Task 5 Technical Memorandum
Link to CALSIM to
Run WARMF Simulations

A Deliverable
for
California Urban Water Agencies (CUWA)
and the
Central Valley Drinking Water Policy Work Group

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1 INTRODUCTION

The Central Valley Drinking Water Policy Work Group is interested in evaluating the concentrations of nutrients, salt and organic carbon at its members' drinking water intakes in the Sacramento Basin and the Sacramento / San Joaquin River Delta. To determine the sources of drinking water constituents both in the present and in the future, the Work Group contracted with Systech Water Resources Inc. to develop analytical models of the Sacramento and San Joaquin River watersheds. The analytical models would then be linked to the DSM2 model of the Delta to determine how pollutants from the upstream watersheds would impact water quality at the Delta drinking water intakes.

The Watershed Analysis Risk Management Framework (WARMF) was applied by Systech to the Sacramento and San Joaquin River watersheds to investigate the effect of sources of organic carbon, nutrients, and salinity loading to the Sacramento-San Joaquin River Delta. The models were calibrated to historical data: 1922-2007 water years for the Sacramento River and 2000-2007 for the San Joaquin River. Historical data is useful for evaluating model calibration to determine how well the model simulates flow and water quality given varying model inputs. To show how proposed watershed management would impact water quality, historical data inputs can be changed and then simulation results can be compared to the original historical model outputs. When run for multiple years, this analysis indicates the benefit of possible management changes for each season in dry, wet, and normal years.

CALSIM II performs simulations of the State Water Project and Central Valley Project operations using the Water Resource Integrated Modeling System model engine. It was developed by the Bureau of Reclamation and the California Department of Water Resources to coordinate water resource planning in the Central Valley. It represents the Central Valley with a node and link structure to simulate natural and managed flows in rivers and canals. It generates monthly flows for water years 1922 through 2003 water years. Simulations show the effect of land use, potential climate change, and water operations on flows throughout the Central Valley. CALSIM does not simulate water quality, but if its generated flows were used as inputs to WARMF, then WARMF could predict water quality under different CALSIM model scenarios.

CALSIM uses a monthly time step, which is an important difference between using its flows as boundary inputs to WARMF versus the daily measured data used for historical simulations. The flows at the boundary inflows are thus constant for each month when linking to CALSIM and thus lack the flow peaks which occur during storms. Another important difference between CALSIM generated flows and historical flows is that CALSIM flows assume water system management which may differ from the management as it actually occurred.

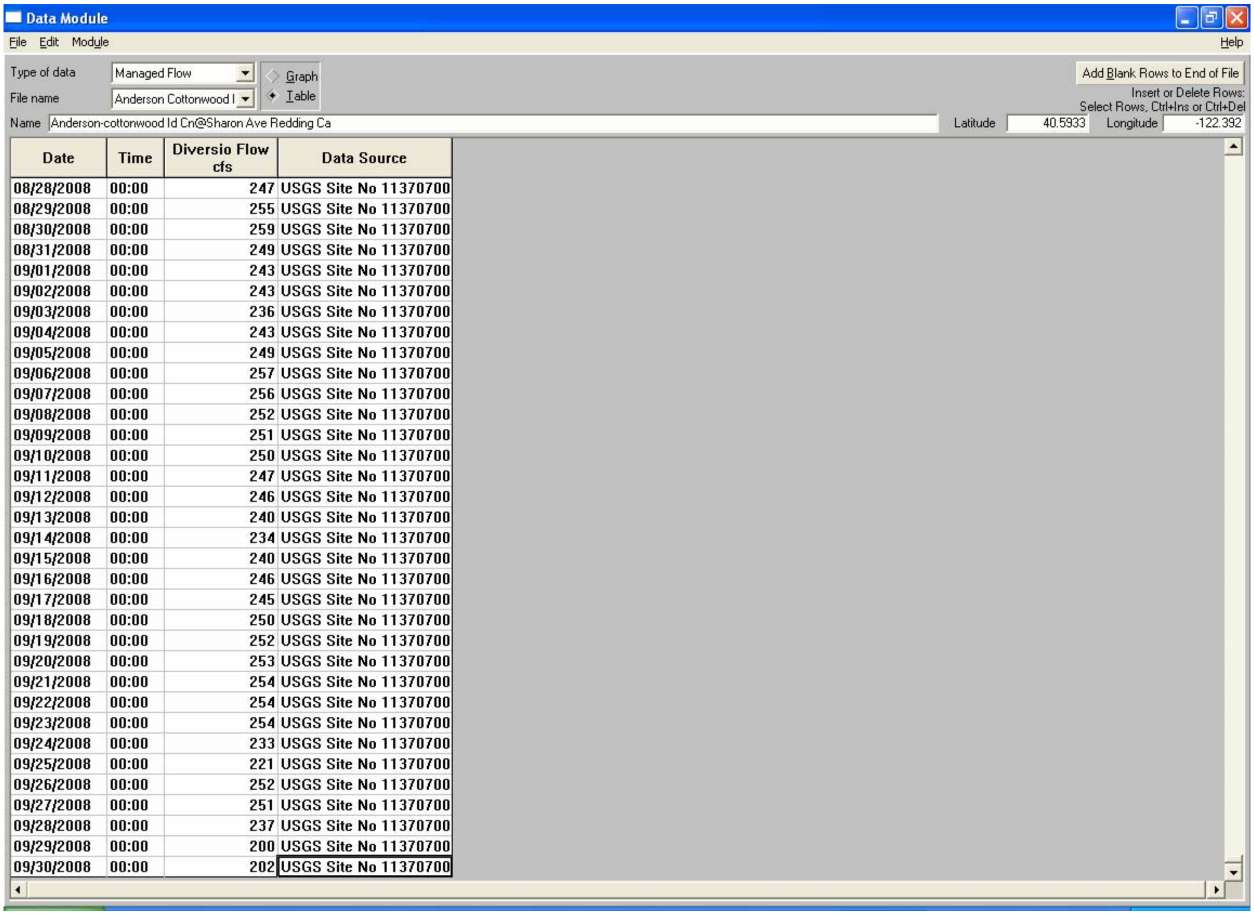
2 LINKING WARMF TO CALSIM

WARMF simulations are driven by time series data: meteorology, air/rain chemistry, point sources, boundary inflows, and diversions. Time series inputs can be historical data, hypothetical values, or a combination of both. To link CALSIM to WARMF, CALSIM's simulated flows can be substituted for the analogous WARMF time series inputs. CALSIM output is stored in the HEC-DSS format developed by the U.S. Corps of Engineers. The DSS format holds multiple time series each with a six-field header. CALSIM includes unique identifiers in the header fields to describe the location of the flow in the corresponding time series.

In WARMF, each point source, boundary inflow, and diversion is represented by a single text format file. Since those files represent historical data, they should not be overwritten by the CALSIM flows. Each file linked with CALSIM must be copied in order to preserve the original data. The flows in the copy can then be modified for running simulations in WARMF using CALSIM flows. The original files can be used for future simulations of historical conditions.

Linking Flow

Figure 2-1 shows an example of a WARMF Managed Flow file displayed in spreadsheet form in the WARMF Data Module. The term "managed flow" is used to represent any controlled flow within the WARMF model domain such as reservoir releases and diversions. The diversion file shown in the example (Anderson-Cottonwood Irrigation District) is typical in that it is a simple time series of flow. There are daily values over the entire time for which simulations can be run, water years 1922 through 2007. To use CALSIM flows instead of those in the diversion file, it is a straightforward substitution to replace the historical flow with CALSIM flow. Since CALSIM operates on a monthly time step, the replaced flows in WARMF keep the same constant CALSIM flow for the entire month for which it is applicable.



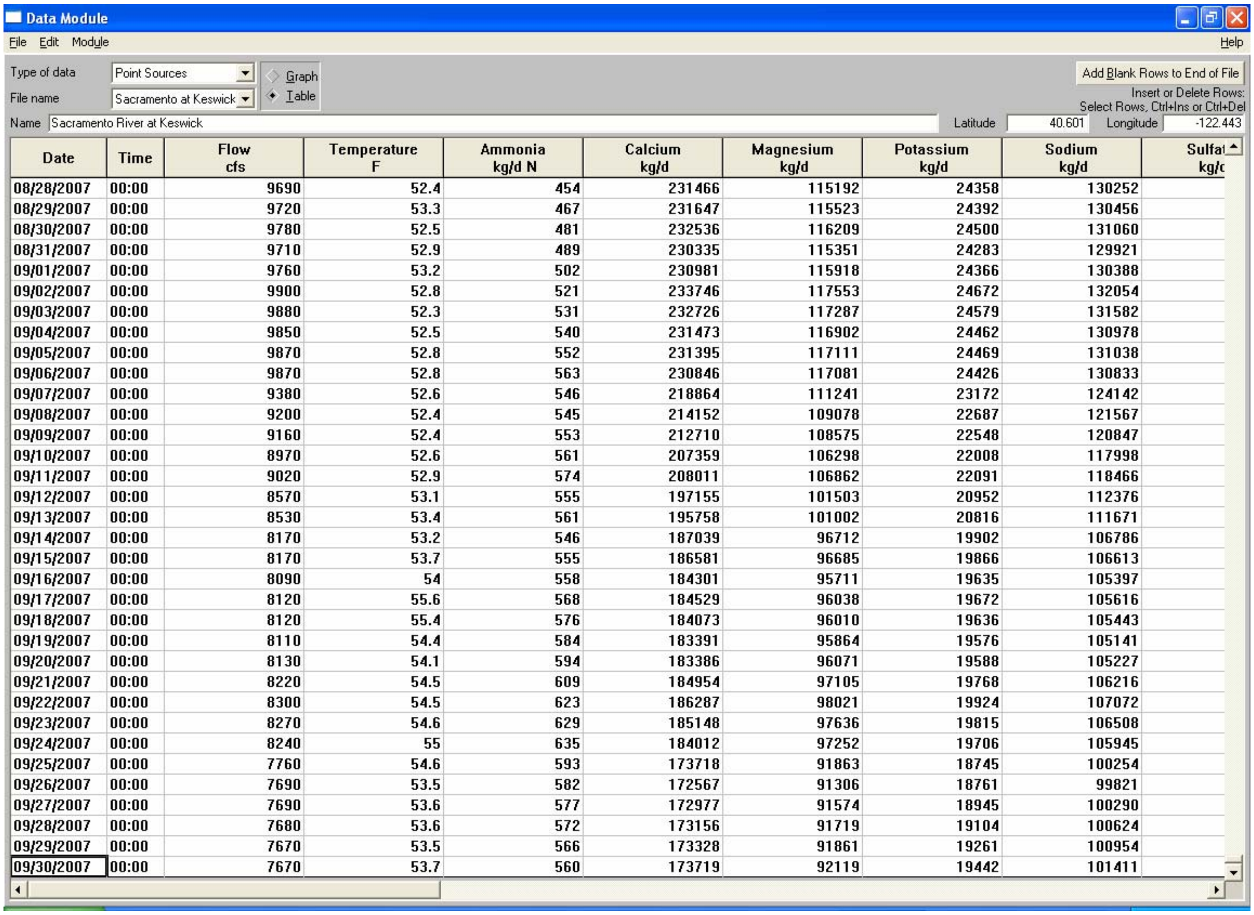
Date	Time	Diversio Flow cfs	Data Source
08/28/2008	00:00	247	USGS Site No 11370700
08/29/2008	00:00	255	USGS Site No 11370700
08/30/2008	00:00	259	USGS Site No 11370700
08/31/2008	00:00	249	USGS Site No 11370700
09/01/2008	00:00	243	USGS Site No 11370700
09/02/2008	00:00	243	USGS Site No 11370700
09/03/2008	00:00	236	USGS Site No 11370700
09/04/2008	00:00	243	USGS Site No 11370700
09/05/2008	00:00	249	USGS Site No 11370700
09/06/2008	00:00	257	USGS Site No 11370700
09/07/2008	00:00	256	USGS Site No 11370700
09/08/2008	00:00	252	USGS Site No 11370700
09/09/2008	00:00	251	USGS Site No 11370700
09/10/2008	00:00	250	USGS Site No 11370700
09/11/2008	00:00	247	USGS Site No 11370700
09/12/2008	00:00	246	USGS Site No 11370700
09/13/2008	00:00	240	USGS Site No 11370700
09/14/2008	00:00	234	USGS Site No 11370700
09/15/2008	00:00	240	USGS Site No 11370700
09/16/2008	00:00	246	USGS Site No 11370700
09/17/2008	00:00	245	USGS Site No 11370700
09/18/2008	00:00	250	USGS Site No 11370700
09/19/2008	00:00	252	USGS Site No 11370700
09/20/2008	00:00	253	USGS Site No 11370700
09/21/2008	00:00	254	USGS Site No 11370700
09/22/2008	00:00	254	USGS Site No 11370700
09/23/2008	00:00	254	USGS Site No 11370700
09/24/2008	00:00	233	USGS Site No 11370700
09/25/2008	00:00	221	USGS Site No 11370700
09/26/2008	00:00	252	USGS Site No 11370700
09/27/2008	00:00	251	USGS Site No 11370700
09/28/2008	00:00	237	USGS Site No 11370700
09/29/2008	00:00	200	USGS Site No 11370700
09/30/2008	00:00	202	USGS Site No 11370700

Figure 2-1 Managed Flow (Diversion) File in WARMF

A point source file represents a source of water which is entering the model. Regulatory point sources including permitted municipal and industrial discharges and boundary inflows are both represented with point source files in WARMF. To describe the point source requires not just a time series of flow, but also temperature and chemical constituents of the water. Figure 2-2 shows an example boundary inflow file for the Sacramento River release from Keswick Reservoir. Flow is shown in cfs, temperature in ^{o}F, and each chemical constituent in kg/d. The chemical constituents are represented as a load, but that can be readily translated to a concentration by dividing load by flow and performing unit conversions as shown below in Equation 1.

$$Concentration(mg/l) = \frac{Load(kg/d)}{Flow(ft^3/s)} x \frac{10^6(mg/kg)}{86400(s/d)x28.32(l/ft^3)} \qquad \textbf{(1)}$$

If only the flow in a point source file is to be changed by CALSIM, this can be achieved by changing the flow and then scaling the loads of all constituents proportionately to the change in flow to maintain the same concentrations.



Date	Time	Flow cfs	Temperature F	Ammonia kg/d N	Calcium kg/d	Magnesium kg/d	Potassium kg/d	Sodium kg/d	Sulfat kg/c
08/28/2007	00:00	9690	52.4	454	231466	115192	24358	130252	
08/29/2007	00:00	9720	53.3	467	231647	115523	24392	130456	
08/30/2007	00:00	9780	52.5	481	232536	116209	24500	131060	
08/31/2007	00:00	9710	52.9	489	230335	115351	24283	129921	
09/01/2007	00:00	9760	53.2	502	230981	115918	24366	130388	
09/02/2007	00:00	9900	52.8	521	233746	117553	24672	132054	
09/03/2007	00:00	9880	52.3	531	232726	117287	24579	131582	
09/04/2007	00:00	9850	52.5	540	231473	116902	24462	130978	
09/05/2007	00:00	9870	52.8	552	231395	117111	24469	131038	
09/06/2007	00:00	9870	52.8	563	230846	117081	24426	130833	
09/07/2007	00:00	9380	52.6	546	218864	111241	23172	124142	
09/08/2007	00:00	9200	52.4	545	214152	109078	22687	121567	
09/09/2007	00:00	9160	52.4	553	212710	108575	22548	120847	
09/10/2007	00:00	8970	52.6	561	207359	106298	22008	117998	
09/11/2007	00:00	9020	52.9	574	208011	106862	22091	118466	
09/12/2007	00:00	8570	53.1	555	197155	101503	20952	112376	
09/13/2007	00:00	8530	53.4	561	195758	101002	20816	111671	
09/14/2007	00:00	8170	53.2	546	187039	96712	19902	106786	
09/15/2007	00:00	8170	53.7	555	186581	96685	19866	106613	
09/16/2007	00:00	8090	54	558	184301	95711	19635	105397	
09/17/2007	00:00	8120	55.6	568	184529	96038	19672	105616	
09/18/2007	00:00	8120	55.4	576	184073	96010	19636	105443	
09/19/2007	00:00	8110	54.4	584	183391	95864	19576	105141	
09/20/2007	00:00	8130	54.1	594	183386	96071	19588	105227	
09/21/2007	00:00	8220	54.5	609	184954	97105	19768	106216	
09/22/2007	00:00	8300	54.5	623	186287	98021	19924	107072	
09/23/2007	00:00	8270	54.6	629	185148	97636	19815	106508	
09/24/2007	00:00	8240	55	635	184012	97252	19706	105945	
09/25/2007	00:00	7760	54.6	593	173718	91863	18745	100254	
09/26/2007	00:00	7690	53.5	582	172567	91306	18761	99821	
09/27/2007	00:00	7690	53.6	577	172977	91574	18945	100290	
09/28/2007	00:00	7680	53.6	572	173156	91719	19104	100624	
09/29/2007	00:00	7670	53.5	566	173328	91861	19261	100954	
09/30/2007	00:00	7670	53.7	560	173719	92119	19442	101411	

Figure 2-2 Point Source (or Boundary Inflow) File in WARMF

Linking Water Quality

Although CALSIM does not address water quality, the capability to import water quality into WARMF in a similar manner to the flow would accommodate any future water quality upgrade to CALSIM and allow for import of water quality time series generated independently. Since managed flows in WARMF do not have water quality as an input, the ability to import water quality is limited to point source files including boundary inflow files. Concentration time series provided in DSS format with CALSIM flows is converted into load by reversing Equation 1 and substituting the new load for the existing load.

Some WARMF chemical constituents are not independently calculated in WARMF but rather are calculated from other chemical constituents. Total dissolved solids, for example, is calculated by adding up the concentrations of each ionic constituent in the water (NH_4, NO_3, PO_4, Ca, Mg, K, Na, SO_4, Cl, HCO_3). Electrical conductivity is calculated from TDS using an assumed linear relationship. Since there is no direct input of TDS or EC in WARMF input files, an extra step is taken within WARMF when TDS or EC is used in conjunction with the CALSIM linkage. WARMF scales each component ion proportionately so that in total they will equal the prescribed TDS or EC.

3 LINKAGE PROCEDURE

The linkage between WARMF and CALSIM has been incorporated into the Data Module within the WARMF graphical user interface. All that is required is a DSS format file with the CALSIM flows, optionally augmented by corresponding water quality information added independently of CALSIM. Following are step by step instructions for using the linkage. The instructions assume basic knowledge of using WARMF. For complete instruction on using WARMF, refer to the WARMF User's Guide (Herr et. al. 2001).

Step 1: Create a New Scenario

In WARMF, select Scenario / Manager in the menu. A dialog box will open as shown in Figure 3-1. Click on the "Copy Active Scenario:" button at the top and choose the name of the model scenario to represent the CALSIM linked simulation. The new scenario should be added to the list of project scenarios on the left, then click Open to add it to the list of open scenarios on the right. The Scenario Manager should then have both the original and new scenario in both lists as shown in Figure 3-2.

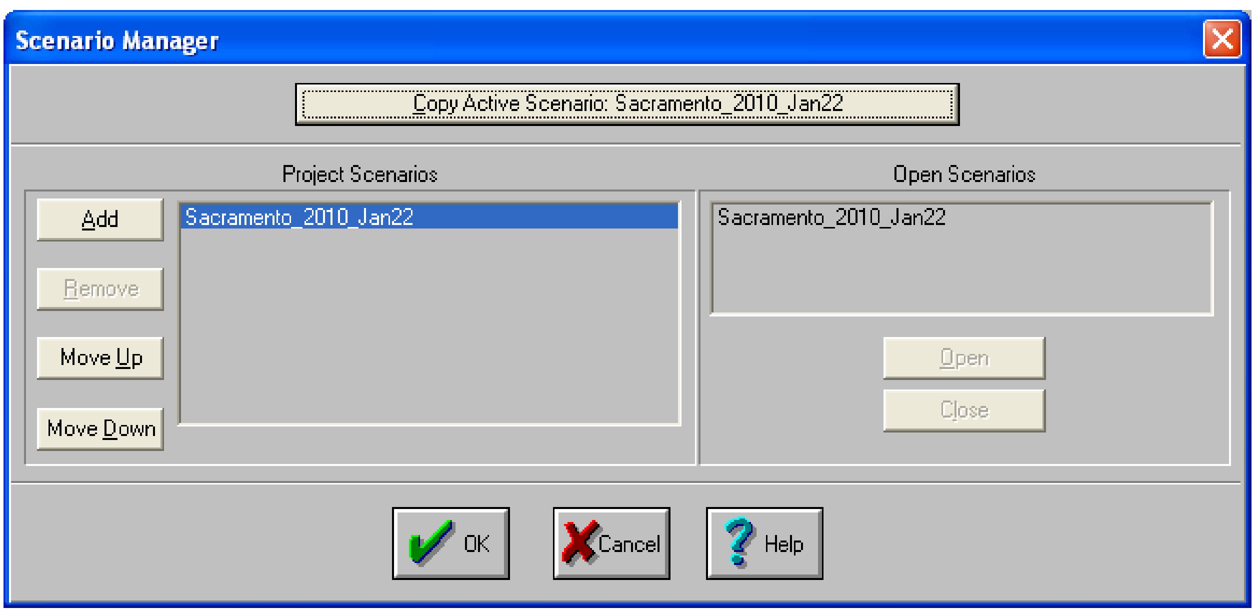


Figure 3-1 Scenario Manager

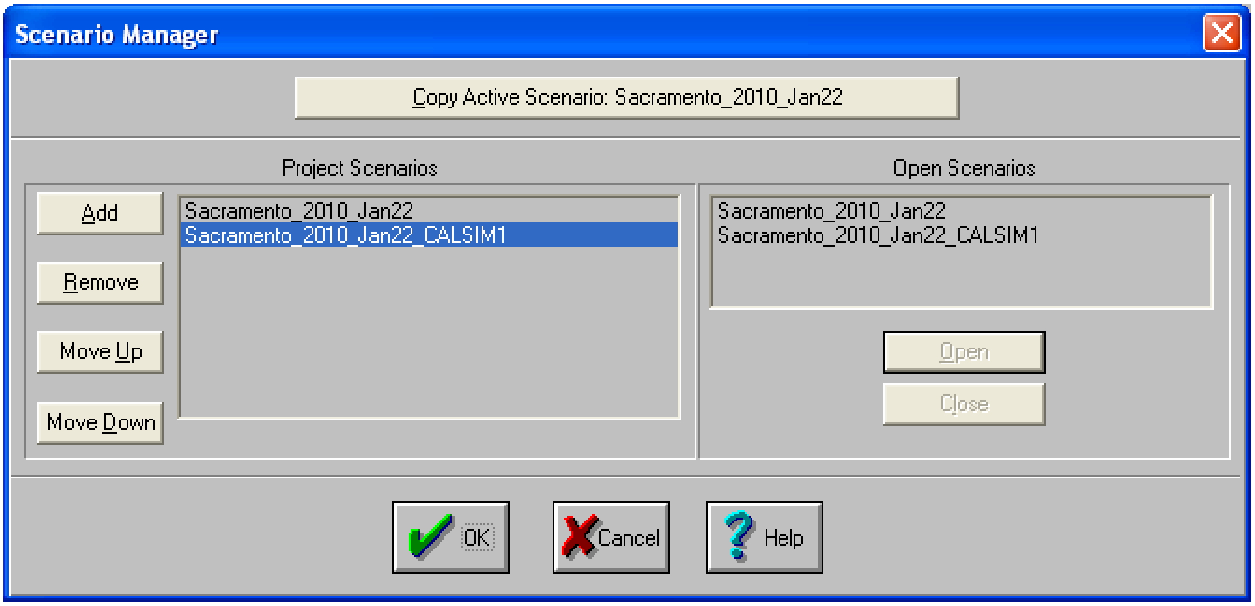


Figure 3-2 Scenario Manager with New CALSIM Linkage Scenario

Click OK on the Scenario Manager dialog. Both scenarios should now appear in the bottom of the Scenario menu. Select the new scenario so that it will be activated as shown in Figure 3-3. The CALSIM linkage will now apply to the new scenario. Go to Module / Data in the menu to go to the Data Module for the next step.

Figure 3-3 Scenario Menu with CALSIM Linkage Scenario Activated

Step 2: Import HEC-DSS File

The heart of the CALSIM-WARMF linkage is importing DSS files. DSS is the format used by CALSIM to store its outputs. In the Data Module menu, select File / Import HEC-DSS. Select the name of the DSS format file which has the CALSIM output to use as WARMF input. When the file is selected, an external utility called DSSUTL will catalog the DSS file and create a list of its contents. The utility will open a Command Prompt style black window with

C:\WINDOWS\system\cmd.exe in its header. To proceed, WARMF needs for the catalog to be complete. A dialog box is activated within WARMF asking the user to click OK when the external process is complete. Figure 3-7 shows the screen while the external utility is running. The external process is complete when the black cmd.exe window disappears, which may take only a few seconds. Then press OK in the WARMF dialog box to see the DSS file catalog presented within WARMF.

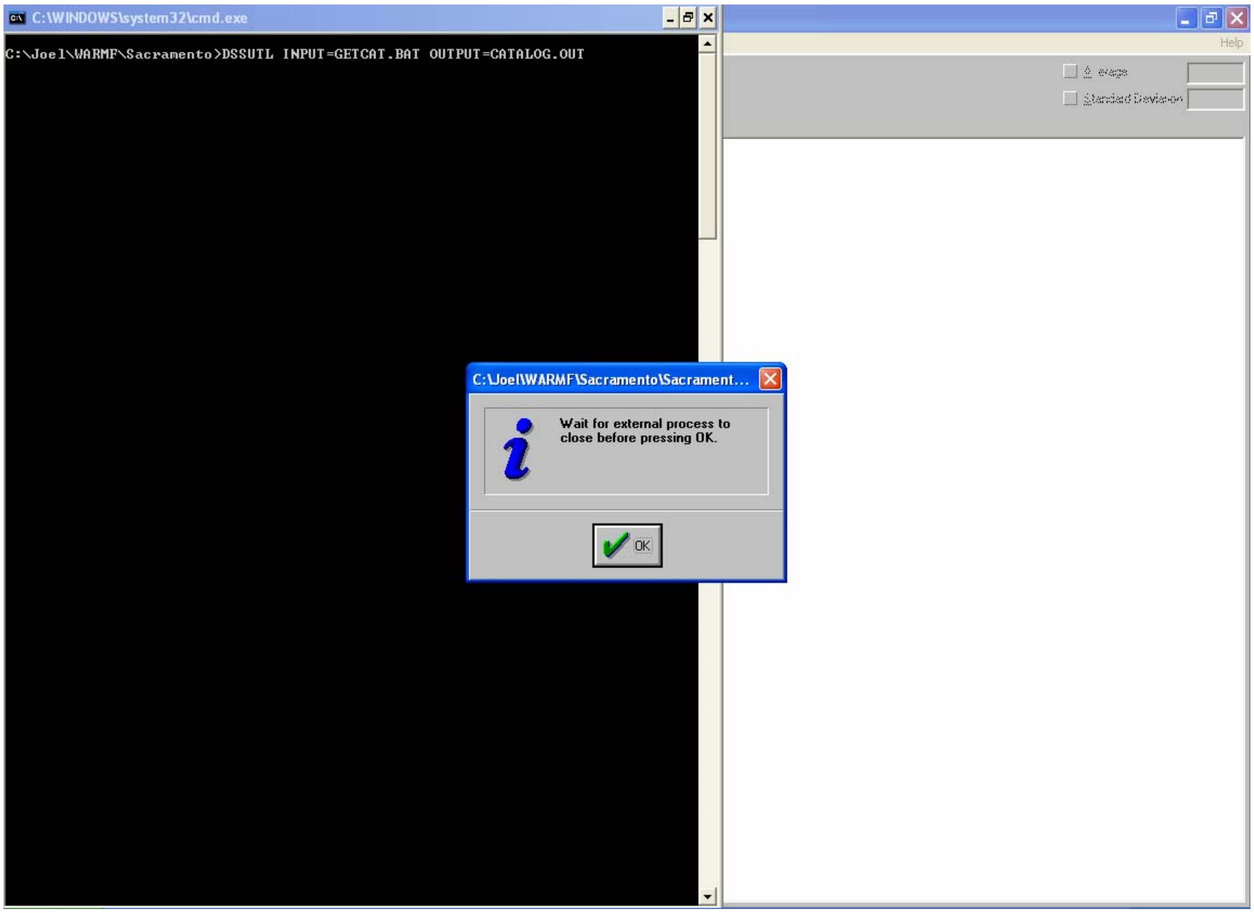
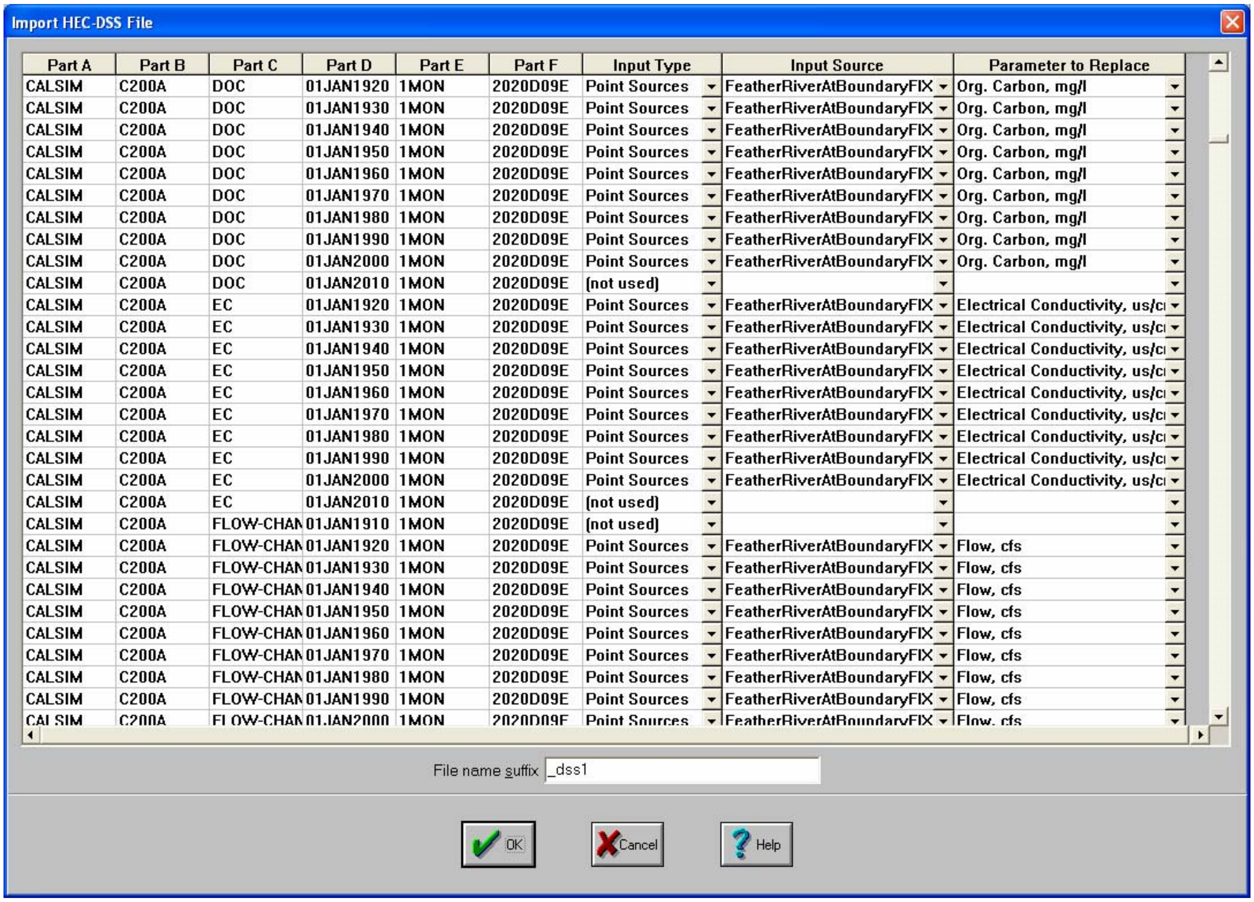


Figure 3-4 External Utility Creating a Catalog of DSS File

Figure 3-5 shows a small part of the catalog of the contents of a CALSIM DSS format file, which is displayed after the completion of Step 2. The first 6 columns in the above spreadsheet (Part A through Part F) represent the headers of the DSS file. The last three columns are used to select the type of WARMF file, specific file, and specific parameter corresponding to the CALSIM headers. A summary of the DSS import spreadsheet is shown in Table 3-1.



Part A	Part B	Part C	Part D	Part E	Part F	Input Type	Input Source	Parameter to Replace
CALSIM	C200A	DOC	01JAN1920	1MON	2020D09E	Point Sources	FeatherRiverAtBoundaryFlX	Org. Carbon, mg/l
CALSIM	C200A	DOC	01JAN1930	1MON	2020D09E	Point Sources	FeatherRiverAtBoundaryFlX	Org. Carbon, mg/l
CALSIM	C200A	DOC	01JAN1940	1MON	2020D09E	Point Sources	FeatherRiverAtBoundaryFlX	Org. Carbon, mg/l
CALSIM	C200A	DOC	01JAN1950	1MON	2020D09E	Point Sources	FeatherRiverAtBoundaryFlX	Org. Carbon, mg/l
CALSIM	C200A	DOC	01JAN1960	1MON	2020D09E	Point Sources	FeatherRiverAtBoundaryFlX	Org. Carbon, mg/l
CALSIM	C200A	DOC	01JAN1970	1MON	2020D09E	Point Sources	FeatherRiverAtBoundaryFlX	Org. Carbon, mg/l
CALSIM	C200A	DOC	01JAN1980	1MON	2020D09E	Point Sources	FeatherRiverAtBoundaryFlX	Org. Carbon, mg/l
CALSIM	C200A	DOC	01JAN1990	1MON	2020D09E	Point Sources	FeatherRiverAtBoundaryFlX	Org. Carbon, mg/l
CALSIM	C200A	DOC	01JAN2000	1MON	2020D09E	Point Sources	FeatherRiverAtBoundaryFlX	Org. Carbon, mg/l
CALSIM	C200A	DOC	01JAN2010	1MON	2020D09E	(not used)		
CALSIM	C200A	EC	01JAN1920	1MON	2020D09E	Point Sources	FeatherRiverAtBoundaryFlX	Electrical Conductivity, us/c
CALSIM	C200A	EC	01JAN1930	1MON	2020D09E	Point Sources	FeatherRiverAtBoundaryFlX	Electrical Conductivity, us/c
CALSIM	C200A	EC	01JAN1940	1MON	2020D09E	Point Sources	FeatherRiverAtBoundaryFlX	Electrical Conductivity, us/c
CALSIM	C200A	EC	01JAN1950	1MON	2020D09E	Point Sources	FeatherRiverAtBoundaryFlX	Electrical Conductivity, us/c
CALSIM	C200A	EC	01JAN1960	1MON	2020D09E	Point Sources	FeatherRiverAtBoundaryFlX	Electrical Conductivity, us/c
CALSIM	C200A	EC	01JAN1970	1MON	2020D09E	Point Sources	FeatherRiverAtBoundaryFlX	Electrical Conductivity, us/c
CALSIM	C200A	EC	01JAN1980	1MON	2020D09E	Point Sources	FeatherRiverAtBoundaryFlX	Electrical Conductivity, us/c
CALSIM	C200A	EC	01JAN1990	1MON	2020D09E	Point Sources	FeatherRiverAtBoundaryFlX	Electrical Conductivity, us/c
CALSIM	C200A	EC	01JAN2000	1MON	2020D09E	Point Sources	FeatherRiverAtBoundaryFlX	Electrical Conductivity, us/c
CALSIM	C200A	EC	01JAN2010	1MON	2020D09E	(not used)		
CALSIM	C200A	FLOW-CHAN	01JAN1910	1MON	2020D09E	(not used)		
CALSIM	C200A	FLOW-CHAN	01JAN1920	1MON	2020D09E	Point Sources	FeatherRiverAtBoundaryFlX	Flow, cfs
CALSIM	C200A	FLOW-CHAN	01JAN1930	1MON	2020D09E	Point Sources	FeatherRiverAtBoundaryFlX	Flow, cfs
CALSIM	C200A	FLOW-CHAN	01JAN1940	1MON	2020D09E	Point Sources	FeatherRiverAtBoundaryFlX	Flow, cfs
CALSIM	C200A	FLOW-CHAN	01JAN1950	1MON	2020D09E	Point Sources	FeatherRiverAtBoundaryFlX	Flow, cfs
CALSIM	C200A	FLOW-CHAN	01JAN1960	1MON	2020D09E	Point Sources	FeatherRiverAtBoundaryFlX	Flow, cfs
CALSIM	C200A	FLOW-CHAN	01JAN1970	1MON	2020D09E	Point Sources	FeatherRiverAtBoundaryFlX	Flow, cfs
CALSIM	C200A	FLOW-CHAN	01JAN1980	1MON	2020D09E	Point Sources	FeatherRiverAtBoundaryFlX	Flow, cfs
CALSIM	C200A	FLOW-CHAN	01JAN1990	1MON	2020D09E	Point Sources	FeatherRiverAtBoundaryFlX	Flow, cfs
CALSIM	C200A	FLOW-CHAN	01JAN2000	1MON	2020D09E	Point Sources	FeatherRiverAtBoundaryFlX	Flow, cfs

Figure 3-5 Catalog of DSS File Displayed in WARMF Data Module

Table 3-1 Description of Headers in DSS Import Catalog Spreadsheet

Header	Description
Part A	DSS header part A; labeled “CALSIM” for CALSIM output
Part B	DSS header part B; indicating the location in the CALSIM network
Part C	DSS header part C; the parameter of the CALSIM output
Part D	DSS header part D; the beginning time of the CALSIM output
Part E	DSS header part E; the time step (frequency) of the CALSIM output
Part F	DSS header part F; the name of the CALSIM simulation
Input Type	The type of WARMF input file
Input Source	The specific WARMF input file
Parameter to Replace	The WARMF parameter corresponding to the CALSIM parameter

The next step is to link CALSIM headers with WARMF. Of the 6 headers present in DSS files, the second one is a unique identifier to the location within the CALSIM network. The third CALSIM header indicates the type of data. Original CALSIM files do not have water quality included, but the one shown above includes dissolved organic carbon (DOC) and electrical conductivity (EC) which were estimated outside of CALSIM and added to the CALSIM DSS file.

Figure 3-6 shows the Feather River area of the CALSIM system schematic to demonstrate the linkage between CALSIM and WARMF. C200A is the portion of Lake Oroville release which passes down the Feather River instead of being directed to the Diversion Pool and Thermalito Complex. C7 represents release to the Feather River from the Thermalito Afterbay. C200A and C7 are thus analogous to the WARMF Feather River and Thermalito boundary inflows. To link the CALSIM headers to WARMF, select whether the analogous WARMF component is a diversion (Managed Flow) or a Point Source (including boundary inflows). Then select the individual WARMF Managed Flow or Point Source file. Finally, select the WARMF constituent analogous to what is stored in the CALSIM output. If the third column in the CALSIM header is FLOW-CHANNEL, the WARMF parameter to replace is Flow.

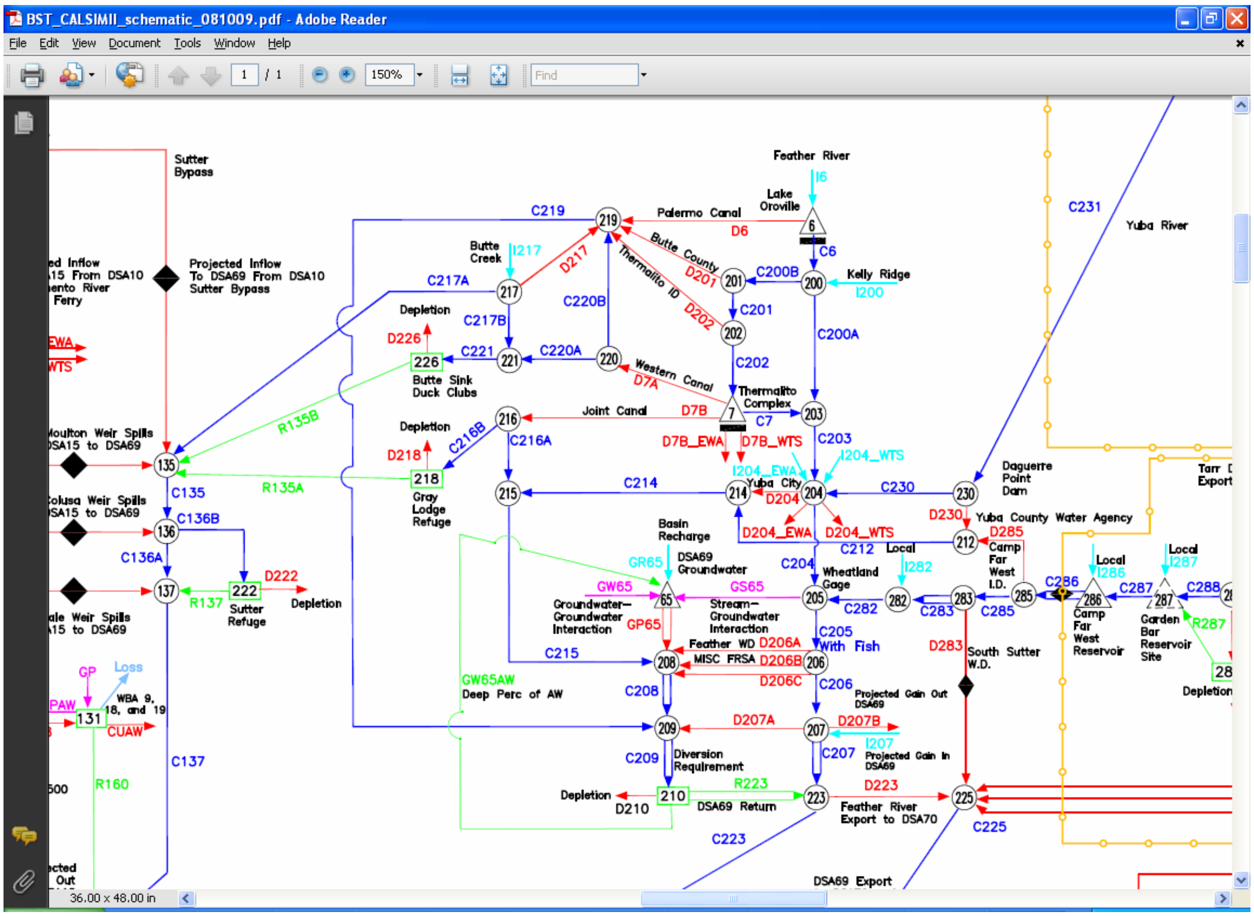


Figure 3-6 CALSIM Representation of Feather River Area

Not everything in the CALSIM network has an analogous WARMF input. CALSIM has more detail than WARMF on canal networks while WARMF has more detail in the stream network and with diversions. WARMF simulates infiltration and inflows based on meteorology and physical processes whereas CALSIM specifies these flows through more simplified means. Many time series inputs to which the WARMF model is most sensitive, like inflows to the WARMF model domain and major diversions, do have analogs in the CALSIM network. Table 3-2 and Table 3-3 show the linkages for the Sacramento and San Joaquin River watersheds respectively.

Table 3-2 Linkages Between CALSIM Outputs and WARMF Inputs: Sacramento River

CALSIM DSS Part B	WARMF File Type	WARMF File
C3	Point Sources	Clear Creek Inflow.PTS
C5	Point Sources	Sacramento River Inflow.PTS
C7	Point Sources	Thermalito Inflow_TSSpost68.PTS
C9	Point Sources	American River Inflow.PTS
C37	Point Sources	Yuba River Inflow.PTS
C42	Point Sources	Stony Creek Inflow.PTS
C200A	Point Sources	Feather River Inflow_TSSpost68.PTS
C285	Point Sources	Bear River Inflow.PTS
D104	Managed Flow	Cottonwood ID.FLO
D114	Managed Flow	Glenn-Colusa ID.FLO
D122B	Managed Flow	Provident ID 2.FLO
D124	Managed Flow	Moulton Weir.FLO
D125	Managed Flow	Colusa Weir.FLO
D126	Managed Flow	Tisdale Weir.FLO
D128	Managed Flow	Sutter Mutual WC.FLO
D129A	Managed Flow	Reclamation Dist 108.FLO
D160	Managed Flow	Fremont Weir.FLO
D162	Managed Flow	Natomas Central MWC.FLO
D163	Managed Flow	Conaway.FLO
D165	Managed Flow	City of West Sacramento.FLO
D166A	Managed Flow	Sacramento Weir.FLO
D172	Managed Flow	Kirkwood WD.FLO
D174	Managed Flow	Orland-Artois WD.FLO
D17502	Managed Flow	Colusa County WD.FLO
D180	Managed Flow	Provident ID 3.FLO
D182A	Managed Flow	Princeton-Codora ID 2.FLO
D182B	Managed Flow	Maxwell ID (008267).FLO
D183	Managed Flow	Davis Ranches 1.FLO
D18302	Managed Flow	Davis Ranches 2.FLO
D285	Managed Flow	Camp Far West ID.FLO

Table 3-3 Linkages Between CALSIM Outputs and WARMF Inputs: San Joaquin River

CALSIM DSS Part B	WARMF File Type	WARMF File
C18	Point Sources	Friant Inflow.PTS
C52	Managed Flow	Hensley.FLO
C528	Point Sources	Stanislaus Inflow.PTS
C545	Point Sources	Tuolumne Inflow.PTS
C566	Point Sources	Merced Inflow.PTS
C605B	Managed Flow	Eastside.FLO
C611	Point Sources	San Joaquin Inflow.PTS
D418	Point Sources	DMC Inflow.PTS
D540A	Point Sources	ModestoCanal.PTS
D540B	Point Sources	TurlockCanal.PTS
D630B	Managed Flow	Patterson WD SJR.FLO

Because it is a laborious process to enter all these inflows in the spreadsheet shown in Figure 3-5, the linkages are saved each time a DSS file is imported. This means that all linkages from the previous usage of the CALSIM linkage will be displayed the next time it is used. Note below the spreadsheet in Figure 3-5, there is space to enter a file name suffix. If this were blank, the historical data files would be overwritten with the CALSIM outputs. With the suffix, the original data files are left intact and copies are made with the suffix. For example, if a suffix of _dss1 were used, Clear Creek Inflow.PTS would be copied to Clear Creek Inflow_dss1.PTS. The latter file would then be modified with the CALSIM output.

Once all the linkages are established in Figure 3-5, press OK on the dialog to continue the process. An external process will start in a black DOS style window to extract the CALSIM output as shown in Figure 3-7. The process may take several minutes to complete, at which time the black window will disappear. After the process is complete, press OK on the dialog so the WARMF Data Module can incorporate the extracted CALSIM output into its own input files. It may take WARMF a few minutes to complete this process where it copies its original files, modifies the copies with CALSIM output, and then reassigns its elements to use the CALSIM modified files.

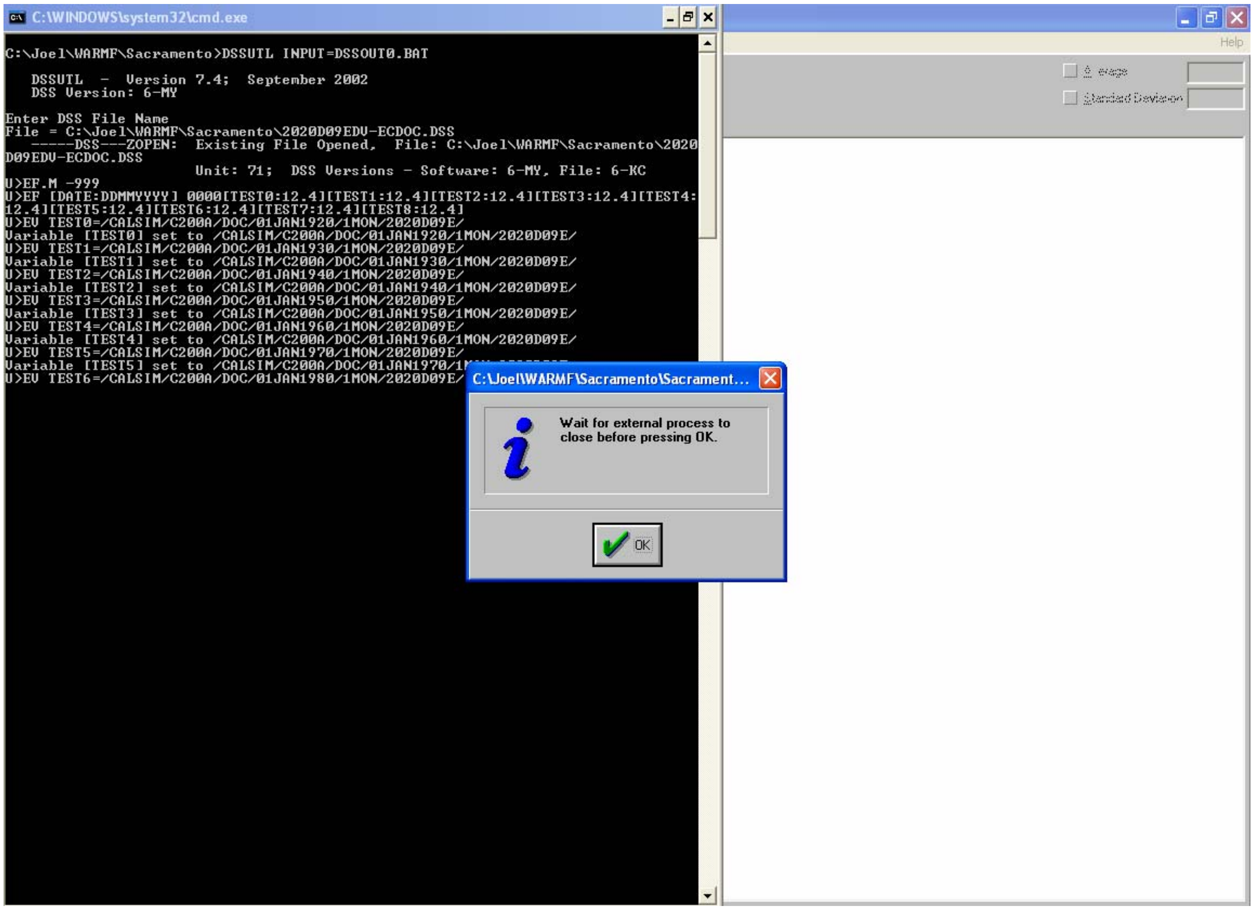


Figure 3-7 External Utility Extracting CALSIM Output from DSS File

Step 3: Run Simulation

The final step in the CALSIM-WARMF linkage process is to run a simulation, incorporating CALSIM outputs and WARMF simulation processes. If not already there, go to the Engineering Module by selecting Module / Engineering in the menu. Then select Scenario / Run. It may take a minute or two for the simulation dialog to appear as WARMF scans the input files. Once the processing is complete, a dialog appears as shown in Figure 3-8. Press OK to start the simulation. A black DOS style window will appear as in Figure 3-9 showing the progress of the simulation. When the simulation is complete, a message will appear in the window stating "WARMF Simulation Completed Successfully".

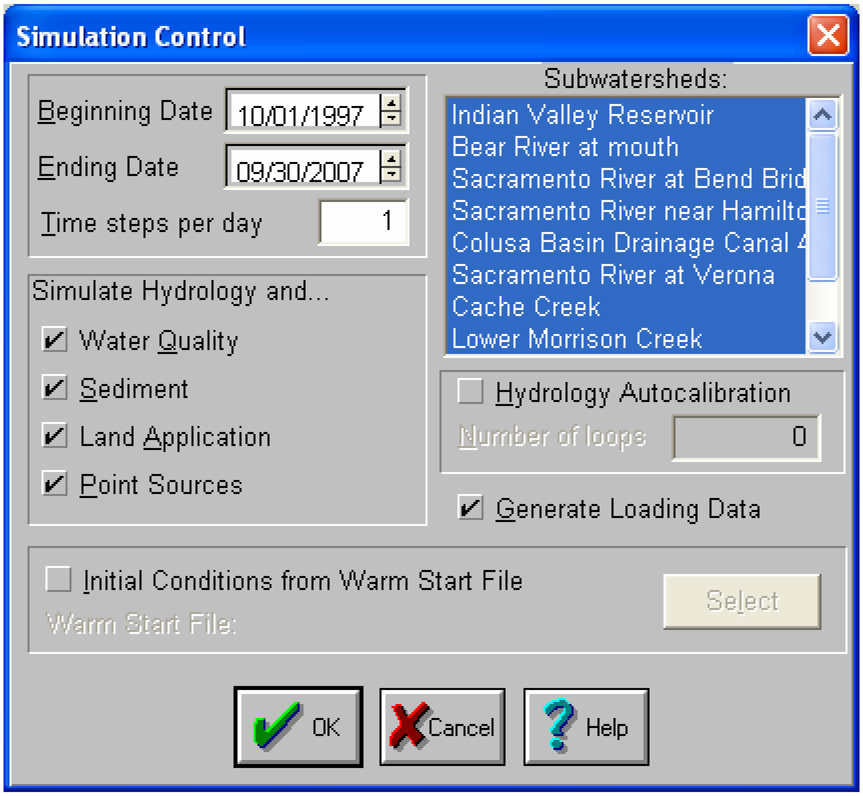


Figure 3-8 WARMF Simulation Dialog

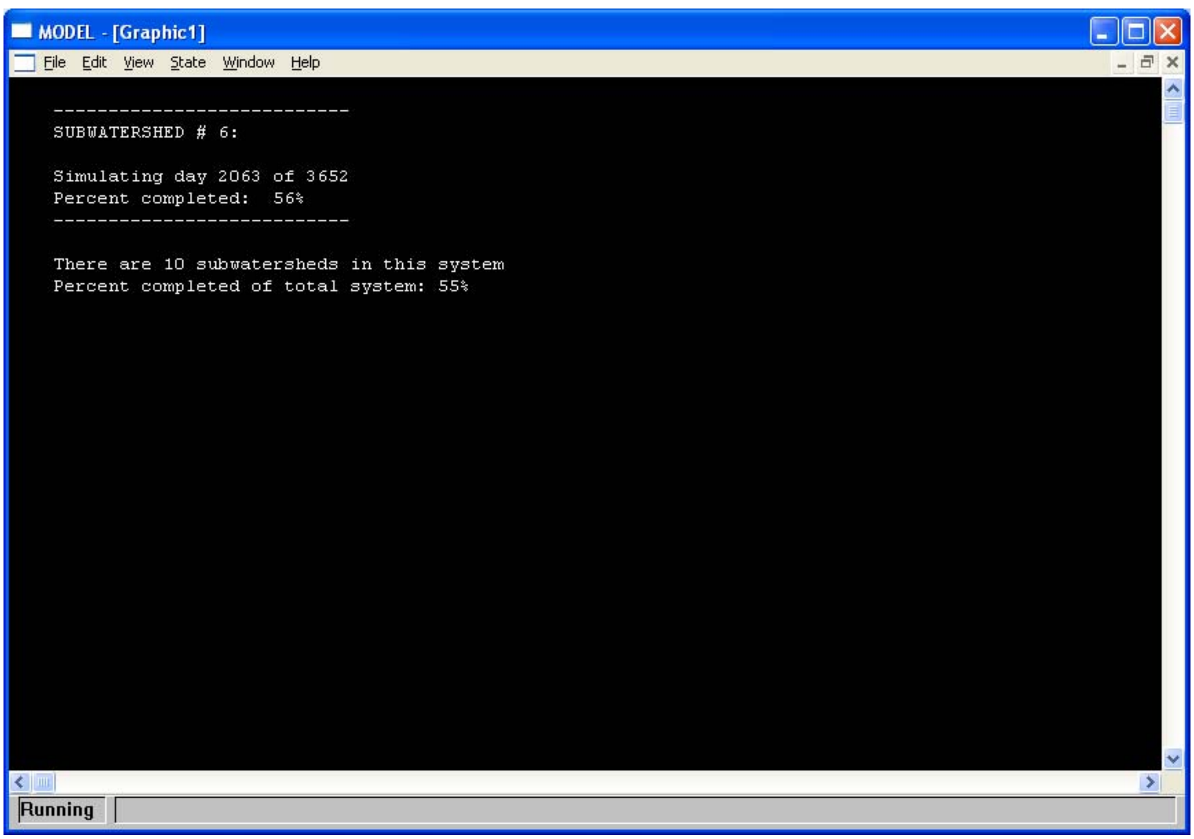


Figure 3-9 WARMF Simulation Window

4 EXAMPLE CALSIM-WARMF LINKAGE

To test the CALSIM-WARMF linkage, the procedure outlined in Section 3 was used for the Sacramento River watershed. A historical simulation was performed for the 1976 through 1991 water years for the Sacramento River watershed. CALSIM output was obtained in DSS format for a simulation representing current climate and operating conditions. Bob Suits and Lan Liang of the California Department of Water Resources developed estimated ammonia, nitrate, phosphate, organic carbon, and electrical conductivity concentrations in the tailwater of each of the reservoirs to go with the flows from CALSIM. The CALSIM DSS file was augmented with the water quality information. Time invariant model input coefficients including land use are the same in both the historical and CALSIM linked simulations. Time series inputs which are not part of the CALSIM linkage, such as meteorology and point source discharges, are also the same between the two simulations.

The resulting simulation results are shown for the Sacramento River at Freeport in Figure 4-1 through Figure 4-6. Although the two types of simulations are compared with each other, they shouldn't necessarily match each other precisely. Since CALSIM runs on a monthly time step, the linked flow input to WARMF is constant for each month. The influence of the monthly time step is seen in the WARMF simulated flow in the Sacramento River. The monthly time step averages out flows, so extreme high and low flow are more moderate with the linkage. Differences in simulated concentration for each of the parameters is caused by the different flows and the difference between the specified concentrations at the reservoir releases and the historical water quality synthesized from measured data.

There is considerable uncertainty in filling large data gaps of measured water quality at the reservoir releases, so it is valuable to compare multiple approaches. In the following plots, the blue and red lines both represent WARMF simulation results. The blue line uses the original historical boundary inflows and inflow water quality synthesized from measured data. The red line uses the CALSIM boundary inflows and water quality estimated by Bob Suits and Lan Liang of California Department of Water Resources. Measured data is shown in black circles. Some caution should be used in evaluating the boundary inflow model inputs by comparing simulation results for the Sacramento River at Freeport. An improved match could be caused by boundary inflows more closely matching actual conditions or by introducing an error which cancels out a model error in the other direction. Calibration statistics of each simulation's fit compared to observed data is shown in Table 4-1. Relative error is the average of simulated minus observed, a measure of accuracy. Absolute error is the average absolute value of the difference between simulated and observed data points, a measure of precision. The simulation using the CALSIM linkage organic carbon and nitrate concentrations showed a closer fit to observed data at Freeport.

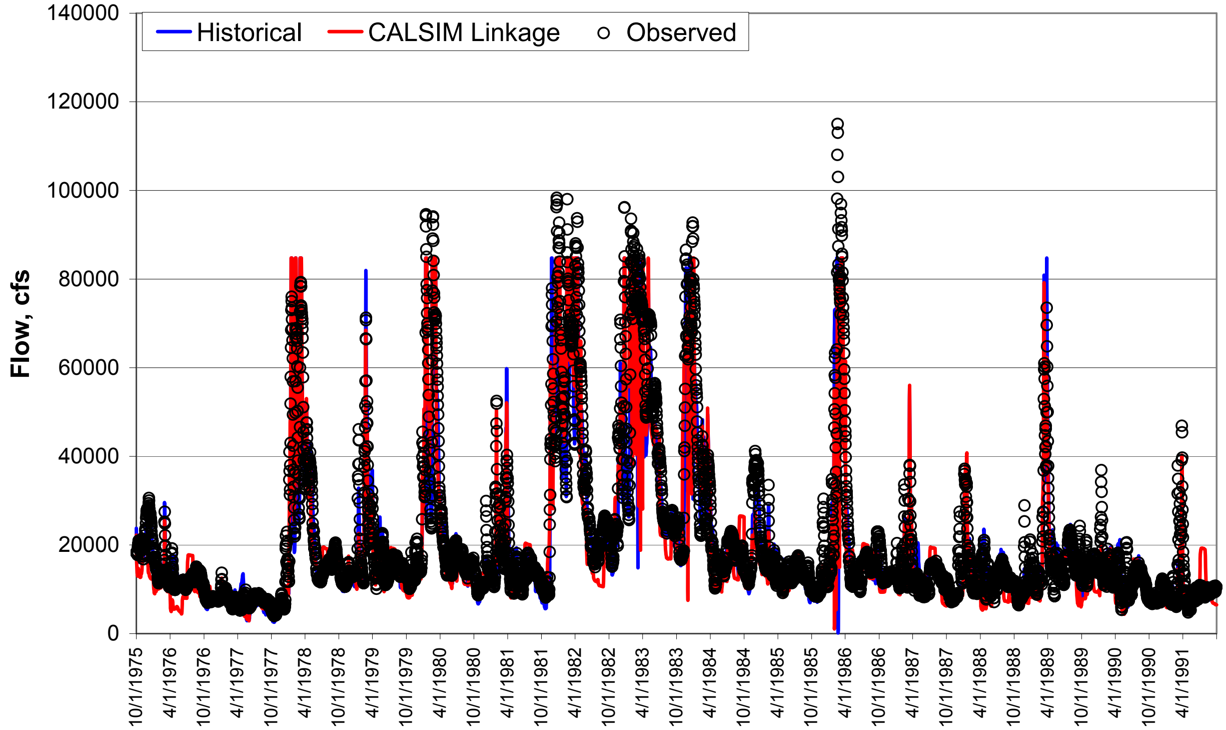


Figure 4-1 Simulated Historical and CALSIM Linked Flow, Sacramento R. at Freeport

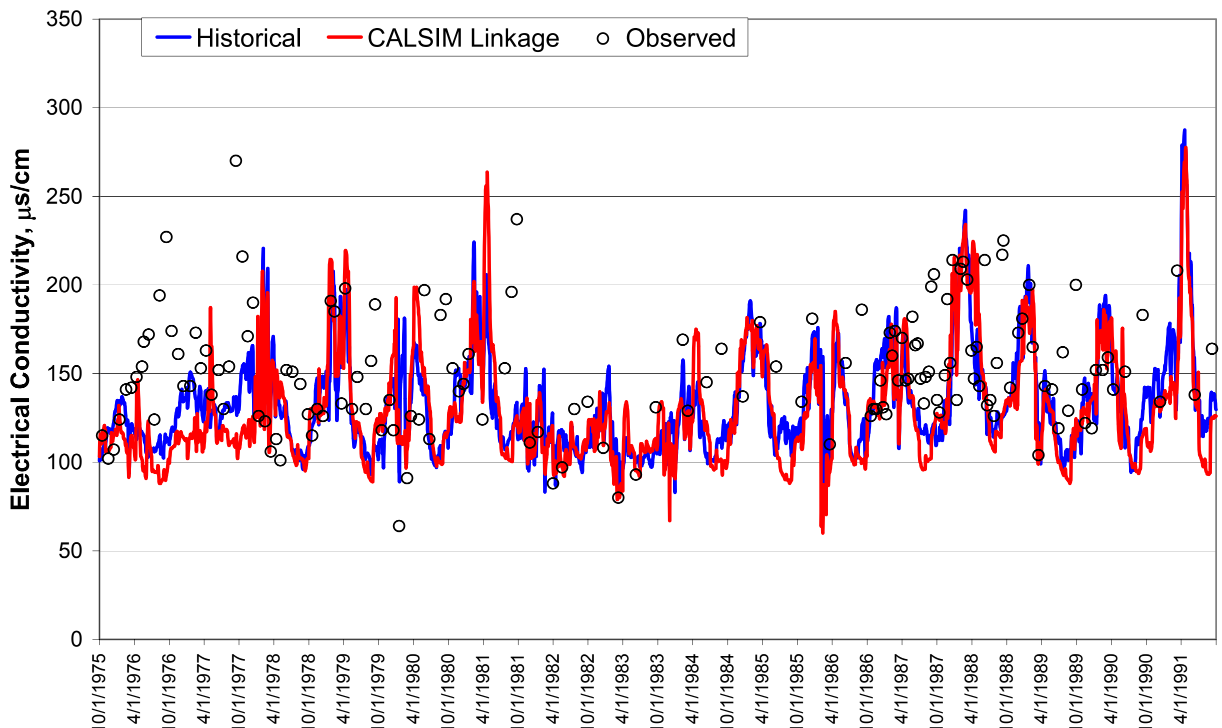


Figure 4-2 Simulated Historical and CALSIM Linked EC, Sacramento R. at Freeport

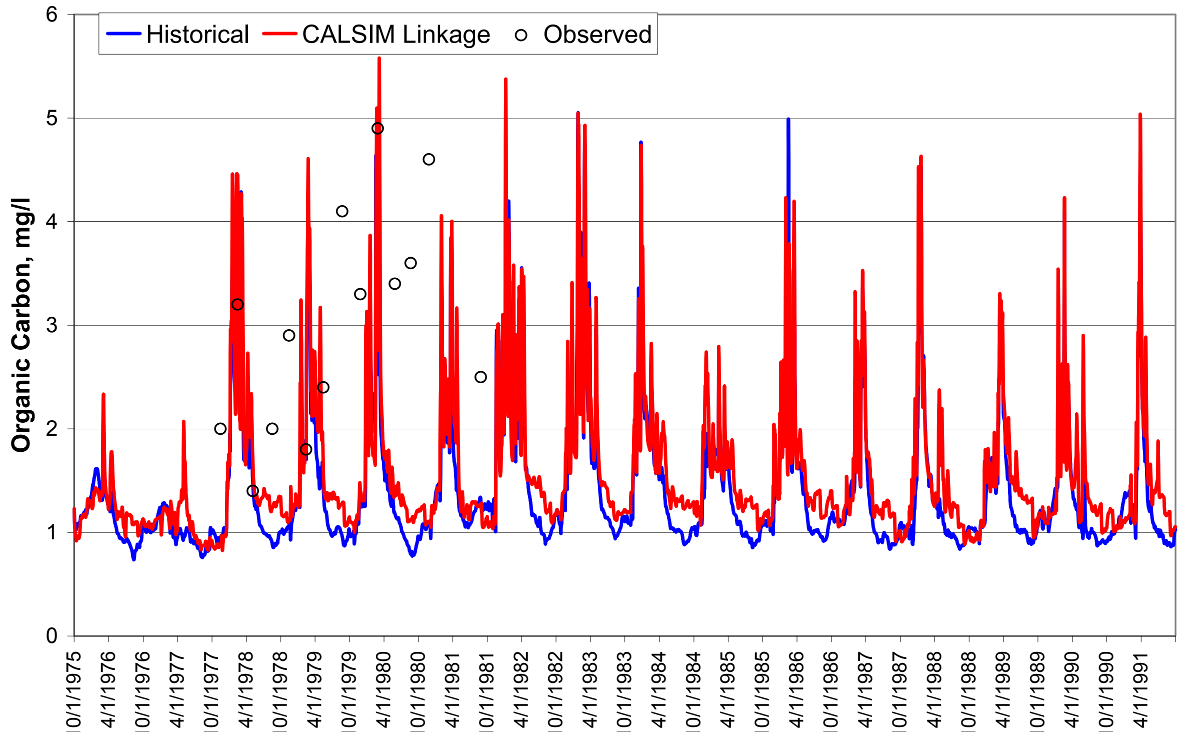


Figure 4-3 Simulated Historical and CALSIM Linked Organic Carbon, Sacramento R. at Freeport

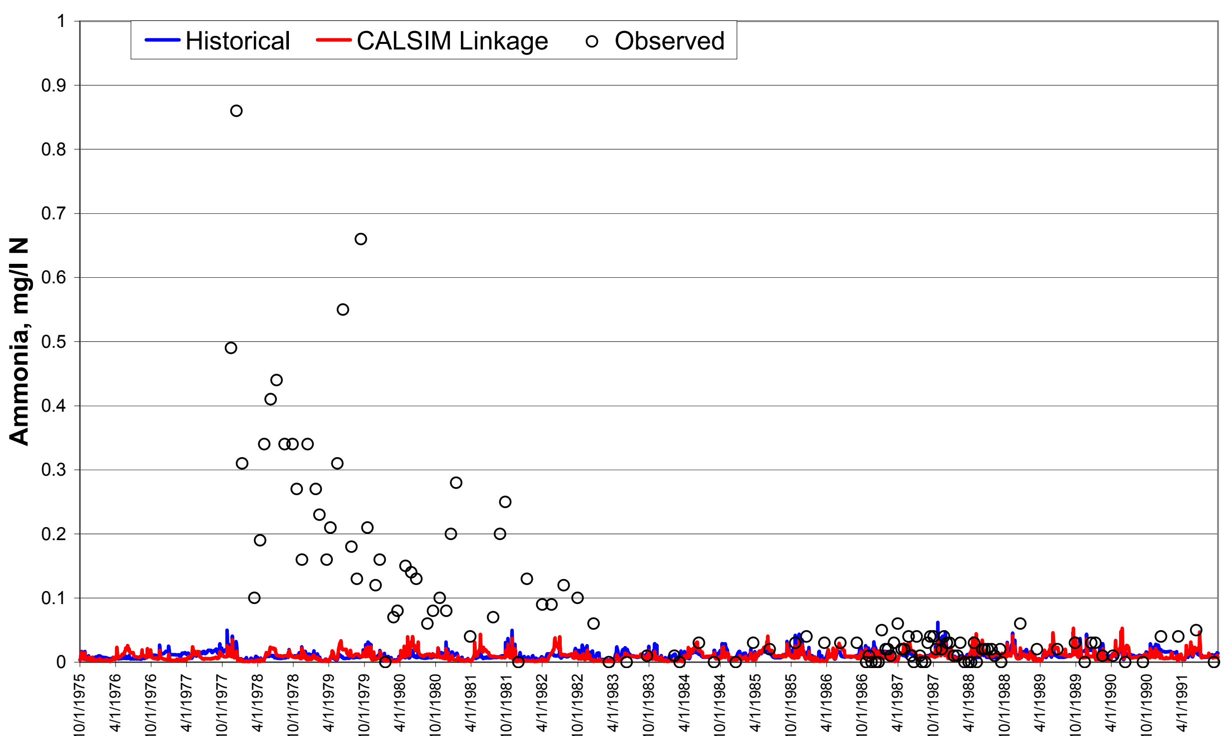


Figure 4-4 Simulated Historical and CALSIM Linked Ammonia, Sacramento R. at Freeport

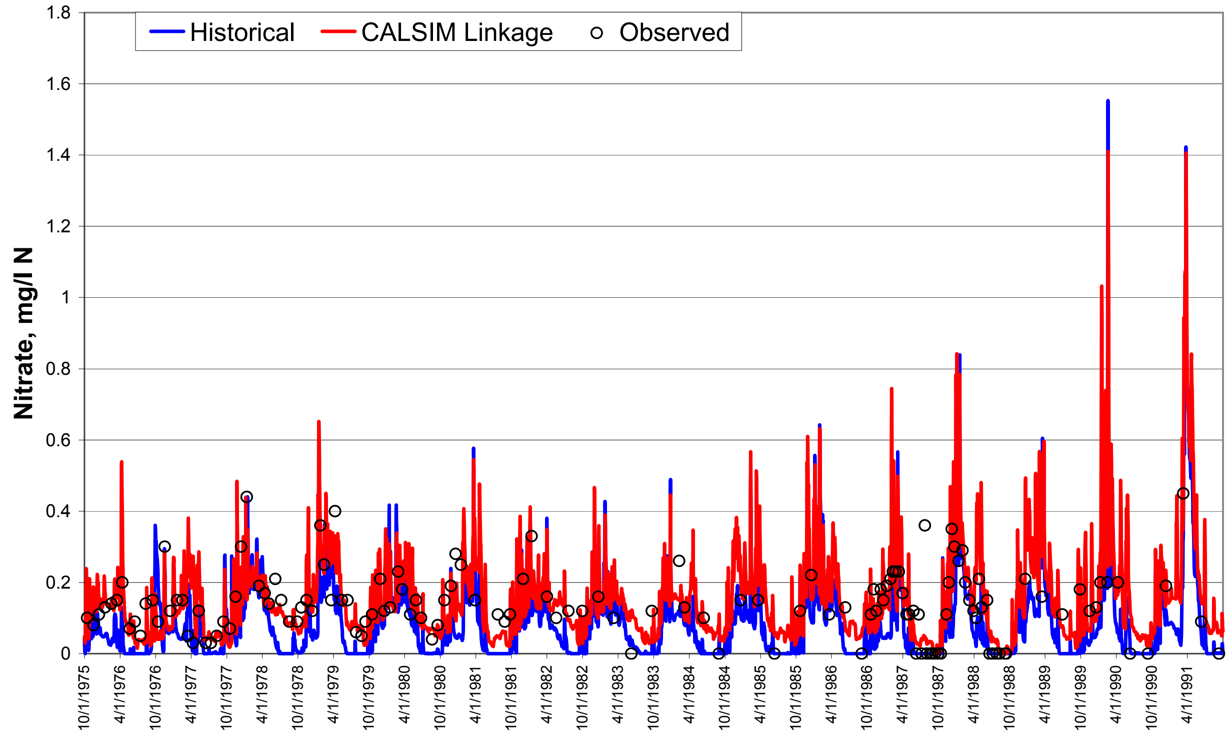


Figure 4-5 Simulated Historical and CALSIM Linked Nitrate, Sacramento R. at Freeport

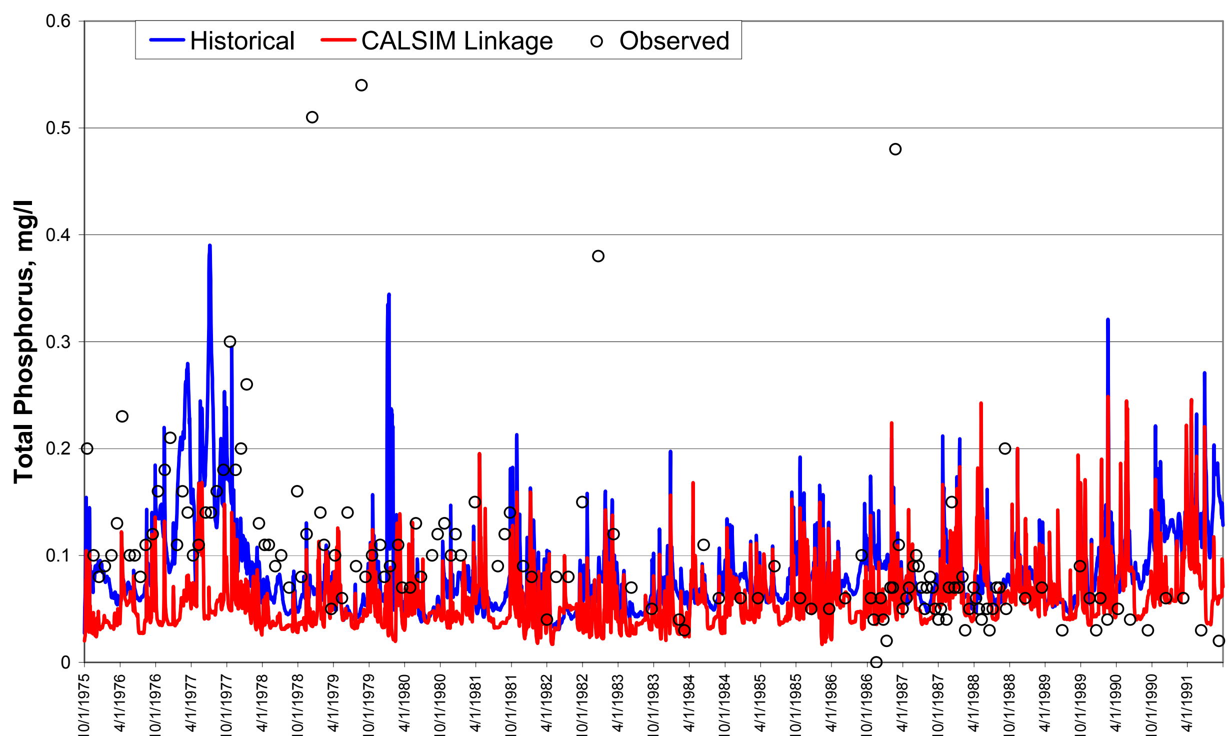


Figure 4-6 Simulated Historical and CALSIM Linked Total Phosphorus, Sacramento R. at Freeport

Table 4-1 Calibration Statistics for Each Simulation Compared to Observed Data

Parameter	Historical Boundary Inflow & Quality			CALSIM Boundary Inflow & Quality		
	Average	Relative Error	Absolute Error	Average	Relative Error	Absolute Error
Flow	20,060 cfs	-4.7%	15.3%	18,859 cfs	-10.5%	24.2%
EC	133 µs/cm	-11.3%	18.0%	129 µs/cm	-13.3%	22.0%
DOC	1.40 mg/l	-52.2%	55.6%	1.54 mg/l	-46.1%	53.2%
NH_4,	0.011 mg/l N	-88.7%	93.8%	0.01 mg/l N	-89.7%	93.8%
NO_3,	0.086 mg/l N	-42.3%	54.4%	0.153 mg/l N	4.0%	42.3%
TP	0.086 mg/l	-16.5%	51.5%	0.058 mg/l	-42.7%	59.2%

A complete discussion of model calibration and error is in the Sacramento River calibration report (Systech 2011). The above table shows the effect of boundary conditions on the model calibration. The historical boundary inflows and water quality provided a closer match to measured data for flow, electrical conductivity, and total phosphorus. The CALSIM boundary conditions resulted in a closer match to observed data for organic carbon and nitrate. Neither matches the high ammonia concentrations measured from 1977-1982. If sources of error discussed in the calibration report were reduced, that could affect the relative performance of each of the boundary condition alternatives presented here.

5 CONCLUSION

The WARMF graphical user interface was upgraded to incorporate a method of linking to time series data stored in DSS format. The tool to import DSS data was added to the WARMF Data Module and includes the capability of importing meteorology, point source, and managed flow data. The import tool makes it possible to efficiently run WARMF scenarios with different sets of time series inputs. This enables a linkage to the CALSIM model, which stores its output in DSS format.

A test of the linkage was performed for the Sacramento River watershed in northern California. CALSIM output was imported into WARMF in place of historical data for many inflows and diversions, augmented by water quality inputs for reservoir releases. The time series were successfully imported into WARMF. A simulation with the imported data showed similar results compared to using historical data to drive the model, with expected differences resulting from the changes. The simulation using the CALSIM linkage had a better match to observed nitrate and organic carbon concentrations at the Sacramento River at Freeport, but did not improve the match to observed data for other parameters. With the DSS importing function, WARMF can now run a wider variety of scenarios of projected future management actions.

The linkage is ideal for simulating changes in external time series inputs to the watershed, not necessarily limited to CALSIM outputs. This includes reservoir management scenarios, future conditions, and climate change. Using the CALSIM linkage can also be used to make WARMF compatible with the Delta DSM2 model, which also uses CALSIM for its model inputs. When using the linkage, it is important to ensure that the inputs from CALSIM are compatible with other WARMF model inputs, especially land use and diversion flows. Using the linkage with monthly CALSIM output results in a loss of temporal resolution, but the resulting WARMF simulations are informative when their outputs are compared against other simulations also using the linkage. The comparison between historical and CALSIM linked simulation demonstrated in this document are useful for evaluating the effect of the CALSIM assumptions on WARMF smulation results. Caution should be used when comparing historical simulations with CALSIM linked simulations for any other reason because of the effect of the linkage itself.

6 REFERENCES

Herr, J., Weintraub, L.H.Z., and Chen, C.W. 2001. "User's Guide to WARMF: Documentation of Graphical User Interface," EPRI, Palo Alto, CA. Topical Report.

Systech Water Resources. 2011. "Task 3 Technical Memorandum: Analytical Modeling of the Sacramento River", Prepared for the California Urban Water Agencies and the Central Valley Drinking Water Policy Workgroup, Walnut Creek, CA.