Chapter 11 Model Use and Limitations

Over the last decade, computer simulation model have been widely used in California to support a diverse range of policy and regulatory decisions, planning processes, and environmental review. With expanding use of models, it becomes increasingly important to identify the purpose for which the model has been developed, appropriate model use, model limitations, and guide the interpretation of model results. This chapter briefly reviews these aspects of SacWAM.

11.1 Model Objective

SacWAM has been developed by the State Water Board to support update of the 2006 Bay-Delta Plan. The model may be used to inform the following types of analyses as part of the agency's assessment of potential alternative regulatory requirements:

- Estimates of flow conditions under a range of alternative regulatory requirements.
- Estimates of changes in water diversions for use in an evaluation of the impacts of alternative regulatory requirements on agricultural resources, water suppliers, and groundwater.
- Estimates of changes in reservoir storage for use in an analysis of the impacts of alternative regulatory requirements on hydropower generation, recreation, and fisheries.
- To inform other analyses or models, such as Delta hydrodynamics, Delta water quality, water temperature, economic, and fisheries benefits models.

It is intended that SacWAM be transparent, easy to use, and freely available. The WEAP software and its interactive GUI was designed to facilitate a shared model vision. However, the SacWAM application is complex, highly detailed, and requires the model user to be familiar with both system operations modeling and California water. Additionally, SacWAM requires a significant investment of time to become familiar with the schematic, properties of objects, and user-defined variables and constraints. This imposes barriers to widespread model use.

The WEAP software is freely available to California water agencies. Before the development of SacWAM, all WEAP applications used a free MIP solver. However, given the unprecedented size and complexity of SacWAM, it was necessary to substitute the free solver with a commercial product (XA) to decrease run time and eliminate failures to solve. [22] A single XA license costs between $1,000 and $2,000, which again imposes barriers to widespread use of the model. Full model results are large, of the order of 4 GB, and so cannot easily be distributed with SacWAM.

11.2 Appropriate Use of Model

SacWAM should be used in a comparative manner in which model results for a particular alternative are compared to a base simulation. In the comparative analysis, differences in certain factors, such as

[22] Solution time for a 10-year simulation period with the free solver is approximately 3 hours. In a test run, the free solver was forced to relax constraints in 14 months over the 10 years to find a feasible solution. Model run time with the XA solver for an 88-year period of simulation is less than 1.5 hours with no relaxation of constraints.

deliveries or reservoir storage levels, are analyzed to determine the impact of the alternative. SacWAM should not be used in an absolute, stand-alone analysis in which model results are used to predict an outcome.

SacWAM results are believed to be more reliable in a comparative study than an absolute study. All of the assumptions are the same for baseline and alternative model runs, except the action itself, and the focus of the analysis is the differences in the results. Model errors, introduced through necessary simplification of the real world and which render absolute analysis unreliable, are assumed to be independent of the scenario being considered, so that these errors will largely cancel out in a comparative analysis.

11.3 Interpretation of Model Results

SacWAM is a long-term planning model developed for planning analysis. It is not intended to be used to support real-time reservoir operations and water delivery decisions. Although SacWAM uses historical hydrology to represent a reasonable range of water supply conditions, SacWAM does not simulate historical water conditions. Simulated results for a particular year will not correspond to historical storage and flows and do not provide information about historical events. Model results are best interpreted using various statistical measures such as long-term or year-type averages.

11.3.1 Temporal Resolution

SacWAM uses a monthly time step for all operational decisions and for routing water through the SacWAM schematic. Operational requirements that affect day-to-day management of water infrastructure are not included in the model, such as hourly and daily reservoir flow ramping rate criteria. Average monthly flows may not accurately represent operations that respond to daily variability in water conditions, such as reservoir flood control operations. Therefore, disaggregation of monthly model results to finer time scales should be undertaken with caution and may not be an appropriate use of the model.

11.3.2 Spatial Resolution

SacWAM is built on a very detailed spatial representation of the water supply network in the Sacramento Valley and Delta. However, the model necessarily simplifies the depiction of streamflows by aggregating surface water diversions, return flows, surface runoff, and groundwater inflows to the stream network. Only downstream from these points of aggregation will SacWAM accurately simulate streamflows.

11.3.3 Drought Conditions

SacWAM operational decisions are based on a set of predefined rules that represent existing regulations, contract agreements, and obligations. The model has no capability to dynamically adjust these rules based on extreme hydrologic events such as prolonged drought. For example, the model does not represent the Temporary Urgent Change Petitions (TUCP) that were submitted by DWR and Reclamation to the State Water Board in 2014 and 2015. The TUCP resulted in temporary changes to Delta Cross Channel operations, Delta outflow requirements, and Delta export limits. Similarly, in 2014, drought conditions resulted in Reclamation meeting San Joaquin River exchange contractor water

demands with a mix of Delta and San Joaquin River sources. Currently, SacWAM does not have the ability to represent this type of operational change from a standard procedure. This simplification results in excessive water demands on SWP/CVP reservoirs and excessive reservoir draw down in individual dry years. Model results for drought conditions should be presented in terms of water year type averages and operations for specific dry year such as 1924, 1977, and 1991 should not be the focus of the analysis.

11.3.4 Time Frame

The SacWAM simulation represents "existing conditions", or approximately 2010, for land use, population, infrastructure, and regulatory environment. Currently, no model version has been developed for future (No Project/No Action) conditions, as is typically required for environmental review and documentation.

11.4 Computational Methods

11.4.1 Objective Function

WEAP uses a MIP solver to solve a series of equations that seek to maximize an objective function that will best allocate water resources according to a user-defined set of delivery, flow, and storage priorities (weights). This set of equations also includes physical and operational constraints of the system as defined by the user.

The WEAP solution algorithm facilitates the development of the objective function through simply classifying a hierarchy of priorities, which are met sequentially. However, this approach prevents trade-offs between high priority objectives and those of lower priorities. It also limits model functionality and flexibility, for example, the model user cannot use negative weights to discourage certain actions.

11.4.2 Iterative Solution Technique

The MIP solver does not optimize across multiple time steps or across multiple objectives. Rather, the MIP solver runs iteratively within each time step to allocate current water resources within the system, priority by priority. Successive solution of priorities and preferences are known as allocation orders. The WEAP algorithm moves sequentially through priority levels 1 through priority 99 before moving to the next time step and through supply preferences within a priority. Objectives achieved for a given allocation order are enforced as constraints in all successive priorities and solutions.

A significant amount of model development time was spent eliminating "relaxation of constraint" errors caused by numerical rounding and the iterative WEAP solution technique. These problems were resolved by modifying the WEAP software to allow injection of small amounts of water to overcome model infeasibilities. The amounts injected are typically much less than 1 cfs, but in a new run the model user must check that amounts injected are not significant.

11.4.3 Flexibility

WEAP has no ability to refer to values of decision variables established in previous allocation orders within the same time step. Regulations that require layering of requirements based on the previous state of the system (within the same time step) cannot easily be modeled. For example, simulation of

SWP use of unused Federal share of water under COA requires some model 'tricks' that make model operations less transparent.

Typically, user-defined constraints are active through all allocation orders. For example, Delta outflow requirements are imposed as a model constraint when determining allocation decisions regarding local operations in tributary watersheds. Additionally, priorities are only active in one allocation order, so that storage in a particular reservoir is only valued in one allocation order. Results from individual allocation orders prior to the final solution may not be meaningful.

11.4.4 Robustness

Model development has focused on the base simulation of existing conditions. Less effort has been focused on testing the model over a wide range of alternative scenarios or conducting a sensitivity analysis to check that the model correctly responds to different changes in regulatory requirements. However, the State Water Board has worked with DWR staff to validate SacWAM using a comparative analysis of a 50 percent unimpaired flow alternative to existing conditions.

11.5 Model Calibration and Validation

SacWAM is a monthly accounting tool. Some of its routines are physically-based and can be calibrated to observed data, e.g., the MABIA root-zone daily soil moisture simulation. However, many aspects of SacWAM are not physically based, being simplifications of complex operating criteria and regulations. These management aspects of the model cannot be calibrated. Instead SacWAM simulation has been validated through comparison with CalSim II, a management or planning model for the SWP and CVP.

11.6 Climate Change

Climate change is a key consideration in planning for the State's water management. California's aging water infrastructure was designed and built based on an analysis of historical hydrology; past weather patterns have long been assumed to be representative of future conditions. However, as climate change continues to affect California, past hydrology is no longer a reliable guide to the future.

SacWAM uses a historical sequence of 88-years inflow hydrology and historical climate data to simulate both water supply and water demands. Currently, no climate change scenarios have been developed for the model. Additionally, no adaptive management actions or model code have been developed to help offset climate change effects. For example, reservoir flood space reservations could be adjusted in response to changing seasonal inflow patterns.

SacWAM offers two modes of simulation with respect to the upper watersheds: use of historical unimpaired inflows that are inputs to the model; and climate driven runoff simulated using WEAP's catchment objects. Historical streamflow records are usually incomplete and unimpaired inflows input to the model are often derived using statistical techniques. Inflows have been developed assuming stationarity over the historical period and assuming statistical relationships between (unimpaired) streamflows are constant. This assumption of stationarity is not appropriate when there has been significant land use change in the upper watersheds or when climate change has occurred. The effects of climate change can be simulated through the use of the WEAP catchment objects as this effectively

changes the inputs into the model from streamflows to climatic inputs such as precipitation, temperature, wind speed, and humidity.

11.7 Sea-Level Rise

Sea levels have increased steadily over the past century and are projected to continue to increase throughout this century. Sea level rise will affect the eastward movement of salt into the Delta, requiring additional freshwater Delta outflow to repel salinity and meet existing Delta water quality standards. SacWAM uses an ANN embedded within the model to translate water quality standards to a Delta outflow requirement. The ANN was developed by DWR for use in its planning studies and seeks to emulate flow-salinity relationships derived from DWR's one-dimensional hydrodynamic and water quality model, DSM2. DWR has developed several versions of ANN that are appropriate for representing existing conditions, 15 cm sea-level rise (~2025 conditions), and 45 cm sea-level rise (~2060 conditions).

Currently, SacWAM has only been linked to the ANN for existing conditions. Additionally, no operational logic has been developed for potential adaptive management actions to address future Delta conditions affected by sea-level rise.

11.8 Model Limitations

This section discusses limitations of particular aspects of SacWAM.

11.8.1 Watershed Hydrology

WEAP uses a one-dimensional lumped parameter hydrologic model to estimate monthly runoff, baseflow, ET, groundwater recharge, and soil water storage. The SacWAM domain is divided into upper watersheds and valley floor. The upper watersheds are further divided into sub-catchments based on elevation so that the model can simulate snow accumulation and snowmelt processes. However, elevation bands are coarse, 500 meters. Refinement of these elevation bands and additional calibration would improve simulated flows derived by climate data (precipitation and temperature).

11.8.1 Water Supply Forecasts

SacWAM uses a mix of perfect foresight and forecasts to estimate water supply conditions. For example, water supply indices and water years types that control many regulatory flow requirements may either be set equal to historical values, or be dynamically forecasted based on simulated winter snowpack and regression analysis that associates snowpack within each of the watersheds to future runoff. SWP and CVP contract allocations are based on current month reservoir levels and future inflows determined using 90 percent or 99 percent exceedence forecasts. However, simulation of local agency operations are typically based on perfect foresight of water supply conditions.

11.8.2 Upstream Watershed Operations

SacWAM implements a very simple approach in simulating most of the reservoirs in the upper watersheds of the Sierra Nevada Mountains. The top of the conservation pool is set equal to average monthly historical storage. In wet years, simulated storage will follow this rule curve. Under drier conditions, reservoir storage will fall to lower values. Further refinement is needed to more accurately simulate these reservoirs, which are typically operated for hydropower.

11.8.3 Sacramento - San Joaquin Delta

The complexity of Delta channel flows and Delta salinity cannot be included in a flow-based accounting model, such as SacWAM.

SacWAM does not simulate Delta water quality conditions that drive operation of Contra Costa WD's Los Vaqueros Project.

In the default set-up, SacWAM uses values of Delta channel accretions and depletions that were developed by DWR for use in their planning models. While this maintains consistency with past analysis, DWR has recognized that that their estimates of channel depletions may underestimate Delta consumptive use because of low estimates of crop evapotranspiration.

11.8.4 San Joaquin River at Vernalis

San Joaquin River flows at Vernalis and associated water quality are inputs to the model and must be derived from other modeling activities. SacWAM contains no dynamic links between San Joaquin River conditions at the Delta boundary and other parts of the model. San Joaquin River flows and salinity are treated as being independent of SWP and CVP water deliveries to the San Joaquin Valley, which are dynamically determined at run-time.

11.8.5 Groundwater

Ten groundwater basins are simulated in SacWAM using the WEAP groundwater objects. Parameters governing the stream-groundwater interaction were calibrated to match results from DWR's distributed groundwater model of the Central Valley, C2VSim. Stream-groundwater interaction is simulated as a linear function of streamflow and may fluctuate in direction, but is independent of groundwater levels. Thus, surface water flows are independent of the state of the underlying aquifer.

Simulation of groundwater overdraft in SacWAM may not be realistic as there is no feedback mechanism to limit groundwater outflows as elevations fall (or conversely as elevations rise).

11.8.1 Hydropower Operations

SacWAM does not simulate hydropower operations or power generation. Reservoirs with associated hydropower facilities are either simulated using a fixed rule curve, or for multi-purpose reservoirs it is assumed that hydropower generation is secondary to water supply objectives.

11.8.2 Water Temperature Objectives

SWP and CVP operations are often dictated by water temperature considerations. For example, the NMFS 2009 BiOp specifies actions to protect fall-, winter-, and spring-run chinook through cold water pool management of Lake Shasta. The BiOp establishes water temperature and compliance points at various locations on the Sacramento River above Bend Bridge and on Clear Creek (Action Suite 1.2). The BiOp also establishes objectives for end-of-September carryover storage in Lake Shasta. Long-term performance measures are specified in terms of exceedence.

SacWAM contains no specific actions to meet the requirements of Action Suite 1.2 contained in the NMFS 2009 BiOp. SacWAM cannot operate to meet exceedence-based performance criteria. SacWAM

has no ability to translate water temperature based objectives in to flow equivalents. The model specifies flow requirements below Keswick based on Reclamation modeling of CVPIA 3406(b)2 actions undertaken for the 2008 OCAP for the CVP and SWP. Post-processing of SacWAM results is required to assess exceedence-based metrics. Additional analysis using a water temperature model is required to assess water temperatures resulting from SacWAM actions. In the future, this type of analysis may result in refinement of current flow schedules implemented in SacWAM.

11.8.3 Biological Objectives

Regulatory requirements that were established to protect threatened and endangered fish species and their habitats are often triggered by metrics other than flow and storage. For example, the 2008 USFWS RPAs may be triggered by water temperatures, turbidity, spawning, migration, salvage, and results of fish surveys. These triggers cannot be dynamically implemented in SacWAM, and the model must use either flow surrogates or preset schedules of actions. For example, OMR reverse flow criteria, as simulated in SacWAM, will only approximate real-time decisions made by the fishery management agencies.

11.8.4 Water Rights

Currently, the SacWAM portrayal of water rights is limited to major water agencies and water districts that divert from the Sacramento River and its major tributaries.

11.8.5 Contract Allocations

The procedures used in SacWAM to compute allocations for CVP and SWP include lookup tables that estimate the amount of the available water supply that can be used for delivery and/or carryover storage. These lookup tables are referred to as the WSI-DI curves. The curves are developed through an iterative process wherein they are updated with each successive model run until the model is able to deliver the allotted allocation with no delivery deficits. The WSI-DI relationship depends on three key features of the modeled system: hydrology; water supply infrastructure; and the regulatory environment. If significant changes are applied to any of these three model elements, then new WSI-DI curves should be developed to prevent over or under allocation to SWP and CVP contractors. Currently, SacWAM has no automated procedures to develop new WSI:DI curves.

11.8.6 Water Transfers

Water transfers are currently not simulated in SacWAM

This page intentionally left blank

.