Description of Analytical Tools

Name (s): CALSIM II – CVP-SWP System Simulation Model;
WRIMS (a.k.a CALSIM) -- Water Resources Integrated Modeling System

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Availability of technical support: A summary of CALSIM II/WRIMS documentation available on DWR modeling web site.

http://modeling.water.ca.gov/hydro/model/index.html

Analytical tool Categories: WRIMS, a generalized water resources simulation model for evaluating alternatives in a Water Resources System. CALSIM II is the application of WRIMS, and specifically used as a planning tool to simulate the State Water Project (SWP) and the Central Valley Project (CVP).

Main Features and Capabilities:

- Monthly time step. (Daily time step is available for a simplified, aggregated schematic of SWP-CVP system)
- Areal extent covers Central Valley, Sacramento-San Joaquin Delta and SWP and CVP systems
- WRIMS is written in JAVA and FORTRAN. Knowledge of these two languages is not required; however, knowledge of Water Resources Simulation Language (WRESL) is necessary to run CALSIM II.
- CALSIM II is designed to be data driven in order to easily represent different “what-if” scenarios of system changes, operations criteria, regulatory requirements etc., without changing the underlying engine.

Applications: CALSIM II model has been applied to simulate the CVP and SWP systems at various levels of Development, system configurations, demand scenarios and operations rules. Currently CALSIM II uses 73 years of hydrology (1922-1994). For In-Delta storage studies daily version of the CALSIM II has been used.
USBR has recently applied WRIMS to the Klamath River basin.

Calibration/Validation/Sensitivity Analysis: CALSIM II, as a planning model, cannot be calibrated. However comparison of modeled and actual historical SWP/CVP operations for the period 1975-1998 has been conducted and reported in a DWR technical memorandum published in November 2003. A report on sensitivity analysis is under preparation and should be completed soon; in addition a study on “Uncertainty Analysis” will be planned in the near future.

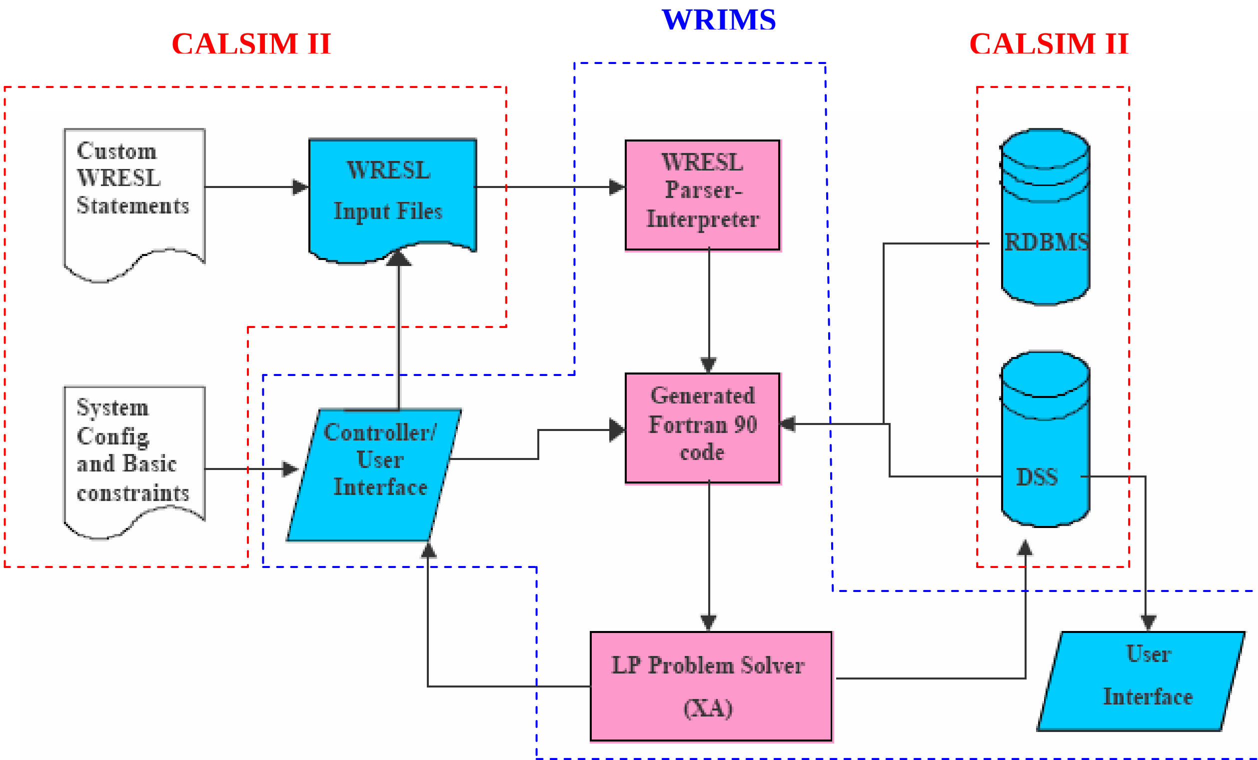
Peer Review: The expert peer review on CALSIM II and WRIMS was completed in December 2003, and the report on the review has been posted on the CALFED web site. A response to the review report, along with a work plan for short-term improvements to CALSIM II, are being finalized and will be posted on the web in near future.

Anatomy of CALSIM II:

Conceptual basis - WRIMS has been designed to separate the physical and operational criteria from the actual process of determining the allocations of water to competing interests. This separation of ***what*** are the goals of the system from ***how*** the problem is solved represents a fundamental change from traditional systems modeling. WRIMS avoids requiring the user to specify procedures and allows for easy specification of system rules and constraints.

A graphical user interface has been developed for defining the system configuration and basic constraints, as well as viewing the results of a simulation. The user describes the physical system (reservoirs, channels, pumping plants, etc.), basic operational rules (simple minimum flows, etc.), and priorities for allocating water to different uses through the interface. A key component for specification of the specialized operational constraints is the WRESL language. At run-time the WRESL statements are converted to generated Fortran90 code by a parser-interpreter program. The parser-interpreter has been developed by the use of the Java CC parser generator and contains the entire WRESL language syntax.

Once the WRESL statements have been converted to Fortran90 code, relational and time series data are read from separate databases. WRIMS utilizes the HEC-DSS time-series data storage system developed by the U.S. Army Corps of Engineers Hydrologic Engineering Center in Davis, California. Relational data such as index-dependent flow standards and monthly flood control diagrams are stored in simple, text-based, relational tables. Once the relational and time-series data are read from the databases, the entire problem is assembled into the proper format and passed to the solver at each time step. The process involving the generated code, data access, and solver is repeated for each time period until the simulation is complete. The general flow of information is shown graphically in Figure below.

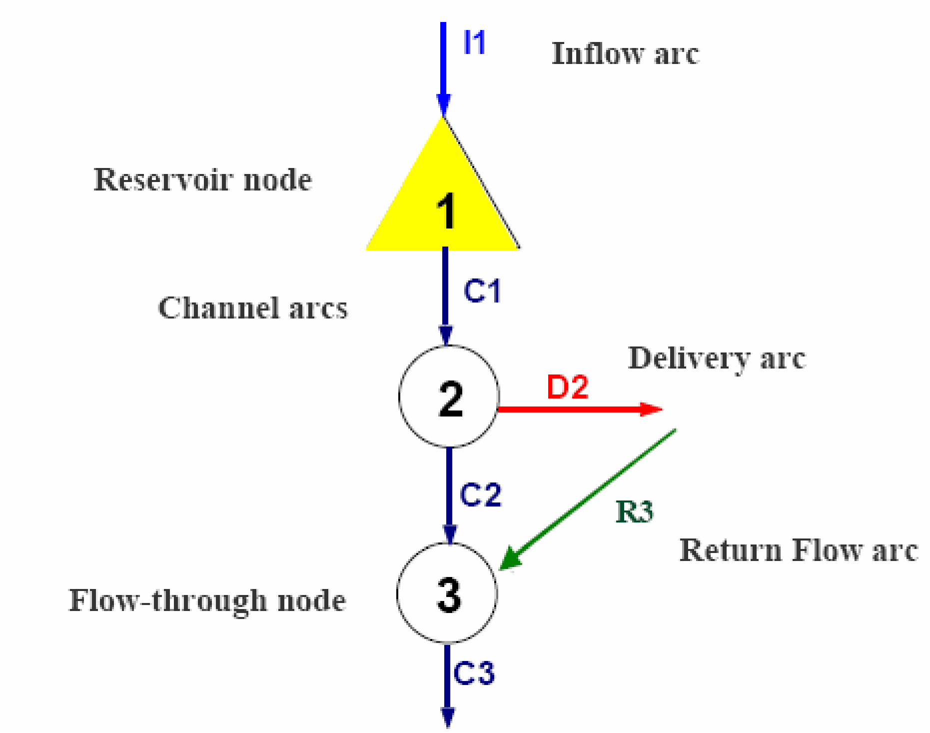


CALSIM II model structure and general flow of information.

Theoretical basis -

The objective function describes the priority in which water should be routed through the network within the set of constraints

The WRIMS model represents water resource systems, consisting of reservoirs and channels (natural and artificial), as a network of nodes and arcs. Nodes in the network may represent reservoirs, groundwater basins, junction points of two or more flows, or simply a point of interest on a channel. Arcs represent water flows between nodes, or out of the system, and may be inflows, channel flows, return flows, or diversions. An example network is shown.



Numerical basis – WRIMS uses single time step optimization techniques to route water through the system according to the user specified objective function and system constraints. A mixed integer linear programming (MIP) solver is used. The MIP solution for a single time step, usually one month, is used to represent the state of the system for the following month. User specified simulation rules link operation of reservoirs, demands and other criteria between these independent MIP solutions.

The mathematical formulation used in the WRIMS model consists of using a linear objective function and a set of linear constraints. The objective function describes the priority in which water should be routed through the network and the constraint set describes the physical and operational limitations toward achieving the objective. WRIMS *maximizes* the objective function in each cycle of each time period to obtain an optimal solution that satisfies all constraints. Priority weights assigned to variables (flow or storage) in the objective function describe the relative importance of that particular variable in the system operation.

WRIMS uses WRESL to represent the entire system and translate the user specified data into the MIP data input format. WRESL consists of the objective function, decision variables, state variables, and constraints.

The objective function in the WRIMS model is linear combination of decision variables and their associated priority weights. In addition, slack and surplus variables are automatically generated from “soft” constraints and are multiplied by their associated penalties (negative weights) and added to the objective function.

Decision variables represent the choices available to the LP model for storing water in nodes (reservoirs) or routing water through arcs. Weights on the decision variables encourage (positive weight) or discourage (negative weight) the solver to allocate water to the specified variable.

State variables describe the state of the system at the beginning of any time period. The term "state" is used rather loosely in this document to describe data as well as states of the system. These variables have known constant values for the upcoming period and can be thought of as the information available to planner/operator prior to any system operation.

Constraints describe the physical system, operating agreements, and regulations. These must remain linear to conform to the MIP formulation. WRIMS generates the WRESL code for the basic physical system as entered in the GUI by the user. Mass balance equations are hard constraints – mass balance is guaranteed for all solutions.

Storage zones are specified for each reservoir or ground water basin representing volumes between physical and operational levels. The zones are weighted and dynamically bounded to insure proper filling of the reservoir, meeting target storage levels, and minimizing encroachment in the flood pool.

Channel constraints represent the physical maximum carrying capacity of the channel and the absolute minimum channel flow. The absolute minimum flow is usually zero, but may be negative to describe reverse flows in channel arcs.

A minimum in-stream flow is formulated in WRIMS by splitting the channel arc into zones and weighting and bounding one zone to the minimum flow target.

Return flows are modeled as a constant or time-varying fraction of the relevant deliveries.

Deliveries from a node to a demand area, or another node, are specified by assigning a weight and bounding the arc flow.

The maximum reservoir release is determined by the hydraulic properties of the outlet works and may be expressed as a piece-wise linear function of storage.

Reservoir surface water evaporation is computed as the period unit evaporation times the period average surface water area. This implies that the beginning and end of period surface water area, a function of reservoir storage, must be known before evaporation can be computed. Evaporation constraints including surface area automatically generated by reservoir system table in user interface.

Hard Constraint – A boundary that cannot be crossed.

Soft constraint – A boundary that can be crossed but where the magnitude of violation is penalized.

Additional constraints may be entered by the user to represent complex operating criteria.

Cycling Solutions – The complex regulatory environment in the CVP and SWP system operations required WRIMS to be capable of iteratively simulating the system with each solution layering additional regulatory criteria. WRIMS allows this cycling to occur on either a single monthly or annual basis. For monthly cycling, several MIP solutions are made for a single month. Each MIP problem has access to the previously solved results allowing decisions to be made regarding the next MIP problem. The procedure works similarly for the annual cycling with the addition of the possibility for these to contain the monthly cycling embedded within.

Input and Output data – Input time series data is stored in HEC-DSS format and relational data is stored in simple text base tables. All WRIMS output data are time series and is stored in HEC-DSS format.

Data Management – For efficient storage of WRIMS output HEC-DSS time-series data storage system developed by the U.S. Army Corps of Engineers Hydrologic Engineering Center in Davis is used. VISTA (Visualization tool and analyzer) is a GUI for viewing and manipulating DSS data. VISTA can be downloaded from the department web site
http://modeling.water.ca.gov/delta/models/dsm2/tools/vista/index.html

Software – The current version of WRIMS (version 1.2) consists of a combination of software modules developed in FORTRAN, JAVA and WRESL. In addition to these CALSIM II uses relational data base and HEC-DSS for time series data. WRIMS 1.2 requires the proprietary software packages such as Lahey FORTRAN and the XA solver.