Methodology for Flow and Salinity Estimates in the Sacramento-San Joaquin Delta and Suisun Marsh

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Chapter 5:
Use of CALVIN in DSM2 Planning Studies

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5 Use of CALVIN in DSM2 Planning Studies

5.1 Introduction

DSM2 planning studies evaluate potential impacts of hypothetical changes to factors such as hydrologic regimes, water quality standards, system operations, and Delta configurations. To explore the impacts of a given alternative under various hydrologic conditions, DSM2 planning studies are typically run for a 16-year sequence (water years 1976-1991) of Delta inflows and exports derived from statewide water resources operations and storage simulations. Typically, the Delta boundary flows and exports for DSM2 planning studies have been provided by CALSIM, the Department of Water Resources' systems operations model.

Although CALSIM is typically used to provide boundary flows and exports for DSM2 planning studies, the input can be provided by any source or combination of sources that specify the following Delta inflows, exports, and flow control structures operations required to run DSM2:

- Inflows
  - Sacramento River at Sacramento
  - San Joaquin River at Vernalis
  - Eastside streams (Mokelumne and Cosumnes rivers, either separately or combined)
  - Calaveras River
  - Yolo Bypass
- Exports
  - State Water Project (Banks Pumping Plant)
  - Central Valley Project (Tracy Pumping Plant)
  - Contra Costa Canal and Los Vaqueros Reservoir (separately or combined)
  - North Bay Aqueduct and Vallejo (separately or combined)
- Delta Island Consumptive Use (diversions, drainage, and seepage)
- Flow Control Structures Operations
  - Delta Cross Channel
  - South Delta Fish and Agricultural Barriers

Another water resources model that can provide the required inflow and export information to DSM2 is CALVIN, the University of California at Davis' economic-water resources optimization model. This chapter provides a brief overview of CALVIN and describes how it is used to provide flow and export inputs for DSM2 planning studies (Figure 5.1). This chapter also discusses the use of DSM2 to provide feedback to CALVIN on how well the system

operations suggested in CALVIN meet Delta water quality standards and to suggest improvements in CALVIN's representation of Delta salinity requirements.

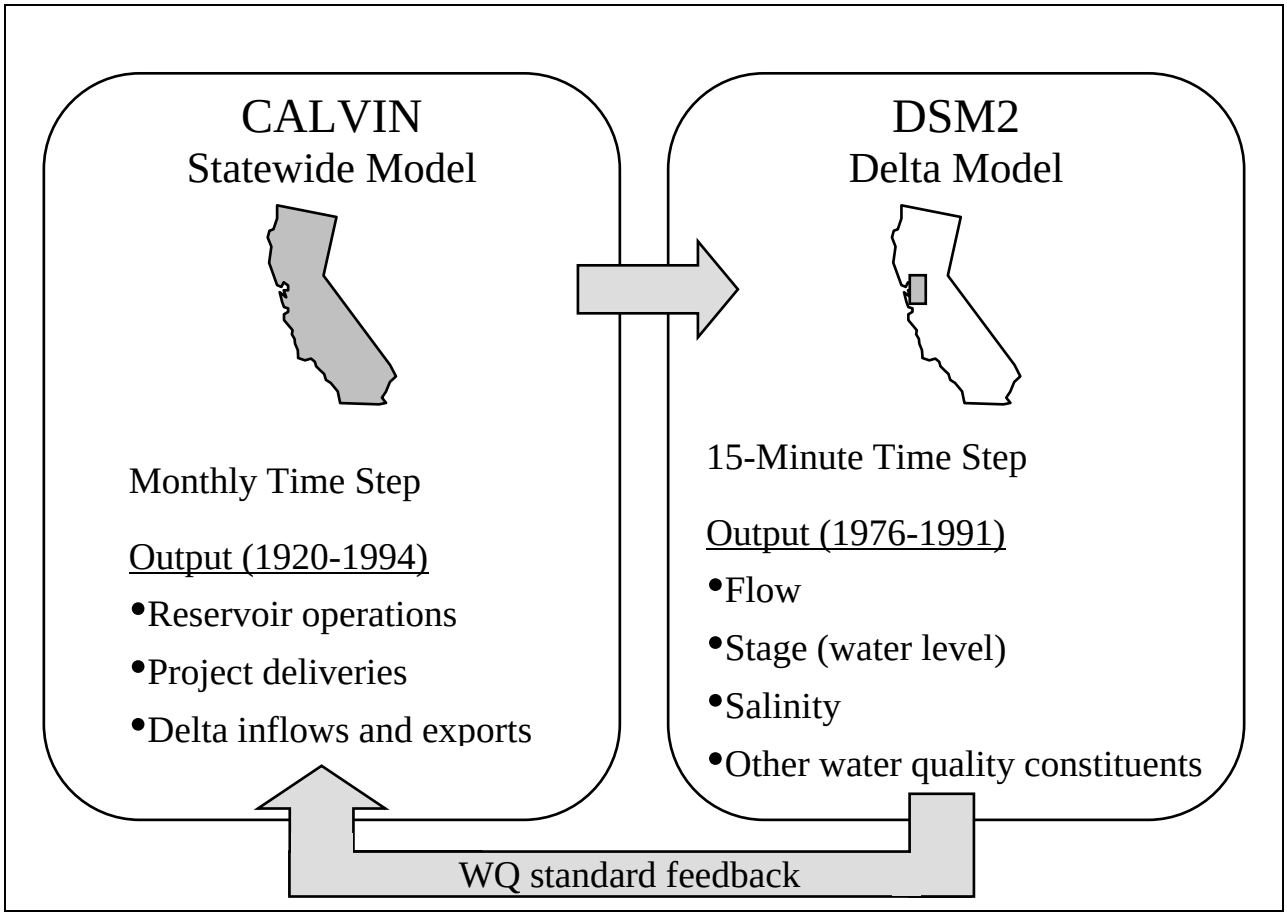

Figure 5.1: CALVIN Inputs to DSM2 and DSM2 Feedback to CALVIN.

5.2 CALVIN Overview

CALVIN (CALifornia Value Integrated Network) is an economic-engineering optimization model of California's water supply system (all information in this section is based on Jenkins et al., 2001 and Lund et al., 2003). A water resources optimization model is able to determine the "least cost" or optimal solution for water allocations given specified constraints. These constraints can be physical (such as facility capacities) or regulatory (such as water quality standards, delivery contracts, etc). Since CALVIN is an economically driven model, CALVIN allocates water and operates facilities to maximize the economic value of urban and agricultural water uses in the absence of other constraints. CALVIN simultaneously manages statewide surface water, groundwater, and water demands. CALVIN's spatial extent covers 88% of California's irrigated acreage and includes water demands from 92% of the current population.

An intricate network of approximately 1,200 elements represents California's complex water system (Figure 5.2) including:

- 51 surface reservoirs
- 28 groundwater basins
- 18 urban economic demand regions
- 24 agricultural economic demand regions
- 39 environmental flow locations
- 113 surface and groundwater inflows
- Numerous conveyance links

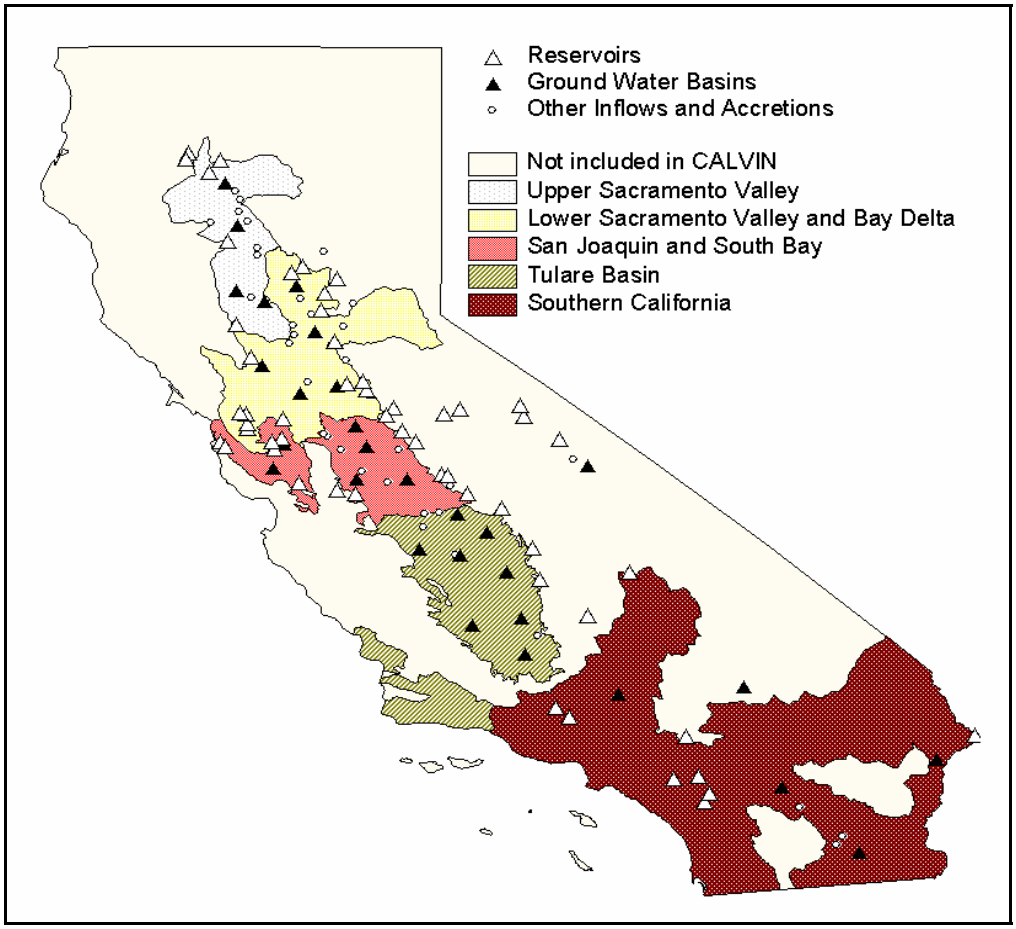

Figure 5.2: Regions, Inflows, and Reservoirs Represented in CALVIN (Lund et al., 2003).

Initial constraints incorporated into CALVIN include:

- Water availability
- Facility capacities
- Environmental restrictions
- Flood control restrictions

Additional constraints may also be incorporated into CALVIN simulations. An environmental constraint used in CALVIN is the minimum Net Delta Outflow (NDO) required to meet salinity standards in the Sacramento-San Joaquin Delta. DWRSIM simulation results for the 2020 level of development were used to calibrate the minimum Net Delta Outflow requirements used in CALVIN.

To incorporate a wide range of hydrologic conditions, CALVIN studies are typically run at a monthly time step for a 72-year period that spans calendar years 1920-1994. CALVIN simulations may be run at different levels of development to reflect projected changes in future water demands. For example, studies at the 2020 level of development assume that California's projected population of approximately 47.5 million people produces an average annual water demand of 10.06 maf/yr. In contrast, studies that project even further into the future to the 2100 level of development reflect an almost doubled water demand of 19.38 maf/yr to support a population of 92 million people. Information provided by the 72-year CALVIN studies includes evaluation of both economic and water supply impacts of proposed changes in facilities, operations, and water allocations.

5.3 Use of CALVIN to Provide Input to DSM2

5.3.1 Inflow and Export Boundary Conditions

Output from CALVIN can provide Delta inflow and export boundary conditions for DSM2 planning studies. The procedure for using CALVIN output to specify inflow and export boundary conditions in DSM2 are summarized below:

- Identify Delta inflow and export locations in CALVIN (Table 5.1)
- Convert CALVIN output from TAF/mo to cfs
- Put converted CALVIN output into a format that DSM2 can read (e.g., DSS)
- Smooth monthly Sacramento and San Joaquin river inflows
- Create a DSM2 boundary input file that refers to the input data from CALVIN

Table 5.1: Summary of CALSIM and CALVIN Boundary Condition Inputs to DSM2.

Boundary Condition	CALSIM Reference	CALVIN Reference
Sacramento River at Sacramento	C169	D44-D503
San Joaquin River at Vernalis	C639	D616-C42
Eastside Streams (Mokelumne and Cosumnes)	C504	D517-D515
Calaveras River	C508	C41-C42
Yolo Bypass	C157	C20-D55
State Water Project (Banks)	D419	D59-BANKS-PMP
Central Valley Project (Tracy)	D418	D59-TRACY-PMP
Contra Costa Canal	D408	D550-CC1-PMP
North Bay Aqueduct	D403B	D55-C22

The reference locations (e.g., model nodes) in CALSIM and CALVIN that correspond to the Delta inflows and exports are summarized in Table 5.1. CALSIM provides flow and export values in cubic feet per second (cfs), and CALSIM output can be used directly in DSM2. However, CALVIN provides flow and export output in units of thousand acre-feet per month (TAF/mo). Thus the output from CALVIN must be converted to cfs before it can be used in DSM2. In addition, the converted CALVIN output must be put into a format that DSM2 can read, such as properly formatted text files or the U.S. Army Corp of Engineers Hydrologic Engineering Center's Data Storage System (DSS) format.

For both monthly CALSIM or CALVIN inputs into DSM2, Sacramento and San Joaquin river flows must be smoothed during the transition from one month to the next to prevent numerical problems due to abrupt changes during the transitions. The Delta Modeling Section does this smoothing using a mass-conserving rational histopolation spline.

Note that for typical DSM2 planning studies, the stage input at Martinez (the downstream boundary condition) is provided by an adjusted astronomical tide regardless of the source of inflow and export boundary conditions (Shrestha, 2002). A sample DSM2 text boundary conditions input file (typically called boundary.inp) is shown in Figure 5.3. Note that in the sample input file, variable names that begin with a "$" are environment variables that are defined in different input files. These variables represent values that change from study to study such as the input file name (e.g., $CALVINFILE, $CALVINSMOOTH, or $TIDE) or the study designation (e.g., $STUDY). Further information on DSM2 input files can be found in Nader-Tehrani and Finch, 1998.

```
# HYDRO Time-varying boundary conditions with inflows and exports from CALVIN
# Created:  4-4-03 Jamie Anderson [jamiea]

#CALVIN boundary flow locations
#D44-D503        Sacramento at Hood
#D616-C42        San Joaquin at Vernalis
#C20-D55         Yolo Bypass
#C41-C42         Calaveras inflow to Delta
#D517-D515       East Side streams other than Calaveras
#D550-CC1-PMP    Contra Costa
#D59-TRACY-PMP   Tracy-CVP
#D59-BANKS-PMP   Banks-SWP
#D55-C22         North Bay Aqueduct

# Monthly boundary flows from CALVIN
INPUTPATHS
name     a_part        b_part        c_part e_part f_part fillin filename
sac      CALVIN-SMOOTH D44-D503      FLOW   1DAY   $STUDY last   $CALVINSMOOTH
sjr      CALVIN-SMOOTH D616-C42      FLOW   1DAY   $STUDY last   $CALVINSMOOTH
yolo     CALVIN        C20-D55       FLOW   1MON   $STUDY last   $CALVINFILE
cal      CALVIN        C41-C42       FLOW   1MON   $STUDY last   $CALVINFILE
eastside CALVIN        D517-D515     FLOW   1MON   $STUDY last   $CALVINFILE
ccc      CALVIN        D550-CC1-PMP  EXPORT 1MON   $STUDY last   $CALVINFILE
cvp      CALVIN        D59-TRACY-PMP EXPORT 1MON   $STUDY last   $CALVINFILE
swp      CALVIN        D59-BANKS-PMP EXPORT 1MON   $STUDY last   $CALVINFILE
nb       CALVIN        D55-C22       EXPORT 1MON   $STUDY last   $CALVINFILE
END

# MTZ stage
INPUTPATHS
Name  a_part     b_part   c_part  e_part  f_part   fillin  filename
MTZ   FILL+CHAN  RSAC054  STAGE   15MIN   PLANNING interp  $TIDE
END
```

Figure 5.3: Sample DSM2 Text Boundary Condition Input File, Using Input from CALVIN.

5.3.2 Delta Island Consumptive Use

There are several options for specifying Delta Island Consumptive Use (DICU) for DSM2 planning studies that use input from CALVIN, including:

- Using historical DICU for studies with historical precipitation and consumptive use demands
- Using the DICU for 2020 CALSIM studies for CALVIN studies at the 2020 level of development
- Separating total DICU computed by CALVIN into point DICU values throughout the Delta using DWR's processing program called ADICU

The representation of DICU in DSM2 planning studies depends on the type of CALVIN study and the amount of effort desired to represent DICU. If a CALVIN study reflects the current level

of development, the historical values for DICU that have already been computed from DWR's DICU model could be used. Additionally, if the CALVIN study represents the 2020 level of development, the DICU for the 2020 level of development used in CALSIM-based planning studies could be used in the DSM2 simulation. If the CALVIN study does not represent the current or 2020 levels of development, or if a more refined representation of DICU is desired, the total Delta consumptive use calculated by CALVIN could be divided into point DICU values throughout the Delta using DWR's processing program called ADICU (Adjusted Delta Island Consumptive Use). This is the only method presented that would provide DICU values based on the CALVIN output results.

5.4 Use of DSM2 to Provide Feedback to CALVIN

In addition to using CALVIN to provide inflow and export boundary conditions to DSM2 for planning studies, DSM2 can be used to provide feedback to CALVIN on how well it is meeting Delta water quality standards. Delta water quality standards in CALVIN are represented by minimum Net Delta Outflow requirements[1] that are intended to provide sufficient outflow to keep water quality constituent concentrations within allowable limits. CALVIN optimizes reservoir releases and exports based on these minimum Net Delta Outflow requirements, however CALVIN does not explicitly simulate water quality constituent concentrations. Thus CALVIN cannot verify that the minimum Net Delta Outflow requirements are associated with water quality constituent concentrations in the Delta that comply with Delta standards. Because DSM2 is a water quality simulation model that determines water quality concentrations throughout the Delta based on specified inflows and exports, DSM2 can be used to assess whether the inflows and exports computed by CALVIN actually meet water quality standards. In other words, DSM2 can be used to verify that the Minimum Net Delta Outflow requirements used in CALVIN are actually sufficient to meet Delta water quality standards. These results can be used in an iterative process to improve the representation of Delta water quality standards in CALVIN.

5.5 Future Directions

It is hoped that the cooperative relationship between DWR and UC Davis will be enhanced by continued use of DSM2 and CALVIN together in the future. Using input from CALVIN for DSM2 planning studies expands the types of studies to which DSM2 can be applied. One feature that distinguishes CALVIN from other system operations models is the economic optimization component; by coupling CALVIN and DSM2 it is possible to assess local impacts on hydrodynamics and water quality of system operations that CALVIN has determined to be economically efficient. DSM2 may also be used in the future to help refine the water quality

[1] Delta water quality standards in CALVIN are represented by minimum Net Delta Outflow requirements that were determined by calibration to the Department of Water Resource's DWRSIM simulation results for the 2020 level of development. DWRSIM is a statewide operations simulation model developed by the Department of Water Resources that was the predecessor to CALSIM. The Net Delta Outflow requirements specified in CALVIN were created prior to the release of CALSIM, thus those requirements are based on DWRSIM results.

constraints in CALVIN. Using DSM2 and CALVIN together provides a powerful set of analysis tools for exploring water resources issues in the Delta.

5.6 References

Jenkins, M., A. Draper, J. Lund, R. Howitt, S. Tanaka, R. Ritzema, G. Marques, S. Msangi, B. Newlin, B. Van Lienden, M. Davis, and K. Ward. (2001). *Improving California Water Management: Optimizing Value and Flexibility*. Report for the CALFED Bay-Delta Program. Sacramento, CA. October, 2001.

Lund, J, R. Howitt, M. Jenkins, T. Zhu, S. Tanaka, M. Pulido, M. Tauber, R. Ritzema, and I. Ferreira. (2003). *Climate Warming and California's Water Future*. Report for the California Energy Commission by the University of California at Davis Departments of Civil and Environmental Engineering and Agricultural and Resource Economics. Report 03-1 Center for Water Resources and Environmental Engineering, University of California, Davis, CA. March 20, 2003.

Nader-Tehrani, P. and R. Finch. (1998). "Chapter 5: DSM2 Input and Output." *Methodology for Flow and Salinity Estimates in the Sacramento-San Joaquin Delta and Suisun Marsh. 19th Annual Progress Report to the State Water Resources Control Board.* California Department of Water Resources. Sacramento, CA.

Shrestha, B. (2002). "Chapter 11: 16-Year DSM2 Planning Studies with Adjusted Astronomical Tides and Daily Hydrology." *Methodology for Flow and Salinity Estimates in the Sacramento-San Joaquin Delta and Suisun Marsh. 23rd Annual Progress Report to the State Water Resources Control Board.* California Department of Water Resources. Sacramento, CA.

5.7 Websites

Additional information on CALVIN can be found at:
http://cee.engr.ucdavis.edu/faculty/lund/CALVIN/

Additional information on DSM2 can be found at:
http://modeling.water.ca.gov/delta/models/dsm2/index.html