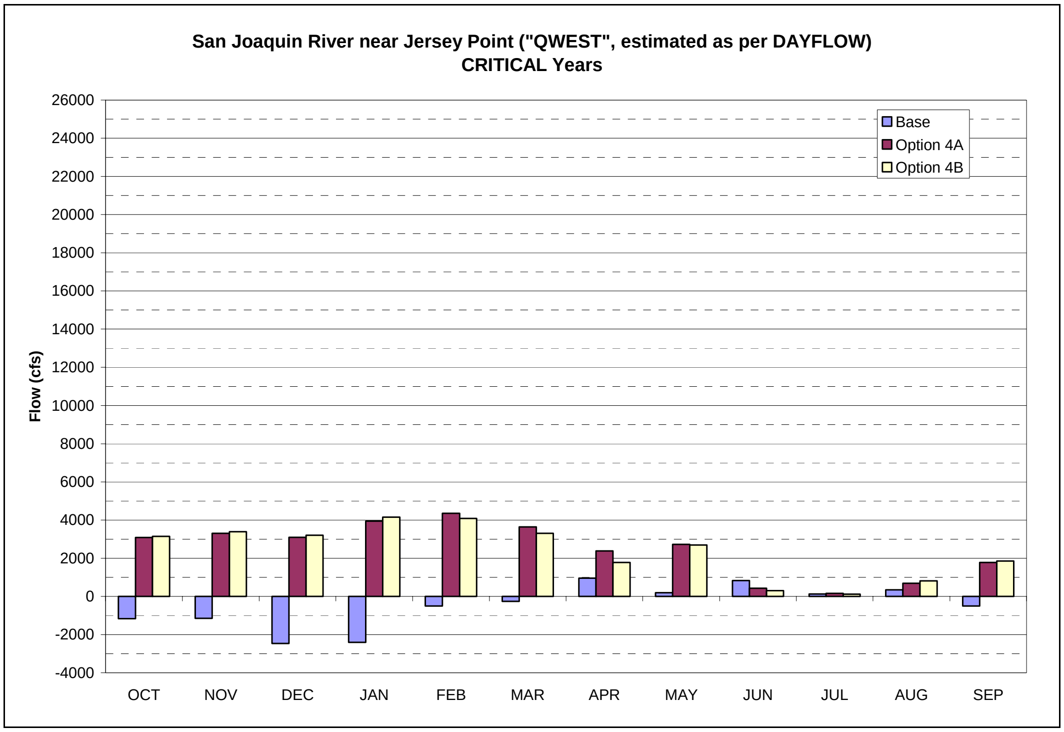


Figure G-5e. QWEST Critical Year Average Flows

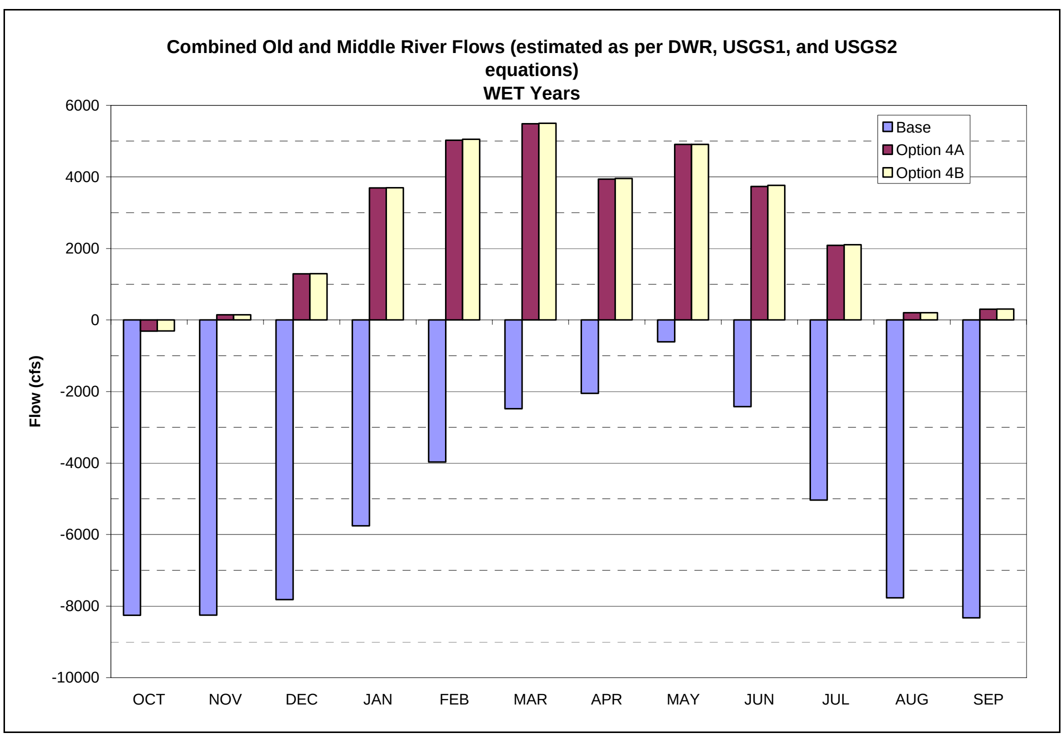


Figure G-6a. Combined Old and Middle River Wet Year Average Flows

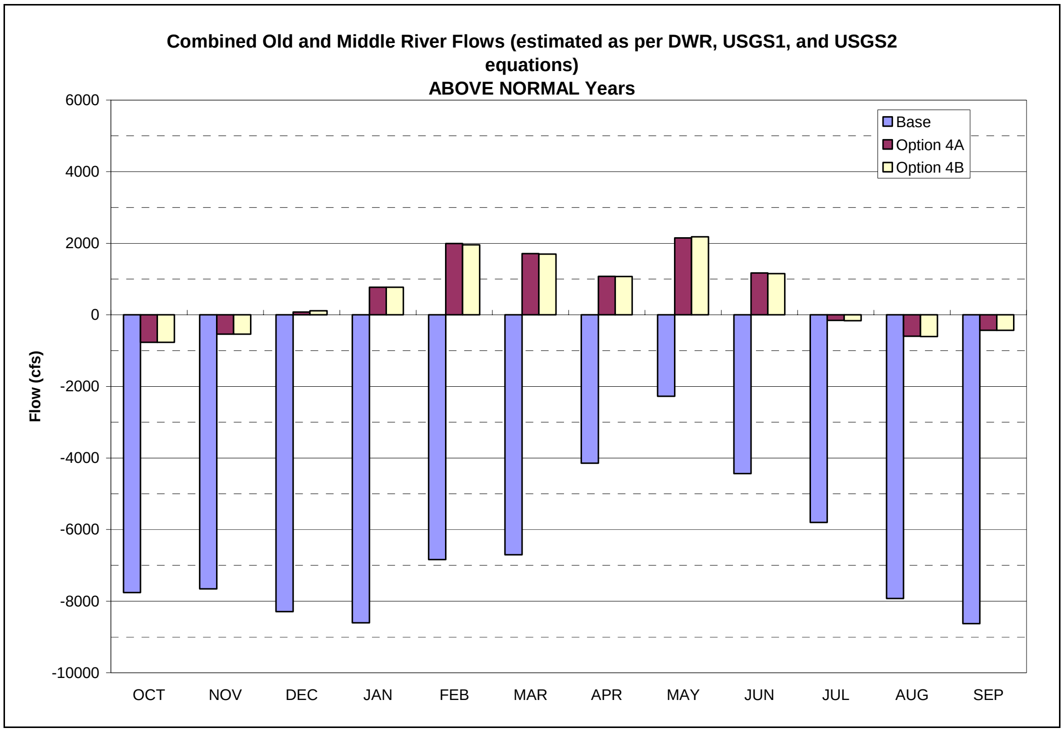


Figure G-6b. Combined Old and Middle River Above Normal Year Average Flows

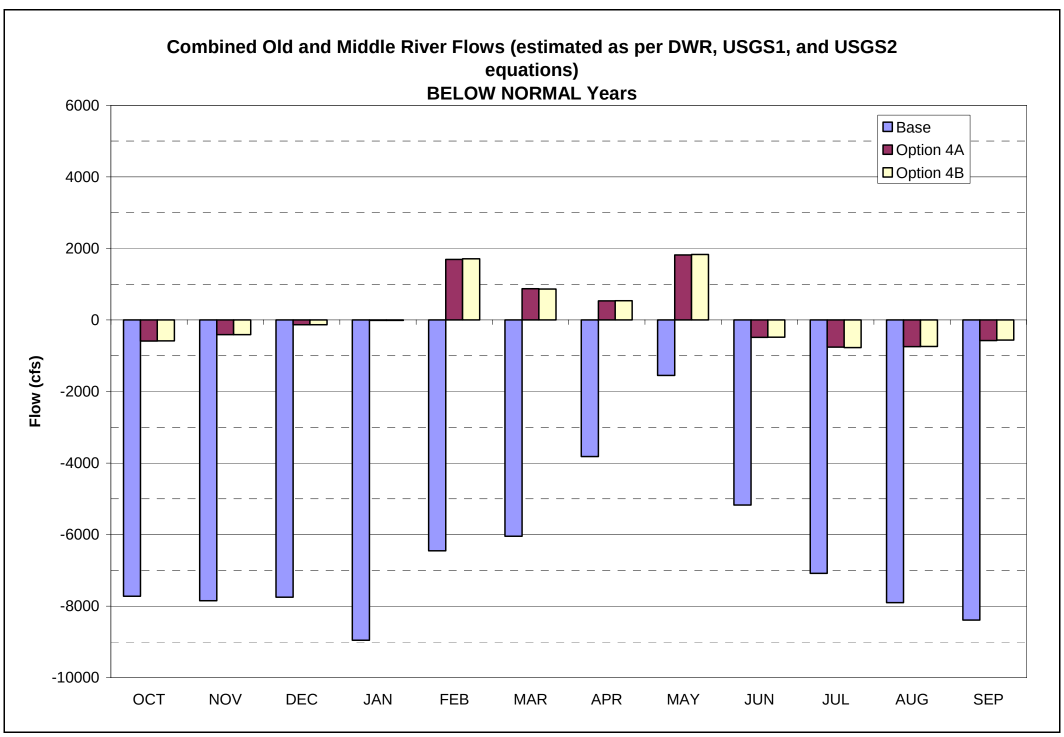


Figure G-6c. Combined Old and Middle River Below Normal Year Average Flows

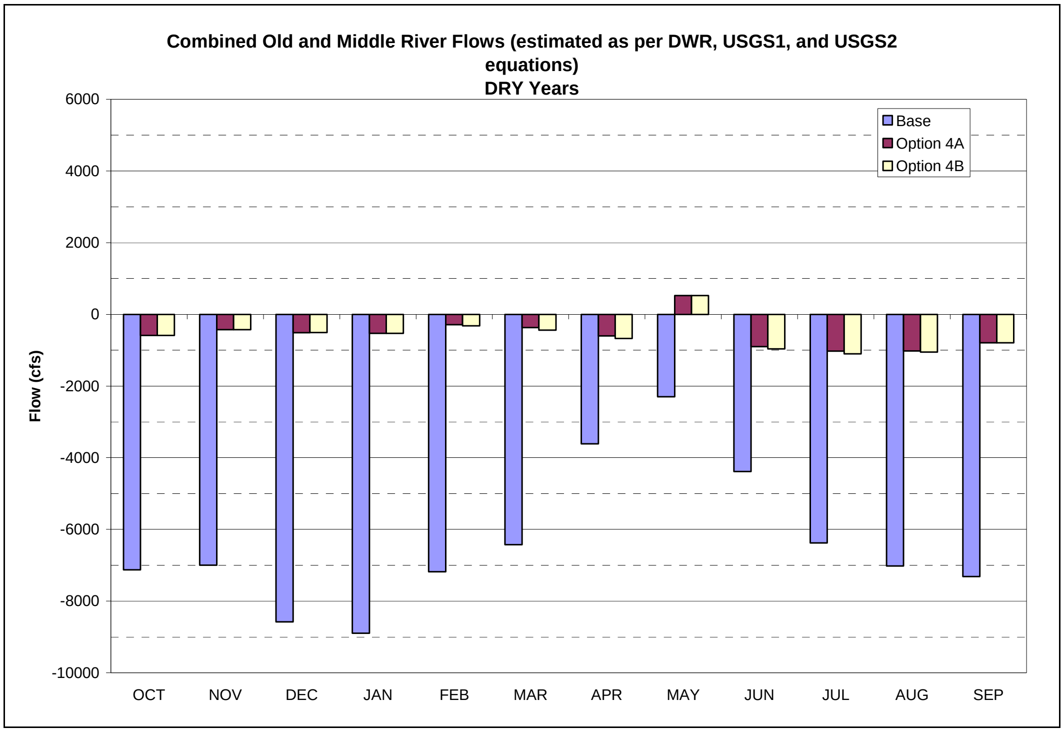


Figure G-6d. Combined Old and Middle River Dry Year Average Flows

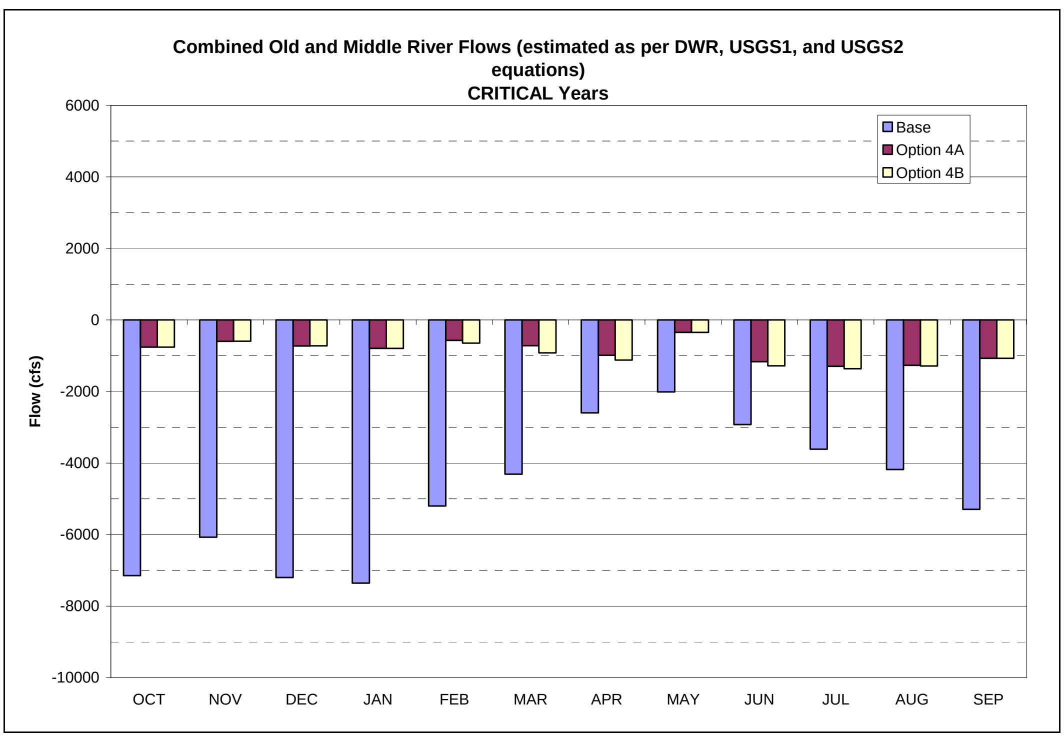


Figure G-6e. Combined Old and Middle River Critical Year Average Flows

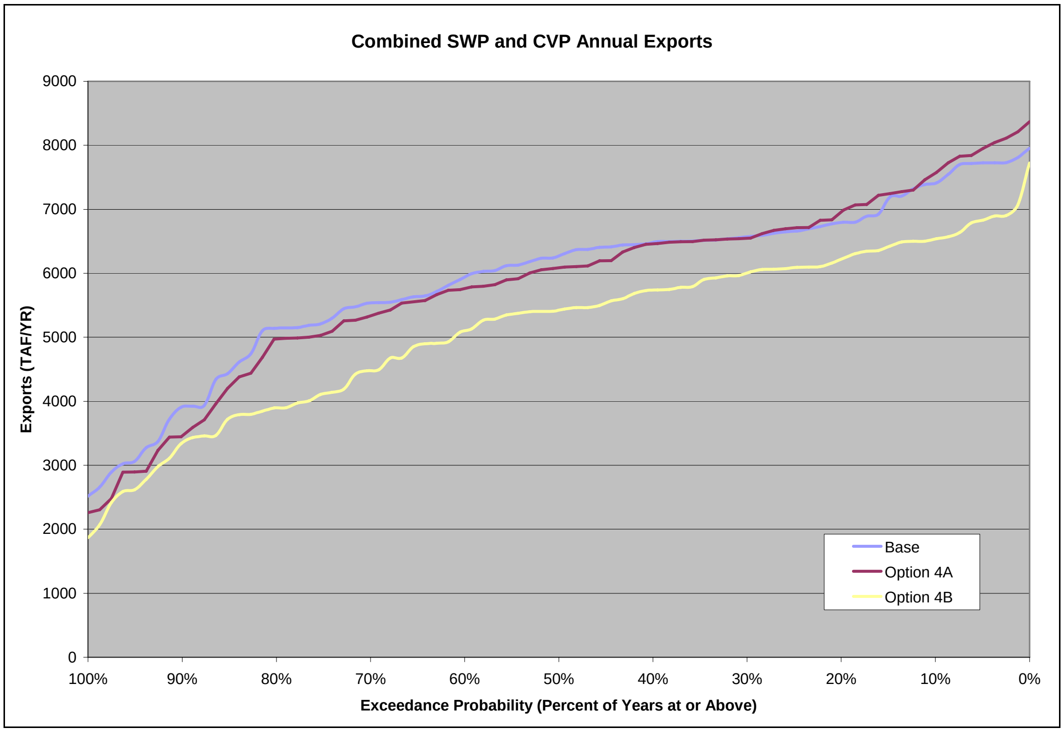


Figure G-7. Water Supply Frequency: Combined SWP and CVP Annual Delta Exports

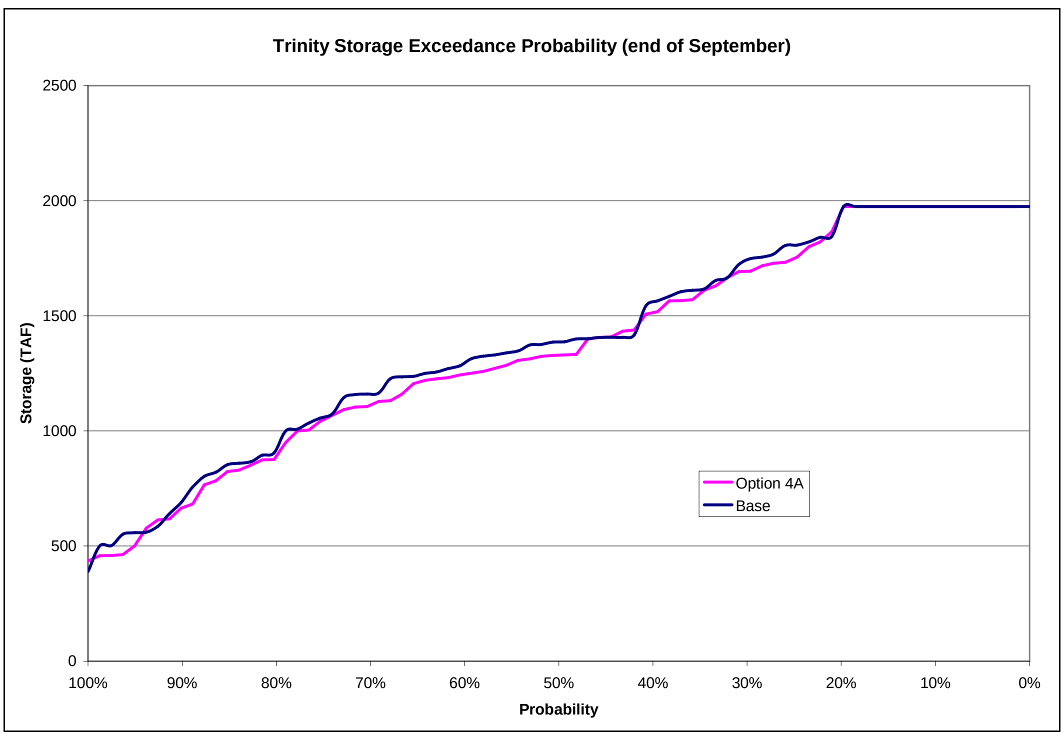


Figure G-8a. Option 4A CVP Northern Delta Storage Frequency: Trinity

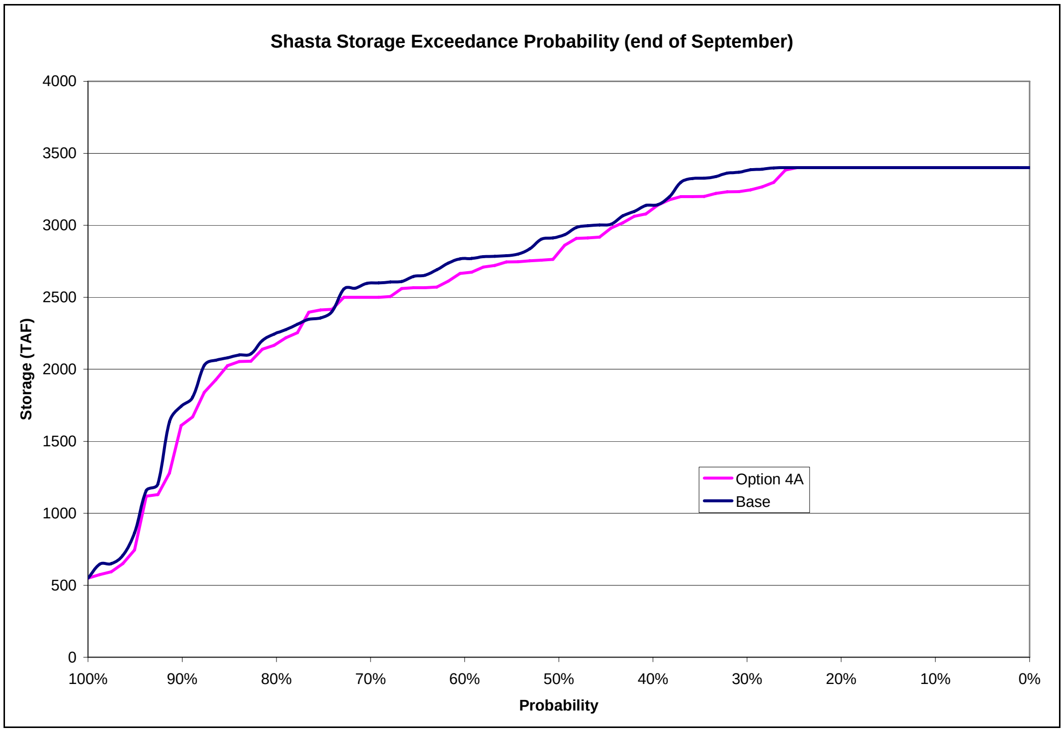


Figure G-8b. Option 4A CVP Northern Delta Storage Frequency: Shasta

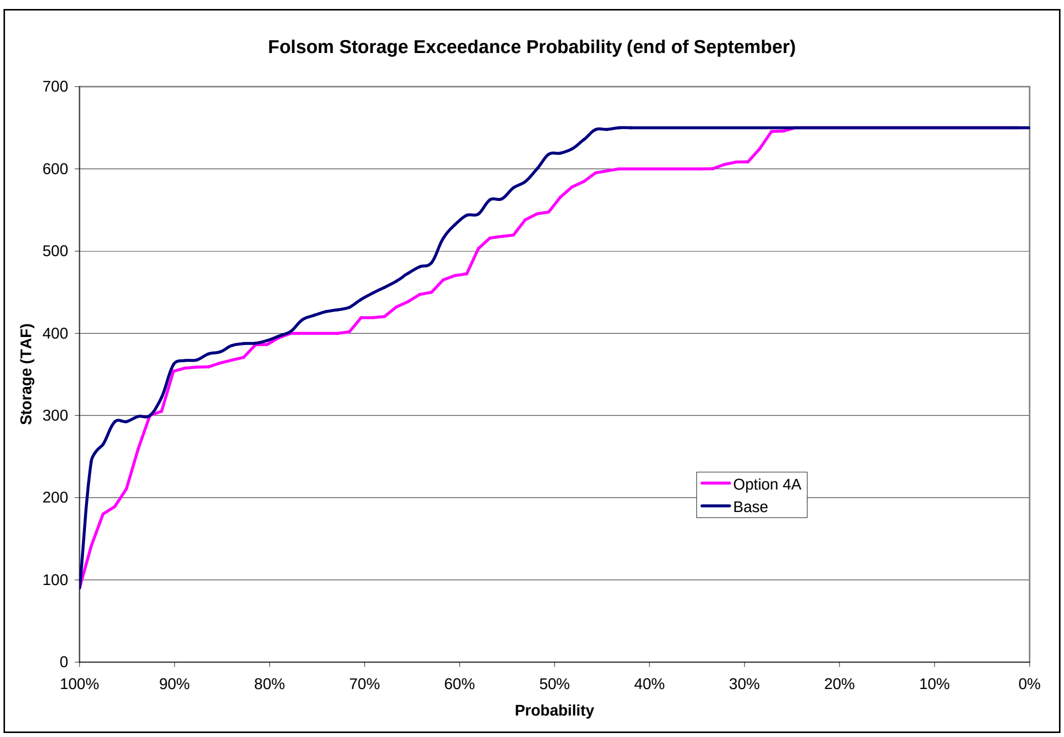


Figure G-8c. Option 4A CVP Northern Delta Storage Frequency: Folsom

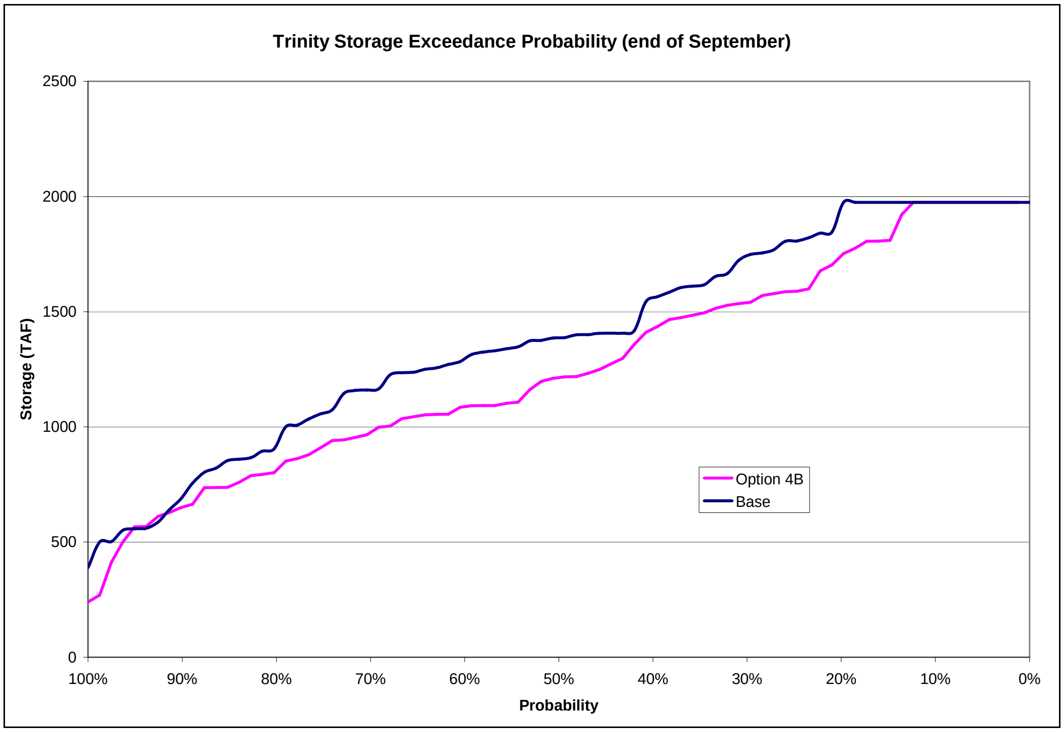


Figure G-9a. Option 4B CVP Northern Delta Storage Frequency: Trinity

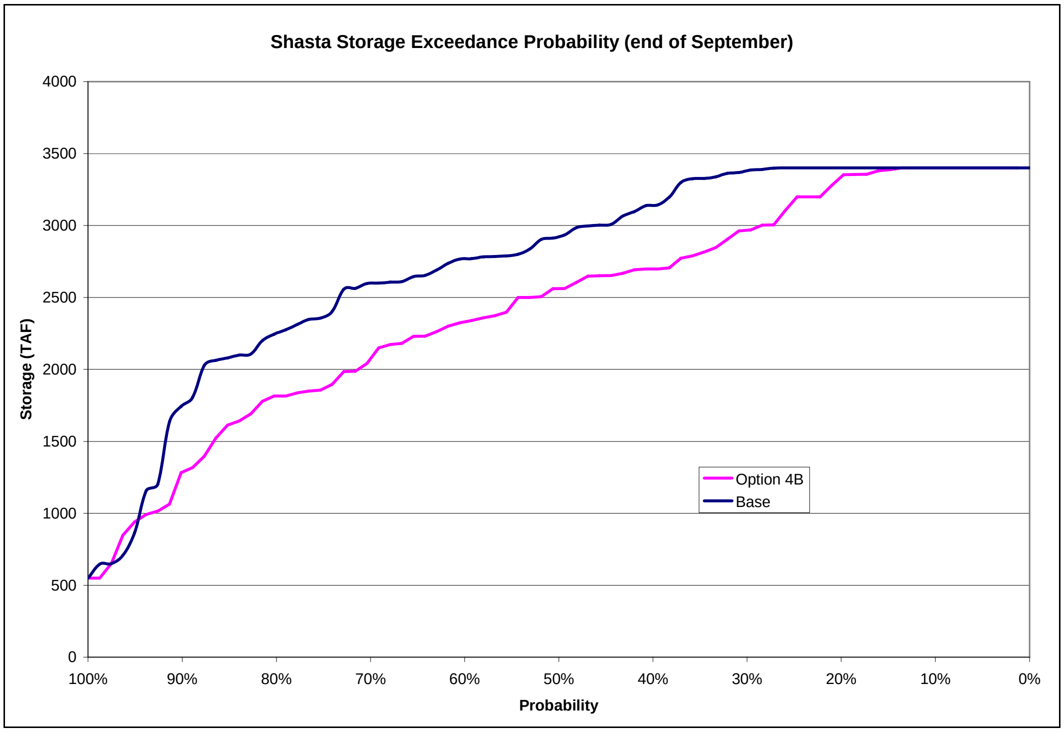


Figure G-9b. Option 4B CVP Northern Delta Storage Frequency: Shasta

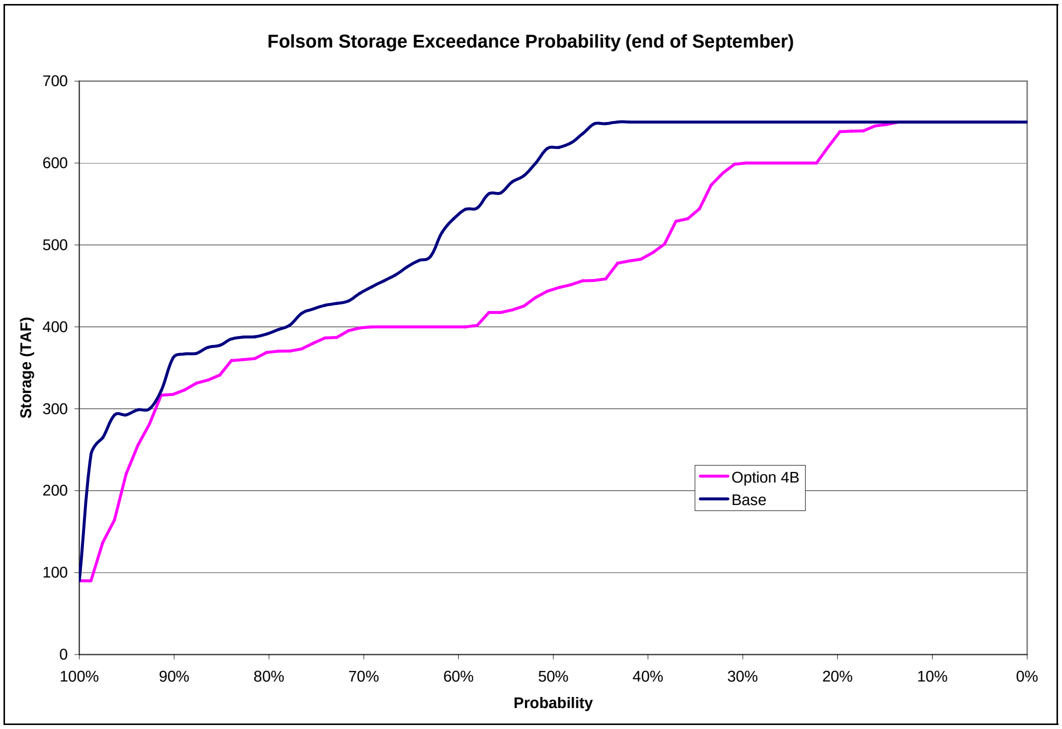


Figure G-9c. Option 4B CVP Northern Delta Storage Frequency: Folsom

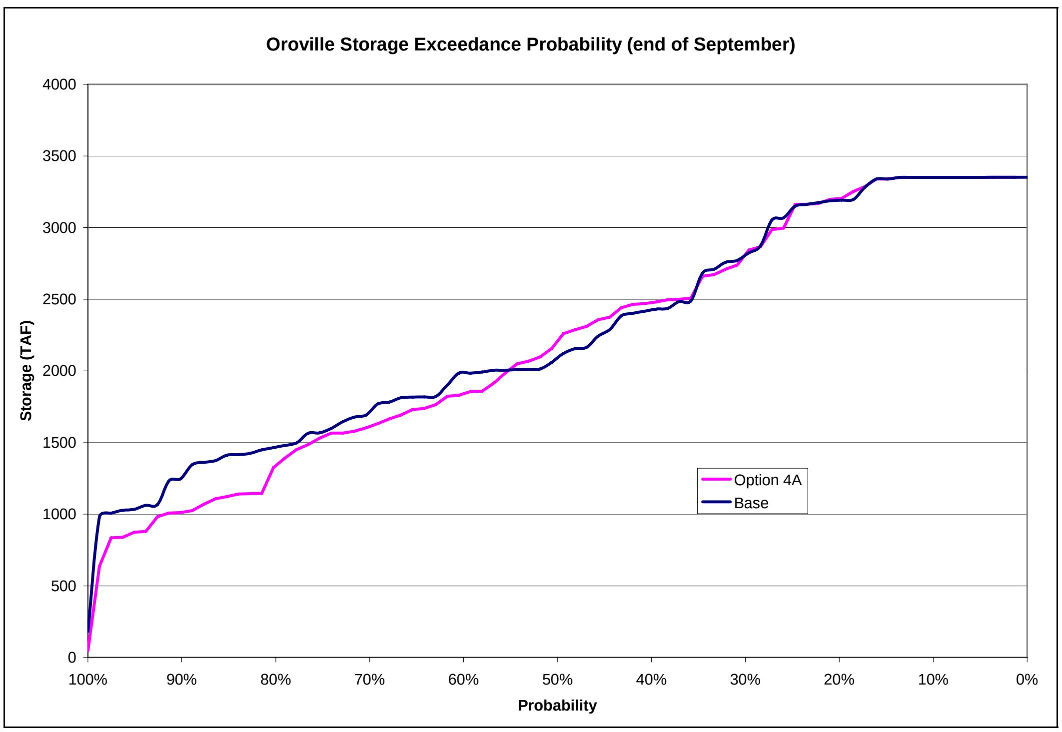


Figure G-10. Option 4A SWP Northern Delta Storage Frequency: Oroville

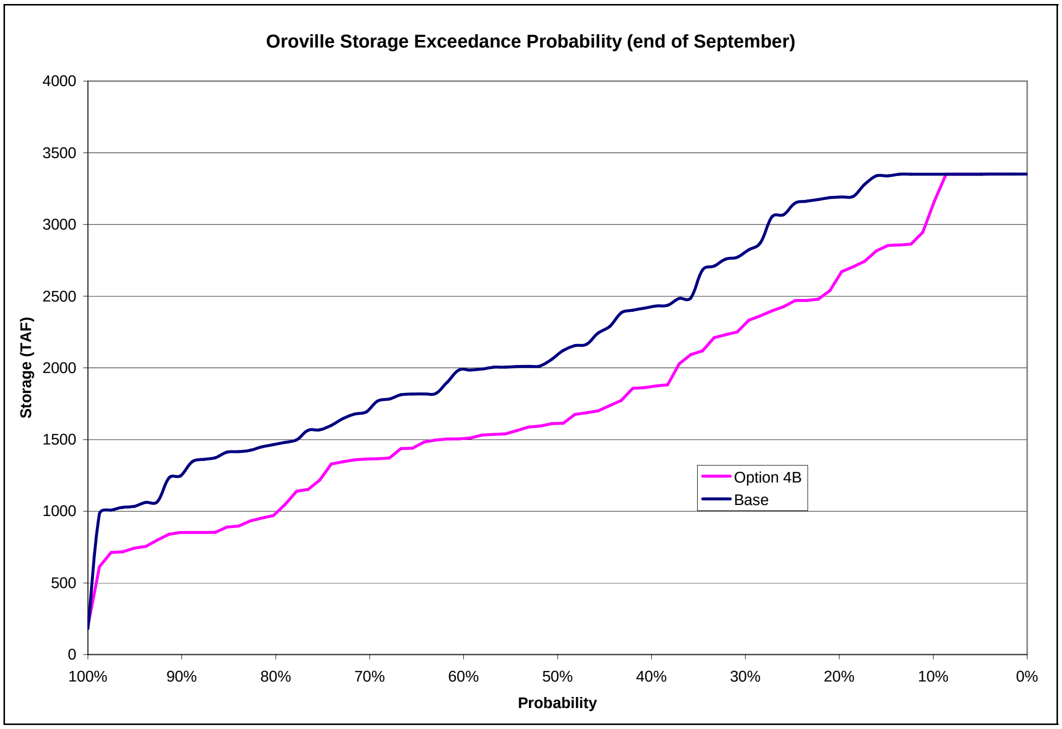


Figure G-11. Option 4B SWP Northern Delta Storage Frequency: Oroville

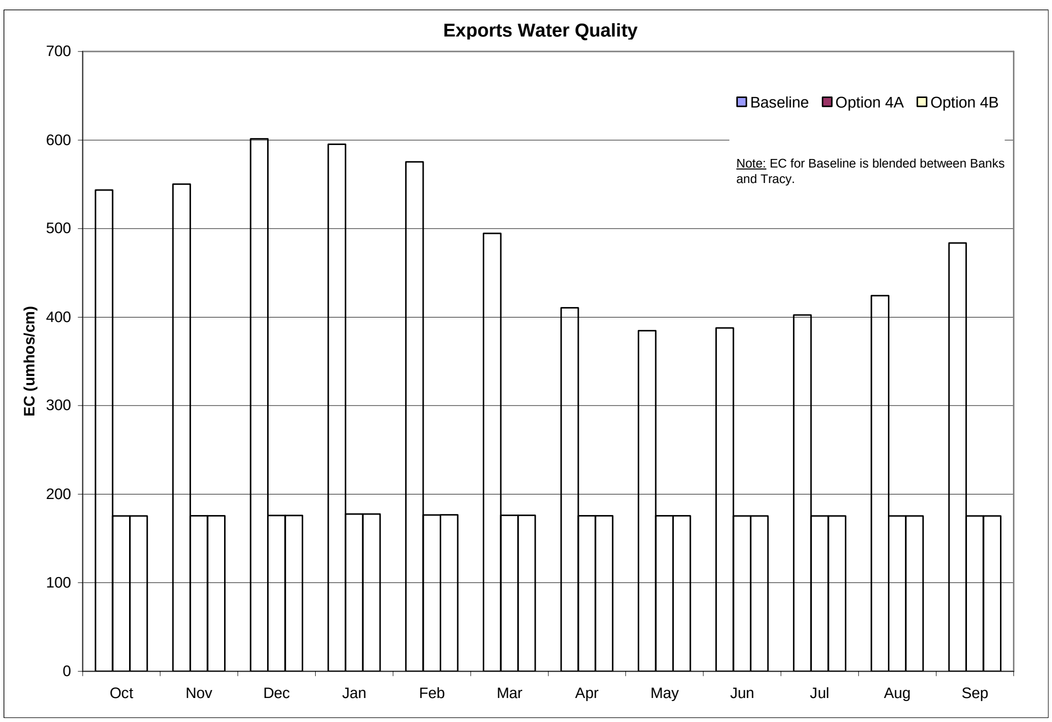


Figure G-12. Export Water Quality Annual Average, 1975-1991

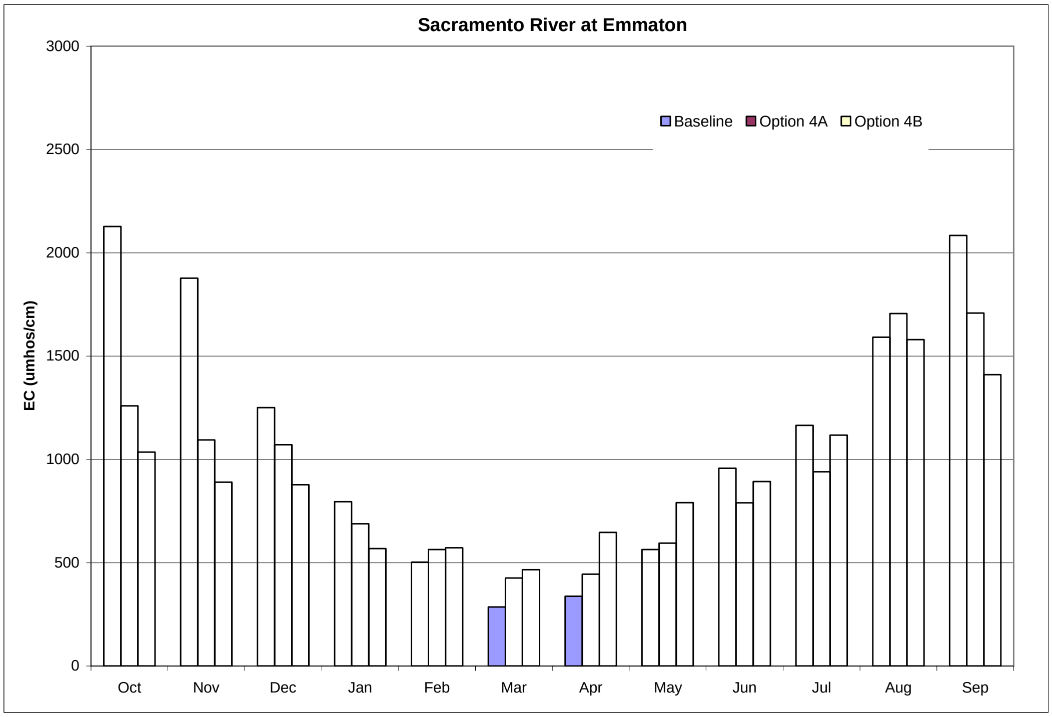


Figure G-13. In Delta Water Quality Annual Average, 1975-1991: Sacramento River at Emmaton

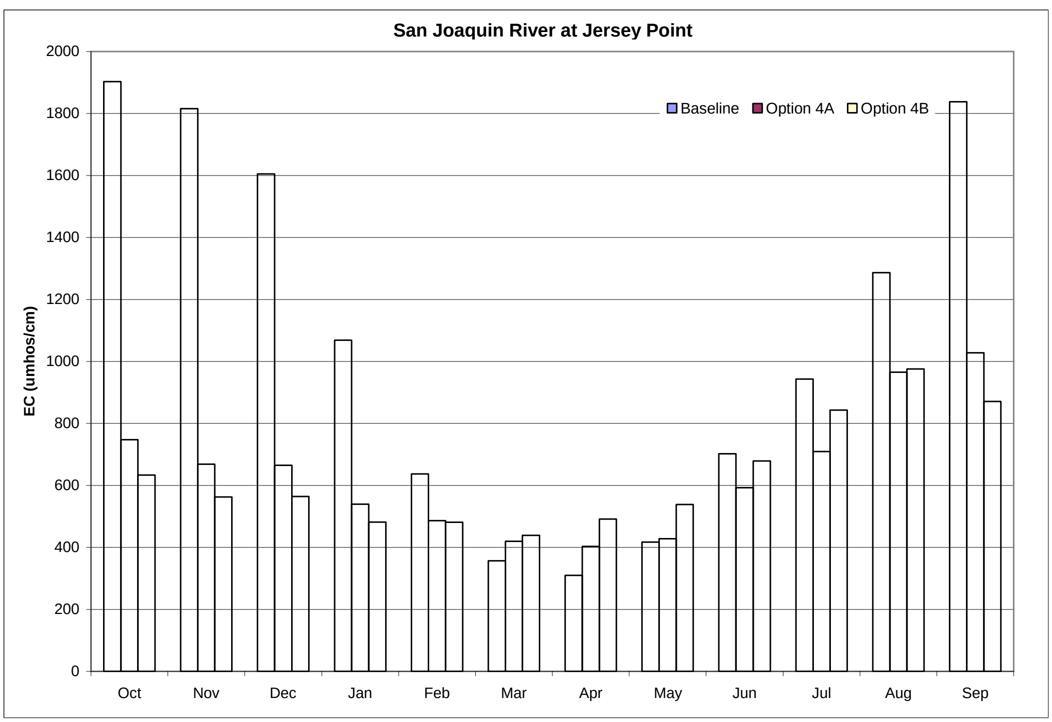


Figure G-14. In Delta Water Quality Annual Average, 1975-1991: San Joaquin River at Jersey Point

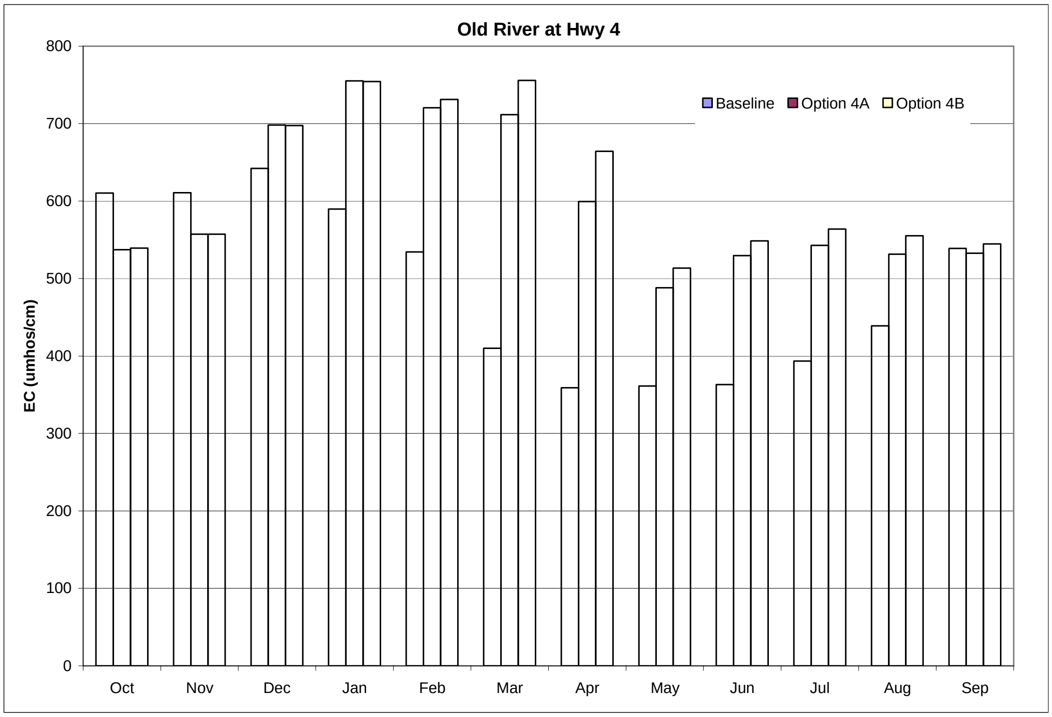


Figure G-15. In Delta Water Quality Annual Average, 1975-1991: Old River at Hwy 4

Table G-2. Option 4A Cumulative Particle Fate – September 1977

	Old River Sep 1977 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 4A	Base	Option 4A	Base	Option 4A	Base	Option 4A	Base	Option 4A
DIVERSION_AG	1.7	0.7	4.0	1.0	5.0	1.4	5.6	2.1	6.7	2.9
PAST_CHIPPS	0.0	0.1	0.0	0.4	0.1	5.0	0.3	5.8	1.7	19.9
TO_SUISUN	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.3
EXPORTS*	53.1	0.0	67.5	0.0	75.3	0.0	79.9	0.0	84.3	0.0
CENTRAL	45.2	99.2	28.5	98.6	19.6	93.5	14.2	92.1	7.3	76.9

	Middle River Sep 1977 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 4A	Base	Option 4A	Base	Option 4A	Base	Option 4A	Base	Option 4A
DIVERSION_AG	0.4	0.4	1.2	0.4	1.7	0.7	2.8	1.0	3.4	2.5
PAST_CHIPPS	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.3	0.0	2.9
TO_SUISUN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EXPORTS*	32.3	0.0	63.5	0.0	80.8	0.0	88.5	0.0	93.3	0.0
CENTRAL	67.3	99.6	35.3	99.6	17.5	99.1	8.7	98.7	3.3	94.6

	San Joaquin River d/s of Dutch Slough Sep 1977 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 4A	Base	Option 4A	Base	Option 4A	Base	Option 4A	Base	Option 4A
DIVERSION_AG	0.0	0.1	0.1	0.1	0.1	0.1	0.3	0.3	0.7	0.4
PAST_CHIPPS	17.0	26.8	17.9	26.7	37.4	51.9	34.8	49.4	48.9	69.2
TO_SUISUN	0.1	0.6	0.0	0.0	0.3	0.2	0.0	0.2	0.2	0.2
EXPORTS*	0.0	0.0	0.5	0.0	2.1	0.0	4.5	0.0	11.0	0.0
CENTRAL	82.9	72.5	81.5	73.2	60.1	47.8	60.4	50.1	39.2	30.2

	Sacramento River Sep 1977 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 4A	Base	Option 4A	Base	Option 4A	Base	Option 4A	Base	Option 4A
DIVERSION_AG	0.1	0.0	0.2	0.0	0.3	0.0	0.7	0.2	1.2	0.3
PAST_CHIPPS	0.3	0.3	1.1	2.1	9.0	12.3	10.0	16.7	20.6	37.5
TO_SUISUN	0.0	0.0	0.0	0.0	0.3	0.1	0.0	0.0	0.3	0.1
EXPORTS*	0.0	0.0	0.9	0.0	4.6	0.0	9.6	0.0	20.2	0.0
CENTRAL	99.6	99.7	97.8	97.9	85.8	87.6	79.7	83.1	57.7	62.1

	San Joaquin River u/s of HOR Sep 1977 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 4A	Base	Option 4A	Base	Option 4A	Base	Option 4A	Base	Option 4A
DIVERSION_AG	7.1	7.1	7.9	10.4	9.8	15.2	11.2	18.6	13.6	23.1
PAST_CHIPPS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TO_SUISUN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EXPORTS*	30.3	0.0	32.4	0.0	33.5	0.0	46.5	0.0	67.1	0.0
CENTRAL	62.6	92.9	59.7	89.6	56.7	84.8	42.3	81.4	19.3	76.9

* In Baseline Exports is the sum of particles entering SWP and CVP. In the Option 4 it is the particles leaving through IF diversion

Table G-3. Option 4A Cumulative Particle Fate – January 1981

	Old River Jan 1981 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 4A	Base	Option 4A	Base	Option 4A	Base	Option 4A	Base	Option 4A
DIVERSION_AG	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.2	0.0
PAST_CHIPPS	0.2	1.7	0.2	22.8	0.2	36.8	0.3	58.1	0.3	69.4
TO_SUISUN	0.0	0.5	0.0	2.2	0.0	4.7	0.0	6.8	0.0	8.6
EXPORTS*	90.4	0.0	95.1	0.0	97.6	0.0	98.0	0.0	98.7	0.0
CENTRAL	9.4	97.8	4.7	75.0	2.2	58.5	1.5	35.1	0.8	22.0

	Middle River Jan 1981 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 4A	Base	Option 4A	Base	Option 4A	Base	Option 4A	Base	Option 4A
DIVERSION_AG	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PAST_CHIPPS	0.0	0.1	0.0	2.3	0.0	6.9	0.0	22.6	0.0	35.6
TO_SUISUN	0.0	0.0	0.0	0.4	0.0	0.9	0.0	1.9	0.0	5.1
EXPORTS*	82.2	0.0	97.2	0.0	99.7	0.0	99.8	0.0	99.9	0.0
CENTRAL	17.8	99.9	2.8	97.3	0.3	92.2	0.2	75.5	0.1	59.3

	San Joaquin River d/s of Dutch Slough Jan 1981 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 4A	Base	Option 4A	Base	Option 4A	Base	Option 4A	Base	Option 4A
DIVERSION_AG	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PAST_CHIPPS	35.1	63.6	51.5	85.4	54.9	87.6	57.4	88.3	58.4	88.8
TO_SUISUN	4.6	6.8	6.6	9.5	7.1	10.2	7.3	10.6	7.6	10.7
EXPORTS*	1.7	0.0	8.5	0.0	16.7	0.0	23.2	0.0	28.8	0.0
CENTRAL	58.6	29.6	33.4	5.1	21.3	2.2	12.1	1.1	5.2	0.5

	Sacramento River Jan 1981 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 4A	Base	Option 4A	Base	Option 4A	Base	Option 4A	Base	Option 4A
DIVERSION_AG	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PAST_CHIPPS	46.1	46.5	57.4	78.7	60.4	82.7	62.4	86.5	62.6	87.7
TO_SUISUN	4.8	4.5	6.3	8.8	6.6	10.5	6.9	11.0	6.9	11.2
EXPORTS*	2.4	0.0	10.2	0.0	16.9	0.0	22.2	0.0	27.0	0.0
CENTRAL	46.7	49.0	26.1	12.5	16.1	6.8	8.5	2.5	3.5	1.1

	San Joaquin River u/s of HOR Jan 1981 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 4A	Base	Option 4A	Base	Option 4A	Base	Option 4A	Base	Option 4A
DIVERSION_AG	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.5
PAST_CHIPPS	0.0	0.0	0.0	0.1	0.0	0.7	0.0	5.9	0.0	20.9
TO_SUISUN	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.5	0.0	2.3
EXPORTS*	65.1	0.0	70.4	0.0	86.3	0.0	93.5	0.0	96.1	0.0
CENTRAL	34.9	100.0	29.6	99.9	13.7	99.2	6.5	93.5	3.9	76.3

* In Baseline Exports is the sum of particles entering SWP and CVP. In the Option 4 it is the particles leaving through IF diversion

Table G-4. Option 4A Cumulative Particle Fate – March 1990

	Old River Mar 1990 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 4A	Base	Option 4A	Base	Option 4A	Base	Option 4A	Base	Option 4A
DIVERSION_AG	0.4	0.1	0.6	0.4	1.8	0.4	2.2	0.4	3.3	1.2
PAST_CHIPPS	0.0	0.6	0.1	2.2	0.9	13.1	0.8	13.5	1.6	28.8
TO_SUISUN	0.0	0.0	0.0	0.6	0.2	2.8	0.5	5.5	0.8	8.9
EXPORTS*	52.9	0.0	71.9	0.0	79.9	0.0	84.0	0.0	85.3	0.0
CENTRAL	46.7	99.3	27.4	96.8	17.2	83.7	12.5	80.6	9.0	61.1

	Middle River Mar 1990 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 4A	Base	Option 4A	Base	Option 4A	Base	Option 4A	Base	Option 4A
DIVERSION_AG	0.2	0.0	0.6	0.2	1.2	0.3	2.0	0.5	2.6	2.3
PAST_CHIPPS	0.0	0.1	0.0	0.4	0.0	1.6	0.0	1.9	0.1	6.2
TO_SUISUN	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.7	0.0	1.3
EXPORTS*	24.6	0.0	61.0	0.0	77.6	0.0	85.0	0.0	87.4	0.0
CENTRAL	75.2	99.9	38.4	99.4	21.2	97.8	13.0	96.9	9.9	90.2

	San Joaquin River d/s of Dutch Slough Mar 1990 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 4A	Base	Option 4A	Base	Option 4A	Base	Option 4A	Base	Option 4A
DIVERSION_AG	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.5	0.0
PAST_CHIPPS	31.6	37.3	35.3	37.9	51.8	56.3	47.2	51.9	56.5	64.5
TO_SUISUN	6.3	9.4	9.8	14.7	12.2	18.3	13.7	21.2	15.8	24.0
EXPORTS*	0.0	0.0	0.4	0.0	1.1	0.0	2.6	0.0	3.7	0.0
CENTRAL	62.1	53.3	54.5	47.4	34.9	25.4	36.3	26.9	23.5	11.5

	Sacramento River Mar 1990 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 4A	Base	Option 4A	Base	Option 4A	Base	Option 4A	Base	Option 4A
DIVERSION_AG	0.0	0.1	0.0	0.1	0.1	0.2	0.1	0.3	0.5	0.7
PAST_CHIPPS	20.6	4.4	26.0	10.2	39.3	29.9	36.7	28.6	47.7	47.6
TO_SUISUN	4.2	0.7	7.4	4.1	10.0	9.0	11.5	13.0	14.1	16.7
EXPORTS*	0.0	0.0	1.2	0.0	3.7	0.0	6.9	0.0	7.6	0.0
CENTRAL	75.2	94.8	65.4	85.6	46.9	60.9	44.8	58.1	30.1	35.0

	San Joaquin River u/s of HOR Mar 1990 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 4A	Base	Option 4A	Base	Option 4A	Base	Option 4A	Base	Option 4A
DIVERSION_AG	14.3	13.4	19.4	20.1	20.1	23.4	20.1	26.0	22.1	33.7
PAST_CHIPPS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
TO_SUISUN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
EXPORTS*	51.1	0.0	54.6	0.0	54.9	0.0	54.9	0.0	55.2	0.0
CENTRAL	34.6	86.6	26.0	79.9	25.0	76.6	25.0	74.0	22.7	65.9

* In Baseline Exports is the sum of particles entering SWP and CVP. In the Option 4 it is the particles leaving through IF diversion

Table G-5. Option 4B Cumulative Particle Fate – September 1977

	Old River Sep 1977 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 4B	Base	Option 4B	Base	Option 4B	Base	Option 4B	Base	Option 4B
DIVERSION_AG	1.7	1.2	4.0	1.9	5.0	2.6	5.6	3.3	6.7	4.3
PAST_CHIPPS	0.0	0.1	0.0	0.6	0.1	6.0	0.3	7.3	1.7	22.3
TO_SUISUN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EXPORTS*	53.1	0.0	67.5	0.0	75.3	0.0	79.9	0.0	84.3	0.0
CENTRAL	45.2	98.7	28.5	97.5	19.6	91.4	14.2	89.4	7.3	73.4

	Middle River Sep 1977 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 4B	Base	Option 4B	Base	Option 4B	Base	Option 4B	Base	Option 4B
DIVERSION_AG	0.4	0.0	1.2	0.0	1.7	0.3	2.8	0.8	3.4	2.2
PAST_CHIPPS	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.3	0.0	2.5
TO_SUISUN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
EXPORTS*	32.3	0.0	63.5	0.0	80.8	0.0	88.5	0.0	93.3	0.0
CENTRAL	67.3	100.0	35.3	100.0	17.5	99.3	8.7	98.9	3.3	95.2

	San Joaquin River d/s of Dutch Slough Sep 1977 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 4B	Base	Option 4B	Base	Option 4B	Base	Option 4B	Base	Option 4B
DIVERSION_AG	0.0	0.0	0.1	0.0	0.1	0.0	0.3	0.0	0.7	0.4
PAST_CHIPPS	17.0	26.2	17.9	27.4	37.4	53.8	34.8	54.4	48.9	74.0
TO_SUISUN	0.1	0.6	0.0	0.3	0.3	0.4	0.0	0.2	0.2	0.2
EXPORTS*	0.0	0.0	0.5	0.0	2.1	0.0	4.5	0.0	11.0	0.0
CENTRAL	82.9	73.2	81.5	72.3	60.1	45.8	60.4	45.4	39.2	25.4

	Sacramento River Sep 1977 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 4B	Base	Option 4A	Base	Option 4B	Base	Option 4A	Base	Option 4B
DIVERSION_AG	0.1	0.1	0.2	0.2	0.3	0.2	0.7	0.2	1.2	0.5
PAST_CHIPPS	0.3	0.5	1.1	3.0	9.0	18.2	10.0	21.0	20.6	45.9
TO_SUISUN	0.0	0.0	0.0	0.0	0.3	0.2	0.0	0.0	0.3	0.1
EXPORTS*	0.0	0.0	0.9	0.0	4.6	0.0	9.6	0.0	20.2	0.0
CENTRAL	99.6	99.4	97.8	96.8	85.8	81.4	79.7	78.8	57.7	53.5

	San Joaquin River u/s of HOR Sep 1977 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 4B	Base	Option 4B	Base	Option 4B	Base	Option 4B	Base	Option 4B
DIVERSION_AG	7.1	6.5	7.9	9.5	9.8	15.9	11.2	20.4	13.6	23.2
PAST_CHIPPS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TO_SUISUN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EXPORTS*	30.3	0.0	32.4	0.0	33.5	0.0	46.5	0.0	67.1	0.0
CENTRAL	62.6	93.5	59.7	90.5	56.7	84.1	42.3	79.6	19.3	76.8

* In Baseline Exports is the sum of particles entering SWP and CVP. In the Option 4 it is the particles leaving through IF diversion

Table G-6. Option 4B Cumulative Particle Fate – January 1981

	Old River Jan 1981 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 4B	Base	Option 4B	Base	Option 4B	Base	Option 4B	Base	Option 4B
DIVERSION_AG	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.2	0.0
PAST_CHIPPS	0.2	1.4	0.2	18.2	0.2	28.5	0.3	53.6	0.3	65.0
TO_SUISUN	0.0	0.5	0.0	1.8	0.0	3.9	0.0	6.5	0.0	9.7
EXPORTS*	90.4	0.0	95.1	0.0	97.6	0.0	98.0	0.0	98.7	0.0
CENTRAL	9.4	98.1	4.7	80.0	2.2	67.6	1.5	39.9	0.8	25.3

	Middle River Jan 1981 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 4B	Base	Option 4B	Base	Option 4B	Base	Option 4B	Base	Option 4B
DIVERSION_AG	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PAST_CHIPPS	0.0	0.0	0.0	1.5	0.0	5.1	0.0	18.3	0.0	33.1
TO_SUISUN	0.0	0.0	0.0	0.2	0.0	1.1	0.0	2.7	0.0	5.1
EXPORTS*	82.2	0.0	97.2	0.0	99.7	0.0	99.8	0.0	99.9	0.0
CENTRAL	17.8	100.0	2.8	98.3	0.3	93.8	0.2	79.0	0.1	61.8

	San Joaquin River d/s of Dutch Slough Jan 1981 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 4B	Base	Option 4B	Base	Option 4B	Base	Option 4B	Base	Option 4B
DIVERSION_AG	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PAST_CHIPPS	35.1	47.6	51.5	77.3	54.9	79.1	57.4	84.6	58.4	85.5
TO_SUISUN	4.6	7.2	6.6	11.7	7.1	12.7	7.3	13.5	7.6	13.6
EXPORTS*	1.7	0.0	8.5	0.0	16.7	0.0	23.2	0.0	28.8	0.0
CENTRAL	58.6	45.2	33.4	11.0	21.3	8.2	12.1	1.9	5.2	0.9

	Sacramento River Jan 1981 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 4B	Base	Option 4B	Base	Option 4B	Base	Option 4B	Base	Option 4B
DIVERSION_AG	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PAST_CHIPPS	46.1	19.5	57.4	62.9	60.4	69.3	62.4	80.0	62.6	82.1
TO_SUISUN	4.8	5.1	6.3	9.8	6.6	12.8	6.9	13.6	6.9	14.9
EXPORTS*	2.4	0.0	10.2	0.0	16.9	0.0	22.2	0.0	27.0	0.0
CENTRAL	46.7	75.4	26.1	27.3	16.1	17.9	8.5	6.4	3.5	3.0

	San Joaquin River u/s of HOR Jan 1981 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 4B	Base	Option 4B	Base	Option 4B	Base	Option 4B	Base	Option 4B
DIVERSION_AG	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.3
PAST_CHIPPS	0.0	0.0	0.0	0.0	0.0	0.4	0.0	5.2	0.0	18.8
TO_SUISUN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	2.0
EXPORTS*	65.1	0.0	70.4	0.0	86.3	0.0	93.5	0.0	96.1	0.0
CENTRAL	34.9	100.0	29.6	100.0	13.7	99.6	6.5	94.4	3.9	78.9

* In Baseline Exports is the sum of particles entering SWP and CVP. In the Option 4 it is the particles leaving through IF diversion

Table G-7. Option 4B Cumulative Particle Fate – March 1990

	Old River Mar 1990 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 4B	Base	Option 4B	Base	Option 4B	Base	Option 4B	Base	Option 4B
DIVERSION_AG	0.4	0.2	0.6	0.3	1.8	0.4	2.2	0.5	3.3	1.9
PAST_CHIPPS	0.0	0.9	0.1	2.0	0.9	7.6	0.8	7.9	1.6	14.3
TO_SUISUN	0.0	0.1	0.0	0.9	0.2	2.4	0.5	3.9	0.8	7.3
EXPORTS*	52.9	0.0	71.9	0.0	79.9	0.0	84.0	0.0	85.3	0.0
CENTRAL	46.7	98.8	27.4	96.8	17.2	89.6	12.5	87.7	9.0	76.5

	Middle River Mar 1990 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 4B	Base	Option 4B	Base	Option 4B	Base	Option 4B	Base	Option 4B
DIVERSION_AG	0.2	0.1	0.6	0.3	1.2	0.7	2.0	1.2	2.6	3.3
PAST_CHIPPS	0.0	0.0	0.0	0.1	0.0	0.7	0.0	1.1	0.1	2.4
TO_SUISUN	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.7	0.0	1.1
EXPORTS*	24.6	0.0	61.0	0.0	77.6	0.0	85.0	0.0	87.4	0.0
CENTRAL	75.2	99.9	38.4	99.6	21.2	98.3	13.0	97.0	9.9	93.2

	San Joaquin River d/s of Dutch Slough Mar 1990 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 4B	Base	Option 4B	Base	Option 4B	Base	Option 4B	Base	Option 4B
DIVERSION_AG	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.5	0.0
PAST_CHIPPS	31.6	37.2	35.3	37.2	51.8	53.5	47.2	47.2	56.5	53.0
TO_SUISUN	6.3	8.0	9.8	13.2	12.2	17.1	13.7	20.2	15.8	23.6
EXPORTS*	0.0	0.0	0.4	0.0	1.1	0.0	2.6	0.0	3.7	0.0
CENTRAL	62.1	54.8	54.5	49.6	34.9	29.4	36.3	32.6	23.5	23.4

	Sacramento River Mar 1990 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 4B	Base	Option 4B	Base	Option 4B	Base	Option 4B	Base	Option 4B
DIVERSION_AG	0.0	0.1	0.0	0.2	0.1	0.2	0.1	0.3	0.5	0.3
PAST_CHIPPS	20.6	3.2	26.0	7.3	39.3	26.4	36.7	23.6	47.7	33.3
TO_SUISUN	4.2	1.0	7.4	3.6	10.0	7.6	11.5	10.9	14.1	15.3
EXPORTS*	0.0	0.0	1.2	0.0	3.7	0.0	6.9	0.0	7.6	0.0
CENTRAL	75.2	95.7	65.4	88.9	46.9	65.8	44.8	65.2	30.1	51.1

	San Joaquin River u/s of HOR Mar 1990 Release - Cumulative particles (%)									
	7 Days		14 Days		21 Days		28 Days		40 Days	
	Base	Option 4B	Base	Option 4B	Base	Option 4B	Base	Option 4B	Base	Option 4B
DIVERSION_AG	14.3	18.4	19.4	30.3	20.1	33.8	20.1	36.0	22.1	44.9
PAST_CHIPPS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TO_SUISUN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EXPORTS*	51.1	0.0	54.6	0.0	54.9	0.0	54.9	0.0	55.2	0.0
CENTRAL	34.6	81.6	26.0	69.7	25.0	66.2	25.0	64.0	22.7	55.1

* In Baseline Exports is the sum of particles entering SWP and CVP. In the Option 4 it is the particles leaving through IF diversion

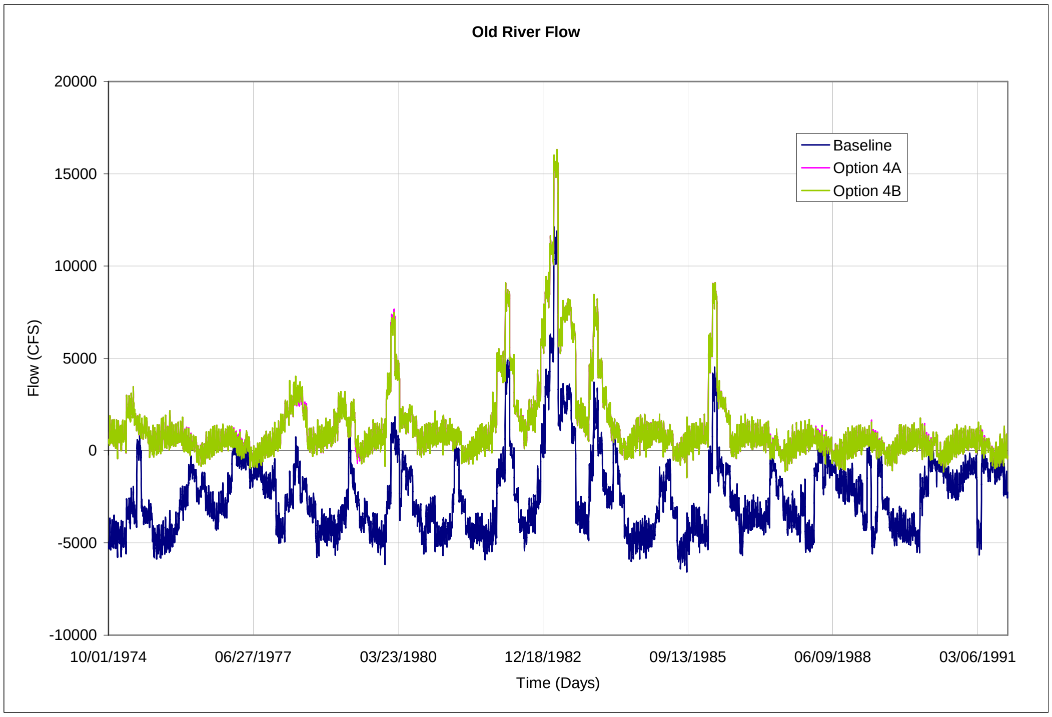


Figure G-16. DSM2 Simulated Daily Averaged Old River Flows

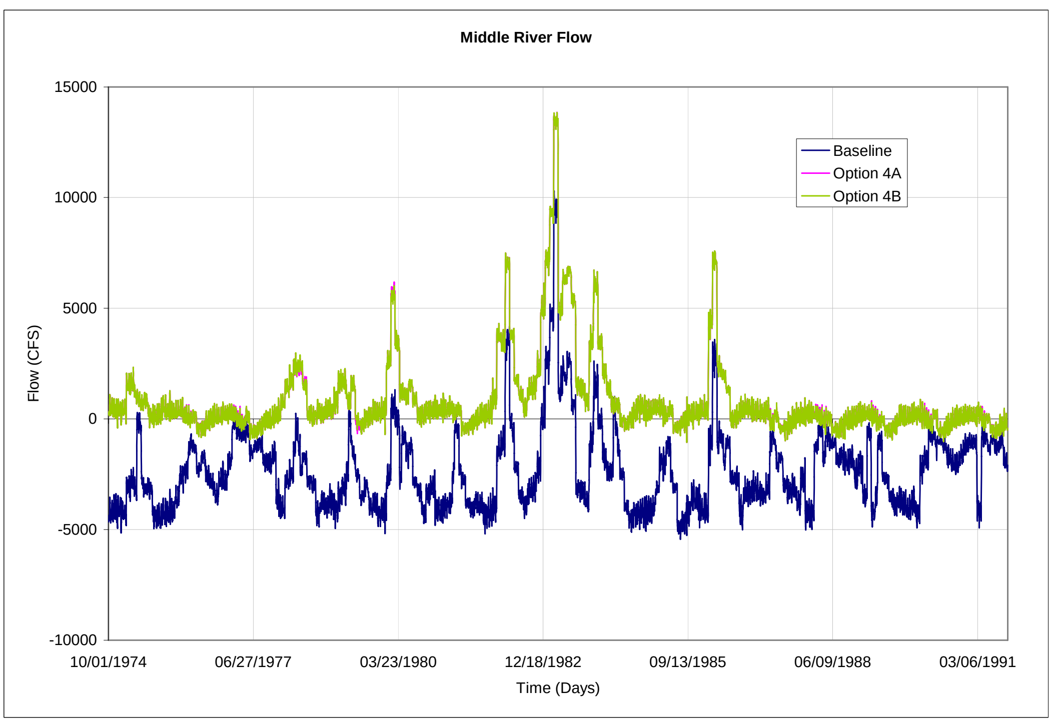


Figure G-17. DSM2 Simulated Daily Averaged Middle River Flows

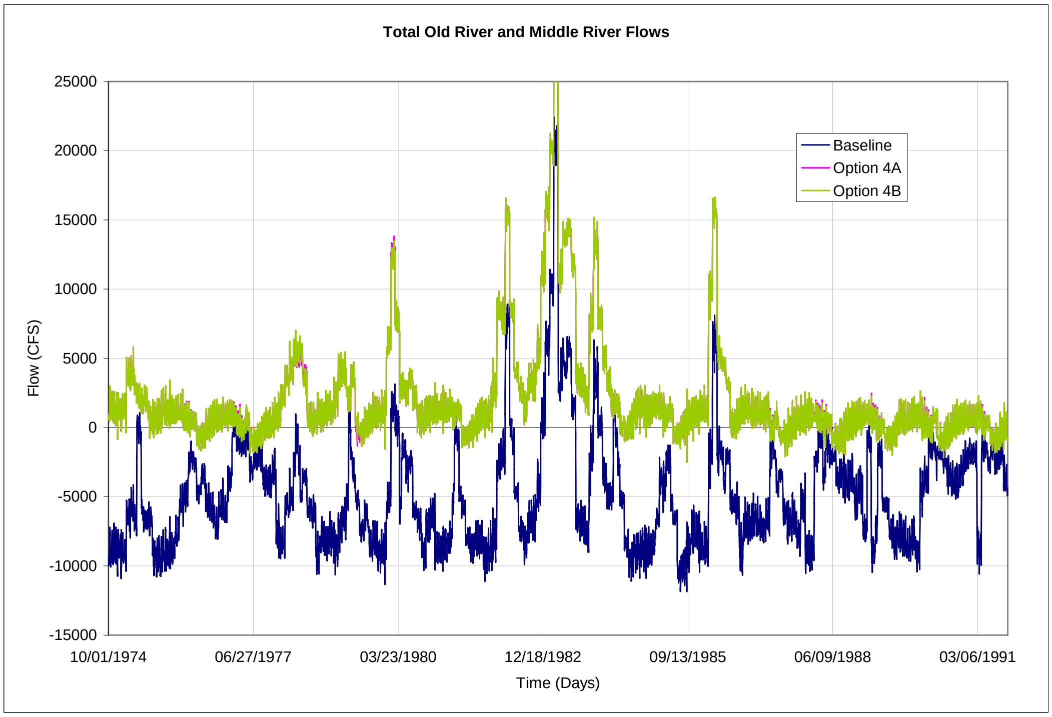


Figure G-18. DSM2 Simulated Daily Averaged Combined Old and Middle River Flows

Appendix H. Comparison of Options by Biological Criterion

This appendix presents scores of each Option by biological criteria in Table H-1 through H-9. Table H-10 presents scores by metrics and tools for each biological criterion according to scales presented in Table 2-2.

Appendix H. Comparison of Options by Biological Criterion

Table H-1. Delta Smelt: Comparison of Options by Biological Criterion

Criterion	Certainty[1]	Effects[2,3]			
		Option 1	Option 2	Option 3	Option 4
1. Relative degree to which the Option would reduce species mortality attributable to non-natural mortality sources, in order to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species (BDCP Conservation Objective).	3	●	●●	●●●	●●●●
2. Relative degree to which the Option would provide water quality and flow conditions necessary to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species (BDCP Conservation Objective).	3	●	●	●	●
3. Relative degree to which the Option would increase habitat quality, quantity, accessibility, and diversity in order to enhance and sustain production (reproduction, growth, survival), abundance, and distribution; and to improve the resiliency of each of the covered species' populations to environmental change and variable hydrology (BDCP Conservation Objective).	3	●	●●	●●●	●●●●
4. Relative degree to which the Option would increase food quality, quantity, and accessibility (e.g., phytoplankton, zooplankton, macro-invertebrates, forage fish) to enhance production (reproduction, growth, survival) and abundance for each of the covered fish species (BDCP Conservation Objective).	3	●	●●	●●●	●●●●
5. Relative degree to which the Option would reduce the abundance of non-native competitors and predators to increase native species production (reproduction, growth, survival), abundance and distribution for each of the covered fish species (BDCP Conservation Objective).	2	●●	●●●	●●●	●●●●
6. Relative degree to which the Option improves ecosystem processes in the BDCP planning area to support aquatic and associated habitats (BDCP Conservation Objective).	3	●	●●	●●●	●●●●
7. Relative degree to which the Option can be implemented within a timeframe to meet the near-term needs of each covered fish species (post BDCP authorization).	NA	●	●	●	●

[1]**Relative degree of certainty** of the magnitude of Option effect on the stressor: **4** = High **3** = Moderate **2** = Low **1** = little or no certainty. Relative degree of certainty assigned here is based on a qualitative combination of the certainty levels assigned to impact mechanisms relative to stressors (Appendix C) and the certainty level assigned to tools relative to metrics (Section 2)
[2]Derived from information presented in Table H-10
[3]**Effects (relative to base conditions):** ● = very low benefit, ●● = low benefit, ●●● = moderate benefit, ●●●● =high, ⊗ = no change, ○ = very low adverse effect, ○○ = low adverse effect, ○○○ = moderate adverse effect, ○○○○ = high adverse effect

Table H-2. Longfin Smelt: Comparison of Options by Biological Criterion

Criterion	Certainty[1]	Effects[2,3]			
		Option 1	Option 2	Option 3	Option 4
1. Relative degree to which the Option would reduce species mortality attributable to non-natural mortality sources, in order to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species (BDCP Conservation Objective).	3	●	●●	●●●	●●●●
2. Relative degree to which the Option would provide water quality and flow conditions necessary to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species (BDCP Conservation Objective).	3	●	●	●	●
3. Relative degree to which the Option would increase habitat quality, quantity, accessibility, and diversity in order to enhance and sustain production (reproduction, growth, survival), abundance, and distribution; and to improve the resiliency of each of the covered species' populations to environmental change and variable hydrology (BDCP Conservation Objective).	3	●	●●	●●	●●●
4. Relative degree to which the Option would increase food quality, quantity, and accessibility (e.g., phytoplankton, zooplankton, macro-invertebrates, forage fish) to enhance production (reproduction, growth, survival) and abundance for each of the covered fish species (BDCP Conservation Objective).	3	●	●●	●●●	●●●●
5. Relative degree to which the Option would reduce the abundance of non-native competitors and predators to increase native species production (reproduction, growth, survival), abundance and distribution for each of the covered fish species (BDCP Conservation Objective).	2	●●	●●●	●●●	●●●●
6. Relative degree to which the Option improves ecosystem processes in the BDCP planning area to support aquatic and associated habitats (BDCP Conservation Objective).	3	●	●●	●●●	●●●●
7. Relative degree to which the Option can be implemented within a timeframe to meet the near-term needs of each covered fish species (post BDCP authorization).	NA	●	●	●	●

[1]**Relative degree of certainty** of the magnitude of Option effect on the stressor: **4** = High **3** = Moderate **2** = Low **1** = little or no certainty. Relative degree of certainty assigned here is based on a qualitative combination of the certainty levels assigned to impact mechanisms relative to stressors (Appendix C) and the certainty level assigned to tools relative to metrics (Section 2)
[2]Derived from information presented in Table H-10
[3]**Effects (relative to base conditions):** ● = very low benefit, ●● = low benefit, ●●● = moderate benefit, ●●●● =high, ⊗ = no change, ○ = very low adverse effect, ○○ = low adverse effect, ○○○ = moderate adverse effect, ○○○○ = high adverse effect

Table H-3. Sacramento River Chinook Salmon: Comparison of Options by Biological Criterion

Criterion	Certainty[1]	Effects[2,3] Option 1	Option 2	Option 3	Option 4
1. Relative degree to which the Option would reduce species mortality attributable to non-natural mortality sources, in order to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species (BDCP Conservation Objective).	3	●	●	●●	●●●●
2. Relative degree to which the Option would provide water quality and flow conditions necessary to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species (BDCP Conservation Objective).	3	⊗	⊗	○○	○
3. Relative degree to which the Option would increase habitat quality, quantity, accessibility, and diversity in order to enhance and sustain production (reproduction, growth, survival), abundance, and distribution; and to improve the resiliency of each of the covered species' populations to environmental change and variable hydrology (BDCP Conservation Objective).	3	●●	●●	⊗	●●●
4. Relative degree to which the Option would increase food quality, quantity, and accessibility (e.g., phytoplankton, zooplankton, macro-invertebrates, forage fish) to enhance production (reproduction, growth, survival) and abundance for each of the covered fish species (BDCP Conservation Objective).	3	⊗	⊗	⊗	⊗
5. Relative degree to which the Option would reduce the abundance of non-native competitors and predators to increase native species production (reproduction, growth, survival), abundance and distribution for each of the covered fish species (BDCP Conservation Objective).	2	●●	●●	●●	●●●●
6. Relative degree to which the Option improves ecosystem processes in the BDCP planning area to support aquatic and associated habitats (BDCP Conservation Objective).	3	●	●●	●●●	●●●●
7. Relative degree to which the Option can be implemented within a timeframe to meet the near-term needs of each covered fish species (post BDCP authorization).	NA	●	●	●	●

[1]**Relative degree of certainty** of the magnitude of Option effect on the stressor: **4** = High **3** = Moderate **2** = Low **1** = little or no certainty. Relative degree of certainty assigned here is based on a qualitative combination of the certainty levels assigned to impact mechanisms relative to stressors (Appendix C) and the certainty level assigned to tools relative to metrics (Section 2)

[2]Derived from information presented in Table H-10

[3]**Effects (relative to base conditions):** ● = very low benefit, ●● = low benefit, ●●● = moderate benefit, ●●●● =high, ⊗ = no change, ○ = very low adverse effect, ○○ = low adverse effect, ○○○ = moderate adverse effect, ○○○○ = high adverse effect

Table H-4. Sacramento River Steelhead: Comparison of Options by Biological Criterion

Criterion	Certainty[1]	Effects[2,3]			
		Option 1	Option 2	Option 3	Option 4
1. Relative degree to which the Option would reduce species mortality attributable to non-natural mortality sources, in order to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species (BDCP Conservation Objective).	3	●	●	●●	●●●●
2. Relative degree to which the Option would provide water quality and flow conditions necessary to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species (BDCP Conservation Objective).	3	⊗	⊗	○○	○
3. Relative degree to which the Option would increase habitat quality, quantity, accessibility, and diversity in order to enhance and sustain production (reproduction, growth, survival), abundance, and distribution; and to improve the resiliency of each of the covered species' populations to environmental change and variable hydrology (BDCP Conservation Objective).	3	●●	●●	⊗	●●
4. Relative degree to which the Option would increase food quality, quantity, and accessibility (e.g., phytoplankton, zooplankton, macro-invertebrates, forage fish) to enhance production (reproduction, growth, survival) and abundance for each of the covered fish species (BDCP Conservation Objective).	3	⊗	⊗	⊗	⊗
5. Relative degree to which the Option would reduce the abundance of non-native competitors and predators to increase native species production (reproduction, growth, survival), abundance and distribution for each of the covered fish species (BDCP Conservation Objective).	2	●●	●●	●●	●●●●
6. Relative degree to which the Option improves ecosystem processes in the BDCP planning area to support aquatic and associated habitats (BDCP Conservation Objective).	3	●	●●	●●●	●●●●
7. Relative degree to which the Option can be implemented within a timeframe to meet the near-term needs of each covered fish species (post BDCP authorization).	NA	●	●	●	●

[1]**Relative degree of certainty** of the magnitude of Option effect on the stressor: **4** = High **3** = Moderate **2** = Low **1** = little or no certainty. Relative degree of certainty assigned here is based on a qualitative combination of the certainty levels assigned to impact mechanisms relative to stressors (Appendix C) and the certainty level assigned to tools relative to metrics (Section 2)
[2]Derived from information presented in Table H-10
[3]**Effects (relative to base conditions):** ● = very low benefit, ●● = low benefit, ●●● = moderate benefit, ●●●● =high, ⊗ = no change, ○ = very low adverse effect, ○○ = low adverse effect, ○○○ = moderate adverse effect, ○○○○ = high adverse effect

Table H-5. San Joaquin River Chinook Salmon: Comparison of Options by Biological Criterion

Criterion	Certainty[1]	Effects[2,3] Option 1	Option 2	Option 3	Option 4
1. Relative degree to which the Option would reduce species mortality attributable to non-natural mortality sources, in order to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species (BDCP Conservation Objective).	3	⊗	●●	●●●	●●●●
2. Relative degree to which the Option would provide water quality and flow conditions necessary to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species (BDCP Conservation Objective).	3	⊗	⊗	○	○
3. Relative degree to which the Option would increase habitat quality, quantity, accessibility, and diversity in order to enhance and sustain production (reproduction, growth, survival), abundance, and distribution; and to improve the resiliency of each of the covered species' populations to environmental change and variable hydrology (BDCP Conservation Objective).	3	●●	●●	●●	●●●●
4. Relative degree to which the Option would increase food quality, quantity, and accessibility (e.g., phytoplankton, zooplankton, macro-invertebrates, forage fish) to enhance production (reproduction, growth, survival) and abundance for each of the covered fish species (BDCP Conservation Objective).	3	⊗	⊗	⊗	⊗
5. Relative degree to which the Option would reduce the abundance of non-native competitors and predators to increase native species production (reproduction, growth, survival), abundance and distribution for each of the covered fish species (BDCP Conservation Objective).	2	●●	●●●	●●●	●●●●
6. Relative degree to which the Option improves ecosystem processes in the BDCP planning area to support aquatic and associated habitats (BDCP Conservation Objective).	3	●	●●	●●●	●●●●
7. Relative degree to which the Option can be implemented within a timeframe to meet the near-term needs of each covered fish species (post BDCP authorization).	NA	●	●	●	●

[1]**Relative degree of certainty** of the magnitude of Option effect on the stressor: **4** = High **3** = Moderate **2** = Low **1** = little or no certainty. Relative degree of certainty assigned here is based on a qualitative combination of the certainty levels assigned to impact mechanisms relative to stressors (Appendix C) and the certainty level assigned to tools relative to metrics (Section 2)
[2]Derived from information presented in Table H-10
[3]**Effects (relative to base conditions):** ● = very low benefit, ●● = low benefit, ●●● = moderate benefit, ●●●● =high, ⊗ = no change, ○ = very low adverse effect, ○○ = low adverse effect, ○○○ = moderate adverse effect, ○○○○ = high adverse effect

Table H-6. San Joaquin River Steelhead: Comparison of Options by Biological Criterion

Criterion	Certainty[1]	Effects[2,3]			
		Option 1	Option 2	Option 3	Option 4
1. Relative degree to which the Option would reduce species mortality attributable to non-natural mortality sources, in order to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species (BDCP Conservation Objective).	3	⊗	●●	●●●	●●●●
2. Relative degree to which the Option would provide water quality and flow conditions necessary to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species (BDCP Conservation Objective).	3	⊗	⊗	○	○
3. Relative degree to which the Option would increase habitat quality, quantity, accessibility, and diversity in order to enhance and sustain production (reproduction, growth, survival), abundance, and distribution; and to improve the resiliency of each of the covered species' populations to environmental change and variable hydrology (BDCP Conservation Objective).	3	●●	●●	●●	●●●●
4. Relative degree to which the Option would increase food quality, quantity, and accessibility (e.g., phytoplankton, zooplankton, macro-invertebrates, forage fish) to enhance production (reproduction, growth, survival) and abundance for each of the covered fish species (BDCP Conservation Objective).	3	⊗	⊗	⊗	⊗
5. Relative degree to which the Option would reduce the abundance of non-native competitors and predators to increase native species production (reproduction, growth, survival), abundance and distribution for each of the covered fish species (BDCP Conservation Objective).	2	●●	●●●	●●●	●●●●
6. Relative degree to which the Option improves ecosystem processes in the BDCP planning area to support aquatic and associated habitats (BDCP Conservation Objective).	3	●	●●	●●●	●●●●
7. Relative degree to which the Option can be implemented within a timeframe to meet the near-term needs of each covered fish species (post BDCP authorization).	NA	●	●	●	●

[1]**Relative degree of certainty** of the magnitude of Option effect on the stressor: **4** = High **3** = Moderate **2** = Low **1** = little or no certainty. Relative degree of certainty assigned here is based on a qualitative combination of the certainty levels assigned to impact mechanisms relative to stressors (Appendix C) and the certainty level assigned to tools relative to metrics (Section 2)
[2]Derived from information presented in Table H-10
[3]**Effects (relative to base conditions):** ● = very low benefit, ●● = low benefit, ●●● = moderate benefit, ●●●● =high, ⊗ = no change, ○ = very low adverse effect, ○○ = low adverse effect, ○○○ = moderate adverse effect, ○○○○ = high adverse effect

Table H-7. Green Sturgeon: Comparison of Options by Biological Criterion

Criterion	Certainty[1]	Effects[2,3] Option 1	Option 2	Option 3	Option 4
1. Relative degree to which the Option would reduce species mortality attributable to non-natural mortality sources, in order to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species (BDCP Conservation Objective).	3	⊗	⊗	○	○
2. Relative degree to which the Option would provide water quality and flow conditions necessary to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species (BDCP Conservation Objective).	2	⊗	⊗	○	○
3. Relative degree to which the Option would increase habitat quality, quantity, accessibility, and diversity in order to enhance and sustain production (reproduction, growth, survival), abundance, and distribution; and to improve the resiliency of each of the covered species' populations to environmental change and variable hydrology (BDCP Conservation Objective).	3	●●	●●	●●	●●●
4. Relative degree to which the Option would increase food quality, quantity, and accessibility (e.g., phytoplankton, zooplankton, macro-invertebrates, forage fish) to enhance production (reproduction, growth, survival) and abundance for each of the covered fish species (BDCP Conservation Objective).	2	⊗	●●	●●	●●●
5. Relative degree to which the Option would reduce the abundance of non-native competitors and predators to increase native species production (reproduction, growth, survival), abundance and distribution for each of the covered fish species (BDCP Conservation Objective).	2	⊗	⊗	⊗	⊗
6. Relative degree to which the Option improves ecosystem processes in the BDCP planning area to support aquatic and associated habitats (BDCP Conservation Objective).	3	●	●●	●●●	●●●●
7. Relative degree to which the Option can be implemented within a timeframe to meet the near-term needs of each covered fish species (post BDCP authorization).	NA	●	●	●	●

[1]**Relative degree of certainty** of the magnitude of Option effect on the stressor: **4** = High **3** = Moderate **2** = Low **1** = little or no certainty. Relative degree of certainty assigned here is based on a qualitative combination of the certainty levels assigned to impact mechanisms relative to stressors (Appendix C) and the certainty level assigned to tools relative to metrics (Section 2)
[2]Derived from information presented in Table H-10
[3]**Effects (relative to base conditions):** ● = very low benefit, ●● = low benefit, ●●● = moderate benefit, ●●●● =high, ⊗ = no change, ○ = very low adverse effect, ○○ = low adverse effect, ○○○ = moderate adverse effect, ○○○○ = high adverse effect

Table H-8. White Sturgeon: Comparison of Options by Biological Criterion

Criterion	Certainty [1]	Effects [2,3]			
		Option 1	Option 2	Option 3	Option 4
1. Relative degree to which the Option would reduce species mortality attributable to non-natural mortality sources, in order to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species (BDCP Conservation Objective).	3	⊗	⊗	○	●
2. Relative degree to which the Option would provide water quality and flow conditions necessary to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species (BDCP Conservation Objective).	2	⊗	○	○	●●
3. Relative degree to which the Option would increase habitat quality, quantity, accessibility, and diversity in order to enhance and sustain production (reproduction, growth, survival), abundance, and distribution; and to improve the resiliency of each of the covered species' populations to environmental change and variable hydrology (BDCP Conservation Objective).	3	●	●●	●●	●●●
4. Relative degree to which the Option would increase food quality, quantity, and accessibility (e.g., phytoplankton, zooplankton, macro-invertebrates, forage fish) to enhance production (reproduction, growth, survival) and abundance for each of the covered fish species (BDCP Conservation Objective).	3	●	●●	●●	●●●
5. Relative degree to which the Option would reduce the abundance of non-native competitors and predators to increase native species production (reproduction, growth, survival), abundance and distribution for each of the covered fish species (BDCP Conservation Objective).	2	⊗	⊗	⊗	⊗
6. Relative degree to which the Option improves ecosystem processes in the BDCP planning area to support aquatic and associated habitats (BDCP Conservation Objective).	3	●	●●	●●●	●●●●
7. Relative degree to which the Option can be implemented within a timeframe to meet the near-term needs of each covered fish species (post BDCP authorization).	NA	●	●	●	●

[1]**Relative degree of certainty** of the magnitude of Option effect on the stressor: **4** = High **3** = Moderate **2** = Low **1** = little or no certainty. Relative degree of certainty assigned here is based on a qualitative combination of the certainty levels assigned to impact mechanisms relative to stressors (Appendix C) and the certainty level assigned to tools relative to metrics (Section 2)
[2]Derived from information presented in Table H-10
[3]**Effects (relative to base conditions):** ● = very low benefit, ●● = low benefit, ●●● = moderate benefit, ●●●● =high, ⊗ = no change, ○ = very low adverse effect, ○○ = low adverse effect, ○○○ = moderate adverse effect, ○○○○ = high adverse effect

Table H-9. Sacramento Splittail: Comparison of Options by Biological Criterion

Criterion	Certainty[1]	Effects[2,3]			
		Option 1	Option 2	Option 3	Option 4
1. Relative degree to which the Option would reduce species mortality attributable to non-natural mortality sources, in order to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species (BDCP Conservation Objective).	3	●	●●	●●●	●●●●
2. Relative degree to which the Option would provide water quality and flow conditions necessary to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species (BDCP Conservation Objective).	2	⊗	●	○	○
3. Relative degree to which the Option would increase habitat quality, quantity, accessibility, and diversity in order to enhance and sustain production (reproduction, growth, survival), abundance, and distribution; and to improve the resiliency of each of the covered species' populations to environmental change and variable hydrology (BDCP Conservation Objective).	3	●●	●●●	●●●	●●●●
4. Relative degree to which the Option would increase food quality, quantity, and accessibility (e.g., phytoplankton, zooplankton, macro-invertebrates, forage fish) to enhance production (reproduction, growth, survival) and abundance for each of the covered fish species (BDCP Conservation Objective).	3	●	●●	●●●	●●●●
5. Relative degree to which the Option would reduce the abundance of non-native competitors and predators to increase native species production (reproduction, growth, survival), abundance and distribution for each of the covered fish species (BDCP Conservation Objective).	2	●●	●●	●●●	●●●●
6. Relative degree to which the Option improves ecosystem processes in the BDCP planning area to support aquatic and associated habitats (BDCP Conservation Objective).	3	●	●●	●●●	●●●●
7. Relative degree to which the Option can be implemented within a timeframe to meet the near-term needs of each covered fish species (post BDCP authorization).	NA	●	●	●	●

[1]**Relative degree of certainty** of the magnitude of Option effect on the stressor: **4** = High **3** = Moderate **2** = Low **1** = little or no certainty. Relative degree of certainty assigned here is based on a qualitative combination of the certainty levels assigned to impact mechanisms relative to stressors (Appendix C) and the certainty level assigned to tools relative to metrics (Section 2)
[2]Derived from information presented in Table H-10
[3]**Effects (relative to base conditions):** ● = very low benefit, ●● = low benefit, ●●● = moderate benefit, ●●●● =high, ⊗ = no change, ○ = very low adverse effect, ○○ = low adverse effect, ○○○ = moderate adverse effect, ○○○○ = high adverse effect

Table H-10. Scores by Metrics and Tools for Biological Criteria

Metric	Relationship	Tools	Option scores[1] 1	2	3	4
Criterion #1. Relative degree to which the Option would reduce species mortality attributable to non-natural mortality sources, in order to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species (BDCP Conservation Objective)						
B1. Opportunity for restoration of aquatic and intertidal habitat under the Option	Improving the quality and extent of aquatic and intertidal habitat in the Delta is hypothesized to reduce mortality by: ▪ Improving the abundance and availability of food that is more nutritious than non-native species; ▪ Create conditions that are less favorable for supporting non-native species that compete for food; and ▪ Create conditions that are less favorable to non-native predators and that reduce the susceptibility of covered fish species to predation. **Certainty:** 2	A. Proportion of the planning area available for restoration of high-function aquatic and intertidal habitats	**2**	**3**	**3**	**4**

[1] First score corresponds to Scenario A, second score corresponds to Scenario B where applicable

Table H-10. Scores by Metrics and Tools for Biological Criteria

Metric	Relationship	Tools	Option scores[1]			
			1	2	3	4
B2. Opportunity for improving inflows into the Delta	Changes in peak total Delta inflows during peak runoff periods change the frequency and duration of floodplain inundation and affect: ▪ Inputs of nutrients to the Delta, which affects food production and availability, ▪ Turbidity, which affects the foraging efficiency and predation vulnerability of delta and longfin smelt, ▪ Extent of food available for Sacramento splittail rearing. **Certainty:** 3	A. Change from base conditions in hydrologic modeling results for peak total Delta inflows during January-March	**3/4**	**4/4**	**1/1**	**1/1**
	The potential range of spring Delta inflow is indicative of the ability of the Option to dilute contaminants that could result in mortality **Certainty:** 3	B. Change from base conditions in hydrologic modeling results for Sacramento River flows at Rio Vista during March and April	**4/3**	**4/3**	**2/3**	**2/2**
	The potential range of spring Delta inflow is indicative of the ability of the Option to dilute contaminants that could result in mortality **Certainty:** 3	C. Change from base conditions in hydrologic modeling results for total Delta inflow during March and April	**4/4**	**4/4**	**2/3**	**2/3**

Table H-10. Scores by Metrics and Tools for Biological Criteria

Metric	Relationship	Tools	Option scores[1]			
			1	**2**	**3**	**4**
B3. Opportunities to improve hydraulic residence time	Changes in hydraulic residence time within the central Delta affect food production and turbidity which affects the foraging efficiency and vulnerability to predation of all species but splittail (splittail are addressed separately below). The particle tracking model approximates the likelihood of nutrients and food remaining in the central Delta **Certainty:** 3	A. Change from base conditions in particle tracking modeling results for percentage of particles after 14 days with "central" fate for the three hydrology conditions (50%, 70%, and 90% exceedance)	**2/3**	**4/4**	**5/5**	**5/5**
		B. Change from base conditions in particle tracking modeling results for percentage of particles after 28 days with "central" fate for the three hydrology conditions (50%, 70%, and 90% exceedance)	**1/4**	**5/4**	**5/5**	**5/5**
	Changes in hydraulic residence time within the central Delta affect food production and turbidity which affects the foraging efficiency and vulnerability to predation of splittail. The particle tracking model approximates the likelihood of nutrients and food remaining in the central Delta under drier conditions, when food is limiting to splittail **Certainty:** 4	A. Change from base conditions in particle tracking modeling results for percentage of particles after 14 days with "central" fate for the 50% exceedance hydrology	**2/1**	**3/3**	**4/4**	**4/4**
		B. Change from base conditions in particle tracking modeling results for percentage of particles after 28 days with "central" fate for the 50% exceedance hydrology	**1/1**	**4/3**	**5/5**	**5/5**

Table H-10. Scores by Metrics and Tools for Biological Criteria

Metric	Relationship	Tools	Option scores[1]			
			1	**2**	**3**	**4**
B4. Ability to reduce the export of nutrients and food from the Delta	The SWP/CVP export facilities and agricultural diversions entrain food and nutrients from the Delta that can affect food production and availability to all fish species but splittail. The particle tracking model approximates the likelihood for entrainment of nutrients and food of these diversions. **Certainty:** 3	A. Change from base conditions in particle tracking modeling results for percentage of particles after 14 days with either "SWP/CVP exports" or "agricultural diversions" fate for the three hydrology conditions (50%, 70%, and 90% exceedance)	**2/4**	**5/5**	**5/5**	**5/5**
		B. Change from base conditions in particle tracking modeling results for percentage of particles after 28 days with either "SWP/CVP exports" or "agricultural diversions" fate for the three hydrology conditions (50%, 70%, and 90% exceedance)	**1/4**	**4/4**	**5/5**	**5/5**
	The SWP/CVP export facilities and agricultural diversions entrain food and nutrients from the Delta that can affect food production and availability to splittail. The particle tracking model approximates the likelihood for entrainment of nutrients and food of these diversions under drier conditions, when food is limiting to splittail. **Certainty:** 4	C. Change from base conditions in particle tracking modeling results for percentage of particles after 14 days with either "SWP/CVP exports" or "agricultural diversions" fate for the 50% exceedance hydrological condition	**2/1**	**5/4**	**5/5**	**5/5**
		D. Change from base conditions in particle tracking modeling results for percentage of particles after 28 days with either "SWP/CVP exports" or "agricultural diversions" fate for the 50% exceedance hydrological condition	**2/2**	**4/4**	**4/4**	**5/5**

Table H-10. Scores by Metrics and Tools for Biological Criteria

Metric	Relationship	Tools	Option scores[1]			
			1	**2**	**3**	**4**
B5. Ability to reduce entrainment at the SWP/CVP export facilities	Entrainment of particles using the particle tracking model approximate the likelihood for entrainment of larval delta smelt and longfin smelt at the SWP/CVP facilities **Certainty:** 2	B. Change from base conditions in particle tracking modeling results for percentage of particles after 14 days for with "CVP/SWP exports" fate for the three hydrology conditions (50%, 70%, and 90% exceedance)	**2/4**	**5/5**	**5/5**	**5/5**
		C. Change from base conditions in particle tracking modeling results for percentage of particles after 28 days with "CVP/SWP exports" fate for the three hydrology conditions (50%, 70%, and 90% exceedance)	**1/4**	**4/4**	**5/5**	**5/5**
	There is evidence that the degree of reverse flow in Old and Middle Rivers is positively correlated to entrainment levels of juvenile and adult fish **Certainty:** 3	D. Change from base conditions in Old and Middle River reverse flows in modeling results during January	**4/5**	**5/5**	**5/5**	**5/5**
		E. Change from base conditions in Old and Middle River reverse flows in modeling results during April	**4/5**	**5/5**	**5/5**	**5/5**
Criterion #2. Relative degree to which the Option would provide water quality and flow conditions necessary to enhance production (reproduction, growth, survival) , abundance, and distribution for each of the covered fish species (BDCP Conservation Objective)						
B6. Ability to improve the location of the low salinity zone during sensitive periods	The location of X_2 during April is related to the production, growth, and survival of delta smelt and longfin smelt **Certainty:** 3	A. Change in modeling results for the location of X_2 during April from base conditions	**2/3**	**3/3**	**2/2**	**2/2**

Table H-10. Scores by Metrics and Tools for Biological Criteria

Metric	Relationship	Tools	Option scores[1]			
			1	**2**	**3**	**4**
B7. Ability to improve turbidity of Delta waters	Changes in turbidity of Delta waters affects foraging efficiency and predation vulnerability of delta and longfin smelt. The particle tracking model approximates the likelihood for entrainment of algae and other particles that contribute to turbidity at the SWP/CVP facilities. **Certainty:** 3	A. Change from base conditions in particle tracking modeling results for percentage of particles after 14 days with "central" fate for the three hydrology conditions (50%, 70%, and 90% exceedance)	**2/3**	**4/4**	**5/5**	**5/5**
		B. Change from base conditions in particle tracking modeling results for percentage of particles after 28 days with "central" fate for the three hydrology conditions (50%, 70%, and 90% exceedance)	**1/4**	**5/4**	**5/5**	**5/5**
	Changes in peak total Delta inflows during peak runoff periods affects sediment inputs that govern turbidity in Delta waters which affects the foraging efficiency and vulnerability to predation. **Certainty:** 3	C. Change from base conditions in hydrologic modeling results for peak total Delta inflows during January-March	**3/4**	**4/4**	**1/1**	**1/1**
	Reduction in abundance of non-native species like filter-feeding clams (*Corbula*, *Corbicula*) and aquatic vegetation (*Egeria*, water hyacinth) could result in an increase in turbidity, Certainty: 2	D. Proportion of the planning area available for restoration of high-function aquatic and intertidal habitats	**2**	**3**	**3**	**4**

Table H-10. Scores by Metrics and Tools for Biological Criteria

Metric	Relationship	Tools	Option scores[1]			
			1	2	3	4
B8. Ability to improve net downstream flow	Changes in net downstream flow affects downstream transport of larval and juvenile fish. The particle tracking model approximates downstream transport of larvae and young juveniles from all Covered Species of fish except green and white sturgeon. **Certainty:** 2	A. Change from base conditions in particle tracking modeling results for percentage of particles after 14 days with either "past Chipps Island" or "to Suisun Marsh" fate for the three hydrology conditions (50%, 70%, and 90% exceedance)	**2/5**	**4/5**	**3/2**	**3/3**
		B. Change from base conditions in particle tracking modeling results for percentage of particles after 28 days with either "past Chipps Island" or "to Suisun Marsh" fate for the three hydrology conditions (50%, 70%, and 90% exceedance)	**2/5**	**5/5**	**4/3**	**4/4**
	Changes in spring Sacramento River flow at Rio Vista affects downstream transport of larval and juvenile fish and upstream migration cues for adult salmonids. **Certainty:** 2	C. Change from base conditions in hydrologic modeling results for Sacramento River flows at Rio Vista during March and April	**4/3**	**4/3**	**2/3**	**2/2**
	Changes in spring total Delta outflow affects downstream transport of larval and juvenile fish and upstream migration cues for adult salmonids. **Certainty:** 3	D. Change from base conditions in hydrologic modeling results for total Delta outflow during March and April	**3/5**	**5/5**	**2/2**	**2/3**

Table H-10. Scores by Metrics and Tools for Biological Criteria

Metric	Relationship	Tools	Option scores[1] 1	2	3	4
B9. Ability to provide cool water flows in the Sacramento, American, and Feather Rivers	The temperatures of water released from Shasta, Oroville, and Folsom Reservoirs may vary under the Options and, therefore, have differing effects on Sacramento River salmonids and sturgeon **Certainty:** 3	Change from base conditions in hydrologic modeling results for Shasta Reservoir storage volume	**3/3**	**4/3**	**3/3**	**3/1**
		Change from base conditions in hydrologic modeling results for Oroville Reservoir storage volume	**3/3**	**5/5**	**4/3**	**3/1**
		Change from base conditions in hydrologic modeling results for Folsom Reservoir storage volume	**3/4**	**4/4**	**3/3**	**2/1**
Criterion #3. Relative degree to which the Option would increase habitat quality, quantity, accessibility, and diversity in order to enhance and sustain production (reproduction, growth, survival), abundance, and distribution; and to improve the resiliency of each of the covered species' populations to environmental change and variable hydrology (BDCP Conservation Objective).						
B10. Opportunity for restoration of aquatic and intertidal habitat under the Option	Improving the quality and extent of aquatic and intertidal habitat in the Delta for covered species will increase the production, abundance, and distribution of covered species. **Certainty:** 2	A. Proportion of the planning area available for restoration of high-function aquatic and intertidal habitats	**2**	**3**	**3**	**4**

Table H-10. Scores by Metrics and Tools for Biological Criteria

Metric	Relationship	Tools	Option scores[1]			
			1	**2**	**3**	**4**
B11. Improve accessibility to spawning and rearing habitat	Changes in peak total Delta inflows during peak runoff periods change the frequency and duration of floodplain inundation that provides splittail spawning and larval rearing habitat. **Certainty:** 4	B. Change from base conditions in modeling results for peak total Delta inflows during January-March	**3/4**	**4/4**	**1/1**	**1/1**
	The location of X_2 during April determines the extent of rearing habitat available for delta and longfin smelt **Certainty:** 3	A. Change from base conditions in modeling results for the location of X_2 during April	**2/3**	**3/3**	**2/2**	**2/2**
B12. Ability to improve turbidity of Delta waters	Changes in turbidity of Delta waters affects foraging efficiency and predation vulnerability of delta and longfin smelt. The particle tracking model approximates the likelihood for entrainment of algae and other particles that contribute to turbidity at the SWP/CVP facilities. **Certainty:** 3	A. Change from base conditions in particle tracking modeling results for percentage of particles after 14 days with "central" fate for the three hydrology conditions (50%, 70%, and 90% exceedance)	**2/3**	**4/4**	**5/5**	**5/5**
		B. Change from base conditions in particle tracking modeling results for percentage of particles after 28 days with "central" fate for the three hydrology conditions (50%, 70%, and 90% exceedance)	**1/4**	**5/4**	**5/5**	**5/5**

Table H-10. Scores by Metrics and Tools for Biological Criteria

Metric	Relationship	Tools	Option scores[1]			
			1	**2**	**3**	**4**
	Changes in peak total Delta inflows during peak runoff periods affects sediment inputs that govern turbidity in Delta waters which affects the foraging efficiency and vulnerability to predation. **Certainty:** 3	C. Change from base conditions in hydrologic modeling results for peak total Delta inflows during January-March	**3/4**	**4/4**	**1/1**	**1/1**
	Reduction in abundance of non-native species like filter-feeding clams (*Corbula, Corbicula*) and aquatic vegetation (*Egeria*, water hyacinth) could result in an increase in turbidity, Certainty: 2	D. Proportion of the planning area available for restoration of high-function aquatic and intertidal habitats	**2**	**3**	**3**	**4**
B13. Ability to improve net downstream flow	Changes in net downstream flow affects downstream transport of larval and juvenile fish to rearing habitat. The particle tracking model approximates downstream transport of larvae and young juveniles from all Covered Species of fish except green and white sturgeon. . **Certainty:** 2	A. Change from base conditions in particle tracking modeling results for percentage of particles after 14 days with either “past Chipps Island” or “to Suisun Marsh” fate for the three hydrology conditions (50%, 70%, and 90% exceedance)	**2/5**	**4/5**	**3/2**	**3/3**
		B. Change from base conditions in particle tracking modeling results for percentage of particles after 28 days with either “past Chipps Island” or “to Suisun Marsh” fate for the three hydrology conditions (50%, 70%, and 90% exceedance)	**2/5**	**5/5**	**4/3**	**4/4**

Table H-10. Scores by Metrics and Tools for Biological Criteria

Metric	Relationship	Tools	Option scores[1]			
			1	2	3	4
	Changes in spring Sacramento River flow affects downstream transport of larval and juvenile delta smelt, longfin smelt and splittail to rearing habitat. **Certainty:** 3	E. Change from base conditions in hydrologic modeling results for Sacramento River flows at Rio Vista during March and April	**4/3**	**4/3**	**2/3**	**2/2**
	Changes in total spring Delta outflow affects downstream transport of larval and juvenile delta and longfin smelt to rearing habitat. **Certainty:** 3	D. Change from base conditions in hydrologic modeling results for total Delta outflow during March and April	**3/5**	**5/5**	**2/2**	**2/3**
Criterion #4. Relative degree to which the Option would increase food quality, quantity, and accessibility (e.g., phytoplankton, zooplankton, macro-invertebrates, forage fish) to enhance production (reproduction, growth, survival) and abundance for each of the covered fish species (BDCP Conservation Objective).						
B14. Opportunities for restoration of aquatic and intertidal habitat	Improving the quality and extent of aquatic and intertidal habitat in the Delta is hypothesized to reduce mortality by: ▪ Improving the abundance and availability of native prey species that are more nutritious than non-native species; and ▪ Create conditions that are less favorable for supporting non-native species that compete for food. **Certainty:** 2	A. Proportion of the planning area available for restoration of high-function aquatic and intertidal habitats	**2**	**3**	**3**	**4**

Table H-10. Scores by Metrics and Tools for Biological Criteria

Metric	Relationship	Tools	Option scores[1]			
			1	2	3	4
B15. Opportunities for improving peak inflows into the Delta	Changes in peak total Delta inflows during peak runoff periods change the frequency and period of floodplain inundation affect: ▪ Inputs of nutrients to the Delta, which affects food production and availability, ▪ Turbidity, which affects the foraging efficiency and predation vulnerability of delta and longfin smelt, ▪ Extent of food available for Sacramento splittail rearing. **Certainty:** 3	A. Change from base conditions in modeling results for peak total Delta inflows during January-March	**3/4**	**4/4**	**1/1**	**1/1**
B16. Opportunities to improve hydraulic residence time	Changes in hydraulic residence time within the central Delta affect food production and turbidity which affects the foraging efficiency to all fish species but splittail (splittail are addressed separately below). The particle tracking model approximates the likelihood for particles remaining in the central Delta.	A. Change from base conditions in particle tracking modeling results for percentage of particles after 14 days with "central" fate for the three hydrology conditions (50%, 70%, and 90% exceedance)	**2/3**	**4/4**	**4/5**	**5/5**

Table H-10. Scores by Metrics and Tools for Biological Criteria

Metric	Relationship	Tools	Option scores[1]			
			1	**2**	**3**	**4**
	Certainty: 3	B. Change from base conditions in particle tracking modeling results for percentage of particles after 28 days with "central" fate for the three hydrology conditions (50%, 70%, and 90% exceedance)	**1/4**	**5/4**	**5/5**	**5/5**
	Changes in hydraulic residence time within the central Delta affect food production and turbidity which affects the foraging efficiency to all fish species but splittail. The particle tracking model approximates the likelihood for particles remaining in the central Delta under drier conditions, when food is limiting to splittail **Certainty:** 4	C. Change from base conditions in particle tracking modeling results for percentage of particles after 14 days with "central" fate for the 50% exceedance hydrological condition	**2/1**	**3/3**	**4/4**	**4/4**
		D. Change from base conditions in particle tracking modeling results for percentage of particles after 28 days with "central" fate for the 50% exceedance hydrological condition	**1/1**	**4/3**	**5/5**	**5/5**
B17. Ability to reduce the export of nutrients and food from the Delta	The SWP/CVP export facilities and agricultural diversions entrain food and nutrients from the Delta that can affect food production and availability to all fish species but splittail. The particle tracking model approximates the likelihood for entrainment of nutrients and food of these diversions. **Certainty:** 3	A. Change from base conditions in particle tracking modeling results for percentage of particles after 14 days with either "SWP/CVP exports" or "agricultural diversions" fate for the three hydrology conditions (50%, 70%, and 90% exceedance)	**2/4**	**5/5**	**5/5**	**5/5**

Table H-10. Scores by Metrics and Tools for Biological Criteria

Metric	Relationship	Tools	Option scores[1]			
			1	2	3	4
		B. Change from base conditions in particle tracking modeling results for percentage of particles after 28 days with either "SWP/CVP exports" or "agricultural diversions" fate for the three hydrology conditions (50%, 70%, and 90% exceedance)	**1/4**	**4/4**	**5/5**	**5/5**
	The SWP/CVP export facilities and agricultural diversions entrain food and nutrients from the Delta that can affect food production and availability to splittail. The particle tracking model approximates the likelihood for entrainment of nutrients and food of these diversions under drier conditions, when food is limiting to splittail.. **Certainty:** 4	C. Change from base conditions in particle tracking modeling results for percentage of particles after 14 days with either "SWP/CVP exports" or "agricultural diversions" fate for the 50% exceedance hydrological condition	**2/1**	**5/4**	**5/5**	**5/5**
		D. Change from base conditions in particle tracking modeling results for percentage of particles after 28 days with either "SWP/CVP exports" or "agricultural diversions" fate for the 50% exceedance hydrological condition	**2/2**	**4/4**	**4/4**	**5/5**
Criterion #5. Relative degree to which the Option would reduce the abundance of non-native competitors and predators to increase native species production (reproduction, growth, survival), abundance and distribution for each of the covered fish species (BDCP Conservation Objective).						

Table H-10. Scores by Metrics and Tools for Biological Criteria

Metric	Relationship	Tools	Option scores[1] 1	2	3	4
B18. Opportunity for restoration of aquatic and intertidal habitat under the Option	Improving the quality and extent of aquatic and intertidal habitat in the Delta is hypothesized to: ▪ Create conditions that are less favorable for supporting non-native species that compete for food; and ▪ Create conditions that are less favorable to non-native predators and that reduce the vulnerability of covered fish species to predation. **Certainty:** 2	A. Proportion of the planning area available for restoration of high-function aquatic and intertidal habitats	**2**	**3**	**3**	**4**
Criterion #6. Relative degree to which the Option improves ecosystem processes in the BDCP planning area to support aquatic and associated habitats (BDCP Conservation Objective).						
B19. Opportunities for restoration of aquatic and intertidal habitat under the Option	Improving the quality and extent of aquatic and intertidal habitat in the Delta is hypothesized to contribute to higher levels of ecosystem function **Certainty:** 2	A. Proportion of the planning area available for restoration of high-function aquatic and intertidal habitats	**2**	**3**	**3**	**4**

Table H-10. Scores by Metrics and Tools for Biological Criteria

Metric	Relationship	Tools	Option scores[1] 1	2	3	4
B20. Opportunity to improve hydraulic residence time	Changes in hydraulic residence time within the central Delta affect food production and turbidity, which should contribute to higher levels of ecosystem function to all fish species but splittail (splittail are addressed separately below). The particle tracking model approximates the likelihood for particles remaining in the central Delta. **Certainty:** 3	A. Change from base conditions in particle tracking modeling results for percentage of particles after 14 days with "central" fate for the three hydrology conditions (50%, 70%, and 90% exceedance)	**2/3**	**4/4**	**4/5**	**5/5**
		B. Change from base conditions in particle tracking modeling results for percentage of particles after 28 days with "central" fate for the three hydrology conditions (50%, 70%, and 90% exceedance)	**1/4**	**5/4**	**5/5**	**5/5**
Criterion #7. Relative degree to which the Option can be implemented within a timeframe to meet the near-term needs of each covered fish species (post BDCP authorization).						
B21. Likelihood that the Option can be implemented before populations decline sufficiently to inhibit the likelihood for their future recovery	The longer the period required for implementation of the Option the less likely the Option will meet the near-term needs of covered fish species **Certainty:** Definitions not applicable.	Estimated time post-BDCP approval required to complete planning, design, and construction phases of Option implementation infrastructure	**5**	**5**	**5**	**5**

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