CALFED GAME 5

Gaming Years 1981-1992 5/19/00

Model: CALSIM version of DWRSIM ???

Base Run (b(2) baseline)
1995 Level of Development
Level 2 Refuge Water supply
American River D-893
D-1485
Trinity @ 390-750 TAF

WQCP Run
1995 Level of Development
Level 2 Refuge Water supply
~D-1400 (mod.)
D-1641
Trinity @ 390-750 TAF

Asset Assumptions

JPOD
- 6,680 cfs with no new facilities
- 1st priority Cross Valley Canal
- 2nd priority 50% CVP, 50% EWA

Banks + additional 500 cfs
- Total 7,180 cfs July thru Sept
- 100% SWP with 2:1 State operations smelt biological opinion

Unused San Luis Storage
- 1st priority CVP/SWP
- 2nd priority EWA

Source Shifting
- Up to 200 TAF 50% CVP, 50% EWA Repay in 3 years

E/I Flex
- 100% EWA

Water Acquisitions
- 200 TAF north and/or south of Delta

Empty Storage Space
- 180 TAF south of Delta

Options
- 100 TAF north of Delta & 100 TAF south of Delta, 3 out of 10 years

SWP Gain
- 25% SWP, 75% EWA

Results of Game 5

Fish Benefits (AF/Year)

	Critical	Dry	Below Normal	Above Normal	Wet	Average
WQCP						
b(2)						
EWA						
Total						

CVP South of Agricultural Delta Service Contract Allocation (% of 1.95 MAF)

	Critical	Dry	Below Normal	Above Normal	Wet	Average
Game 5						
Land Ret.						
Total						

Report on Game 5

- 1981 – 1985 Completed
- Game very complex.

- **Assets**
  - Empty Storage (200)
  - Purchases (150 SOD, 50 NOD (35 in Year 1981)
  - E/I
  - 50% JPOD
  - 75% State Gain
  - Source Shifting (100 for EWA, 100 for CVP).
  - B(2) w/ limited reset and Offset

Issues

- **Interaction between Collateral/Assets**
  - When storage empty, collateral is very weak
  - If then use very strict requirements for collateral, EWA is highly constrained.
    - 1981. Peak debt of 225 May. Given 150 kaf purchases plus source shifting, this could be supported, but requires staking some of next year's purchases.
    - 1982. Peak debt of 570 kaf in May. Insupportable. Even by staking this year + next year's purchases, still 270 short. Needed 270 kaf of magic water this year.
    - 1983. Minimal debt. Groundwater storage fills.
    - 1984. Peak debt of 390 in SLR. But with 200 in groundwater storage + 150 purchases, not a major problem.
    - 1985. Peak debt of 297. Again, with groundwater + purchases, collateral adequate to cover.
  - Note. Debt carried across years was always paid off succeeding winter. Will not always be so, but shows utility of carrying debt rather than immediate payback.

- **CVP Export Cuts**. None made during game. However, reduced carryover storage could have effect during model runs.
- **Reset**. Not a major factor.
- **Offset**. Only appeared in 1985. 133 kaf of offset water. 97 kaf was recovered later in year. 36 not recovered and not given credit. Clear benefit to CVP contractors. Actual benefit closer to 133.
- **Source Shifting for CVP**. Appears to work fine. Same principles as EWA source shift, but with lower collateral problems (CVP always has collateral).

To: Federal/State Team
From: Ron Ott
Subject: Trinity, 2:1, 500cfs

At the EWA meeting on Thursday there were two concerns you ask the EWA team to check out ASAP.

1. Verify the assumptions on the Trinity Flow Requirements in the base model and Gaming runs for Game 5.

Ans.: Trinity flow requirements NEVER exceed 6000 cfs in our Game5 baselines (max is 4050 cfs in May). The requirements were provided to us by the USBR planning office from their CVPIA baseline scenarios Trinity at (390-750). Capped at 6,000 cfs for the first two years.

2. What are the long-term impacts on SWP deliveries of using the 2:1 as opposed to a 1:1 smelt biological ratio and how much is made-up with the increased 500cfs pumping at Banks.

Ans.: A CALSIM model run today produced the follow results:

For the Oct 1921 – Sep 1994 Period

	2:1	500 cfs	2:1 + 500 CFS
Average Impact on Deliveries	-13 TAF	+6 TAF	-7 TAF
Max Year Impact (1965) Wet Year	-144 TAF	+90 TAF	-54 TAF
Min Year Impact (1933) Critical Year	+ 11 TAF	0	+11 TAF

Game 5 Summary

June 1, 2000

Results

Year	Year Type	Allocation SOD CVP Ag*	Notes
1981	Dry	68%	
1982	Wet	81%	Need Tier 3 water purchase
1983	Wet	100%	
1984	Wet	63%	
1985	Dry	68%	
1986	Wet	52%	Wet year, but late rain
1987	Dry	48%	
1988	Critical	44%	b(2) for fish benefits resulted in delivery reduction
1989	Dry	34%	b(2) for fish benefits resulted in delivery reduction
1990	Critical	28%	
1991	Critical	0%	
1992	Critical	27%	
1993	Above Norm	100%	
1994	Critical	60%	

*Includes delivery reductions due to b(2) WQCP.
Unless otherwise noted, b(2) for fish benefit does not result in delivery reduction.
Does not include source shifting for CVP.
Does not include land retirement.

	Critical	Dry	Below Normal	Above Normal	Wet
Average Game Result	32%	55%			74%
Interpolated			61%	67%	

Weighted Average (All Years)	60%

Game 5 Observations

1. EWA water stored in San Luis helps with low point.
2. Fully utilizing JPOD at 6,680 cfs may result in South Delta water level impacts. To address impacts consider: a) lowered pumps with automated fish screens, b) increased duration of temporary barriers.
3. We need to explore utlizing unused JPOD to offset WQCP impacts.
4. The largest range of delivery impacts occurs in critical and wet years.
5. Gaming should be considered for operations forecasting.
6. Integrated management of State and federal operations with all environmental objectives maximizes benefits.

EWA Essentials

1. For effective borrowing, logistics with State must be worked out.
2. MWD (and other) source shifting contracts must be executed.
3. Need capability to purchase 150 TAF south of Delta every year and 50 TAF north of Delta twice in the next four years.
4. Need to start with filled storage (200 TAF) or a firm "option" (could be cheaper) south of Delta. Storage then refilled with acquired water or surplus flows.
5. Need Tier 3 capability (200 TAF) once in the next four years.

Game 5 Date: 06/01/2000
Operations Report
Preliminary

Fish Benefits (AF/Year)

	Critical	Dry	BN	AN	Wet	Average
b(2)	587	770		800	777	720
EWA	376	249		432	522	318
Total	963	1018		1232	1299	1038

CVP South of Delta Agricultural Service Contract Allocation (% of 1.915 MAF)

	Critical	Dry	BN	AN	Wet	Average
Planning Study	34	60	65	100	75	57
Game Results	32	55	60	100	74	55
Weighted According to Year Type Frequency (Below Normal Value Interpolated)						
Planning Study						67
Game Results						65

	1981D	1982W	1983W	1984W	1985D	1986W	1987D	1988C	1989D	1990C	1991C	1992C	1993AN	1994C
Maximum Gross Spring Debt	225	702	0	391	531	531	450	53	37	0	0	241	240	365
Firm Collateral														
This Year SOD Purchase	120	120	150	90	120	120	90	150	150	150	0	90	90	90
This Year NOD Purchase							40	40	40	40	40	40	40	
Next Year SOD Purchase	150	150	150	150	150	150	150	150	150	150	150	150	150	150
SLR Storage										208	56			
Ground Water Storage			100	200	200	200	200	200	200	200	200	200	200	200
Maximum Net Debt	0	432	0	0	0	60	0	0	0	0	0	0	0	0

Magic Water Needed For Collateral 330? 0?

(Assumes source shifting in 1983 to carry remaining debt into 1984. Else need is for 432 kaf).
Assumes source shifting to carry into 1987. Else 60 needed.
If source shifting not acceptable then 10.

Offsets	1981D	1982W	1983W	1984W	1985D	1986W	1987D	1988C	1989D	1990C	1991C	1992C	1993AN	1994C	Average
Total offsets	0	0	0	22	133	0	160	234	122	164	0	145	16	246	89
Exports recovered from offsets	0	0	0	0	97	0	119	0	0	53	0	100	0	180	39

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	1981D	1982W	1983W	1984W	1985D	1986W	1987D	1988C	1989D	1990C	1991C	1992C	1993AN	1994C	Average	Min	Max
E/I for EWA	0	0	0	0	0	0	0	35	50	0	0	34	90	0	15	0	90
JPOD Using Excess Flows to EWA	0	51	519	0	240	105	230	0	0	0	0	0	0	0	82	0	519
JPOD Using Excess Flows to CVP	0	51	519	0	240	105	230	0	0	0	0	0	0	0	82	0	519
JPOD Shifting NOD Storage to SOD by EWA	0	0	0	0	0	46	0	0	28	0	0	150	0	0	16	0	150
JPOD Shifting NOD Storage to SOD by CVP	371	100	0	120	80	0	60	0	0	0	0	0	0	175	65	0	371
Total JPOD	371	202	1038	120	560	256	520	0	28	0	0	150	0	175	244	0	1038
Transfer NOD Purchases by EWA	30	0	0	0	0	24	0	50	0	0	50	50	50	0	18	0	50
SOD Purchase by EWA	150	300	0	150	150	150	150	150	150	150	0	150	150	150	139	0	300
EWA Share of SWP Gain	161	35	0	0	141	0	102	0	12	50	0	0	0	215	51	0	215
SWP Share of SWP Gain	54	12	0	0	47	0	34	0	4	17	0	0	0	72	17	0	72
Total State Gain	215	47	0	0	188	0	136	0	16	67	0	0	0	287	68	0	287
500 cfs benefit to SWP	30	90	90	80	60	70	50	0	45	0	0	0	75	60	46	0	90
Ground Water Storage	0	0	100	200	200	200	200	200	200	200	200	200	200	200		0	200

CALFED GAME 5 Modeling Conditions

Model: CALSIM
Gaming Years 1981-1994

Base Run (b(2) baseline)
Level of Development: 1995
Refuge Water supply: Level 2
American River: D-893 (modified)
Water Quality: D-1485
Trinity River: 390-750 TAF, capped at 6,000 year 1 and 2

WQCP Run
Level of Development: 1995
Refuge Water supply: Level 2
American River: between D-893 and D-1400
Water Quality: D-1485
Trinity River: 390-750 TAF, capped at 6,000 year 1 and 2

D-018523

California (CALFED) Daily Environmental Water Management Modeling for Fish Protection and Water Supply Evaluation

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Abstract

CALFED is a cooperative venture of Federal and State water and environmental resource management agencies. CALFED's objectives are to provide improved fish protection and increased water supply reliability using the existing storage and pumping facilities. The water supply targets require considerable Delta export pumping. Efforts to reduce fish entrainment would restrict export pumping. The basic strategy is to allow the greatest possible pumping in periods with low risk of entrainment and reduce pumping when entrainment risk is high. One necessary component will be real-time fish monitoring to detect high fish densities. The second component is an Environmental Water Account (EWA) that will allow direct control over pumping restrictions necessary to reduce entrainment.

A gaming approach has been used to interactively simulate the effects of fish protection measures on Delta flows and water supply conditions. A combination of a monthly planning model run in a year-by-year mode and daily operations models were used in the interactive gaming sessions. The monthly DWRSIM results for a year were used to approximate the baseline conditions that might include different facilities or operating constraints. The daily models were used to show the daily patterns of reservoir releases and Delta inflows and the effects of various Delta objectives on required Delta outflow and allowable export pumping. The daily Delta model included the historic Central Valley Project (CVP) and State Water Project (SWP) fish salvage density data, which were used to guide the EWA adjustments to export pumping in a month-by-month gaming exercise, and to calculate the fish entrainment protection achieved.

Introduction

The CALFED Water Management Strategy (WMS) goal is to develop a coordinated approach to operating existing federal and state water projects with new facilities and operational schemes to improve water supply reliability and the quality of water exported, and reduce impacts to fish (CALFED 1999). A Water Management Development Team (WMDT) was formed in 1999 with agency and stakeholder representatives to develop recommendations for the CALFED EWA. The EWA is designed to reduce the loss of fish at state and federal pumping plants in the south Delta and improve habitat conditions including stream flows in Central Valley rivers and Delta channel flows. The EWA would be operated in conjunction with other water management programs such as the CVPIA Anadromous Fish Restoration Program (AFRP), and would provide additional protection compared to existing in-stream flow and Delta flow objectives.

Fish Entrainment Reduction Measures

Fish entrainment losses occur when a vulnerable life stage of a fish species is directly entrained at the pumping facilities or indirectly drawn towards the vicinity of the pumping facilities. The daily entrainment loss is assumed proportional to the density of fish in the south Delta water and the volume of water diverted. The existing fish salvage facilities were designed to effectively screen some of the larger fish life stages (i.e., chinook and striped bass). These fish screening facilities may not be as effective for smaller fish (i.e. Delta smelt). The density of fish in the south Delta is governed by natural spawning and migration events, but may also be influenced by the hydrodynamic transport conditions that are controlled by the Delta inflow and south Delta pumping patterns. The distribution and abundance of each fish population is influenced by the hydrodynamic conditions within the Delta, but is also a function of other habitat conditions important to the various life stages of each fish. The entrainment of fish in the Delta exports may be reduced with the following water management actions:

(1) Sacramento River inflow can be increased to control conditions for fish entering the Delta from the Sacramento River corridor, and to regulate Delta outflow and other channel flows.

(2) The Delta Cross-Channel (DCC) gates can be closed to reduce the diversion of fish into the central Delta. The DCC directly influences hydrodynamic conditions in the central Delta.

(3) San Joaquin River inflow can be increased to control conditions for fish entering the Delta from the San Joaquin River corridor, and to regulate central Delta hydrodynamic conditions.

(4) The Head of Old River (HOR) barrier can be closed to reduce the diversion of fish into the south Delta channels, and to influence hydrodynamic conditions in the south Delta.

(5) Delta export pumping can be reduced to protect vulnerable life stages of fish species of interest during periods when high densities of these fish are observed in the south Delta or in central Delta habitat. This shifting of export pumping is the focus of this paper.

Water Supply Targets

The water supply delivery targets assuming 1995 level-of-demands require about 6 million acre-feet (MAF) of Delta exports. The demand follows a seasonal pattern with the majority of water needed in the summer months for agricultural purposes. The San Luis Reservoir capacity of

2,038 TAF, with an assumed carryover storage of 250 TAF, allows some (i.e. 1,775 TAF) of the water supply to be pumped in the winter period and stored until needed in the summer. Demands for the October-March period total about 1.8 MAF, so the exports during these months cannot be more than about 3.5 MAF (with existing storage and demand patterns). The remaining exports (2.5 MAF) must occur during the April-September period of high demands.

The currently permitted maximum combined CVP and SWP pumping rate is about 11,280 cfs, which allows a maximum of about 22 TAF of exports per day. The 6 MAF water supply target would require about 275 days of maximum permitted pumping. If full pumping capacity at SWP is allowed (i.e. about 15,000 cfs combined capacity), then a maximum of about 30 TAF can be exported per day, and about 200 days of maximum capacity pumping could supply the 6 MAF water supply target.

To fill San Luis Reservoir by the end of March from an initial volume of 250 TAF and to meet the 1.8 MAF of demands would require 160 days of maximum permitted pumping, leaving less than 30 days of suspended (i.e., minimum) pumping during this period. To meet the demands in the second half or the year would require 115 days of maximum pumping, leaving a maximum of about 65 days of suspended pumping for fish protection.

Because the relatively high inflows necessary to allow full pumping under current Delta water quality control plan objectives are not available during all years, some fish protection is already obtained because of the water supply limitations on Delta export pumping. In dry years there are very limited opportunities to further restrict pumping without causing a water supply reduction.

Environmental Water Account Assets

The basic actions of the EWA would be reservoir release flow changes and export reductions. The EWA as presently proposed by CALFED would have assets that would allow changes in upstream reservoir releases that would benefit fish populations. Other EWA assets would provide for export reductions at specified times to reduce fish losses at pumping plants or to improve fish passage through the Delta. The EWA could also change operations of the Delta Cross Channel gates, and the Head-of-Old-River barrier to enhance EWA measures in reducing fish losses at the pumping plants or to improve fish passage through the Delta.

EWA assets may be obtained from several potential sources, such as relaxation of existing standards, allocated "shares" in new water facilities, storage of "surplus" water in new storage facilities, or purchases with public funds from willing sellers. To be effective an EWA needs access and use of CVP and SWP pumping, storage, and conveyance facilities. A unique aspect of the EWA observed in gaming simulations was that assets will often only be needed as collateral or insurance. Exports reductions may occur without penalty to the EWA if San Luis reservoir can refill after the export reductions and all necessary deliveries can be made from San Luis Reservoir before the summer low-point. If export reductions can be matched with cutbacks in upstream storage releases, the EWA can bank the water in the upstream reservoirs for possible later release and export to make-up the EWA export reduction (i.e., delivery debt). Reservoir releases requested by the EWA may occur without penalty to the EWA if reservoirs later refill to flood control levels (i.e., spill).

Interactive Simulation of Fish Protection Actions

A gaming approach has been used to interactively simulate the effects of fish protection measures on flows and water supply conditions. A combination of a monthly planning model run in a year- by-year mode and interactive daily operations models are used in the interactive gaming sessions. The monthly DWRSIM results for a year were used to approximate the baseline conditions that might include different facilities or operating constraints. The daily models were then used to show the daily patterns of reservoir releases and Delta inflows and the effects of various Delta objectives on required Delta outflow and allowable export pumping. The daily model included the historic CVP and SWP fish salvage density data, which were used to guide the EWA adjustments in a month-by-month gaming exercise. The recent period of record (i.e. 1981-1995) was used for the gaming because it covers both wet and dry conditions and historical fish salvage records from the CVP and SWP facilities are available.

The daily models include the historic flows, reservoir storages, diversions, and Delta export pumping records. Historical conditions and operations provide a reference that many people recognize and understand. Historical operations can be used as the initial reference for comparison with results from the monthly planning model. The daily model imports the monthly values from the planning model and displays these monthly values along with the historical daily patterns. The graphical display of daily historic records increases the participation by project operators who are familiar with daily patterns. Environmental conditions can vary substantially within a month, so that accurate evaluations of habitat conditions and fish entrainment effects under alternative operations can only be performed with daily models.

The daily Delta simulation model uses historical inflows, channel depletions and south of Delta deliveries that are adjusted to match the monthly DWRSIM results. The difference between the monthly model and the historical monthly average is added to the daily values to match the planning model results while retaining the historical hydrograph patterns. The daily Delta model calculates daily outflow requirements and export/inflow ratio limits on pumping, calculates the maximum permitted pumping (that depends on the San Joaquin River flows) and the maximum pumping for deliveries if San Luis Reservoir is filled. Figure 1 shows these various possible limits on combined CVP and SWP export pumping for 1985. The daily simulated baseline exports were 6,200 TAF. The historical pumping under water right decision D-1485 objectives was 5,470 TAF, and the monthly model exports were 6,568 TAF. The monthly model exports are generally higher than daily simulated pumping because the monthly averaging of inflow hydrographs uses flow that is greater than export capacity to balance lower inflow periods.

The daily Delta model can simulate fish protection trigger(s) or specified export restrictions that are based on historical salvage records for selected fish species. Export limits or reductions can be specified weekly during the gaming sessions. The daily model can also be used to simulate increased exports that could have been made if some operational limit were relaxed. The daily model can simulate additional exports that could have been made if water supply demands or available storage had been greater than historical values. The daily Delta model allows the effects of operational flexibility and possible fish protection measures, as well as various methods of managing the EWA under a wide range of hydrological conditions to be explored.

The daily reservoir model simulates daily operational constraints and targets for Shasta (Sacramento River), Clair Engle (Trinity River), New Bullards Bar (Yuba River) Oroville (Feather River), Folsom (American River), and New Melones (Stanislaus River) Reservoirs. The model starts with historical daily inflows, storages, diversions, and releases for each reservoir along with downstream Sacramento River flows at Freeport and San Joaquin River flows at Vernalis. The monthly maximum flood control storage and minimum carryover storage values are specified for each reservoir. Diversion targets are specified for each tributary (including Trinity exports to Sacramento). Monthly minimum fish flow targets can be fixed values or can vary with reservoir storage and projected inflows. New Melones Reservoir releases for salinity control at Vernalis are calculated from historical salinity (EC) and San Joaquin River flows.

Initial storage values for each year of simulation are specified to match the monthly planning model values. The DWRSIM calculated storage and reservoir release values are imported and displayed along with the historical values. Adjustments in the release flows for increased fish protection or improved habitat conditions (i.e. temperature) are made during the gaming sessions. Opportunities to reduce reservoir releases during periods of export reductions for fish protection are also identified during the gaming. Figure 2 shows the Sacramento River inflow at Freeport for 1985. The historical flow is given as the thin line. The baseline adjustments from the monthly planning model results (big circle) are shown as triangles. December had the greatest adjustment from historical flows. Upstream reservoir releases were increased during the EWA gaming to improve habitat and migration conditions in October (2000 cfs), December (1000 cfs), January (3000 cfs), June (2000 cfs) and September (3000cfs). These adjustments may have allowed greater exports or increased the Delta outflow compared to the baseline conditions.

Calculation of potential biological benefits

Perhaps the most difficult tasks for operating a successful EWA will be the development of the biological decision-making framework for EWA actions and performance measures for evaluating EWA fish protection actions. The biological effects are much more difficult to estimate and quantify than the water supply effects.

The daily Delta model calculates the fish salvage for five fish with historic exports, baseline exports, and EWA adjusted exports, using the daily CVP and SWP salvage densities, as the basic measure of fish protection. The daily model also provides estimates of salmon survival indices for historical, baseline and EWA adjusted flows and exports as another measure of fish protection achieved. Projecting the effects of the EWA export adjustments on fish populations is beyond the modeling capabilities and current biological understanding. Figure 3 shows the historical 1985 fish densities from the SWP pumping facility. The density (i.e., fish per TAF of pumping) is displayed each day that fish were salvaged on a logarithmic scale. The historical SWP export pumping is also shown to indicate when fish density estimates are relatively uncertain because of low pumping rate. The striped bass were numerically the most abundant fish salvaged in 1985. Fish biologists use fork-length and seasonal life-stage information to interpret the fish density data.

Fish protection "templates" were designed to guide EWA actions during the simulations based on the perceived needs of key fish species in terms of flows and export restrictions as determined from the historical operation and hydrology conditions and fish density information for each year of the gaming simulation. Each need or concern identified was given a priority based on perceived risk to the respective fish populations, which included the state of the fish population in the year in question. Fish protection actions were applied during the gaming sessions based on the fish templates and systems operations information as the daily allowable exports were simulated. Actions included export reductions and upstream storage releases. Upstream releases provided instream benefits as well as potential outflow or export benefits. Export reductions led either to increased outflow or lower upstream storage releases.

Figure 4 shows the EWA adjusted exports for 1985. The EWA adjusted exports were 6,110 TAF. Export reductions for fish protection were specified by the fish biologists in December, February, March, April, and May. Increased exports were achieved in October, January, June, and September from the increased inflows caused by increased upstream reservoir releases. The total export pumping that was reduced for fish protection from the baseline was about 665 TAF, and the increased exports achieved in other periods were about 575 TAF. The net export reduction of about 90 TAF exports would have been purchased by EWA from CVP or SWP willing sellers.

Summary of Interactive EWA Modeling Results and Findings

Figure 5 shows the San Luis Reservoir storage for 1985. The baseline daily simulation of San Luis Reservoir storage using the monthly planning model specified delivery targets differs from the monthly planning model results, because the simulated daily exports are different (i.e., 300 TAF lower) than the monthly model exports. The historical storage pattern is different because the deliveries and exports were different than simulated. The EWA adjusted storage indicates the seasonal effects of reductions in export pumping that were made for fish protection, increases in exports from upstream releases, and delivery reductions achieved through purchases.

Figure 6 shows the simulated delivery pattern specified from the monthly planning model compared with the historical delivery. The historical delivery of 5,510 TAF was considerably less than the monthly model projection of 6,700 TAF. Because the daily model indicated that less water could be exported, a reduction in the monthly model deliveries of 250 TAF was made during the EWA gaming session (50 TAF reduction for May-September). Some of these

D-018529

reductions would be considered as necessary changes in the monthly baseline, and the 100 TAF of export reductions for fish protection would have been achieved with EWA purchases.

Gaming simulations have identified obvious water supply and EWA benefits from the SWP and CVP operating under a more flexible Joint Point of Diversion (JPOD) and Coordinated Operations Agreement (COA) for Delta exports and storage in San Luis Reservoir. Increasing the permitted SWP export capacity, with some necessary improvements in fish screening facilities and south Delta channel conditions, will substantially increase the export pumping flexibility needed to avoid high pumping during periods with high fish density. Gaming also identified opportunities to share upstream storage facilities that would provide increased environmental as well as water supply benefits.

The EWA gaming sessions have been very successful in providing an opportunity for agency and stakeholder representatives to increase their understanding of water management system operations and the potential environmental consequences of alternative reservoir releases and export patterns. The combination of monthly planning model results and the daily operations models with fish density information has provided an exceptional learning environment.

Model simulations have reinforced our understanding that several environmental water management actions may provide cumulative results that are quite substantial. Although the EWA actions generally shift only about 10-15% of the export pumping, the potential reductions in fish entrainment losses are considered worthwhile. The EWA is viewed as an important supplemental measure of fish protection management actions that may be more effective than additional fixed monthly minimum Delta outflows and other prescribed export limitations. The EWA is viewed as an adaptive management framework for manipulating flows and exports without further reducing water supplies.

Acknowledgments

The CALFED Water Management Development Team and the technical coordination group has invested considerable time in the EWA concepts and gaming exercises. This effort has been coordinated by Ron Ott, CALFED consultant team leader. Agency and stakeholder representatives have actively participated in the gaming. The California Department of Water Resources modeling staff have also cooperated in modifying the monthly planning model for use in these EWA gaming exercises.

References

CALFED Bay-Delta Program (1999). "Water Management Strategy" in Revised Phase II Report. Technical Appendix to Draft Programmatic Environmental Impact Statement/Environmental Impact Report. June 1999. 1416 Ninth St. Sacramento CA. 95814

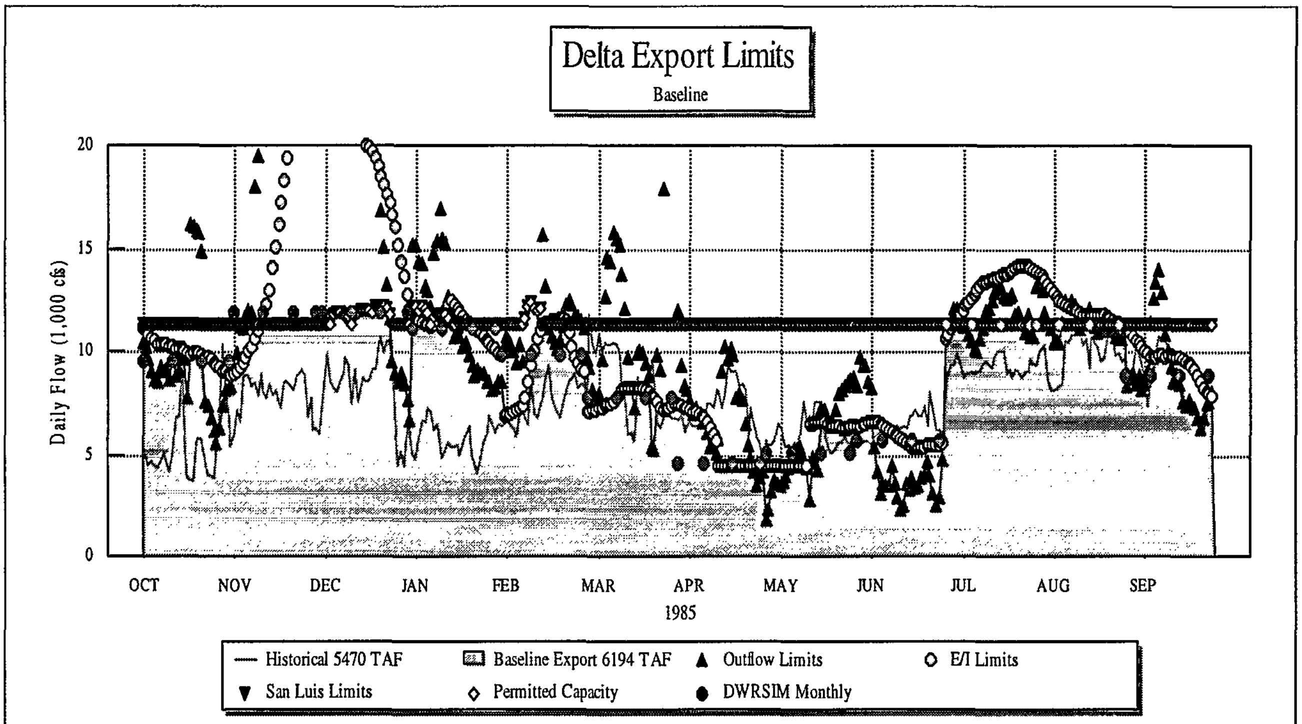

Figure 1. Simulated Baseline Daily Allowable Delta Exports Compared with DWRSIM Monthly and Historical CVP and SWP Export Pumping for 1985

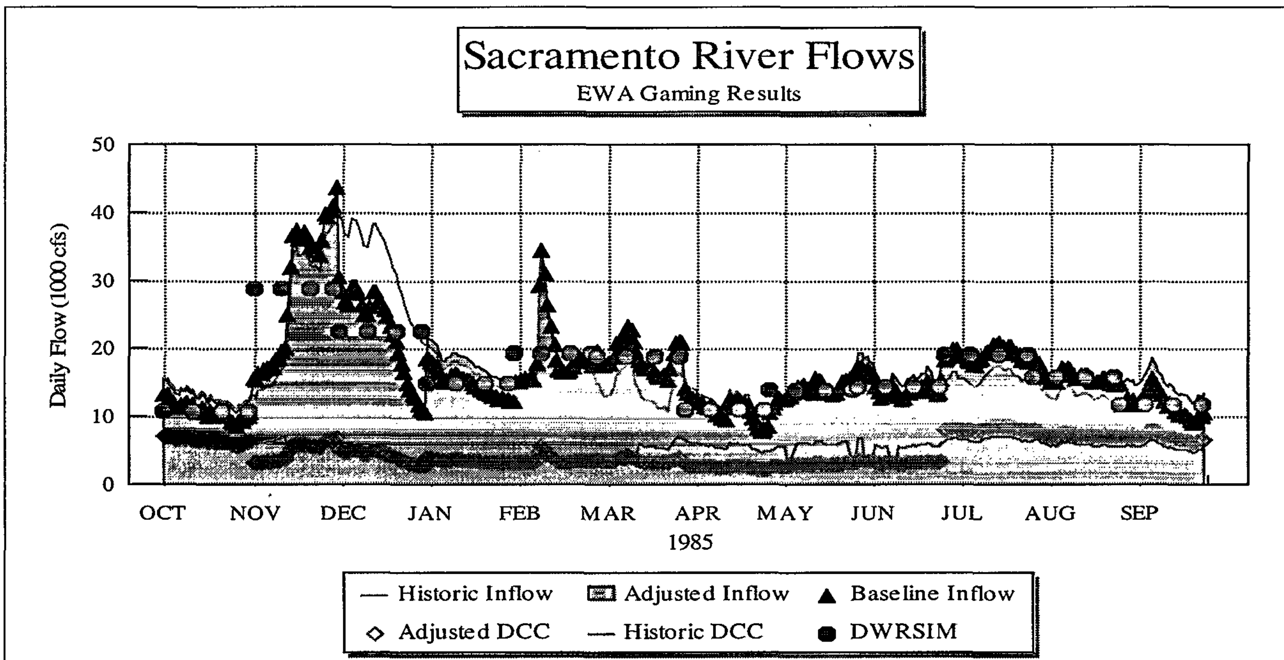

Figure 2. Simulated Sacramento River Inflow for Baseline and EWA Adjusted Upstream Releases Compared with Historical Inflow for 1985

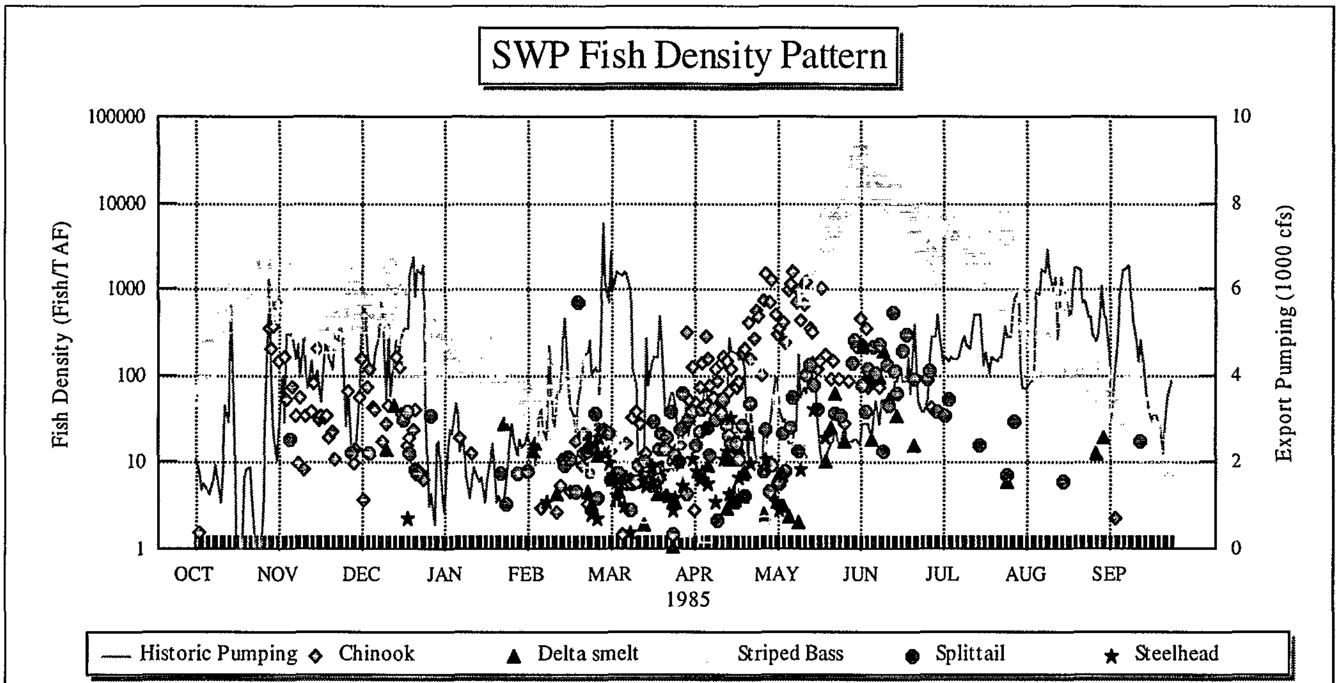

Figure 3. Historic SWP Salvage Density Patterns Used to Guide EWA Export Reductions

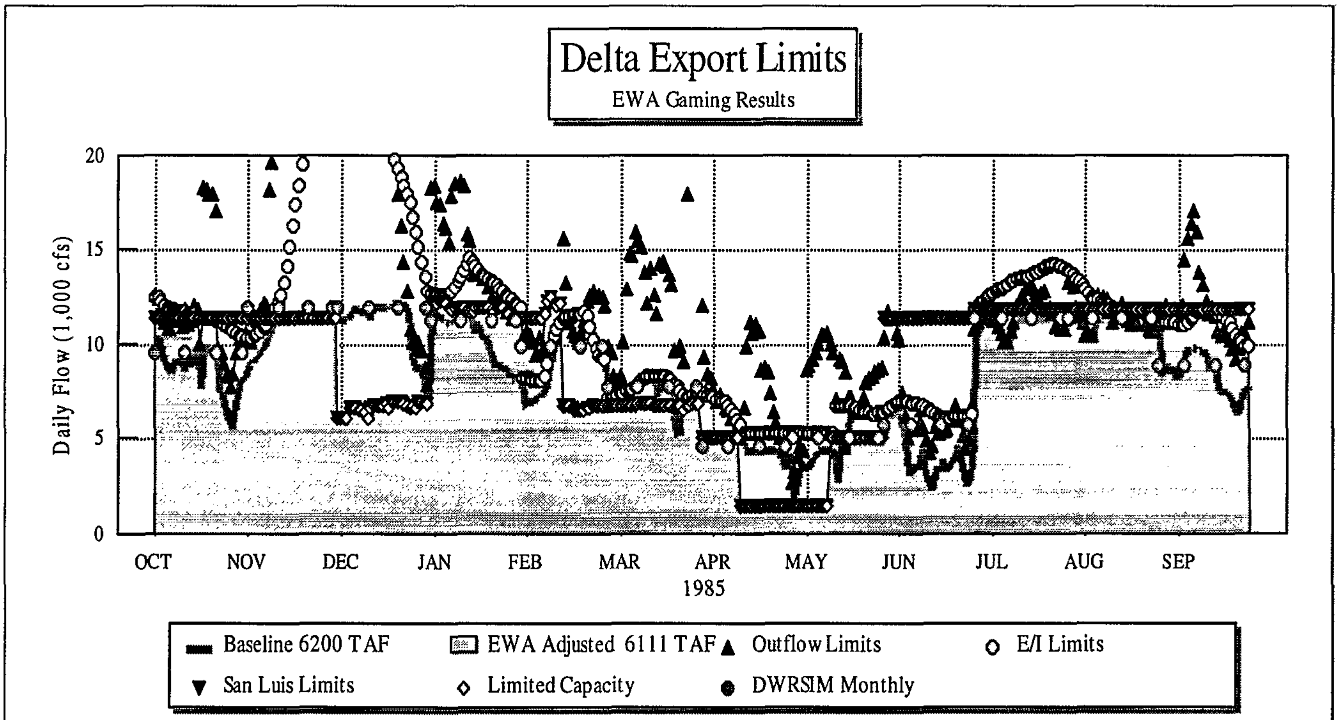

Figure 4. Simulated EWA Adjustments in Exports for Fish Protection

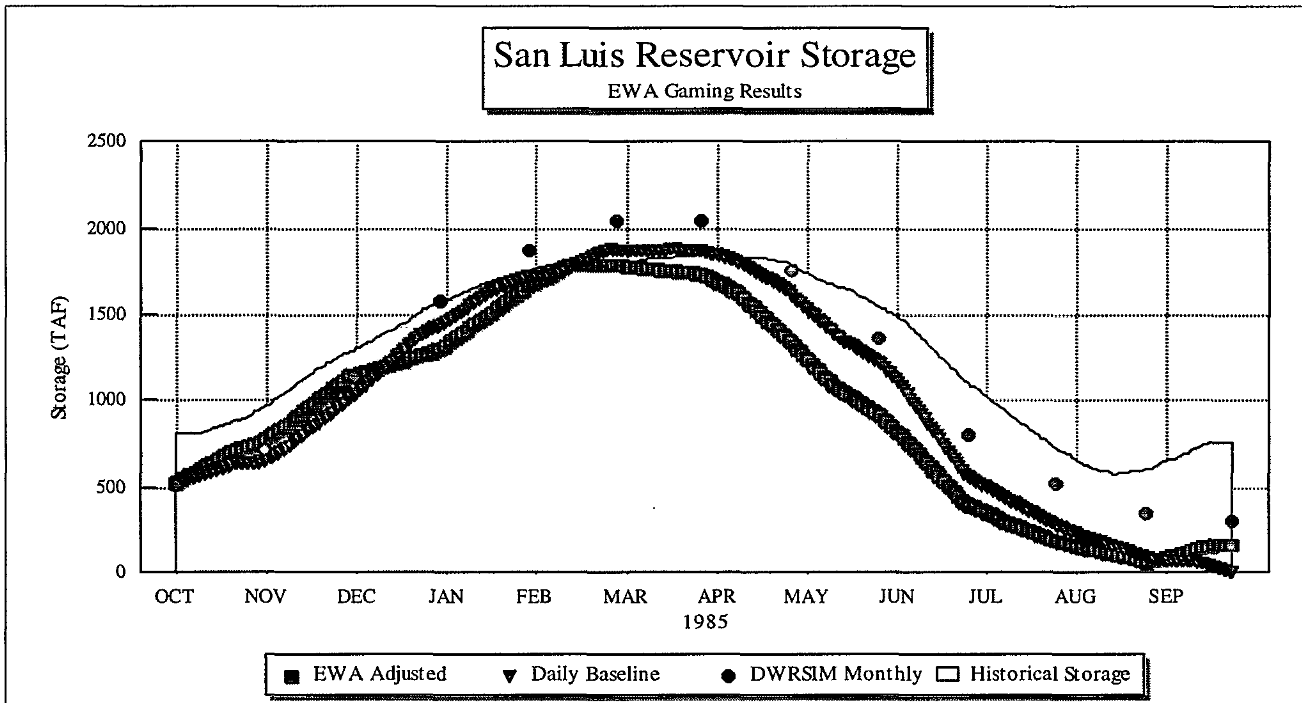

Figure 5. Simulated Daily Baseline and EWA Adjusted San Luis Reservoir Storage Compared with Monthly and Historical

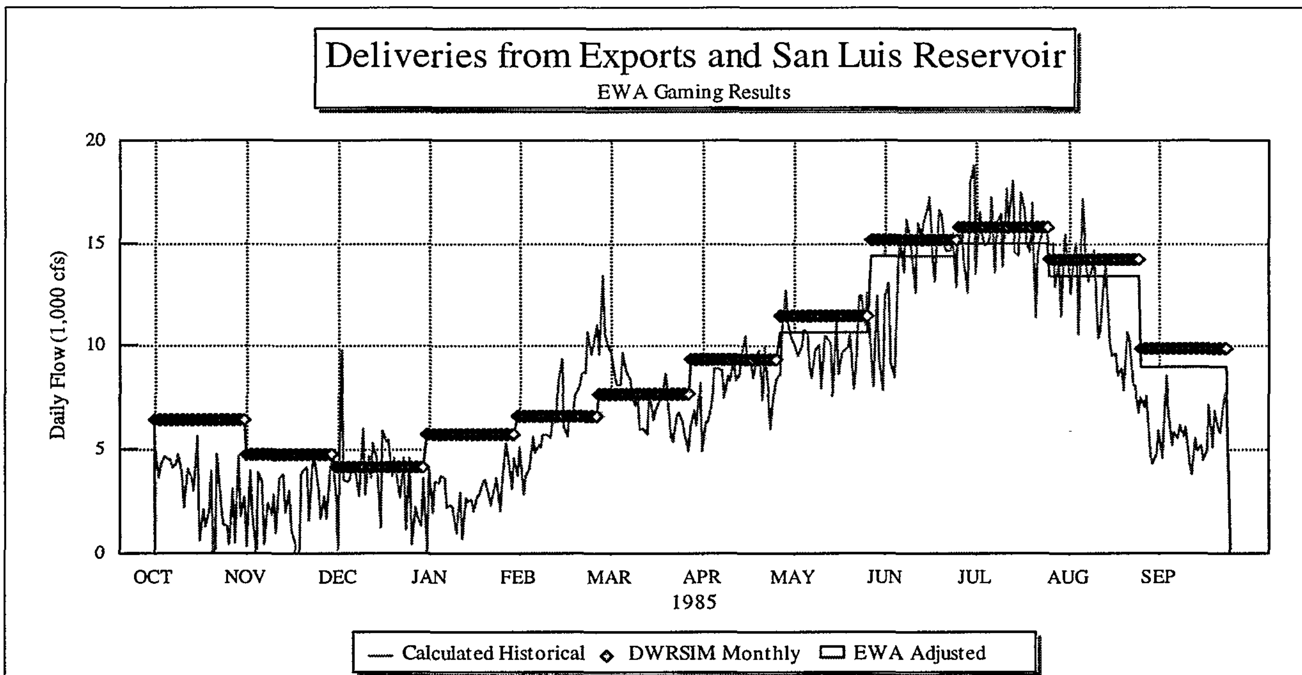

Figure 6. Simulated Baseline and EWA Adjusted Delivery Compared with Historical