SHASTA LAKE
WATER RESOURCES INVESTIGATION

APPENDIX A

CALSIM II System Operation Simulation

TABLE OF CONTENTS

Items **Page**

CHAPTER I INTRODUCTION

CHAPTER II SLWRI HYDROLOGIC ANALYSIS

CHAPTER III SUMMARY

TABLES

THIS PAGE LEFT BLANK INTENTIONALLY

CHAPTER I
INTRODUCTION

CALSIM II, a water resources planning model, was used in the Shasta Reservoir Water Resources Investigation (SLWRI) to evaluate hydrologic impacts of Shasta Reservoir enlargement and/or changes in system operation of the California water supply system. In hydrologic analyses, a benchmark is established first and, by modifying benchmark facilities or operational rules, an alternative is built. Hydrologic impacts are the differences between an alternative and the benchmark condition.

This appendix introduces CALSIM II and its characteristics, and documents CALSIM II simulation methodology for the SLWRI and modeling results.

CALSIM II

CALSIM II is a generalized hydrologic modeling framework developed by the California Department of Water Resources (DWR) and the United States Department of the Interior, Bureau of Reclamation (Reclamation), to evaluate statewide operations of the Central Valley Project (CVP) and State Water Project (SWP). Its geographic coverage includes the valley floor drainage area of the Sacramento and San Joaquin rivers, the upper Trinity River, the San Joaquin Valley, a portion of the Tulare River basin, and southern California areas served by the CVP and SWP.

CALSIM II uses Water Resources Engineering Simulation Language (WRESL) to describe the physical water supply system (e.g., dams, reservoirs, channels, pumping plants), operational rules (e.g., flood-control diagrams, minimum flows, delivery requirements), and water allocation priorities. Once operational objectives and constraints are established, CALSIM II uses an optimization technique, Linear Programming (LP)/Mixed Integer Linear Programming (MILP), to determine monthly water allocations.

The CALSIM II Benchmark Study provides a common baseline condition for modeling CALFED projects and other water resources studies. The Benchmark Study incorporates applicable water rights, laws, regulations, biological opinions (BOs), contracts, agreements, and standards, such as the 1986 CVP/SWP Coordinated Operation Agreement (COA), State Water Resources Control Board (SWRCB) Water Right Decision 1641 (D-1641), and Central Valley Project Improvement Act (CVPIA), especially Section 3406(b)(2). (See Draft Benchmark Study Assumptions[1] for details of assumptions used in the Benchmark Study.) The latest public release of the CALSIM II Benchmark Study was dated September 30, 2002. The model simulation period is 73 years, from water years 1922 through 1994 (October 1921 to September 1994), with monthly time-steps. Levels of development (LOD) are 2001 for existing condition and 2020 for future condition.

[1] Draft Benchmark Study Assumptions and the September 2002 Benchmark Study are available on the DWR Web site: http://modeling.water.ca.gov/hydro/studies/SWPReliability/index2.html

Five-Step Simulation

A complete scenario in CALSIM II is a five-step simulation, performed in sequence. Each step represents a "layer" of constraints and operations. The five steps are listed below in the order in which they are performed:

1. D1485 step, for SWRCB D-1485, includes the old Sacramento-San Joaquin River Delta (Delta water quality standards, issued in August 1978.

2. D1641 step, for SWRCB D-1641, includes a water rights decision issued in December 1999 recognizing current Delta water quality standards (the 1995 Water Quality Control Plan for the San Francisco Bay-Sacramento-San Joaquin River Delta (Bay-Delta)).

3. B2 step, for CVPIA(3406b)(2) legal actions (commonly known as B2 actions), annually dedicating 800 thousand acre-feet (TAF) or 600 TAF in Shasta critical years for targeted fish actions of CVP yield.

4. JPOD step, for the CVP/SWP joint point of diversion (JPOD), is the use of one project's diversion facility by the other project, approved in D-1641.

5. EWA step, for the CALFED Environmental Water Account, provides water for fishery protection through changes in CVP/SWP operations.

The five-step simulation process is as follows: for each water year, CASLIM II models the first step, D1485, for 12 months, then models to the next step for the same 12 months, and then models the next step for the same 12 months, etc., through all five steps. The output of each step is transferred and used as input for the next step. For example, the B2 step requires cumulative results from the D1485 and D1641 steps to determine the required fishery release for a particular month. At the end of the last step, EWA, all operational constraints and objectives have been applied, water allocations for a particular water year are finalized, and the EWA results become the initial conditions (input) for modeling the next water year, beginning with the first step, D1485.

In addition to running the entire five-step simulation, a study can be run independently as single-step simulation. Single-step simulations can only address regulations and operations associated with an individual layer; however, computation time is approximately one-fifth of the time required for a multistep simulation.

CALSIM II users also can run a partial multistep simulation. Management of California water resources gradually tighten as a simulation progresses from layer to layer. Most legal requirements in CVP/SWP operations are resolved in Step 2 for SWRCB D-1641. CVP operations after Step 3 simulation for B2 actions are considered more realistic since CVP is the sole responsible party for reducing Delta exports due to operations related to implementing B2 actions. Currently, it is optional for projects that related to the CALFED ROD to include the remaining two steps in model implementation, but this could change in the future.

Highlights of Benchmark Operational Rules for the SLWRI

Operations of Shasta Reservoir depend on conditions in Trinity Lake, Whiskeytown Lake, and Keswick Reservoir. This section describes selected assumptions of the CALSIM II Benchmark Study related to operational rules for Shasta Reservoir, Keswick Reservoir, Trinity Lake, and Whiskeytown Lake. **Figure I-1** is a schematic of the CALSIM II Benchmark Study in the vicinity of Shasta Reservoir.

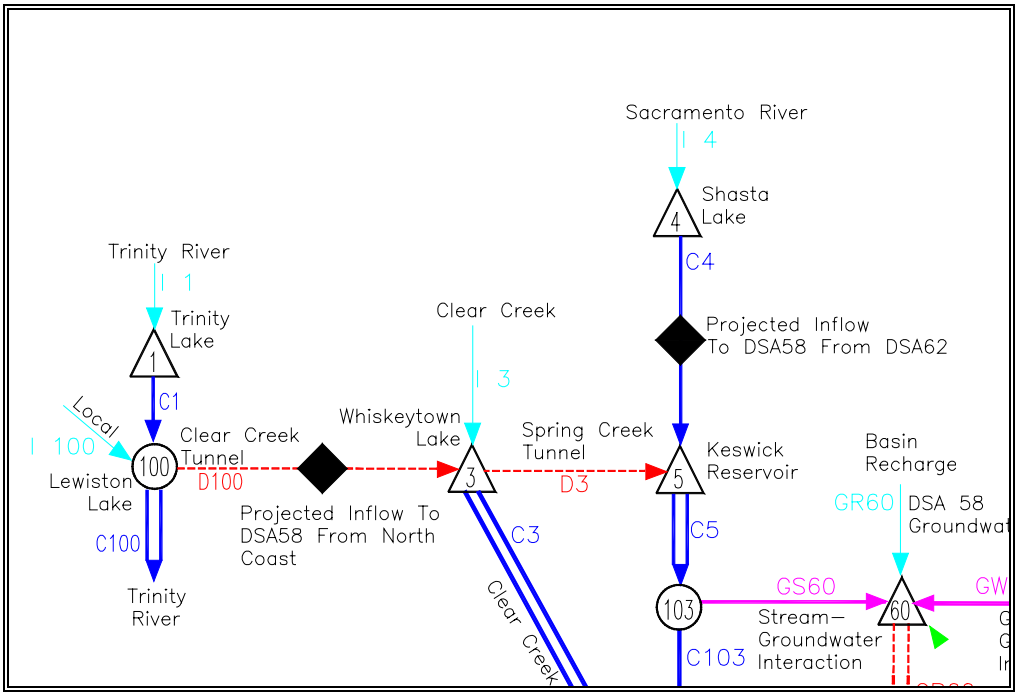

Figure I-1. CALSIM II Benchmark Study schematic for Shasta Reservoir vicinity.

A 1993 winter-run chinook salmon BO was issued by the National Marine Fisheries Service (NMFS), now the National Oceanic and Atmospheric Administration (NOAA) Fisheries, and adopted by the California Department of Fish and Game (CDFG). The BO includes requirements for Sacramento River flows and temperature at various locations, CVP and SWP coordination and cooperation, Shasta Reservoir carryover storage, and operational restrictions at the Red Bluff Diversion Dam (RBDD). Major Shasta Reservoir operations must address these issues. Since CALSIM II lacks temperature simulation capability, additional cold water releases from Shasta Reservoir were used as a surrogate for meeting temperature requirements.

Highlights of operational rules in the CALSIM II Benchmark Study for the SLWRI include the following:

- **Shasta Reservoir operation.** Shasta Reservoir capacity is 4,552 TAF, with maximum objective release capacity of 79,000 cubic feet per second (cfs). The end-of-September storage target for Shasta Reservoir is 1,900 TAF, except in the driest 10 percent of water years, to conserve sufficient cold water for meeting temperature criteria for the winter-run chinook incubation period (summer to early fall). Storage levels are lowest by October to

provide sufficient flood protection and capture capacity during the following wet months. The storage target gradually increases from October to full pool in May. Then storage is withdrawn for high water demand (municipal, agricultural, fishery, and water quality uses, etc.) during summer.

- **Keswick Dam hydropower generation.** The assumed total Keswick Dam hydropower capacity is 15,000 cfs.
- **Imports from the Trinity River Watershed.** Since 1964, Trinity River water has been imported into the Sacramento River basin through Clear Creek and Spring Creek tunnels (capacity 3,300 and 4,200 cfs, respectively). After meeting the monthly minimum instream flow requirement below Lewiston Lake,[2] and the Trinity Lake end-of-September minimum storage target of 600 TAF, Trinity River water is diverted into Whiskeytown Lake. Monthly diversions are based on the beginning-of-month storage in Shasta Reservoir and Trinity Lake. For example, imports can be as much as 3,000 cfs for July to September when Trinity Lake storage is high and Shasta Reservoir storage is low. Whiskeytown Lake receives inflow from Clear Creek. After making releases to meet the minimum flow requirement downstream of Whiskeytown Dam,[3] water is diverted through Spring Creek Tunnel to Keswick Reservoir.
- **Minimum flow requirement below Keswick Dam.** A minimum flow time-series was derived from the 1993 winter-run chinook salmon BO with temperature requirements for April through September. For months without temperature requirements (October through March), the monthly flow requirement is 3,250 cfs. The minimum flow requirement is relaxed when the end-of-March Shasta Reservoir storage level is low.
- **Minimum flow requirement below the RBDD.** The monthly value of minimum flow below the RBDD is a lookup value based on the Shasta index.[4] The requirement (taken from the previous water resources planning model, PROSIM, FWQ_b203.dat file) varies from 3,000 to 3,900 cfs.
- **Flow objective for navigation control point.** The monthly navigational flow objective at Wilkins Slough is 3,500, 4,000, or 5,000 cfs according to the beginning-of-month Shasta Reservoir storage. Pumping stations along the Sacramento River use 5,000 cfs as a basis for design and 4,000 cfs is the lowest operable flow limit for some pumps.

[2] This minimum requirement, an annual amount of 369 to 815 TAF per the Trinity Environmental Impact Statement (EIS) Preferred Alternative, is a lookup value that varies by month and the Trinity index; the Trinity index changes in April.

[3] This requirement is a lookup value that varies with the month and Shasta index.

[4] Hydrologic water year classification according to the unimpaired inflow into Lake Reservoir, defined by CVP. This index changes in March.

CHAPTER II
SLWRI HYDROLOGIC ANALYSIS

According to Chapter V of the SLWRI Initial Alternatives Information Report, the primary planning objectives of the SLWRI including the following:

- Increase the survival of anadromous fish populations in the Sacramento River primarily upstream from the RBDD (increase anadromous fish survival).
- Increase water supplies and water supply reliability for agricultural, municipal and industrial (M&I), and environmental purposes to help meet future water demands, with a focus on enlarging Shasta Dam and Reservoir (increase water supply reliability).

As part of plan formulation for the SLWRI, various Shasta Reservoir enlargements and operational changes were identified to address the planning objectives. These measures were combined to form concept plans. Concept plans with hydrologic impacts on the California water supply system (e.g., changes in channel flow rates or water allocation logic) were simulated in CALSIM II. Differences between without-project and with-project conditions are hydrologic effects of the different SLWRI concept plans.

A two-stage approach was applied to effectively select realistic concept plans among many. The first stage, the **measure stage**, used a single-step D1641 simulation to identify constraints/targets for detailed concept plan evaluation. The second stage, **concept plan-evaluation stage**, used a multistep simulation (three steps for water supply concept plans and four steps for fish survival) to perform in-depth hydrologic analyses on concept plans identified in the measure stage. Due to different modeling approaches, each stage has its own benchmark, which is an element of the CALSIM II Benchmark Study.

Per discussion with fish and wildlife experts from the California Department of Fish and Game (CDFG), a complete five- step CALSIM II simulation for the SLWRI was not necessary; however, B2 actions had to be accounted for. Therefore, the SLWRI study team decided that the CALSIM II multistep simulation for the SLWRI would stop at the B2 step, excluding the JPOD and EWA layers.

COMMON ASSUMPTIONS AND DEFINITIONS

Although not complete, Reclamation and DWR have been working to develop a set of common hydrologic assumptions for use in CALSIM II modeling and all the CALFED surface water storage programs. Common assumptions and definitions are elements of modeling methodology that were applied to all concept plans. Common assumptions for simulating Shasta Reservoir enlargement in CALSIM II include the following:

- For accounting purposes, the storage enlargement from raising Shasta Dam was simulated as a separate reservoir, S44, offstream of Shasta Reservoir, S4 (**Figure II-1**). The size of S44 is the same as the enlargement. Water moves between the two reservoirs through two conveyances (one for each flow direction) with no capacity constraints. Water is not allowed to simultaneously flow in both directions from one reservoir to the other.

- S44 is filled after Shasta Reservoir storage reaches its flood control level (S4_Level5); after S44 is full, water is stored in the Shasta Reservoir flood pool. Water in the Shasta Reservoir flood pool is evacuated first; after the S4 storage level reaches S4_Level5, S44 is drained until empty. Under this reservoir balance logic, flood flow is pumped and stored in S44 during the wet season; in late spring and summer, water in S44 is released to Shasta Reservoir and then to the Sacramento River for allocation.
- The S44 evaporation rate is zero throughout the simulation period. Total storage for S44 and S4 is used to calculate the corresponding surface area of the enlarged Shasta Reservoir. The monthly evaporation loss for the enlarged Shasta Reservoir is equal to the product of the enlarged Shasta Reservoir surface area and monthly Shasta Reservoir evaporation rate.

The following definitions were used in the SLWRI hydrologic analysis:

- A "year" is equivalent to a water year, starting in October 1 of the preceding calendar year and ending September 30 of the current calendar year.
- "Monthly" means the average condition for a particular month. CALSIM II is a monthly time-step model; it lacks daily or hourly resolution.
- "Year type" is defined as the Sacramento Valley water year hydrologic classification in D-1641. The five year types include wet, above normal, below normal, dry, and critical.
- "Impacts" are the differences between CALSIM II results for a concept plan and the benchmark.

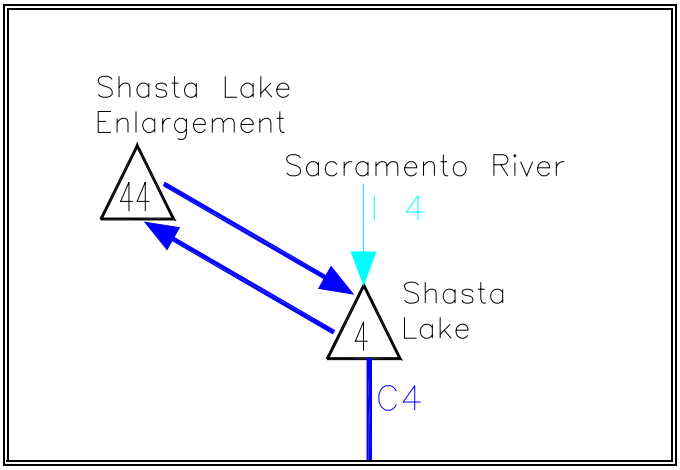

Figure II-1. CALSIM II schematic of Shasta Reservoir enlargement.

MEASURE STAGE

The purpose of the measure stage was to provide an effective procedure for formulating concept plans from a range of possible water resources management measures. A single-step approach with D1641 was used for this stage; only D1641 constraints restricted water allocation in the

simulation. This approach reduced the amount of computing time,[5] allowing more runs to test and iterate possible measures.

Water Supply Reliability Measures

Since these were measures to increase water supply and water supply reliability, the simulation was intuitive – increasing storage without any change in operational rules.

CALSIM II Assumptions

Following are modeling assumptions for water supply reliability measures, which also were applicable to measures for Shasta Reservoir enlargement:

- A single-step approach with D1641 was used. Shasta Enlargement S44 was included as Shasta Reservoir upstream storage and S44 was added in all calculations using S4 as a trigger in water allocation logic.
- The lookup table "Shasta_level.table" was modified by adding enlarged storage to non-zero values in the second column "storage." This modification was to ensure the annual average amount of imported water from the Trinity River watershed was close to the benchmark condition.

Modeling Results

For Shasta Reservoir enlargement, **Table II-1** summarizes annual average increases in CVP and SWP deliveries against the benchmark for all year types and dry and critical years. For a 290 TAF enlargement, CVP long-term deliveries increased by 47 TAF while SWP deliveries decreased by 2 TAF. For a 636 TAF enlargement, the increase in CVP long-term deliveries was greater, 79 TAF.

TABLE II-1
ANNUAL AVERAGE INCREASE IN PROJECT DELIVERIES:
SHASTA RESERVOIR ENLARGEMENTS

Shasta Dam Raise (feet)	Shasta Reservoir Enlargement (TAF)	Increase in Annual Average Deliveries from the Benchmark (TAF)			
		CVP All Year Types	CVP Dry and Critical Years	SWP All Year Types	SWP Dry and Critical Years
6.5	290	47	75	-2	4
18.5	636	79	128	-8	-22

Key: CVP – Central Valley Project SWP – State Water Project TAF – thousand acre-feet

Notes:
1. Year-types are defined as in the Sacramento Valley Water Year Hydrologic Classification Index.
2. Measures and the benchmark were simulated in single-step D1641.

[5] Modeling time for any single study is approximately a fifth of the time for the five-study approach.

Anadromous Fish Survival Measures

These measures focused on increasing the survival of anadromous fish through higher Keswick Dam release targets from October through April.

CALSIM II Assumptions

Following are modeling assumptions for anadromous fish survival measures:

- All water supply reliability assumptions for simulations with Shasta Reservoir enlargement were included.
- A monthly Keswick Dam release schedule was established for October through April that was higher than the benchmark condition. The Final Restoration Plan for the Anadromous Fish Restoration Program (AFRP), or AFRP Plan, set target flows below Keswick Dam for the time period of October 1 to April 30; target flows were proportional to the previous end-of-September Shasta Reservoir storage level, or Shasta carryover storage (**Table II-2**). The AFRP Plan target flows provide a reference for SLWRI flow requirements downstream of Keswick Dam for October through April. For the measure stage, four SLWRI Keswick Dam release schedules are shown in **Table II-3**, designated as AFRP1, AFRP2, AFRP3, and AFRP4. The flow target was based on carryover storage in the enlarged Shasta Reservoir (total of S4 and S44) and each schedule has a different release ceiling level.

TABLE II-2
RECOMMENDED MINIMUM KESWICK DAM RELEASE TARGETS FOR OCTOBER 1 TO APRIL 30, FROM AFRP FINAL RESTORATION PLAN

Carryover Storage[1] (MAF)	Minimum Keswick Dam Release Target (cfs)
1.9 to 2.1	3,250
2.2	3,500
2.3	3,750
2.4	4,000
2.5	4,250
2.6	4,500
2.7	4,750
2.8	5,000
2.9	5,250
3.0	5,500

Key:
AFRP – Anadromous Fish Restoration Program
cfs – cubic feet per second
MAF – million acre-feet

Source: Page 35 of Final Restoration Plan of the Anadromous Fish Restoration Plan
Note:
[1]Carryover storage is the October 1 storage for Shasta Reservoir.

TABLE II-3
SLWRI KESWICK DAM RELEASE SCHEDULES FOR MEASURE STAGE

Total Carryover Storage for S4 and S44[1] (MAF)	Minimum Keswick Dam Release Target (cfs)			
	AFRP1	AFRP2	AFRP3	AFRP4
1.9 to 2.1	3,250	3,250	3,250	3,250
2.2	3,500	3,500	3,500	3,500
2.3	3,750	3,750	3,750	3,500
2.4	4,000	4,000	3,750	3,500
2.5	4,250	4,250	3,750	3,500
2.6	4,500	4,500	3,750	3,500
2.7	4,750	4,500	3,750	3,500
2.8	5,000	4,500	3,750	3,500
2.9	5,250	4,500	3,750	3,500
3.0	5,500	4,500	3,750	3,500

Key:
AFRP – Anadromous Fish Restoration Program
cfs – cubic feet per second

Note:
[1]Carryover storage is the end-of-September storage from the previous water year.

Modeling Results

Ten measures, combinations of different Keswick Dam release schedules and Shasta Reservoir enlargements, were simulated and their impacts on project deliveries are shown in **Table II-4** and **Figure II-2**.

For a Shasta Reservoir enlargement of 290 TAF, the AFRP1 release schedule (same as in the AFRP Plan) led to a reduction of 44 TAF in long-term CVP total deliveries. As the minimum releases were lowered, impacts on long-term CVP total deliveries changed from reductions to increases. In dry and critical years, the lower the releases, the less the reduction in CVP total deliveries. Impacts on SWP total deliveries were the opposite; the higher the Keswick Dam minimum release targets, the greater the increase in SWP total deliveries.

For a Shasta Reservoir enlargement 636 TAF, AFRP1 decreased long-term CVP total deliveries by 6 TAF and increased SWP total deliveries by 45 TAF. The AFRP4 release of 3,500 cfs increased long-term CVP total deliveries by 65 TAF and reduced SWP total deliveries by 8 TAF. The impact trend of the release ceiling is similar to the 290 TAF enlargement.

With zero enlargement, the AFRP4 release with a 3,500 cfs minimum flow had small impacts on project deliveries (a 5 TAF increase in the long-term CVP total deliveries and no change in long-term SWP deliveries). AFRP3, with another 250 cfs increase in minimum release, reduced long-term CVP total deliveries by 10 TAF and increased SWP total deliveries by 7 TAF.

For a Shasta Reservoir enlargement of 290 TAF, the AFRP3 release with a 3,750 cfs minimum release, 500 cfs higher than the benchmark, had few effects on project deliveries. The enlarged storage was devoted to increasing the minimum Keswick Dam release by 500 cfs for anadromous fish survival.

TABLE II-4
ANNUAL AVERAGE INCREASE IN PROJECT DELIVERIES:
SHASTA RESERVOIR ENLARGEMENTS WITH NEW MINIMUM KESWICK DAM RELEASE TARGET SCHEDULE

Shasta Reservoir Enlargement (TAF)	Minimum Keswick Dam Release Target		Increase in Annual Average Deliveries from the Benchmark (TAF)			
	Release Schedule	Release Ceiling (cfs)	CVP All Year Types	CVP Dry and Critical Years	SWP All Year Types	SWP Dry and Critical Years
290	AFRP1	5,500	-44	-82	41	72
	AFRP2	4,500	-10	-44	26	45
	AFRP3	3,750	10	-21	5	6
	AFRP4	3,500	12	-11	3	5
639	AFRP1	5,500	-6	-26	45	67
	AFRP2	4,500	29	29	20	23
	AFRP3	3,750	56	77	-1	-15
	AFRP4	3,500	65	94	-8	-25
0	AFRP3	3,750	-10	-50	7	12
	AFRP4	3,500	5	-24	0	-2

Key:
AFRP – Anadromous Fish Restoration Program cfs – cubic feet per second
CVP – Central Valley Project SWP – State Water Project TAF – thousand acre-feet

Notes:
1. Year-types defined as in the Sacramento Valley Water Year Hydrologic Classification Index.
2. Measures and the benchmark were simulated in single-step D1641.
3. The minimum Keswick Dam release target is for October through April.

Conjunctive Water Management

Conjunctive water management would increase water supply and water supply reliability through conjunctive water management by CVP north-of-Delta agricultural contractors. The purpose of conjunctive water management is to use more surface water and reduce groundwater pumping during wet years (in-lieu banking), and during dry years, pump more groundwater to free up surface water. This practice would benefit project deliveries because additional underground storage is available for floodwater through in-lieu banking and extra water supplies from groundwater stored for dry conditions; however, participants need access to both surface water and groundwater. Along the Sacramento River, some CVP agricultural contractors have an underlying groundwater basin (see **Appendix C)**.

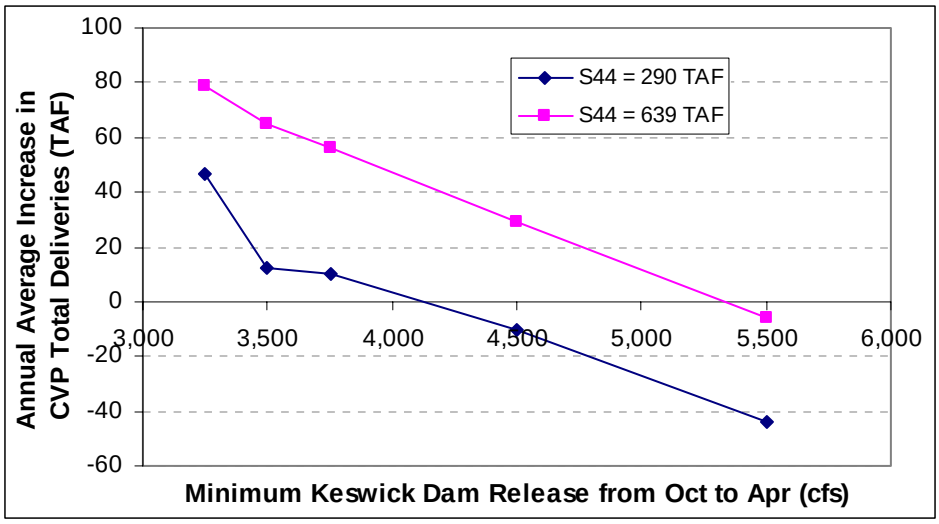

Figure II-2. Annual average increase in CVP total deliveries: Shasta Reservoir enlargements with higher Keswick Dam minimum releases.

CALSIM II Assumptions

In CALSIM II simulations, CVP contractors along the Tehama-Colusa Canal (TCC), or delivery arc D112a in CALSIM II, were used as a surrogate for conjunctive water management because TCC has access to both surface water and groundwater. Following are modeling assumptions for applying conjunctive water management measures to D112a:

- All water supply reliability assumptions for simulations with Shasta Reservoir enlargement were included
- In CVP cutback logic, the D112a delivery was recategorized among the remaining CVP agricultural contractors and assigned to a different CVP cutback schedule. For the CVP agricultural cutback schedule in the CALSIM II Benchmark Study, four tiers exist; within each tier, deliveries are subject to an additional cut-back of up to 25 percent from the previous tier, or 0.25/0.25/0.25/0.25. There are eight conjunctive water management schedules for D112a (the CU5 cut-back schedule of 0.0/0.25/0.25/0.5 is an example). In Tier 1, when the remaining CVP agricultural contractors are subjected to a cutback of up to 25 percent, D112a receives full contract deliveries; in Tier 2, CVP agricultural deliveries can be reduced up to 50 percent while D112a is only reduced 25 percent, etc.

Modeling Results

Results of conjunctive water management measures are summarized in **Table II-5** and **Figure II-3**. **Table II-5(a)** shows increases in total project deliveries and **Table II-5(b)** provides more insight into changes in various groups of CVP agricultural deliveries from the benchmark condition. **Figure II-3(a)** is the exceedence probability for D112a annual delivery while **Figure II-3(b)** shows the exceedence probability for CVP north-of-Delta agricultural total deliveries.

For the same 636 TAF enlargement, different D112a cutback schedules gave different increases in annual average project deliveries, but these increases were larger than the measure without conjunctive water management. In **Table II-5(a)**, CVP total deliveries increased while SWP total deliveries were reduced by a very small amount. The three largest total CVP delivery increases were from schedules CU5, CU6, and CU8 (106, 109, 106, respectively), compared with 79 TAF solely from reservoir enlargement. The greatest increase in D112a delivery was from schedule CU5 (23 TAF); the other two were lower than without conjunctive water management (-3 and 6 TAF against 13 TAF). Both CU6 and CU8 had larger increases in CVP south-of-Delta agricultural deliveries (95 and 86 TAF, respectively) than did CU5 (73 TAF).

TABLE II-5A
ANNUAL AVERAGE INCREASE IN PROJECT DELIVERIES FROM SLWRI BENCHMARK: SHASTA RESERVOIR ENLARGEMENT OF 636 TAF WITH CONJUNCTIVE WATER MANAGEMENT SCHEDULE (A) CVP AND SWP TOTAL DELIVERIES

Conjunctive Water Management Schedule	Cutback Schedule (Tier 1/Tier 2/Tier 3/Tier 4)	Increase in Annual Average Delivery from Benchmark (TAF)			
		CVP All Year-Types	CVP Dry and Critical Years	SWP All Year-Types	SWP Dry and Critical Years
Nil	Nil	79	128	-8	-22
CU1	0.00/0.20/0.40/0.40	84	135	-7	-21
CU2	0.05/0.15/0.45/0.35	82	130	-6	-20
CU3	0.15/0.25/0.35/0.25	90	139	-7	-22
CU5	0.00/0.25/0.25/0.50	106	174	-9	-25
CU6	0.00/0.50/0.50/0.00	109	181	-6	-26
CU7	0.00/0.35/0.65/0.00	103	170	-5	-23
CU8	0.00/0.25/0.75/0.00	106	172	-4	-23
CU9	0.00/0.10/0.90/0.00	94	151	-2	-18

Key:
CVP – Central Valley Project
SWP – State Water Project
SLWRI – Shasta Lake Water Resources Investigation
TAF – thousand acre-feet

Notes:
1. Year-types are defined as in the Sacramento Valley Water Year Hydrologic Classification Index.
2. Conjunctive water management schedule is applied to D112a.
3. Measures and the benchmark were simulated in single-step D1641.

From **Figure II-3(a)**, CU5 increased the annual D112a delivery from the benchmark condition about 60 percent of the time; for CU6 and CU8, the increase was about 25 percent and 47 percent, respectively. Since the purpose of conjunctive water management is to shift water supply to participants from surface water to groundwater during dry years, D112a had no CVP water for 12 percent of the time under the CU5 schedule but had approximately 22 percent under CU6 and CU8. In the SLWRI Benchmark, 188 TAF out of 244 TAF CVP north-of-Delta agricultural deliveries were to D112a; therefore, **Figure II-3(b)** has exceedence patterns similar to those in **Figure II-3(a)**. About 62 percent of the time, CU5 increased the total annual CVP north-of-Delta agricultural deliveries from the benchmark condition.

To increase long-term water supply and water supply reliability, as an incentive to participants in the conjunctive water management, CU5 is the best conjunctive use pattern candidate for the concept plan-evaluation stage.

TABLE II-5B
AVERAGE ANNUAL INCREASE IN PROJECT DELIVERIES OVER THE BENCHMARK: SHASTA RESERVOIR ENLARGEMENT OF 636 TAF WITH CONJUNCTIVE WATER MANAGEMENT
SCHEDULE (B) CVP AGRICULTURAL DELIVERIES

Conjunctive Water Management Schedule	Increase over Benchmark of Annual Average Agricultural Delivery, All Year Types (TAF)			
	Conjunctive Water Management Participant North-of-Delta (D112a)	Total North-of-Delta (including D112a)	Total South-of-Delta	Project Total
Nil	13	18	56	74
CU-1	16	21	59	80
CU-2	13	18	60	78
CU-3	4	11	71	82
CU-5	21	28	73	101
CU-6	-3	5	95	100
CU-7	1	8	87	95
CU-8	6	13	86	99
CU-9	7	14	75	89

Key: CVP – Central Valley Project TAF – thousand acre-feet

Notes:
1. Year-types defined as in the Sacramento Valley Water Year Hydrologic Classification Index.
2. Conjunctive water management schedule applied to D112a.
3. Measures and the benchmark simulated in single-step D1641.

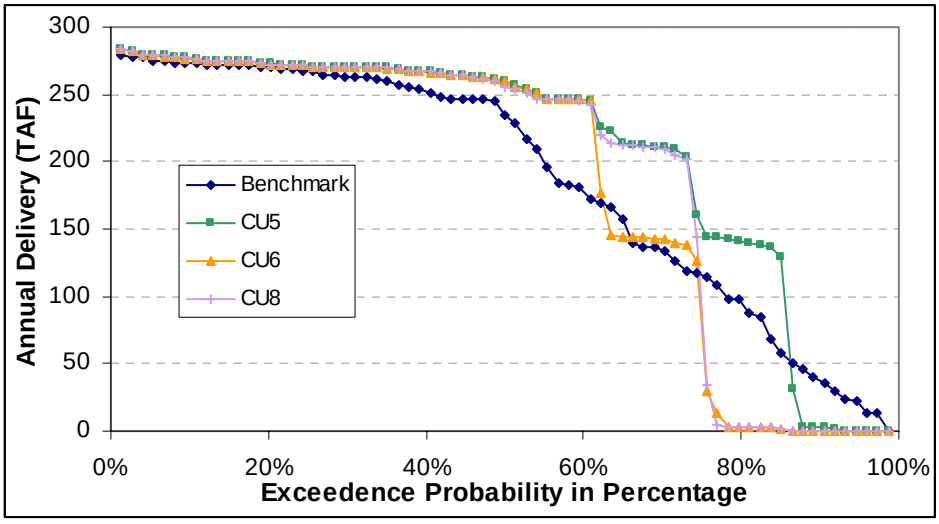

Figure II-3(a). Exceedence probability of CVP delivery (D112a).

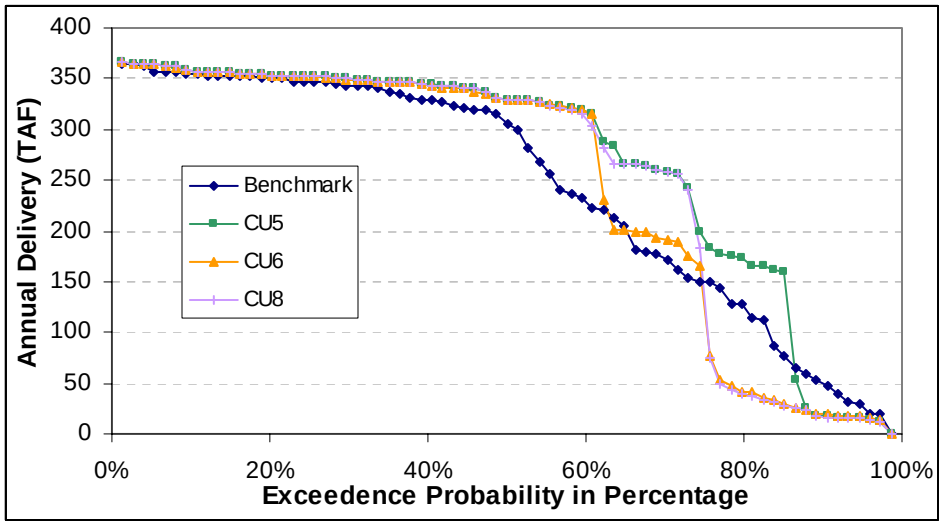

Figure II-3(b). CVP north-of-Delta agricultural total deliveries.

CONCEPT PLAN-EVALUATION STAGE

In the concept plan-evaluation stage, concept plans were focused in three categories: increasing water supply reliability (WSR), increasing anadromous fish survival (AFS), and combined objectives (CO). Hydrologic features of these concept plans are summarized in **Table II-6**. Because this stage requires more refined impact analysis, a multistep simulation is used to account for B2 actions. This multistep approach varies with concept objectives and is discussed in more detail in this section. A new common benchmark, which accounts for B2 actions, was necessary for the concept plan-evaluation stage. Using the B2 results from the CALSIM II Benchmark Study as a multistep baseline for the SLWRI was inappropriate because initial conditions were from the EWA step.

From a modeling perspective, simulation of WSR concept plans is more intuitive because they require no change in operation logic. Concept plans are discussed in this document in the following order: WSR, AFS, and CO.

TABLE II-6
HYDROLOGIC FEATURES OF SLWRI CONCEPT PLANS IN CALSIM II, CONCEPT PLAN-EVALUATION STAGE

	Shasta Dam Raise / Enlarged Shasta Reservoir Active Storage			Operational Change		
	6.5-ft / 290 TAF	18.5-ft / 636 TAF	200-ft / 9,338 TAF	Higher Minimum Keswick Dam Release[1]	Conjunctive Water Management[2]	Remarks
Concept Plans Focused on Water Supply Reliability						
WSR-1	x					
WSR-2		x				
WSR-3			x			
WSR-4		x			x	
Concept Plans Focused on Anadromous Fish Survival						
AFS-1						Not modeled in CALSIM II
AFS-2	x			x		
AFS-3	x			x		Same as AFS-2
Concept Plans Focused on Combined Objectives						
CO-1	x					Same as WSR-1
CO-2		x				Same as WSR-2
CO-3		x		x		
CO-4	x				x	
CO-5		x			x	Same as WSR-4

Key:
AFS – anadromous fish survival CO – combined objectives SLWRI – Shasta Lake Water Resources Investigation
TAF – thousand acre-feet WSR – water supply reliability

Notes:
[1]Higher minimum Keswick Dam release schedule is shown in Table II-2.
[2]Conjunctive water management schedule 0.0/0.25/0.25/0.5 is applied to D112a.

Benchmark Condition

For the concept plan-evaluation stage, the benchmark condition consisted of a three-step simulation using the D1485, D1641, and B2 steps of the CALSIM II Benchmark Study, 2020 LOD, with modified evaporation rates for Lake Oroville and Thermalito Afterbay. The three-step simulation is similar to the five-step simulation, with the JPOD and EWA steps are omitted. As for the measure stage, the benchmark condition for the concept plan-evaluation stage is different from the public release of B2 results.

Table II-7 shows annual average project deliveries in the benchmark for the concept plan-evaluation stage while **Table II-8** shows the project deliveries in more refined components. For the SLWRI, the Cross Valley Canal delivery is defined as part of CVP total deliveries. In

CALSIM II, Shasta and Folsom reservoirs release for Cross Valley Canal delivery south of the Delta, and the water is wheeled through SWP facilities to the canal. Compared to results from the measure stage, long-term CVP total deliveries decreased from 5,276 to 5,025 TAF, mainly due to the B2 actions of reallocating water for fishery benefits. Differences in SWP total deliveries between benchmarks of the two stages are from modeling additional operational constraints.

Figure II-4 is the monthly average Keswick Dam downstream flow in the benchmark for the concept plan-evaluation stage. Two peaks exist in the average flow, one in February from the spring flood control releases and one in July from high summer water consumption (for municipal, fishery, water quality, etc.)

TABLE II-7
ANNUAL AVERAGE CVP AND SWP PROJECT DELIVERIES IN THE BENCHMARK (THREE-STEP B2 RESULTS) FOR CONCEPT PLAN-EVALUATION STAGE

Average Annual Delivery (TAF)	All Year-Types	Dry and Critical Years
CVP	5,025	4,416
SWP	4,322	3,370

Key:
CVP – Central Valley Project SWP – State Water Project TAF – thousand acre-feet

Note:
Year-types defined as in the Sacramento Valley Water Year Hydrologic Classification Index.

Concept Plans Focused on Water Supply Reliability (WSR Concept Plans)

The primary objective of the four WSR concept plans, WSR-1, WSR-2, WSR-3, and WSR-4 (shown in Table II-7), is to increase water supply and water supply reliability. The CALSIM II simulation of WSR concept plans is similar to that in the measure stage, but a three-step approach is used instead of single D1641 study.

TABLE II-8
ANNUAL AVERAGE PROJECT DELIVERIES IN THE BENCHMARK (THREE-STEP B2 RESULTS) FOR THE CONCEPT PLAN-EVALUATION STAGE

Project	Project Delivery Components	Annual Average (TAF)	CALSIM II Output Variable Names
CVP	Refuge NOD	105	DEL_CVP_PRF_N
	Refuge SOD	280	DEL_CVP_PRF_S
	Settlement Contractors NOD	1,859	DEL_CVP_PSC_N
	Exchange Contractors SOD	846	DEL_CVP_PEX_S
	Losses SOD	184	DEL_CVP_PLS_S
	Water Forum	151	DEL_CVP_PWF_N
	Contra Costa Water District	151	D408
	Agricultural NOD	233	DEL_CVP_PAG_N
	Agricultural SOD	952	DEL_CVP_PAG_S
	M&I NOD	68	DEL_CVP_PMI_N
	M&I SOD	118	DEL_CVP_PMI_S
	Cross Valley Canal	78	D855
	Total	**5,025**	
SWP	Water Right	968	Summation of D6, D7A_PRJ, D7B_PRJ, D202_PRJ, D206A_PRJ, and D206B_PRJ
	Agricultural SOD	884	DEL_SWP_PAG
	M&I	2,316	DEL_SWP_MI
	Interruptible	89	DEL_SWP_PIN
	Losses	65	DEL_SWP_PLS
	Total	**4,322**	

Key:
CVP – Central Valley Project M&I – municipal and industrial NOD – north-of-Delta
SOD south-of-Delta SWP – State Water Project TAF – thousand acre-feet

CALSIM II Assumptions

Following are assumptions for the WSR concept plans:

- The three-step simulation used the following steps in sequence: D1485, D1641, and B2. In all three steps, Shasta Reservoir enlargement S44 was included as Shasta Reservoir upstream storage and S44 was added in all calculations to S4 as a trigger in water allocation logic.
- The lookup table, Shasta_level.table, was modified to ensure that the amount of imported water from the Trinity River watershed was the same as the benchmark condition.
- For WSR-4, the D112a cutback schedule was modified as in the conjunctive water management measures for the measure stage.

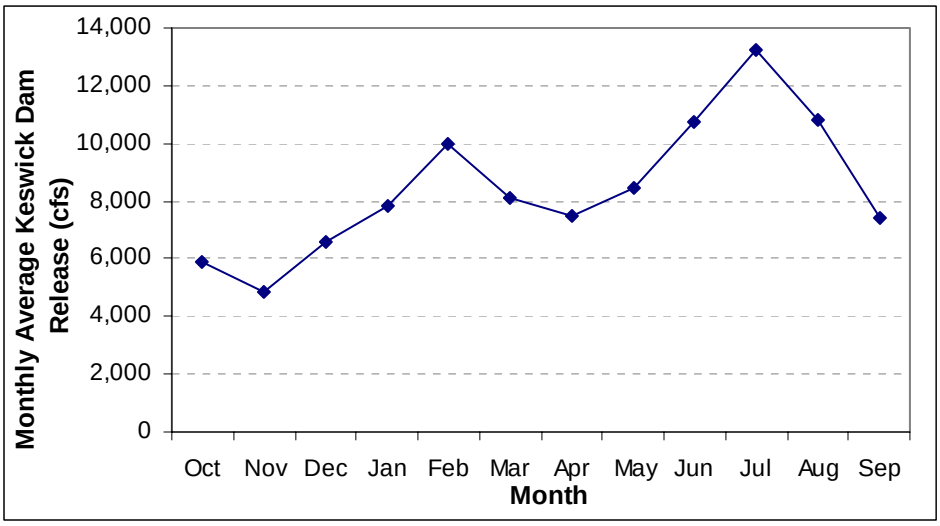

Figure II-4. Monthly average Keswick Dam releases in the benchmark (three-step B2 results) for the concept plan-evaluation stage.

Modeling Results

Increases in project deliveries for the WSR concept plans are shown in **Table II-9**. Long-term CVP total deliveries increased with enlargement size because a bigger enlargement can capture more flood flow and store it for later summer consumption. **Figure II-5** shows that most of the increase went to CVP south-of-Delta agricultural deliveries for all WSR concept plans, followed by CVP north-of-Delta agricultural deliveries. This is because CVP agricultural contractors are subject to a more severe cutback schedule than for M&I contractors.[6]. With a larger Shasta Reservoir, the Cross Valley Canal annual average deliveries also increased.

The shift of Shasta Dam releases is shown in **Figure II-6**. The decrease in Keswick Dam releases from December through March indicates the flood control effects of a larger reservoir; the largest average reduction was caused by a 200-foot Shasta Dam raise with a 9,338 TAF enlargement. The increase in May through September downstream flow reflects releases of stored flood water for summer usage; again, the largest increase was from a 9,338 TAF enlargement.

For the 636 TAF enlargement, conjunctive water management increased the annual average CVP total deliveries from 79 to 89 TAF for all year types and from 138 to 162 TAF in dry and critical years.

[6] For CVP M&I contractors, the cutback tiered schedule is 0.0/0.25/0.0/0.25. Under this schedule, M&I contractors are guaranteed at least 50 percent delivery of their contract amounts.

TABLE II-9
MODELING RESULTS FOR WSR CONCEPT PLANS:
ANNUAL AVERAGE INCREASE IN PROJECT DELIVERIES
FROM THE BENCHMARK

Concept Plan	Features	Increase in Annual Average Delivery from the Benchmark (TAF)			
		CVP All Year Types	CVP Dry and Critical Years	SWP All Year Types	SWP Dry and Critical Years
WSR-1	6.5-foot dam raise (290 TAF enlargement)	50	82	-5	-11
WSR-2	18.5-foot dam raise (636 TAF enlargement)	79	138	-8	-13
WSR-3	200-foot dam raise (9,338 TAF enlargement)	348	768	-17	-65
WSR-4	18.5-foot dam raise (636 TAF enlargement) Conjunctive use: D112a cutback schedule 0.00/0.25/0.25/0.50	89	162	-9	-16

Key:
CVP – Central Valley Project
SWP – State Water Project
TAF – thousand acre-feet
WSR – water supply reliability

Note:
Year-types defied as in the Sacramento Valley Water Year Hydrologic Classification Index.

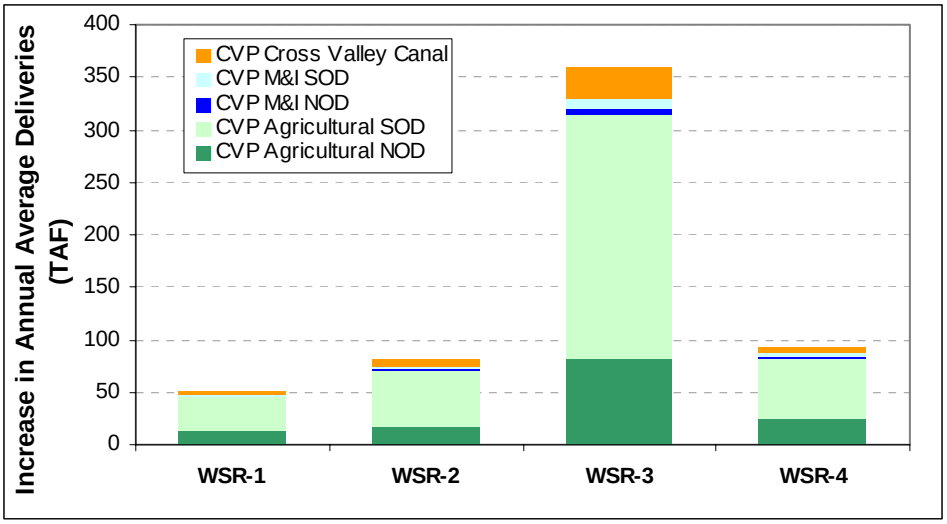

Figure II-5. WSR concept plan modeling results: annual average increase in CVP deliveries from SLWRI benchmark (agricultural, M&I, and Cross Valley Canal).

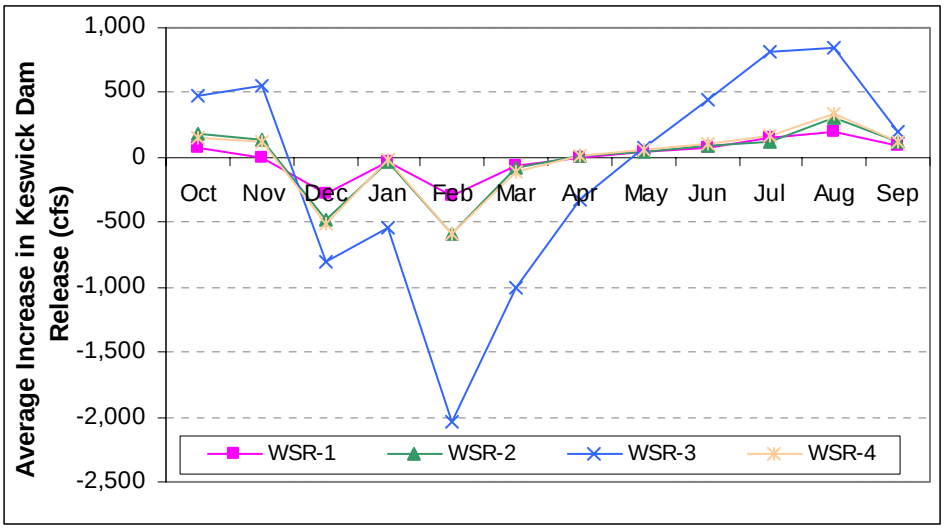

Figure II-6. WSR concept plan modeling results: monthly average increase in Keswick Dam release from benchmark.

Concept Plans Focused on Anadromous Fish Survival (AFS Concept Plans)

The primary objective of the three AFS concept plans, AFS-1, AFS-2, and AFS-3, is to increase anadromous fish survival. Modeling features for the AFS concept plans are summarized in **Table II-7**.

Of the three AFS alternatives, only AFS-2 is simulated in CALSIM II. AFS-1 enlarges the cold water pool in Shasta Reservoir for the purpose of maintaining cooler temperature releases to the Sacramento River. This is achieved through increasing the Shasta Reservoir minimum pool from 550 to 840 TAF with no change in Shasta active storage; no hydrologic impacts will occur from a larger Shasta inactive storage. Impacts of colder Shasta Dam releases were evaluated in the Temperature Model. Therefore, a CALSIM II simulation was not necessary for AFS-1. CALSIM II hydrologic features for AFS-3 are the same as for AFS-2since spawning habitat restoration cannot be modeled in CALSIM II.

CALSIM II Assumptions

The objective of the AFS alternatives is to provide increased Keswick Dam releases for fisheries in addition to the B2 actions, which provide an annual amount of 800 TAF or 600 TAF in Shasta critical years. Due to the ambiguity of B2 accounting metrics in the current CALSIM II Benchmark Study, additional releases from an enlarged Shasta Reservoir for fishery flows cannot be distinguished from B2 waters. To keep B2 accounting neutral, a new layer was created after the B2 step and a four-step approach was used: the first three steps (D1485, D1641, and B2) simulate existing facilities and operational criteria, and the last step, SL44, incorporates Shasta Reservoir enlargement and increases Keswick Dam releases.

AFS assumptions include the following:

- A four-step simulation was used. This approach modeled the following steps in sequence: D1485, D1641, B2, and SL44. In the first three steps, S44 was inactive (no filling and releasing between S4 and S44) and benchmark minimum Keswick Dam releases were simulated.[7] In the SL44 step, a modified version of the B2 step without B2 accounting, S44 was activated and the new Keswick Dam release schedule was modeled. Also, in the SL44 step, S44 was added to all calculations using S4 as a trigger in water allocation logic.
- The SL44 step had a new schedule (**Table II-10**) to increase releases from Keswick Dam for October through April. The schedule was developed from AFRP flows in **Table II-3**. The new monthly flow target varies with the previous end-of-September storage in the enlarged Shasta Reservoir (the total of S4 and S44); however, the flow increment from B2 to SL44 study is subject to an increased ceiling of up to 950 cfs. Simulations using an increase of 500 cfs and 750 cfs for a 290 TAF Shasta enlargement were used to estimate the additional fishery flows from October to April possible without negatively impacting CVP dry and critical year deliveries. The benchmark flow target of October through April is 3,250 cfs; a flow increase of 950 cfs was estimated to result in the same CVP deliveries in dry and critical years as the benchmark study.

TABLE II-10
SLWRI MINIMUM KESWICK DAM RELEASE TARGETS AND FLOW INCREASE CEILINGS FOR OCTOBER THROUGH APRIL IN SL44 STUDY, CONCEPT PLAN-EVALUATION STAGE

Carryover Storage[1] (MAF)	Minimum Keswick Dam Release Target[2] (cfs)	Keswick Dam Release Increase Ceiling[3] (cfs)
1.9 to 2.1	3,250	0
2.2	3,500	250
2.3	3,750	500
2.4	4,000	750
2.5	4,250	950
2.6	4,500	950
2.7	4,750	950
2.8	5,000	950
2.9	5,250	950
3.0	5,500	950

Key: cfs – cubic feet per second MAF – million acre-feet

Notes:
[1]Carryover storage is the Shasta Reservoir end-of-September storage.
[2]As recommended in Final Restoration Plan of the Anadromous Fish Restoration Plan (page 35).
[3]Keswick Dam release increase ceiling" limits the differences between the "minimum Keswick Dam release target" in SL44 study and Keswick Dam release (C5) in B2 step, based on Shasta Reservoir end-of-September storage.

[7] This is possible because S44 is filled when S4 storage reaches flood control levels; when S44 is deactivated, flood flows can be stored in the S4 flood pool or water can be taken from S4. In SL44, S44 is activated and releases from S44 provide additional fishery flows or S44 is filled with water from the S4 flood control pool.

Modeling Results

Hydrologic impacts on project deliveries of AFS concept plans against the benchmark are shown in **Table II-11**. Since the purpose of AFS-1 was to increase the minimum pool, no hydrologic impacts would occur. Following the release schedule in **Table II-10**, AFS-2 dedicated the Shasta enlargement to additional fish flow, with minimal impacts to CVP and SWP deliveries.

Figure II-7 shows the increase in average Keswick Dam releases (C5) in the long term and for different water year types. In critical years, higher flows occurred throughout the year except in February and June; in dry years, increases were from October through March. In wet and above normal years, Keswick Dam releases decreased during wet months due to the Shasta enlargement, which stores flood flows for later releases. The change in long-term average releases was similar to the average of below average years.

TABLE II-11
MODELING RESULTS OF AFS CONCEPT PLANS:
ANNUAL AVERAGE INCREASE IN PROJECT DELIVERIES
FROM THE BENCHMARK

Concept Plan	Features	Increase in Average Annual Delivery from the Benchmark (TAF)			
		CVP All Year-Types	CVP Dry and Critical Years	SWP All Year-Types	SWP Dry and Critical Years
AFS-1	- 6.5-foot dam raise (290 TAF enlargement) - Increase Shasta Reservoir minimum pool by 290 TAF - Not modeled	0	0	0	0
AFS-2, AFS-3	- 6.5-foot dam raise (290 TAF enlargement) - Increase monthly minimum Keswick Dam release	-16	0	18	20

Key: AFS – Anadromous Fish Survival CVP – Central Valley Project TAF – thousand acre-feet

Notes:
1. Year-types defined as in Sacramento Valley Water Year Hydrologic Classification Index.
2. Results of B2 four-step approach.
3. Increases for AFS-2 and AFS-3 were estimated using results from simulations for 3,250 cfs, 3,750 cfs, and 4,000 cfs.

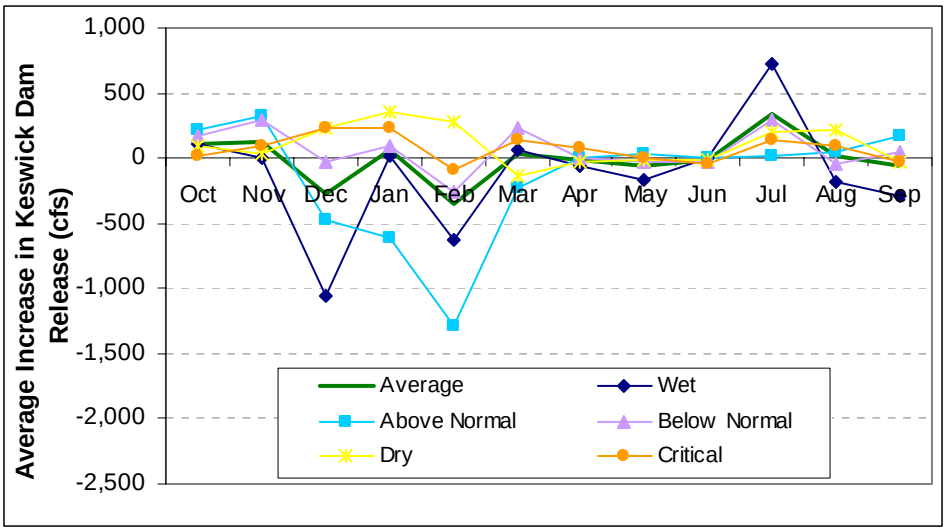

Figure II-7. Modeling results of AFS-2: year-type average increase in Keswick Dam releases from the benchmark.

Concept Plans Focused on Combined Objectives (CO Concept Plans)

CO concept plans address the two major planning objectives of increasing water supply reliability and anadromous fish survival. Of the five alternatives, only two were simulated: CO-3 and CO-4. Because CO-1, CO-2, and CO-5 are hydrologically the same as WSR-1, WSR-2, and WSR-4, in CALSIM II, their hydrologic impacts are equivalent. Another CALSIM II simulation would be redundant.

CALSIM II Assumptions

Simulating CO concept plans combined the modeling methodology used for the WSR and AFS concept plans.

The modeling methodology for CO-3 was similar to that for AFS-2 but the Shasta Reservoir enlargement was 636 TAF, instead of 290 TAF. The simulation for CO-4, was similar to WSR-4 with conjunctive water management, but instead of a 636 TAF Shasta enlargement, the S44 capacity is 290 TAF. See the previous section for detailed modeling assumptions.

Modeling Results

Modeling results for all CO concept plans are shown in **Table II-12** and **Figures II-8** and **II-9**. In **Table I-12**, all CO concept plans increased CVP deliveries. With the same Shasta enlargement of 290 TAF, conjunctive water management for north-of-Delta CVP agricultural contractors gave CO-4 higher CVP deliveries than CO-1, especially in dry and critical years. Conjunctive water management had a similar effect on a 636 TAF enlargement: CO-5 had a higher increase in CVP total deliveries than CO-2. Due to the new Keswick Dam release targets for October to April, part of the 636 TAF enlargement was dedicated to providing higher fishery flows; therefore, the increase in CVP total deliveries was less than CO-2. The impact of all CO concept plans on the SWP was relatively small.

TABLE II-12
MODELING RESULTS OF CO CONCEPT PLANS:
ANNUAL AVERAGE INCREASE IN PROJECT DELIVERIES
FROM THE BENCHMARK

Concept Plan	Features	Increase in Average Annual Delivery from the Benchmark (TAF)			
		CVP All Year-Types	CVP Dry and Critical Years	SWP All Year-Types	SWP Dry and Critical Years
CO-1	- 6.5-foot dam raise (290 TAF enlargement) - Same as WSR-1 - Not modeled	50	82	-5	-11
CO-2	- 18.5-foot dam raise (636 TAF enlargement) - Same as WSR-2 - Not modeled	79	138	-8	-13
CO-3	- 18.5-foot dam raise (636 TAF enlargement) - Increase monthly minimum Keswick Dam release	25	61	12	20
CO-4	- 6.5-foot dam raise (290 TAF enlargement) - Conjunctive water management: D112a cutback schedule 0.00/0.25/0.25/0.50	57	107	-7	-19
CO-5	- 18.5-foot dam raise (636 TAF enlargement) - Conjunctive water management: D112a cutback schedule 0.00/0.25/0.25/0.50 - Same as WSR-4 - Not modeled	89	162	-9	-16

Key: CO – combined objective CVP – Central Valley Project SWP – State Water Project
TAF – thousand acre-feel WSR – water supply reliablilty

Note:
Year-types defined in Sacramento Valley Water Year Hydrologic Classification Index.

Most of the increase in CVP total deliveries went to agricultural deliveries (**Figure II-8**). South-of-Delta agricultural deliveries had the greatest increase, followed by north-of-Delta agricultural deliveries and Cross Valley Canal deliveries.

For all CO concept plans, the monthly average increase in Keswick Dam downstream releases was similar in pattern to **Figure II-9**; however, for concept plans with the same enlargement, the patterns are even more alike. A larger Shasta Reservoir captured more flood flows during December through February and had increased releases for high summer consumption from June through September.

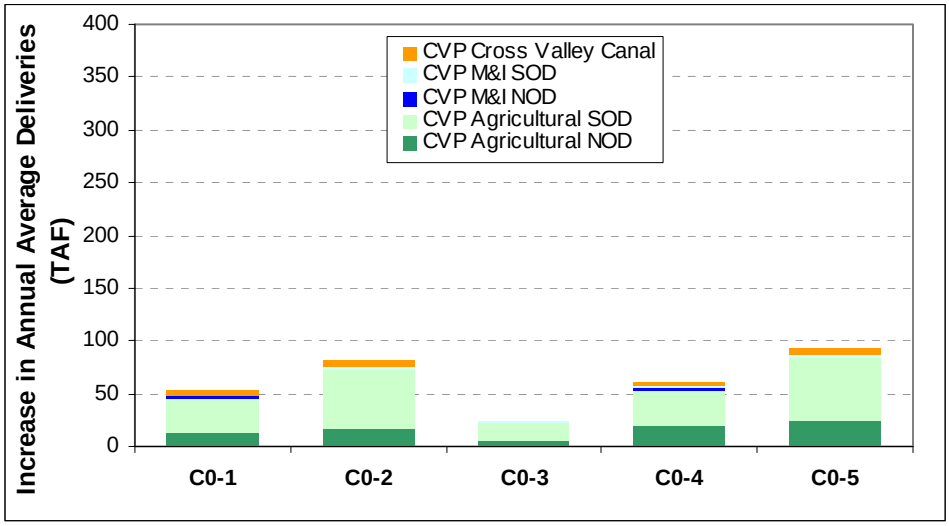

Figure II-8. Modeling results of CO concept plans annual average increase in CVP deliveries from benchmark (agricultural, M&I, and Cross Valley Canal).

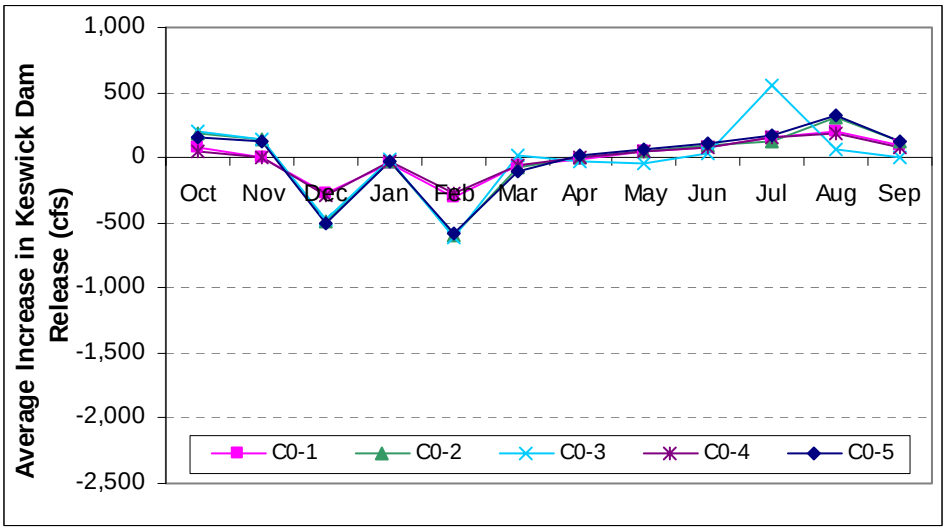

Figure II-9. Modeling results of CO concept plans: monthly average increase in Keswick Dam releases from benchmark.

SENSITIVITY ANALYSIS – BANKS PUMPING PLANT CAPACITY

The purpose of this sensitivity analysis was to evaluate how the system responded when Banks Pumping Plant capacity was increased to 8,500 cfs. The current capacity of SWP's Banks Pumping Plant is 6,680 cfs while the CVP's Tracy Pumping Plant capacity is 4,600 cfs. Under the COA and JPOD, one project's diversion facility can be used by the other project for export. Because of its larger capacity, the Banks Pumping Plant has helped CVP into exporting water to south-of-Delta contractors; therefore, a larger Banks Pumping Plant would impact CVP south-of-Delta deliveries. All SLWRI concept plans were simulated under existing pumping condition; this analysis provides the order of magnitude of impacts from higher export capacity on water supply.

Benchmark

In October 2002, DWR completed the study North-of-Delta Offstream Storage Initial Project Formulation Alternatives (NODOS) to evaluate the operation of Sacramento River offstream storage for different objectives. The NODOS benchmark, Base Scenario, includes a Banks Pumping Plant capacity of 8,500 cfs; it is a multistep simulation using D1485, D1641, B2, and JPOD in sequence. For the SLWRI, the NODOS Base Scenario was also used as a benchmark in the sensitivity analysis. See **Table II-13** for a comparison of project deliveries for the 6,680 cfs benchmark and the 8,500 cfs benchmark.

TABLE II-13
PROJECT DELIVERIES FROM THE MODELING BENCHMARKS

Benchmark	Annual Project Deliveries (TAF)			
	CVP All Year-Types	CVP Dry and Critical Years	SWP All Year-Types	SWP Dry and Critical Years
6,680 cfs Banks	5,025	4,416	4,322	3,370
8,500 cfs Banks	5,092	4,464	4,417	3,431

Key: CVP – Central Valley Project; SWP – State Water Project; cfs – cubic feet per second; TAF – thousand acre-feet

Modeling Assumptions

Simulations for the Shasta Reservoir enlargement were built on the NODOS Base Scenario by incorporating an S44 with 636 TAF into all steps (D1485, D1641, B2, and JPOD), and including S44 in all calculations using S4 as a trigger in water allocation logic, as in other SLWRI CALSIM II simulation.

Modeling Results

For an enlargement of 290 TAF, the larger export capacity changed the average annual CVP yield from 50 to 57 TAF, and from 82 to 92 TAF for dry and critical years. With a 636 TAF

enlargement, a larger export capacity changed the increase in CVP total deliveries from 79 to 96 TAF for all year types, and 138 to 146 TAF in dry and critical years (**Table II-14**). From **Figure II-10(a)** and **10(b)**, the additional pumping capacity increased the long-term annual average deliveries to south-of-Delta CVP agricultural contractors. However, in dry and critical years, the elivery differences between the two cases are smaller because there is a limited amount of water in north-of-Delta storages to be pumped to south of the Delta.

TABLE II-14
MODELING RESULTS OF SENSITIVITY ANALYSIS:
ANNUAL AVERAGE INCREASE IN PROJECT DELIVERIES
FROM THE CORRESPONDING BENCHMARK

Concept Plans	Banks Pumping Plant Capacity (cfs)	Increase in Annual Average Deliveries from the Corresponding Benchmark (TAF)			
		CVP All Year-Types	CVP Dry and Critical Years	SWP All Year-Types	SWP Dry and Critical Years
WSR-1	6,680	50	82	-5	-11
Sensitivity Analysis (290 TAF S44)	8,500	57	92	2	-8
WSR-2	6,680	79	138	-8	-13
Sensitivity Analysis (636 TAF S44)	8,500	96	146	5	1

Key: cfs – cubic feet per second CVP – Central Valley Project SWP – State Water Project
TAF – thousand acre-feet

Note:
Year types defined as in the Sacramento Valley Water Year Hydrologic Classification Index.

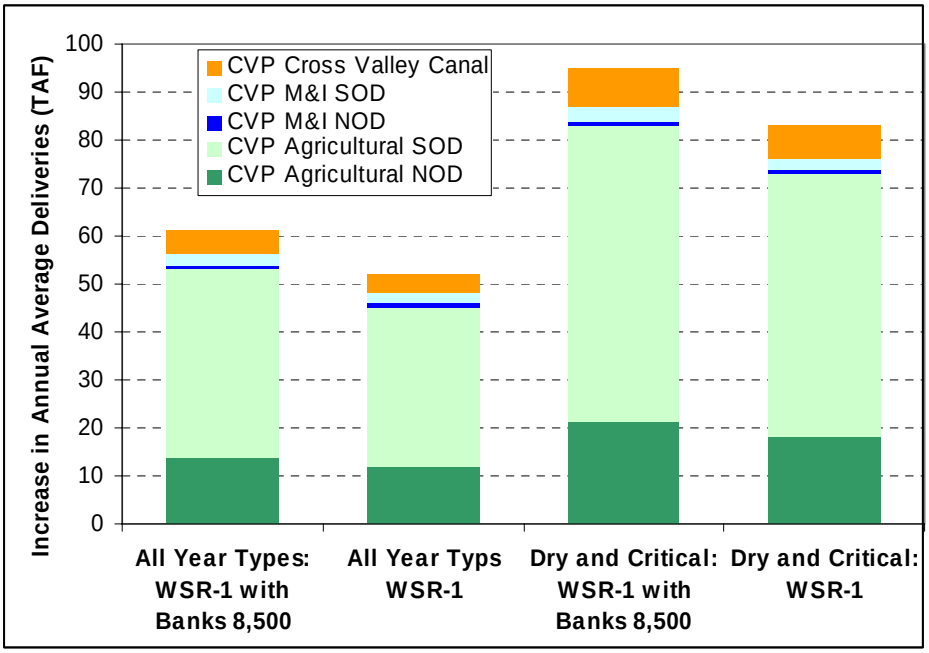

Figure II-10(a). Modeling results of sensitivity analysis for 290 TAF enlargement: annual average increase in CVP deliveries from the benchmark (agricultural, M&I, and Cross Valley Canal).

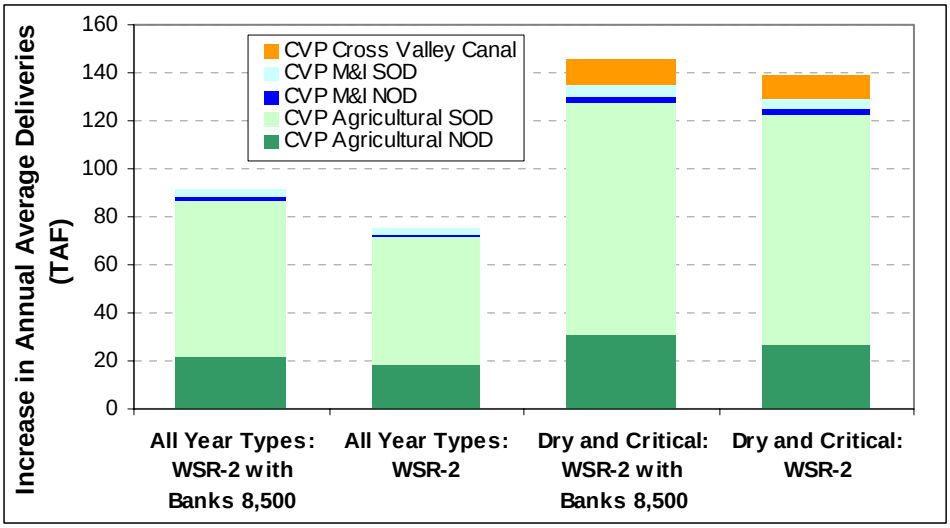

Figure II-10(b). Modeling results of sensitivity analysis for 636 TAF enlargement: annual average increase in CVP deliveries from the benchmark (agricultural, M&I, and Cross Valley Canal).

CHAPTER III
SUMMARY

For the SLWRI, the twelve concept plans were divided into three categories: plans that focused on increasing anadromous fish survival (AFS), increasing water supply reliability (WSR), or combined objective (CO) plans. The twelve concept plans include the following:

- Concept plans focused on anadromous fish survival: AFS-1, AFS-2, and AFS-3
- Concept plans focused on water supply reliability: WSR-1, WSR-2, WSR-3, and WSR-4
- Concept plans focused on CO plans: CO-1, CO-2, CO-3, CO-4, and CO-5

CALSIM II, a statewide water resources planning model, was used in the SLWRI to evaluate hydrologic impacts on the California water supply system from Shasta Reservoir enlargement and/or changes in system operation. In the hydrologic analyses, a benchmark was established first and, by modifying benchmark facilities or operational rules, concept plans were built. Hydrologic impacts were defined as CALSIM II result differences between the concept plans and benchmark conditions. The CALSIM II hydrologic features of each SLWRI concept plans are summarized in **Table III-1**.

CONCEPT PLANS FOCUSED ON ANADROMOUS FISH SURVIVAL (AFS CONCEPT PLANS)

The primary objective of the AFS concept plans was to increase anadromous fish survival through a 290 TAF enlargement of Shasta Reservoir. Of the three AFS concept plans, only AFS-2 was simulated in CALSIM II. AFS-1 increased the cold water pool in Shasta Reservoir and allowed cooler releases to Sacramento River. This is achieved through increasing the Shasta Reservoir minimum pool from 550 to 840 TAF with no change in Shasta active storage; and no hydrologic impacts would occur from a larger Shasta inactive storage. Impacts of colder Shasta Dam releases were evaluated in the Temperature Model. Therefore, a CALSIM II simulation was not necessary for AFS-1. The CALSIM II hydrologic features for AFS-3 are same as for AFS-2, except that spawning habitat restoration cannot be modeled in CALSIM II.

With a 290 TAF enlargement, a new minimum Keswick Dam release schedule for October through April (**Table III-2**) was used to increase minimum Sacramento River flows from 3,250 cfs. The new monthly flow target, developed from the Final Restoration Plan Anadromous Fish Restoration Program (FRP), varies with the previous end-of-September storage in the enlarged Shasta Reservoir and the flow increment is also subject to an increase ceiling of up to 500 cfs.

TABLE III-1
CALSIM II HYDROLOGIC FEATURES OF SLWRI CONCEPT PLANS

	Shasta Dam Raise / Enlarged Shasta Reservoir Active Storage			Operational Change		Remarks
	6.5-ft / 290-TAF	**18-ft / 636-TAF**	**200-ft / 9,338-TAF**	**Increase Fishery Flow below Keswick Dam**	**Conjunctive Water Management**	
Concept Plans Focused on Anadromous Fish Survival						
AFS-1	x					Not modeled in CALSIM II
AFS-2	x			x		
AFS-3	x			x		Same as AFS-2
Concept Plans Focused on Water Supply Reliability						
WSR-1	x					
WSR-2		x				
WSR-3			X			
WSR-4		x			x	
Concept Plans Focused on Combined Objective						
CO-1	x					Same as WSR-1
CO-2		x				Same as WSR-2
CO-3		x		x		
CO-4	x				x	
CO-5		x			x	Same as WSR-4

Key:
AFS – Anadromous Fish Survival
CO – combined objective
TAF – thousand acre-feet
WSR – water supply reliability

Notes:
1. CVP agricultural contractors along Tehama-Colusa Canal (D112a) are a surrogate for conjunctive water management in north-of-Delta. D112a cutback schedule for Tier 1/Tier 2/Tier 3/Tier 4 is 0.0/0.25/0.25/0.5.
2. New minimum Keswick Dam release schedule for higher fishery flows from October through April is shown in Table II-2.

TABLE III-2
SLWRI MINIMUM KESWICK DAM RELEASE TARGETS AND FLOW INCREASE CEILINGS FOR OCTOBER THROUGH APRIL IN SL44 STUDY, CONCEPT PLAN-EVALUATION STAGE

Carryover Storage[1] (MAF)	Minimum Keswick Dam Release Target (cfs)	Keswick Dam Release Increase Ceiling[2] (cfs)
1.9 to 2.1	3,250	0
2.2	3,500	250
2.3	3,750	500
2.4	4,000	500
2.5	4,250	500
2.6	4,500	500
2.7	4,750	500
2.8	5,000	500
2.9	5,250	500
3.0	5,500	500

Key: cfs – cubic feet per second MAF – million acre-feet

Notes:
[1]Carryover storage is the Shasta Reservoir end-of-September storage.
[2]Keswick Dam release increase ceiling" limits the differences between the "minimum Keswick Dam release target" in SL44 study and Keswick Dam release (C5) in B2 shop, based on Shasta Reservoir end-of-September storage.

CONCEPT PLANS FOCUSED ON WATER SUPPLY RELIABILITY (WSR CONCEPT PLANS)

The primary objective of the WSR concept plans was to increase water supply and water supply reliability through Shasta Reservoir enlargement. Of the four WSR concept plans, the first three simulated Shasta Dam raises of 6.5, 18.5, and 200 feet and WSR-4 modeled a Shasta Dam raise of 18.5 feet with conjunctive water management among CVP north-of-Delta agricultural contractors. The purpose of conjunctive water management is to exchange additional surface water supplies in normal water years for reducing deliveries (reliance on groundwater supplies) during dry years. In SLWRI CALSIM II modeling, D112a, CVP agricultural contractors along Tehama-Colusa Canal, were used as a surrogate for conjunctive water management participants. A different CVP cutback schedule exists for D112a; this assumed tiered cutback schedule is 0.0/0.25/0.25/0.5. For the remaining CVP agricultural contractors, the schedule is 0.25/0.25/0.25/0.25.

CONCEPT PLANS FOCUSED ON COMBINED OBJECTIVES (CO CONCEPT PLANS)

The primary objectives of CO concept plans are to increase water supply reliability and anadromous fish survival. Of five concept plans, only two are simulated in CALSIM II: CO-3 and CO-4. Because CO-1, CO-2, and CO-5 have the same CALSIM II hydrological features as WSR-1, WSR-2, and WSR-4, respectively, their hydrologic impacts are equivalent. CO concept

plans were modeled using a combination of one modeling methodology used for the WSR and AFS concept plans.

CALSIM II RESULTS

CALSIM II modeling results for SLWRI concept plans are summarized in **Table III-3** and **Figures III-1** and **III-2**.

Table III-3 is the annual average increase in project deliveries from the SLWRI benchmark while **Figure III-1** shows the breakdown of the increase in CVP deliveries. Most of the increase in the CVP total deliveries went to south-of-Delta agricultural deliveries, followed by north-of-Delta agricultural deliveries and Cross Valley Canal deliveries. All concept plans had higher CVP total deliveries and some had SWP total deliveries reduced by a small amount. The larger the enlargement, the greater the increase in CVP total deliveries. For the same enlargement, concept plans with conjunctive water management had a greater increase but with a new Keswick Dam release target had a smaller increase. Conjunctive water management created additional underground storage for floodwater through in-lieu banking and extra water supplies from groundwater stored for dry conditions. The higher release requirement for Shasta Dam from October through April reduced storage for summer water consumption.

Figure III-2 shows the monthly average increase in Keswick Dam releases from the benchmark. For most of the concept plans, except WSR-3, the patterns were similar; for concept plans with the same enlargement, the patterns were even more alike. A larger Shasta Reservoir captured more flood flows during December through February and increased releases for high summer consumption from June through September.

TABLE III-3
MODELING RESULTS OF CO CONCEPT PLANS:
ANNUAL AVERAGE INCREASE IN PROJECT DELIVERIES
FROM THE BENCHMARK

Concept Plan	Increase in Annual Average Delivery from Benchmark (TAF)			
	CVP All Year-Types	CVP Dry and Critical Years	SWP All Year-Types	SWP Dry and Critical Years
AFS-1	0	0	0	0
AFS-2	3	20	8	7
AFS-3	3	20	8	7
WSR-1	50	82	-5	-11
WSR-2	79	138	-8	-13
WSR-3	348	768	-17	-65
WSR-4	89	162	-9	-16
CO-1	50	82	-5	-11
CO-2	79	138	-8	-13
CO-3	25	61	12	20
CO-4	57	107	-7	-19
CO-5	89	162	-9	-16

Key:
AFS – anadromous fish survival CO – combined objective CVP – Central Valley Project
SWP – State Water Project TAF – thousand acre-feet

Note:
Year-types defined as in Sacramento Valley Water Year Hydrologic Classification Index.

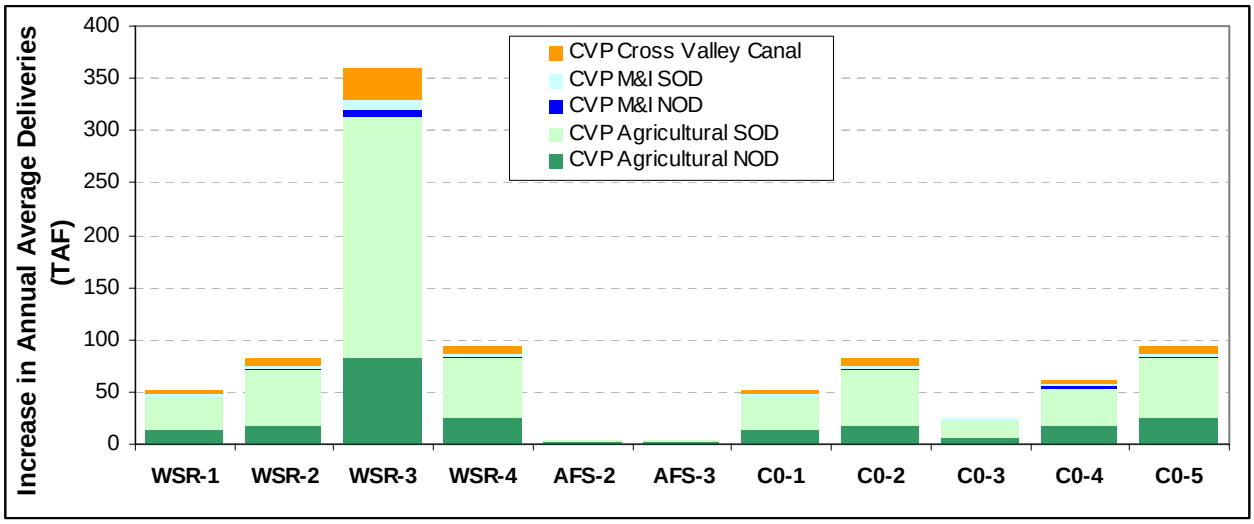

Figure III-1. Modeling results of SLWRI concept plans: annual average increase in CVP deliveries from SLWRI benchmark (agricultural, M&I, and Cross Valley Canal).

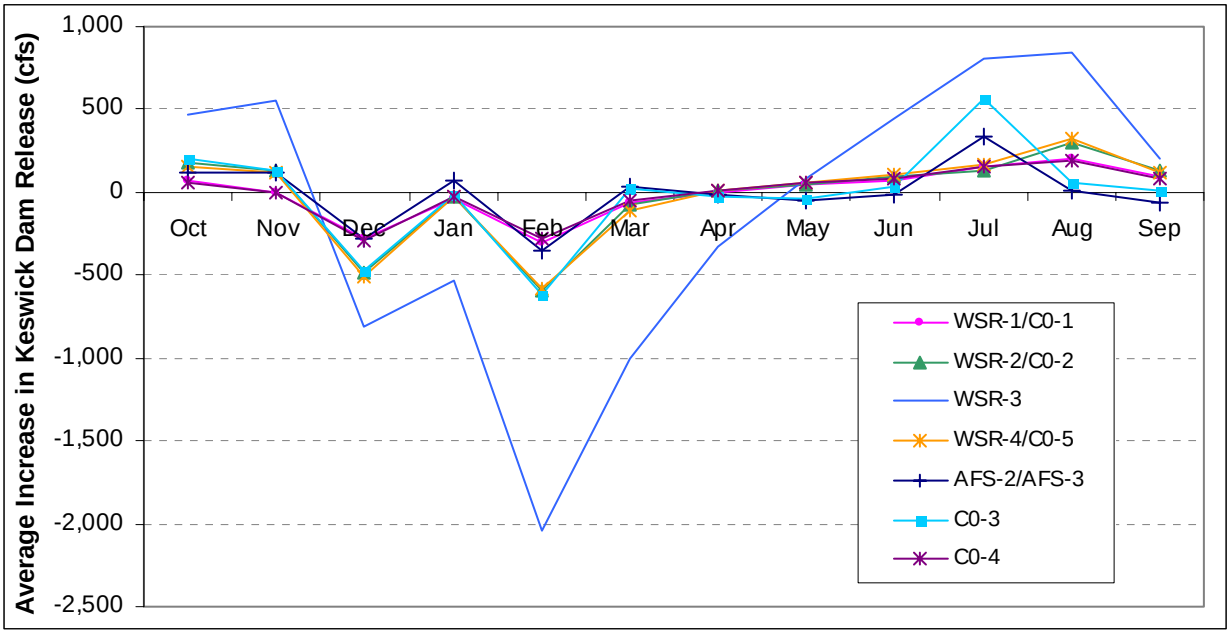

Figure III-2. Modeling results of SLWRI concept plans: monthly average increase in Keswick dam release from benchmark.