Appendix W Sensitivity and Uncertainty Analysis

Introduction

An analysis of sensitivity and uncertainty of model results relative to input parameter variation has been conducted on the CalSim-II model used by Central Valley Operations for studies supporting the Operations Criteria and Plan (OCAP) Biological Assessment. Sensitivity analysis answers questions about how changes to specific model inputs affect model output, while uncertainty analysis examines how collective uncertainty about model inputs translates into uncertainty about model output.

Background

CalSim-II (Draper et al. 2004) is the joint-agency planning model used by the California Department of Water Resources (DWR) and the U.S. Bureau of Reclamation (Reclamation) to study long-term proposed actions for the Central Valley Project and State Water Project systems. The model represents federal, state, and local operations within the Sacramento and San Joaquin River basins.

Peer reviews of the CalSim-II model have recognized the need for guidance on how to interpret the precision and utility of model results for planning applications (Ford et al. 2006), for clarifying which inputs most influence model output (Ferreira et al. 2005) , and for analyzing how collective inputs' uncertainties translate into uncertainties of model outputs (Close et al. 2003).

A technical memorandum, *CalSim-II Model Sensitivity Analysis Study*, produced by DWR in 2005, first addressed the peer review recommendations by measuring the sensitivity of a set of model outputs to key input parameter variations. Uncertainty was not addressed in this effort.

In 2006, following significant upgrades to the representation in CalSim-II of the San Joaquin River Valley (SJR), Reclamation performed sensitivity and uncertainty analyses on this portion of the model, focusing particularly on output associated with recently updated demand, hydrology, and salinity representation (Reclamation, 2006). This comprehensive effort involved developing methods for managing computing needs for the large number of model runs involved and for processing the study outputs.

Building on both of these previous efforts, the current investigation uses the computing methods applied in the SJR study to a new examination of sensitivity and uncertainty, focused on the hydrology and demands in the Sacramento River basin and on Delta flow criteria.

Analysis Objectives

Modeling studies supporting the Long Term Central Valley Project (CVP) and State Water Project (SWP) Operations Criteria and Plan Biological Assessment (BA), evaluate the potential effects of the proposed operation on species listed by the U.S. Fish and Wildlife Service and National Marine Fisheries Service. Given the central role of the CalSim-II model in the analysis process, information about the sensitivity of the model to input parameter variation and about uncertainties in model output that might result from collective uncertainties in model inputs can help to inform those who rely on the model output to make decisions.

As this sensitivity and uncertainty analysis varied common hydrologic inputs and not parameters unique to the OCAP studies, it also serves the larger community of water management specialists who rely on the CalSim-II model for information about the CVP/SWP system. The overall objectives of the analysis were:

- Produce model sensitivity information for Reclamation's CalSim-II model development planners, particularly on which inputs seem most influential on model outputs; and, among these influential inputs, which seem most feasible to target for improved precision through improved model representation or data collection.
- Produce model uncertainty information that might be referenced by decision-makers responsible for interpreting CalSim-II model outputs.
- Document information on model sensitivity and uncertainty.

Methodology

This section describes the base models subjected to input sensitivity and uncertainty analysis. This is followed by descriptions of inputs and outputs considered, sensitivity analysis methods, uncertainty analysis methods, and automation tools that were used to expedite analysis and data-handling.

Base Models

A version of CalSim-II representing a California State Water Resources Control Board D-1641 regulatory environment was used in this analysis. Analysis was performed with input hydrology at both existing and future levels of demand. A detailed description of the system representation for the model at both levels of development is provided in the OCAP documentation. In general, the models include the features of the Sacramento Valley, San Joaquin River, Delta operations, and CVP and SWP export service areas that are typically included in all CalSim-II planning model studies. The period of study is for a sequence of 82 water years (WY) representing the region's climate and hydrology variability experienced during WY1922-2003. The model simulates reservoir operations, water deliveries, and river flows on a monthly time step as determined by a mixed-integer/linear programming solver. Information on the mathematical formulations employed by CalSim-II and more details on its underlying software environment can be obtained at http://modeling.water.ca.gov/hydro/model/index.html.

Scope of Inputs and Outputs

CVP/SWP operations in the Sacramento/SanJoaquin/Bay Delta region are notably complex, and so is the CalSim-II model which represents them. Hundreds of input criteria and parameters could be varied in an examination of sensitivity and uncertainty. As in the SJR and DWR studies, an effort was made to select a range of inputs and outputs for study that would provide a useful analysis group without expanding the scope beyond what would be feasible or informative. General categories of inputs were selected for adjustment and general categories of outputs were identified to serve as indicators of effect. General input categories included inflow, north of Delta demands, and Delta water quality. General output categories were channel flow, delivery, groundwater pumping, return flow, storage, and Delta operations.

Inputs

The analysis considered 27 input types where each type features one or more input variables to be adjusted by one or more factors (Table 1). These input types are subdivided according to the categories mentioned above.

Inflows: The study included adjustments to rim flows and/or accretions for the Trinity, Sacramento, Feather, Yuba/Bear, Folsom, Millerton, Merced, Tuolomne, and Stanislaus rivers. Sacramento River inflow at Shasta Lake, local gains associated with demand area hydrology, and other local Sacramento River inflows were each adjusted independently.

North of Delta Demands: Where demands are calculated outside of CalSim-II by the Consumptive Use (CU) model, adjustments were made to CU model inputs for ET, loss factors, basin efficiency, and deep percolation of applied water. CU model results were then transferred to CalSim-II model inputs. Where demand is calculated internally by CalSim-II (i.e. in the Colusa Basin), adjustments were made directly to input parameters for consumptive use of applied water (CUAW), non-recoverable loss, on-farm efficiency and re-use factors, and deep percolation of applied water. Minimum groundwater pumping assumptions and rice decomposition demands were also adjusted.

Delta Water Quality: Scaling factors were applied to the flow requirements computed for meeting water quality standards at Jersey Point, Rock Slough, Emmaton, and Collinsville, and to X2-based water quality standards at the Confluence, Chipps Island, and Roe Island.

Information is provided in Table 1 on what CalSim-II input variables are associated with the 27 input types (column 4). The location of these inputs varies (column 5) – they can be found in model look-up tables (i.e. text files), pre-processing spreadsheets, or in the time-series database. Assumed scaling limits (column 6) are introduced in the Sensitivity Analysis Section.

Table 1. Inputs Adjusted During Sensitivity Analysis

Input Description	**Abbreviation**	**Num**	**Model Variable(s) to Adjust**	**Location in Model Files**	**Assumed Scaling Factor Limits**
INFLOWS					
Inflow to Shasta	InflowShasta	1	I4	SV.dss database file	+/- 5%
Inflow to Lake Oroville	InflowFeather	2	I6	SV.dss database file	+/- 5%
Yuba River outflow	OutflowYubaBear	3	I230, I285, I282	SV.dss database file	+/- 5%
Inflow to Folsom Reservoir	InflowFolsom	4	I300, I8, I9, I302	SV.dss database file	+/- 5%
Inflow to Trinity Lake	InflowTrinity	5	I1	SV.dss database file	+/- 5%
Inflow to Millerton Lake	InflowMillerton	6	I18	SV.dss database file	+/- 5%
Inflow to Lake McClure	InflowMerced	7	I20	SV.dss database file	+/- 5%
Inflow to New Don Pedro Reservoir	InflowTuol	8	I81	SV.dss database file	+/- 5%
Inflow to New Melones Reservoir	InflowStan	9	I10	SV.dss database file	+/- 5%
Local Sac Basin Inflows not adjusted in other Scenarios and not affiliated with demand area hydrology	InflowSac	10	I108, I110, I11301, I11305, I40, I41, I42, I180, I182, I184	SV.dss database file	+/- 10%
NORTH OF DELTA DEMANDS					
Crop Evapotranspiration, resulting in Projected Depletion of Applied Water for DSA's 58, 65, 69, 70	DSA_ET	11	CU Model Inputs for DSA's 58/65/69/70	CU Model / spreadsheets / SV	+/- 10%
Loss Factors in DSA's 58, 65, 69, 70	DSA_Losses	12	CU Model Inputs for DSA's 58/65/69/70, nrl_58, nrl_65, nrl_69, nrl_70	CU Model / spreadsheets / SV	+/- 20%, +/- 50%
Basin Efficiency	DSA_Eff	13	Timeseries input to CU Model DSA's 58/65/69/70	CU Model / spreadsheets / SV	+/- 10%
Deep Percolation of Applied Water	DSA_Dperc	14	"Alpha_##" factor entered in column E of the cu model post-processing spreadsheets	cu model post processing spreadsheet	+/- 5%
Consumptive Use of Applied Water in Colusa Basin WBA's	CB_CUAW	15	cuaw_17101, cuaw_17201, cuaw_11302, cuaw_11306, cuaw_17302P, cuaw_17302NP, cuaw_17401PAG, cuaw_17401NP, cuaw_17801PAG, cuaw_17801NP, cuaw_14301GCID, cuaw_14301NP,	SV.dss database file	+/- 10%

Input Description	Abbreviation	Num	Model Variable(s) to Adjust	Location in Model Files	Assumed Scaling Factor Limits
			cuaw_14301SC, cuaw_14501GCID, cuaw_14501NP, cuaw_14501SC, cuaw_18301SC, cuaw_18301NP, cuaw_131SC, cuaw_131NP		
Colusa Basin Non-Recoverable Loss Factors	CB_Losses	16	nrl_58, nrl_65, nrl_69, nrl_70, nrlFact_17101, nrlFact_17201, nrlFact_11302, nrlFact_11306, nrlFact_17302P, nrlFact_17302NP, nrlFact_17401, nrlFact_17801, nrlFact_14301, nrlFact_14501, nrlFact_18301, nrlFact_131	NRL column in the CB_Factors.table	+/- 20%
Colusa Basin On Farm Efficiency and Reuse Factors	CB_Eff	17	OnFarmEff_17101, OnFarmEff_17201, OnFarmEff_11302, OnFarmEff_11306, OnFarmEff_17302P, OnFarmEff_17302NP, OnFarmEff_17401, OnFarmEff_17801, OnFarmEff_14301, OnFarmEff_14301NP, OnFarmEff_14501, OnFarmEff_14501GCID, OnFarmEff_14501NP, OnFarmEff_18301, OnFarmEff_18301NP, OnFarmEff_131, OnFarmEff_131NP	OnFarmEff and Reuse columns in the CB_Factors.table	+/- 10%

Input Description	**Abbreviation**	**Num**	**Model Variable(s) to Adjust**	**Location in Model Files**	**Assumed Scaling Factor Limits**
Colusa Basin Deep Perc Factors	CB_Dperc	18	DpercFact_17101, DpercFact_17201, DpercFact_11302, DpercFact_11306, DpercFact_17302P, DpercFact_17302NP, DpercFact_17401, DpercFact_17801, DpercFact_14301, DpercFact_14301NP, DpercFact_14501, DpercFact_14501NP, DpercFact_18301, DpercFact_18301NP, DpercFact_131, DpercFact_131NP	Dperc column in the CB_Factors.table	+/- 5%
Minimum GW Pumping	MinGW	19	minpump_17101, minpump_17201, minpump_11302, minpump_11306, minpump_17302P, minpump_17401, minpump_17801, minpump_14301SC, minpump_14301GCID, minpump_14501SC, minpump_14501GCID, minpump_18301SC, minpump_131SC, minpump_131NP, mingw_58, mingw_65, mingw_69, mingw_70	SV.dss database file	+/- 10%, +/- 20%
Rice Decomp Demand	RDCMP	20	rdcmp_14301_GCID, rdcmp_14301_SC, rdcmp_14301_NP, rdcmp_14501_GCID, rdcmp_14501_SC, rdcmp_14501_NP, dcmp_18301_SC, rdcmp_18301_NP, rdcmp_131_SC, rdcmp_131_NP, rdrf_181A_GCID, rdrf_181A_SC, rdrf_181A_NP, rdrf_184A_GCID, rdrf_184A_SC, rdrf_184A_NP, rdrf_WBA8S_SC, rdrf_WBA8S_NP,	SV.dss database file	+/- 10%

Input Description	Abbreviation	Num	Model Variable(s) to Adjust	Location in Model Files	Assumed Scaling Factor Limits
			rdrf_160_SC, rdrf_160_NP		
DELTA WATER QUALITY					
WQ standard at Rock Slough	ANN_reqs	21	multiplier RS_scale for RSReqSac	scale.table	+/- 10%, +/- 20%
WQ standard at Jersey Point	ANN_reqs	22	multiplier JP_scale for JPReqSac	scale.table	+/- 10%, +/- 20%
WQ standard at Emmaton	ANN_reqs	23	multiplier EM_scale for EMReqSac	scale.table	+/- 10%, +/- 20%
WQ standard at Collinsville	ANN_reqs	24	multiplier CO_scale for COReqSac	scale.table	+/- 10%, +/- 20%
WQ standard for X2 isohaline	X2_reqs	25	multiplier cnf_scale for DO_req_X2cnf	scale.table	+/- 5%, +/- 10%
WQ standard for X2 isohaline	X2_reqs	26	multiplier chs_scale for DO_req_X2chs	scale.table	+/- 5%, +/- 10%
WQ standard for X2 isohaline	X2_reqs	27	multiplier roe_scale for DO_req_X2roe	scale.table	+/- 5%, +/- 10%

Outputs

The analysis considered several types of outputs (i.e. CalSim-II decision variables, Table 2) grouped by model function – storage, channel flow, delta operations, delivery operations, groundwater pumping, and return flow. Scenario results were stored for each output variable listed in Table 2. Sensitivity analysis was performed on the variables for which a “yes” is indicated in column 3. Groundwater pumping and return flow outputs in all north of delta demand areas were analyzed collectively.

Different analysis metrics were examined depending on the type of output variable. Flow-related variables (i.e. river flows, deliveries, depletions, reservoir releases) were processed to derive a period-average annual or monthly flow volume. Storage outputs were presented in terms of period-average end-of-month volumes.

Eight separate averaging periods were considered for all metrics:

- WY1922-2003 (simulation period),
- WY1928-1934 (early drought),
- WY1987-1992 (late drought),
- Sacramento 40-30-30 Wet years,
- Sacramento 40-30-30 Above Normal years,
- Sacramento 40-30-30 Below Normal years,

- Sacramento 40-30-30 Dry years, and
- Sacramento 40-30-30 Critical years

Sensitivity Analysis

Sensitivity analysis procedures were implemented in a manner consistent with those in the two previous studies mentioned above. A uniform input parameter type adjustment was applied to the model for the entire simulation period, and the effect on output response was scrutinized. No variation in adjustment was made for wetter or drier year types, and no basis was considered for making additional adjustments for particular years. Each input parameter type adjustment was made independently to determine its individual effect on output.

Input parameters were adjusted by multiplying the base input value(s) by a scaling factor as shown in the following formulae.

adjusted base value = original base value * (1.0 + scaling factor)

In the above example, the scaling factor is associated with input types in Table 1, column 6, expressed as percentage changes from base in both positive and negative directions. The scaling factors were chosen so that adjusted inputs represent the assumed limit of variation in the input's full-period average value. The sensitivity analysis compares results from three modeling scenarios for each input listed in Table 1:

- simulation using unadjusted input,
- simulation with the input set at its inflated limit using the positive scaling factor,
- simulation with the input set at its deflated limit using the negative scaling factor.

For each input row in Table 1, the input variables listed in the fourth column were scaled as a group, positively or negatively according to the scaling factor limits in the sixth column. In some cases two sets of scaling factor limits were used to examine sensitivity at different levels of input adjustment. Considering all levels of adjustment for each input type, the analysis included 72 sensitivity scenarios and one base model simulation.

Output performance metrics – average annual and/or monthly flows or average end-of-month storage – were computed for the variables identified for analysis in Table 2 (column 3). Metrics were computed for each of the averaging periods mentioned in Section B.2.2 (e.g., WY1922-2003, WY1928-1934, WY1987-1992, and the Sacramento 40-30-30 Index year-type groups). Changes in performance metrics were then identified, representing performance sensitivity to the given input adjustment.

Input types and the assumptions about their scaling factor limits are discussed in the following sections.

Assumptions – Reservoir Inflows and Local Accretions

(Table 1 1, inputs 1-10) Rim flows generally are the inflows into the reservoirs or river confluences that mark the upstream boundaries of the CalSim-II model. The sources of these inflows are a combination of upstream water budget analyses (other models) and calculations based on recorded data. These inputs were considered with the goal of understanding how potential long-term bias in the assumed system inflows would affect simulated operations.

The SJR sensitivity analysis used a scaling factor of 3% for the SJR tributary inflows, based on indications that the potential bias for major reservoir inflow data in the basin was 1% or 2%. The DWR sensitivity analysis used a scaling factor of 5%, based on discussions with data development staff. The current study has implemented scaling factors of +/- 5% for all inflow inputs, repeating the adjustment used in the DWR study for the Sacramento Basin inflows, and imposing an additional level of conservative bias for the SJR inflows.

Assumptions – DSA Demands and Hydrology

(Table 1, Inputs 11-14) CalSim-II inputs for diversion requirements and local inflows are calculated for depletion service areas 58, 65, 69, and 70 using DWR's Consumptive Use Model. These CalSim-II input time series' cannot be adjusted independently. The approach taken by the sensitivity analysis for these variables was to apply scaling factors to the CU model inputs, run the CU model with the adjusted inputs, process CU model results into new CALSIM II input values, and then run CalSim-II with the adjusted inputs. Adjustments were made to CU model inputs for crop evapo-transpiration, non-recoverable losses, basin efficiency, and deep percolation according to the scaling factors given in Table 1.

The scaling factors applied to these inputs were based on those used in the 2005 DWR sensitivity study.

Assumptions – Colusa Basin Demands and Hydrology

(Table 1, Inputs 15-18) Demands and hydrology in the Colusa Basin (DSA's 10, 12, and 15) are modeled directly in CalSim-II – not pre-processed by CU models as for the other DSA's. Inputs for consumptive use of applied water, non-recoverable loss factors, basin efficiency, and deep percolation were each modified separately by the scaling factors in Table 1. Scaling factors were the same as those used for the equivalent input variables in the DSA's.

Assumptions – Minimum North of Delta Groundwater Pumping

(Table 1, Input 19) A minimum level of groundwater pumping is the first source of water supply for meeting demands in DSA's 58, 65, 69, and 70, and in Colusa basin areas east of the Sacramento River. Adjustments to these inputs would have an impact on surface water requirements to meet demands. Scaling factors of +/- 10% were used in the DWR study; here scaling factor limits of both +/- 10% and +/- 20% were used to test relative sensitivity at additional levels of potential bias.

Assumptions – Rice Decomposition Demands and Returns

(Table 1, Input 20) Deliveries for rice decomposition are made in the fall, with associated returns back to the system in winter. The demands and return flows are input to CalSim-II as timeseries. These inputs were scaled together under the assumption that an adjustment to the delivery of rice decomposition water would result in a commensurate adjustment in return flow. Given lack of uncertainty information, scaling factor limits were subjectively set to +/- 10%.

Assumptions – Delta Water Quality Standards

(Table 1, Inputs 21-27) Delta water quality and flow standards in CalSim-II are those required by the 1995 SWRCB Water Quality Control Plan. As with the 2005 DWR study, minimum salinity flow requirements based on the Artificial Neural Network model and X2 flow requirements are analyzed for sensitivity. ANN flow estimates for WQ compliance at four locations – Collinsville, Contra Costa Canal Intake, Emmaton, and Jersey Point – were scaled by +/- 10% and by +/- 20% for each individual station. Flow requirements for maintenance of the X2 standards at Roe Island, Chipps Island, and the Sacramento/San Joaquin Confluence were scaled individually by +/- 5% and by +/- 10%.

Table 2. Output Retained from each Scenario's Simulation

CalSim-II Variable	Description	Analyzed?
	STORAGE	
S10	Storage - New Melones - Stanislaus	yes
S81	Storage - New Don Pedro - Tuolumne	yes
S20	Storage - Lake McClure - Merced	yes
S53	Storage - Eastman Lake - Chowchilla	yes
S52	Storage - Hensley Lake - Fresno	yes
S18	Storage - Millerton Lake - San Joaquin	yes
S1	Storage - Trinity Lake	yes
S4	Storage - Shasta Lake	yes
S6	Storage - Oroville Reservoir	yes
S8	Storage - Folsom Reservoir	yes
S11	Storage - CVP San Luis	yes
S12	Storage - SWP San Luis	yes
	FLOWS	
C3	Clear Creek Flow	
C5	Keswick Flow	yes
C129	Navigation Control Point Flow	yes
C169	Freeport Flow	yes
C203	Oroville Release	yes
C223	Feather River at the Mouth	yes
C9	Nimbus Release	yes
C303	American River at the Mouth	yes
C400	Flow at Hood	
OMR_dwr	Delta flow at Old and Middle Rivers - DWR calculation	yes
OMR_usgsA	Delta flow at Old and Middle Rivers - USGSa calculation	yes
OMR_usgsB	Delta flow at Old and Middle Rivers - USGSb calculation	yes
OMR_ave	Delta flow at Old and Middle Rivers - average of DWR and USGSa calculation	yes
OMR_ph	Delta flow at Old and Middle Rivers - Paul Hutton calculation	yes
	DELTA OUTFLOW, EXPORT, AND OPERATING CRITERIA	
D407	Required Delta Outflow	yes

CalSim-II Variable	Description	Analyzed?
C407	Additional Delta Outflow (Surplus and Carriage Water)	yes
C407_CVP	Additional Delta Outflow - CVP share	
C407_SWP	Additional Delta Outflow - SWP share	
C407_WHLCV	Additional Delta Outflow - Wheeling Carriage Water	
C407_ANN	Additional Delta Outflow - ANN	
DeltaSurplusDV	True Delta Surplus	yes
D419	Banks Pumping	
D419_SWP	Banks Pumping for SWP	yes
D419_CVP	Banks Pumping for CVP	yes
D418	Jones Pumping	yes
UNUSED_FS	Unused Federal Share	
UNUSED_SS	Unused State Share	
UWFE	Unstored Water for Export	
IBU	In Basin Use of Storage Withdrawal	
MRDO_FINAL_OUT	Overall Delta Outflow Requirement	yes
DO_REQ_COL1_OUT	DO Req't to meet WQ standard Collinsville	
DO_REQ_COL2_OUT	DO Req't to meet WQ standard Collinsville	
DO_REQ_EMT1_OUT	DO Req't to meet WQ standard Emmaton	
DO_REQ_EMT2_OUT	DO Req't to meet WQ standard Emmaton	
DO_REQ_JPT1_OUT	DO Req't to meet WQ standard Jersey Point	
DO_REQ_JPT2_OUT	DO Req't to meet WQ standard Jersey Point	
DO_REQ_RSL1_OUT	DO Req't to meet WQ standard Rock Slough	
DO_REQ_RSL2_OUT	DO Req't to meet WQ standard Rock Slough	
DO_REQ_X2CHS_OUT	DO Req't to meet X2 standard at Chipps Island	
DO_REQ_X2CNF_OUT	DO Req't to meet X2 standard at Confluence	
DO_REQ_X2ROE_OUT	DO Req't to meet X2 standard at Roe Island	
DELIVERY OPERATIONS		
DEL_CVP_TOTAL	Total CVP Delivery	
DEL_CVP_TOTAL_N	Total CVP NOD Delivery	yes
DEL_CVP_TOTAL_S	Total CVP SOD Delivery	yes
DEL_SWP_TOTAL	Total SWP Delivery	
DEL_SWP_TOT_N	Total SWP NOD Delivery	yes
DEL_SWP_TOT_S	Total SWP SOD Delivery	yes
CVPTOTALDEL	CVP Total Delivery	
SWPTOTALDEL	SWP Total Delivery	
SHORT_CVP_TOT_N	CVP Shortage NOD	
SHORT_CVP_TOT_S	CVP Shortage SOD	
SHORT_SWP_TOT_N	SWP Shortage NOD	
SHORT_SWP_TOT_S	SWP Shortage SOD	
DELTAR_CVP_SYSDV	CVP Overall Delivery Target	
DELTAR_CVP_SDV	CVP SOD Delivery Target	
DELTAR_SWPDV	SWP Delivery Target	
GROUNDWATER PUMPING		
GP60	DSA 58 GW pumping	yes - total gw
GP61	DSA 10 GW pumping	yes - total gw
GP62	DSA 12 GW pumping	yes - total gw
GP63	DSA 15 GW pumping	yes - total gw
GP64	DSA 65 GW pumping	yes - total gw

CalSim-II Variable	Description	Analyzed?
GP65	DSA 69 GW pumping	yes - total gw
GP66	DSA 70 GW pumping	yes - total gw
GP11302	WBA4@SR groundwater pumping	yes - total gw
GP11306	WBA5 groundwater pumping	yes - total gw
GP14301	WBA8NN groundwater pumping	yes - total gw
GP14302	Sacramento Refuge groundwater pumping	yes - total gw
GP14501	WBA8NS groundwater pumping	yes - total gw
GP17401	WBA7N groundwater pumping	yes - total gw
GP17302	WBA6 groundwater pumping	yes - total gw
GP17801	WBA7N groundwater pumping	yes - total gw
GP17101	Corning groundwater pumping	yes - total gw
GP17201	WBA4@TCC groundwater pumping	yes - total gw
GP18201	Deleavan and Colusa Refuges groundwater pumping	yes - total gw
GP18301	WBA8S groundwater pumping	yes - total gw
GP131	DSA15 groundwater pumping	yes - total gw
	RETURN FLOWS	
R109	DSA58 Return Flow	yes - total rf
R113	Corning Return Flow	yes - total rf
R114A	WBA4@SR Return Flow	yes - total rf
R114B	WBA5 Return Flow	yes - total rf
R114C	WBA4@TCC Return Flow	yes - total rf
R181A	WBA8NN Return Flow	yes - total rf
R181B	Sacramento Refuge Return Flow	yes - total rf
R182A	WBA7N Return Flow	yes - total rf
R182B	WBA7S Return Flow	yes - total rf
R184A	WBA8NS Return Flow	yes - total rf
R184B	Delevan and Colusa Refuges Return Flow	yes - total rf
R160	DSA15 Return Flow	yes - total rf
R134	WBA8S Returns	yes - total rf
R18302	WBA8S Returns	yes - total rf
R156	DSA65 Returns	yes - total rf
R137	Sutter Refuge Returns	yes - total rf
R135A	Gray Lodge	yes - total rf
R135B	Butte Sink Duck Clubs	yes - total rf
R223	DSA69 Returns	yes - total rf
R169	DSA70 Returns	yes - total rf

Uncertainty Analysis

The uncertainty analysis for the full CalSim-II model followed the same methodology used for the 2006 SJR model uncertainty analysis. The key framing assumptions remain unchanged, and they are:

- representation of input uncertainties was constrained to potential long-term input bias, defined as base input value times a scaling factor (i.e. 1.0 + "Table 1, column 6" percentages expressed as fractions)
- each input's scaling factor is a uniformly distributed random value bounded by the input's assumed limits of variation
- each input's scaling factor can take on any value within its distribution, independent of the other inputs' scaling factor values.

A matrix of scaling factors was developed with a row for each scenario and a column for each input type. A random number with a uniform distribution between 0 and 1 was applied to the range of scaling factors used for each input to compute the actual scaling factor used in each scenario. The computation can be written as:

*lower limit + [random number * (upper limit – lower limit)]*

For example, an inflow input subject to a 5% scaling factor would have an adjustment value computed as .95 + random # * (1.05-.95). Under these assumptions and with these scaling factors in place, the same Monte Carlo process applied to the 2006 SJR analysis was used, with the following distinguishing characteristics:

- 1,000 scenarios were generated, each representing a unique set of scaling factors for each of the inputs listed in Table 1. The number of scenarios was the subject of discussion in the 2006 SJR analysis, which discovered that the 10,000 scenarios performed in that effort were more than sufficient and suggested that 1,000 to 2,000 would have been enough. The far longer run times necessary for the full system model and its input pre-processing requirements also contributed to the decision to limit the analysis to 1,000 scenarios.
- input data sets were generated for each scenario according to the row of scaling factors. For each scenario, the same set of scaling factors was used for both the existing and future level models.
- each scenario was simulated in CalSim-II for both existing and future levels of development
- output performance metrics were computed for each scenario
- output results were pooled by variable and performance metric to reveal output uncertainty distributions as a function of collective inputs' uncertainty.

Uniform Distribution Assumption

As in the 2006 SJR study, the lack of information on how to vary input scaling factors within their limits of variation suggests that the use of a uniform distribution is conservative and reasonable. When equal probability is assigned to any scaling factor within the range of variability, it the output uncertainty in the Monte Carlo analysis is maximized.

Assumptions on Inputs' Independence

Input scaling factor distributions were treated as mutually exclusive. The rationale for this approach and its implications are discussed below for each input type. In that the fundamental purpose of the analysis is to examine overall model results uncertainty within a range of input uncertainty, this approach seems satisfactory.

- **Reservoir Inflow:** These inputs are not dependent on downstream assumptions. With base values developed from historical input data or additional models, their interdependence on each other is unlikely.
- **DSA and Colusa Basin Demand Area Inputs:** The base demands have been developed from land-use projections for a given level of development, historical climate and hydrology data, and assumptions about land-use practices. While these may include logical dependencies (i.e under increased ET rates, efforts might be made to increase, rather than decrease, efficiency), it is proposed that this type of analysis would be better performed under specific assumptions about these relationships as part of a separate study.
- **Minimum Groundwater Pumping:** These mainly represent district supply management practices and are not dependent on other assumptions. Of the 20 groundwater pumping locations in the basin that are varied, many may be independent of each other. This would be an opportunity for future study.
- **Rice Decomposition Demands:** these demands are not dependent on upstream or downstream assumptions. It is understood that this input variation reflects uncertainty about the water requirement for rice decomposition and rice acreage.
- **Delta Water Quality Demands:** The flows required to meet water quality standards at specific locations are not dependent on upstream assumptions. While they are likely to be dependent on eachother (i.e. a reduction in flow required to meet the X2 standard at Roe Island would not be coincident with an increase in flow required to meet the standard at the Confluence), this is not an issue due to how the scaling factors are applied in the model. Only one water quality standard or X2 location controls the delta outflow requirement in a particular time step, and it is this value to which the scaling factor is applied. The other scaling factors are not effective in that time step. Under these conditions, it is reasonable to assign scaling factors as done here.

Computational Issues and Automation Tools

This study borrowed substantially from the computational methods developed for the 2006 SJR analysis. The challenges of developing 72 input data sets for sensitivity scenarios and 1,000 input data sets for uncertainty scenarios were minimized by adapting existing MatLab scripts. Likewise, scripts for producing output plots and tables were simply modified for a new number of scenarios, new input variations, and new output variable sets.

With automated computing methods already established for handling multiple scenario runs with scenario-driven load-closure recalculation, new modules for handling CU model runs and WSI-

DI retraining were straightforward additions. Running each scenario at both existing and future levels of development added a few additional steps to the process. For each sensitivity or uncertainty scenario, the process can be outlined as below:

- Adjust *existing condition study* input for the scenario. If this scenario includes an adjustment to DSA input data, make these adjustments to the *existing condition* CU model input files, run the CU models, and use post-processing spreadsheets to develop new input time series.
- Adjust the appropriate delta/export index tables and swp delivery pattern tables, and run the *existing condition model* in wsi-di curve training mode to develop new wsi-di curves for the modified input conditions.
- Replace the appropriate tables and run the *existing condition model* with the new wsi-di curves.
- Use perdv and X2_prv solutions from the *existing condition model* output as input to the San Joaquin water quality calibration process.
- Write new SJR salt load residuals to *both* the existing and future condition SV files.
- Re-run the *existing condition model* with the newly calibrated residuals.
- Adjust *future condition study* input for the scenario. If this scenario includes an adjustment to DSA input data, make these adjustments to the *future condition* CU model input files, run the CU models, and use post-processing spreadsheets to develop new input time series.
- Adjust the appropriate delta/export index tables and swp delivery pattern tables, and run the *future condition model* in wsi-di curve training mode to develop new wsi-di curves for the modified input conditions.
- Replace the appropriate tables and run the *future condition model* with the new wsi-di curves.
- Extract desired output from both existing and future model output files and save in comma separated value format for later processing.

Results

Sensitivity Results

Results Presentation

A standard graphic (example shown in Figure 1) was produced to show period-specific change in output for each input adjustment. Each figure summarizes performance sensitivities for two to five output variables relative to all scoped inputs. The 36 adjustments to input values are labeled along the vertical axis. The left panel shows output response to positive input scaling (inflated input). The right panel shows output response to negative input scaling (deflated input). The Figure 1 example shows three reservoir storage responses (at Trinity, Shasta, and Oroville). Following each variable’s line vertically among the inputs reveals which inputs are relatively more influential on that output’s performance (indicated by greater departure from zero). Specifically for Figure 1, we can see that the most influential inputs acting on end of year Shasta storage (the green line) are Shasta inflow, other Sacramento basin inflows, Colusa Basin demand area efficiency, and water quality at Jersey Point.

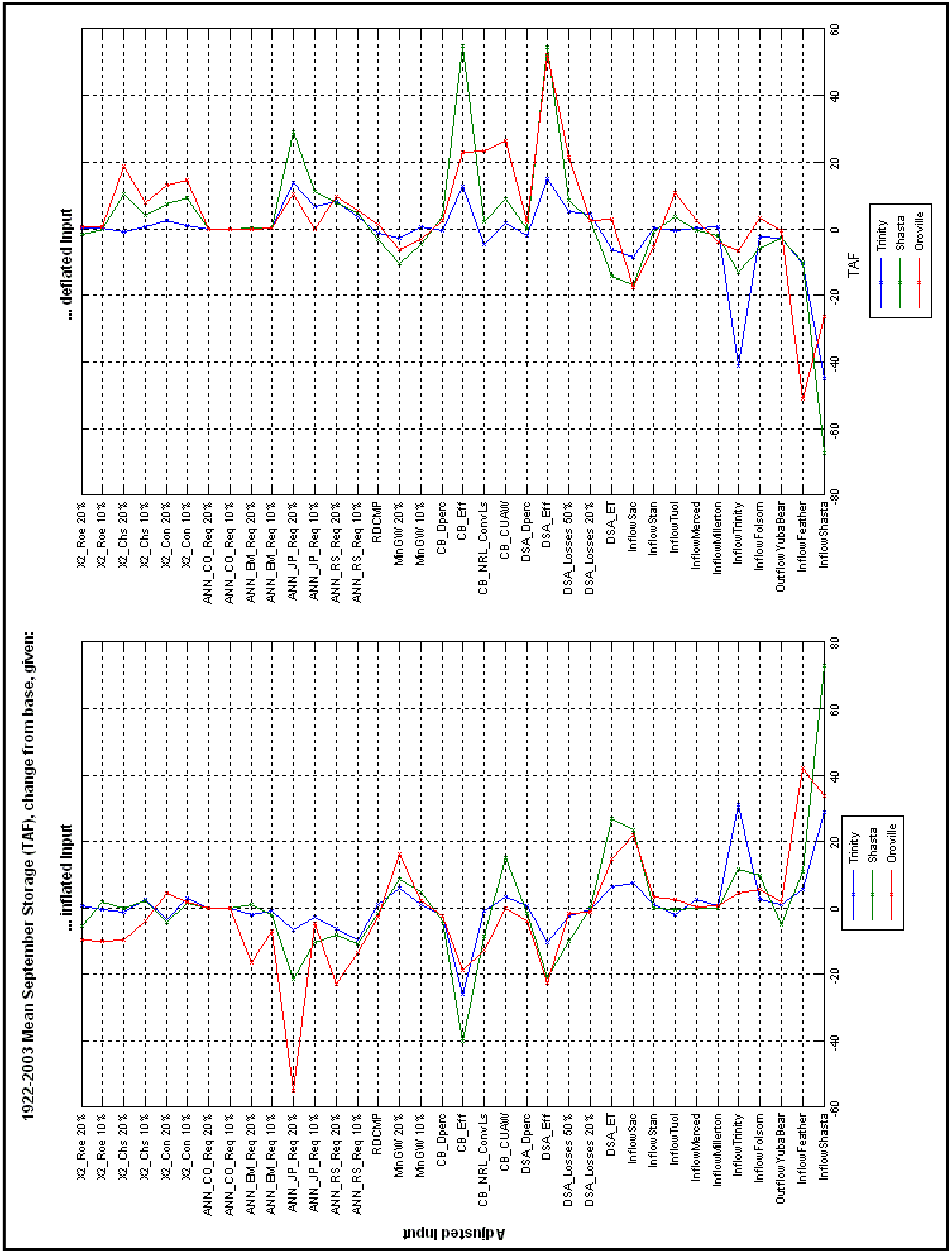

Figure 1. Sensitivity Analysis standard graphic showing multiple variable response for a single metric and averaging period

Knowledge of CVP/SWP operations is important in the interpretation of results. For instance, while it might be counter-intuitive to consider that an increase in delivery area efficiency would result in lower storage, the reality is that lower Settlement Contractor deliveries under the higher efficiencies allow greater allocations to project demands and exports and in turn cause the additional draw on reservoir storage. This is also an opportunity to mention that no calibration is done for each of the scenarios beyond training the wsi-di curves, so while the changes in output indicate sensitivity to particular inputs, the results do not necessarily convey precise changes to operations that would be prompted by the input change.

In addition to the graphical figures, a table of performance sensitivity intervals was produced for each output variable inTable 2, column 3. Tables of mean annual total flows were produced for flow variables, and tables of mean end-of-September values were produced for storage variables. Table 3 shows an example for Shasta Storage. The tables include a header describing measured output (e.g., variable, description, metric, units, averaging period, and metric’s base value by averaging period). Below that is a section on performance sensitivity intervals related to changes in all inputs for all averaging periods.

Library of Results

A total of 395 standard graphics and 26 influence tables were produced for the existing and future models. They are provided on a CD accompanying this report, and will be available for review in an HTML Viewer in a future release.

Key Findings

From the enormous amount of information generated in the analysis, some central findings can be distilled by focusing on groups of output and which inputs can be seen as most influential across the group. The categories of output were:

- Storage – simulated storage in North of Delta Reservoirs and San Luis Reservoir, representing carried over stored water supply
- North of Delta reservoir releases – releases from Shasta/Trinity, Oroville, and Folsom
- North of Delta flows – river flows at Navigation Control Point and Freeport, flows at the mouths of the Feather and American Rivers, and total Sac Basin return flows and groundwater pumping.
- Delta Flows and Exports – minimum delta outflow, additional delta outflow, and exports at Jones and Banks pumping plants
- Deliveries – totals for CVP and SWP delivery north of the delta and in export service areas.

Table 3 Sensitivity Analysis standard influence table for a single output metric

SENSITIVITY SUMMARY

MEASURED OUTPUT

variable: S4

description: Storage - Shasta Lake

output metric: end-of-September mean

output metric units: TAF

sampling period:			1922-2003		1928-1934		1987-1992		SACyr-W		SACyr-AN		SACyr-BN		SACyr-D		SACyr-C	
output metric base value:			2786.3		1763.8		1889.1		3325.6		3161.6		2853.3		2530.8		1547.7	
			Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
ADJUSTED INPUT																		
Scaling Factors:	Max	Min	<-- corresponding to assumed limits of potential bias in base input data															
(see [1])																		
InflowShasta	1.05	0.95	73	-67.3	96.5	-266.4	210	-66.7	10.5	-10.4	37.4	-39.1	120.6	-66.3	100.8	-90.9	147.1	-184.6
InflowFeather	1.05	0.95	11.1	-10	-21.1	-78	53.8	7.6	-0.9	-0.3	8.9	-1.6	23.3	-5.1	14.9	-7.5	19.2	-48.9
OutflowYubaBear	1.05	0.95	-4.9	-2.7	-33.2	-27.3	-17.7	-30.5	0.2	-0.4	2.3	-0.9	-4.4	17.6	-5	-7.5	-23.8	-25.9
InflowFolsom	1.05	0.95	9.8	-5.8	18.3	-48.3	33.6	-34.6	2.1	-3.2	2.3	-3.3	10.4	12.3	14.1	-6.7	26.4	-33.8
InflowTrinity	1.05	0.95	11.9	-13.2	4.7	-118	30.6	-17.4	0.5	-0.5	8.3	-1.4	12.9	5.5	24.6	-14	19.8	-73.1
InflowMillerton	1.05	0.95	-0.3	-1.9	0.9	-9.3	0.9	0.3	-0.1	-1.2	-4.5	-0.4	1.9	-4.3	0.4	-4.9	0.1	2.1
InflowMerced	1.05	0.95	-0.2	-0.4	-9.1	-34.3	4.6	-1.7	-0.5	0.5	5	2	-0.9	16.9	-3.5	-3.4	1	-20.9
InflowTuol	1.05	0.95	-0.5	3.8	-32.7	-42.1	-23.3	34.7	-1	-2.4	2.8	2.1	21.9	27.4	-4.1	-0.4	-23.5	-1.8
InflowStan	1.05	0.95	-0.1	-1	-27.9	-2.7	2.1	5.1	0.1	-0.6	1.1	-0.4	15.9	-10.6	-0.8	1.6	-19.5	4.8
InflowSac	1.1	0.9	23.5	-16.9	16.5	-75	79.7	-15.4	3	-3.6	19.8	-10.7	39.6	-7.9	34.1	-23.8	37.1	-51.9
DSA_ET	1.1	0.9	26.9	-14.3	21.9	-57.1	102.9	-34.8	2.2	-2	-1.9	0.6	40	-1.1	39.4	-35.7	75.3	-39.3
DSA_Losses 20%	1.2	0.8	-0.2	2.4	-39.3	-6.1	58.5	7.6	-1.2	-0.1	-3.6	4.4	4.9	1.2	-2.3	1.8	2.2	8
DSA_Losses 50%	1.5	0.5	-9.9	8.5	-98.4	-6.5	8.1	-6.7	-1.8	0	-6.3	12.2	2.9	15.9	-20.4	20.8	-30.5	-3.6
DSA_Eff	1.1	0.9	-21	54.4	-118.3	126.7	22.6	157	-3.1	6.3	-14.8	21.8	-15.8	62.7	-33.4	85.3	-53.5	135.4
DSA_Dperc	1.05	0.95	-1.4	-0.1	-8.4	-35	13.9	-21.5	-0.4	0.3	-1.3	1.6	-6.6	21.9	-4.8	-2.1	7.3	-25.3
CB_CUAW	1.1	0.9	15.2	8.8	60	-46.9	149	-19.7	-5	9.5	-29.6	41.1	1.8	53.6	33.8	-21.5	91.3	-31.7
CB_NRL_ConvLs	1.2	0.8	-8.4	2.1	-66.8	-90.7	-5.5	37.8	-0.5	-0.8	-9.3	11.9	1.7	24.6	-9.2	-0.8	-35	-23.3
CB_Eff	1.1	0.9	-40.2	54.7	-170.1	135.8	-121.6	275.7	-0.5	0.6	12.2	-2.6	-8.7	47.5	-93.7	90	-134.8	184.7

	Max	Min	1922-2003		1928-1934		1987-1992		SACyr-W		SACyr-AN		SACyr-BN		SACyr-D		SACyr-C	
			Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
CB_Dperc	1.05	0.95	-3.9	3.5	-35.3	0.4	-24.3	60.7	0	-0.9	0.7	-0.3	7.1	-4.6	-5.7	5.7	-27	23.2
MinGW 10%	1.1	0.9	4.7	-4.8	1.4	-37.9	-8.9	10.4	1.4	-1.8	6.8	-5	5.9	1.3	11.4	-10.8	-1.9	-8.8
MinGW 20%	1.2	0.8	8.8	-10.5	-13.3	-60.1	-0.2	4.4	2.7	-1.7	14.9	-11.5	19.6	-7.9	16.5	-12.5	-8.1	-28.3
RDCMP	1.1	0.9	-1.6	-3.3	-4.1	-27	16.1	-18.2	-0.4	0.5	-1.4	2.2	-9.1	-2.9	-5.2	0.2	10	-23
ANN_RS_Req 10%	1.2	0.8	-10.7	5	-101.9	-57	-17.9	60.6	0.1	0.8	0.3	-3.4	10.8	18.8	-15.4	0.4	-63.1	13.1
ANN_RS_Req 20%	1.1	0.9	-8	7.9	-100.7	-52.3	29.3	84.5	0	0.6	-0.9	-6.6	7.1	21	-8.8	5.9	-49.1	25.5
ANN_JP_Req 10%	1.2	0.8	-10.4	11.3	-69.6	-69.5	17.9	34.3	1	3.7	-11.5	13.3	-3.9	37.3	-17.8	22	-30.5	-21
ANN_JP_Req 20%	1.1	0.9	-21.5	28.9	-115	-64.9	-6.1	72.8	0.7	6.8	-25.2	38.1	-10.3	104.9	-40.2	22.4	-51.2	-10.9
ANN_EM_Req 10%	1.2	0.8	-1.8	0.4	-48.5	0.6	11.8	-0.2	0.4	0	-0.5	0.2	13.7	0.1	0.6	0.2	-29.9	2.2
ANN_EM_Req 20%	1.1	0.9	1.2	0.4	-48.3	0.6	10.5	0.1	-0.6	0	-0.7	0.2	23.8	-0.1	-1.7	-0.2	-15.2	2.5
ANN_CO_Req 10%	1.1	0.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ANN_CO_Req 20%	1.1	0.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
X2_Con 10%	1.1	0.9	1.5	9.5	-48.3	11.9	10.8	65.3	0.3	0.4	-2.3	2.1	20.5	10	-1.6	8.4	-9.7	37.6
X2_Con 20%	1	0.95	-4.4	7.3	-89.1	29.7	3.9	48.2	0.6	0	-6.2	2.7	15.8	0.9	-5.7	11.9	-35	28
X2_Chs 10%	1	0.9	2.1	4.2	-34.3	-20.9	50.2	8.5	0.1	-0.1	1.4	-0.8	13	20.4	-5	5.2	5.3	-1.8
X2_Chs 20%	1	0.8	-0.2	10.5	-54.3	-13.2	32	34.3	0.4	0.1	-1.1	1.6	13.8	33.9	-1	13.1	-15.8	10.6
X2_Roe 10%	1.1	0.9	1.9	-0.2	-15	-45.2	52.3	-0.5	0.5	0.3	-2.2	2.9	-9.4	8.8	6.7	1.6	14.8	-17.8
X2_Roe 20%	1.1	1	-5.3	-1.5	-69.3	-46.8	13.4	-2.6	0.5	0.3	-3.9	3.1	3.8	6	-6.8	1.7	-27.8	-23.8

[1] Reclamation 2008. "Sensitivity Analysis for OCAP Standalone D1641"

For each individual output variable, the most influential input on that variable was identified as the one which caused the greatest change in output value. For each output category (group) as described above, the frequency of each input being the most influential was tallied. This exercise was carried out for the overall period and for the set of Wet years and the set of Critical years. Results were plotted on histograms which are displayed in Figures 2-4 respectively. A review of these figures yields the following observations:

- System storage is most influenced by upstream inflows, Colusa Basin efficiency, and by the higher (20%) adjustments to flow requirements to meet delta water quality standards.
- Storage releases are most affected by upstream inflows.
- In-basin flow locations are most influenced by upstream inflows and by demand area efficiencies, with inflows playing an enlarged role in wetter years and demand area parameters controlling more in dry years.
- Delta outflows and exports are most influenced by the higher adjustments to delta water quality flows. Of the X2 standards, Chipps Island is most influential overall, while Roe Island controls more in wet years and the Confluence standard controls more in critically dry years. The WQCP standard at Rock Slough exerts particular influence in dry years. Colusa Basin CUAW is also an influential element for delta variables.
- Deliveries in all year types are most affected by adjustments to demand area evapo-transpiration and efficiency inputs.

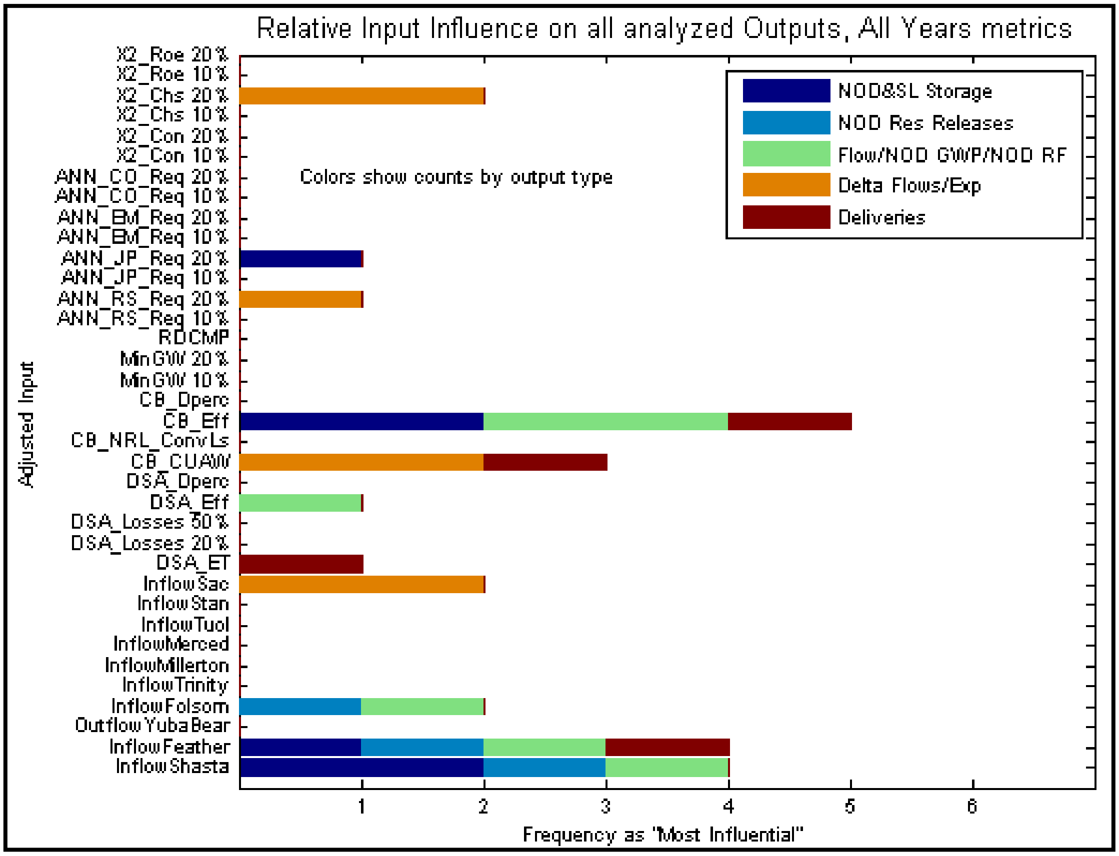

Figure 2. Inputs' Frequent as "Most Influential" on all analyzed outputs, focusing on metrics representing ALL Years

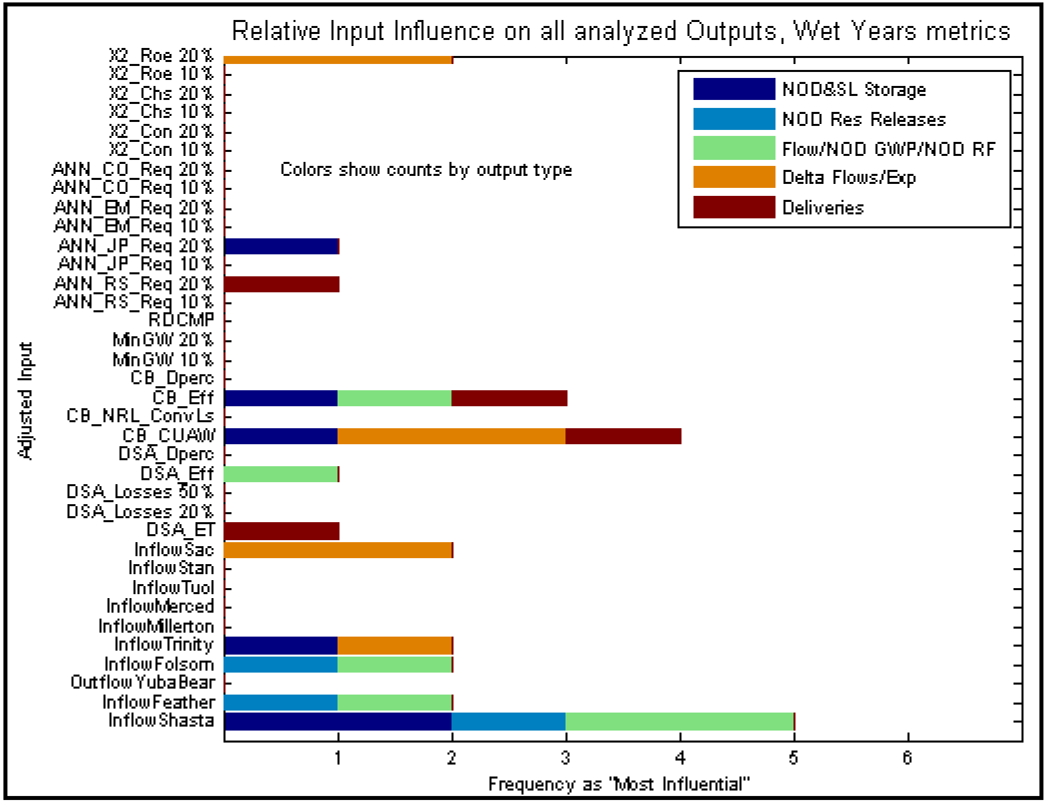

Figure 3. Inputs' Frequent as "Most Influential" on all analyzed outputs, focusing on metrics representing WET Years

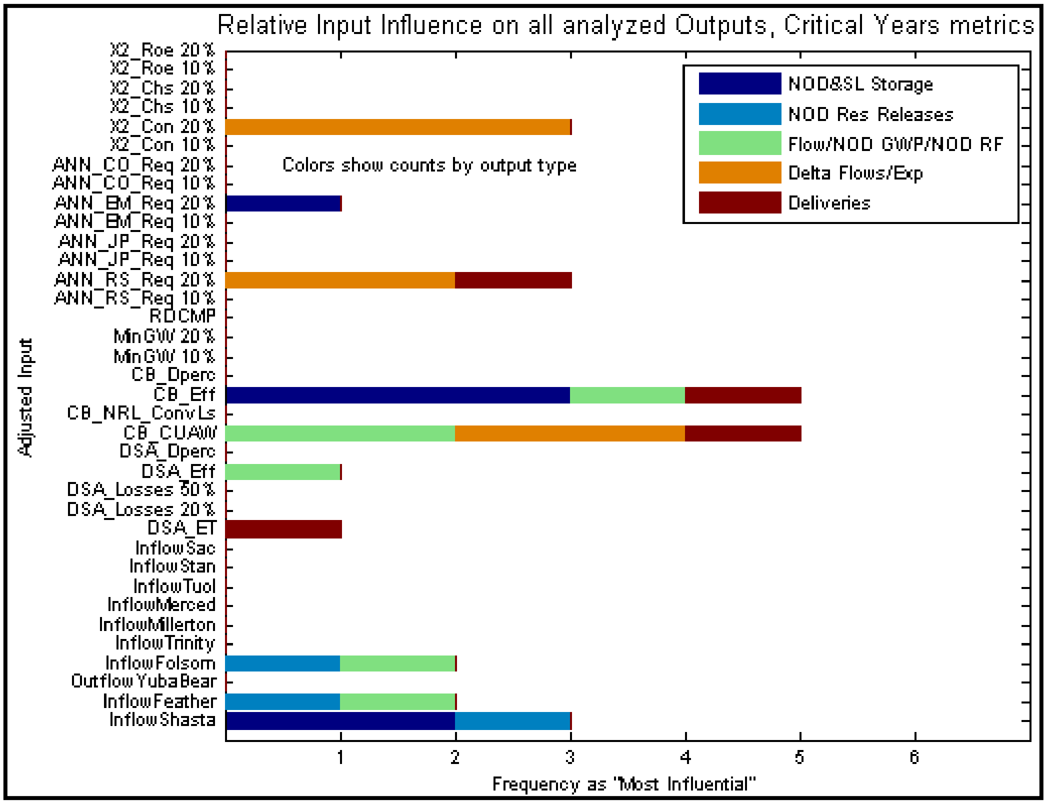

Figure 4. Inputs' Frequent as "Most Influential" on all analyzed outputs, focusing on metrics representing CRITICAL Years

Uncertainty Results

Results Presentation

As mentioned earlier, the output display methods used in the 2006 SJR study were adopted wholesale for the full system study. The descriptions of the output graphics are thus reproduced here from the 2006 document with little editing.

A set of graphics were produced for each of the outputs marked for analysis in Table 2. Each graphic type illustrates uncertainty in a unique way:

- **Type (1) Time-Evolving Uncertainty, Absolute Results:** The purpose of this graphic was to show the base model's time series results, and an overlay of uncertainty showing how it evolves during the simulation (e.g., Figure 5). The overlay of uncertainty results includes 1,000 scenario-specific time series, as analyzed in the Monte Carlo procedure. For flow-related variables, the graphic shows an annual sum time series. For storage variables, the graphic shows a monthly time series.

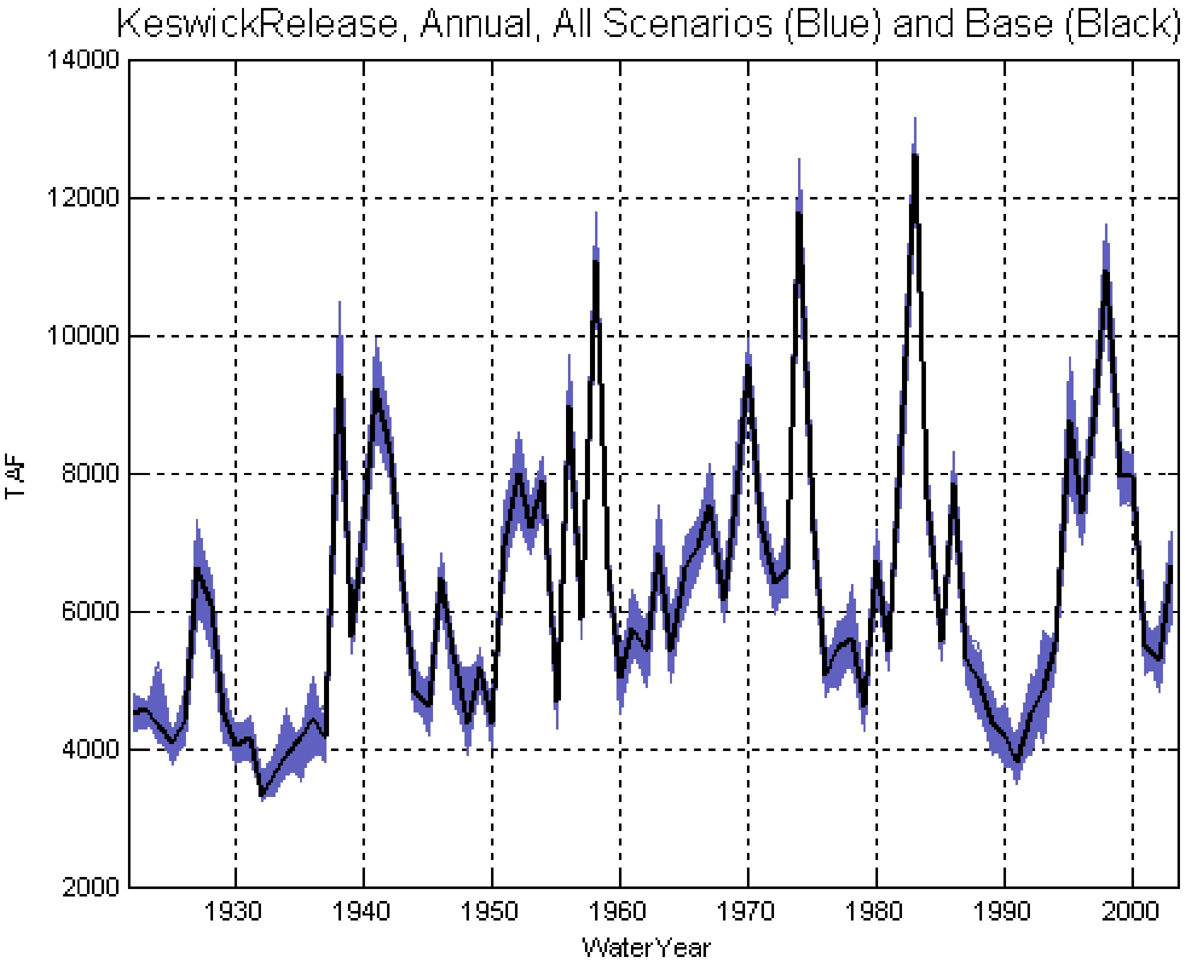

Figure 5. Standard Uncertainty Graphic: Time-evolving uncertainty, absolute results

- **Type (2) Time Evolving Uncertainty Intervals, Changes from Base:** The purpose of this graphic was to show time-changing intervals information embedded in the uncertainty band illustrated in graphic Type (1). First, a WY1922-2003 “difference” time series (scenario minus base) was computed for each of the 1,000 scenarios. Then at each stage in the time series, the ensemble of 1,000 difference values was sorted and sampled at threshold exceedence probabilities (Figure 6). Threshold exceedence probabilities are selected to show a median scenario minus base, 50% uncertainty interval (75% to 25% exceedence), 80% uncertainty interval (90% to 10% exceedence), and full range of uncertainty (mininmum to maximum differences). As with Type (1), for flow-related variables the graphic shows an annual sum time series. For storage variables, the graphic shows a monthly time series.

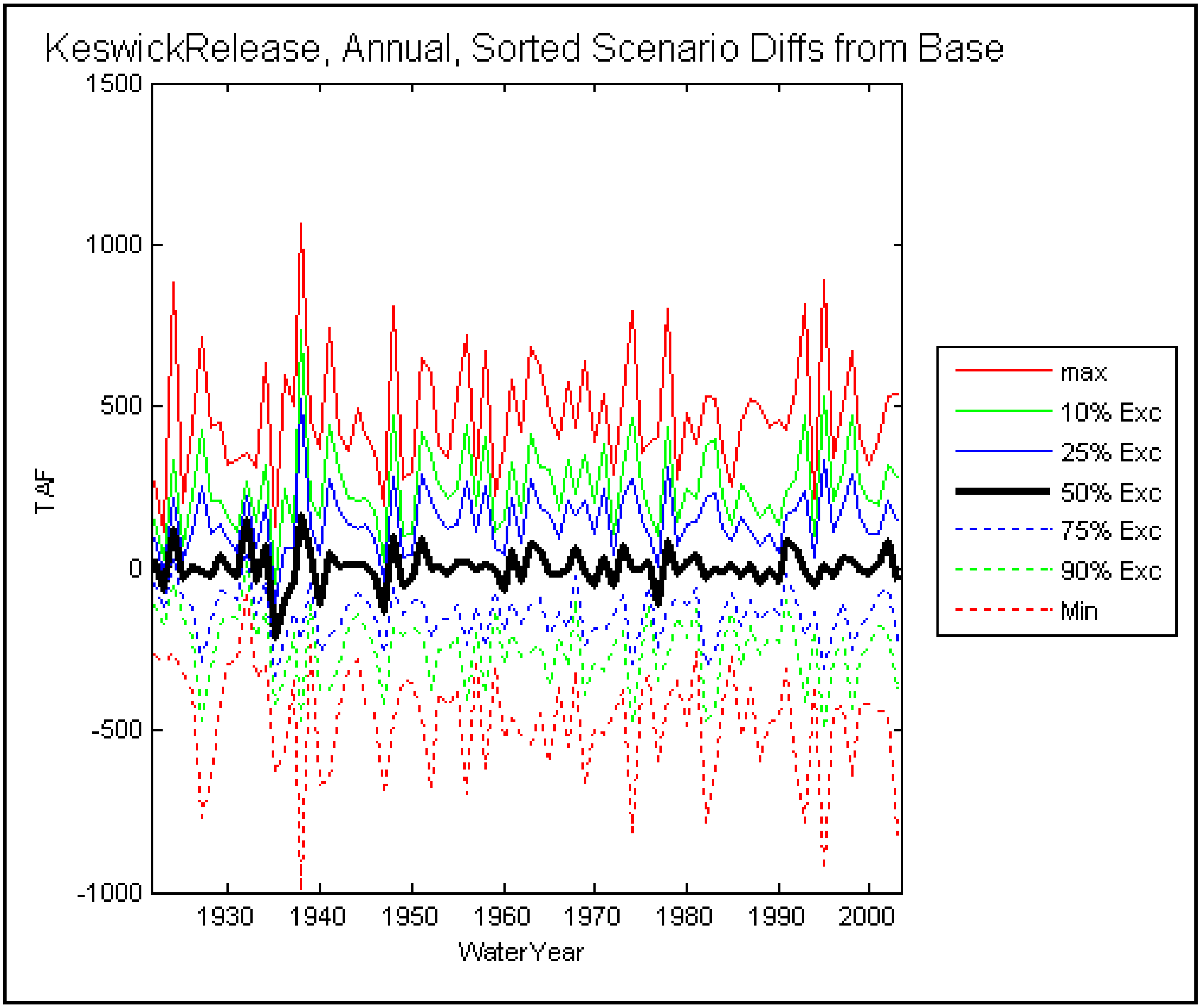

Figure 6. Standard Uncertainty Graphic: Time-evolving uncertainty intervals, changes from base

- **Type (3) Performance Metric Uncertainty – Monthly Absolute Results:** The purpose of this graphic (and the next three) is to show uncertainties of output performance metrics that are frequently used to describe CalSim-II output for long-term planning efforts. This graphic type (and the next three) was repeated for each of the eight averaging periods discussed in the Sensitivity Analysis. One example graphic for averaging period WY1922-2003 is shown in Figure 7. The uncertainty of monthly mean values is displayed using a collection of monthly box plots. For each month, the blue box indicates the 50% confidence interval on the monthly mean (i.e. interquartile range, or 75% to 25% exceedence range). The red line through the blue box plot shows the median value for monthly mean among the 1,000 scenarios analyzed. Red symbols above and below the blue box indicate scenarios that produced monthly mean values outside the interquartile range. Green markers (upward and downward triangles, respectively) indicate 10% and 90% exceedence values for monthly mean among the 1,000 scenarios analyzed.

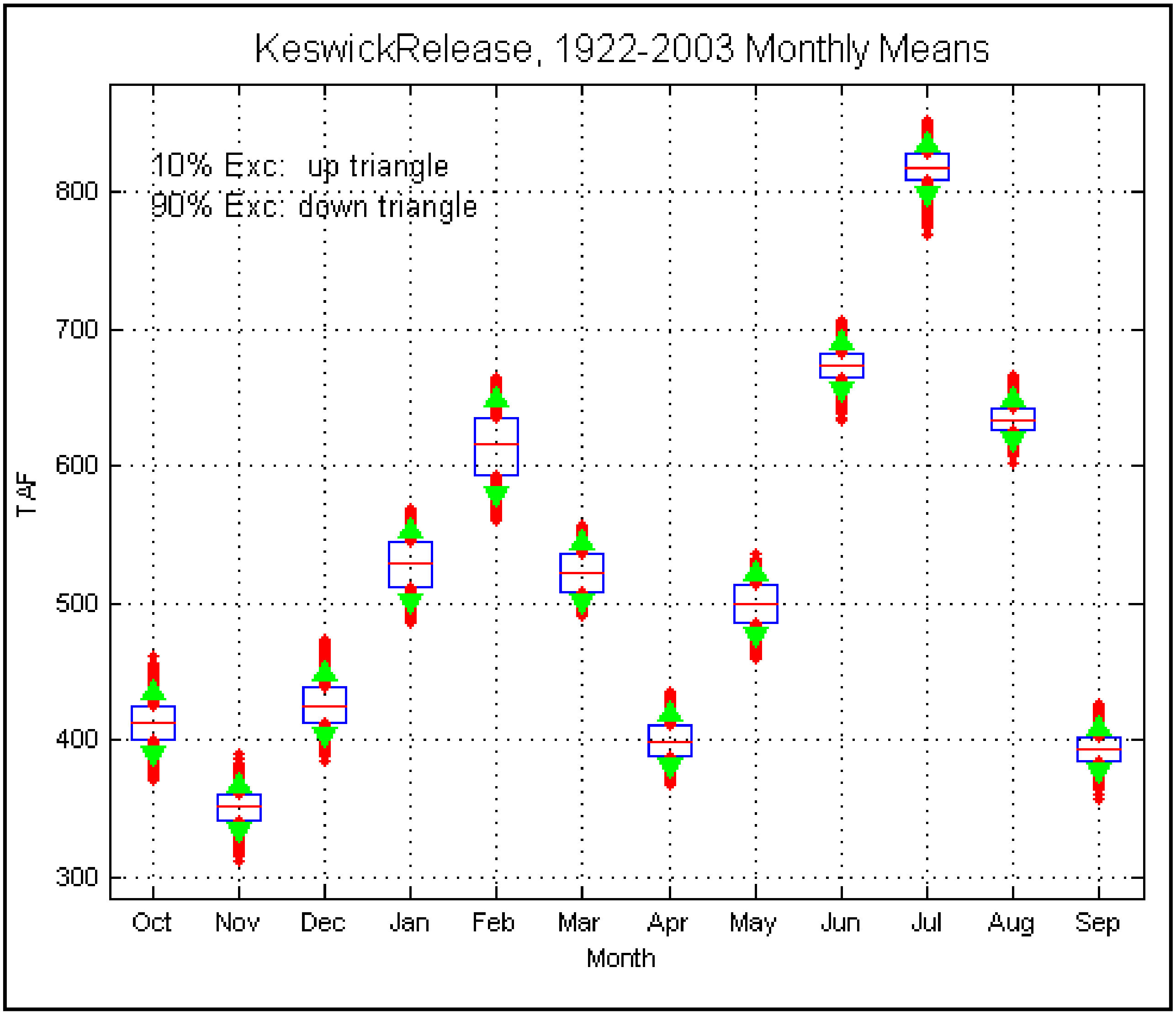

Figure 7. Standard Uncertainty Graphic: Performance metric uncertainty, monthly absolute result

- **Type (4) Performance Metric Uncertainty – Annual Absolute Results:** Similar to plot type (3), but for annual mean rather than monthly mean (e.g. Figure 8).

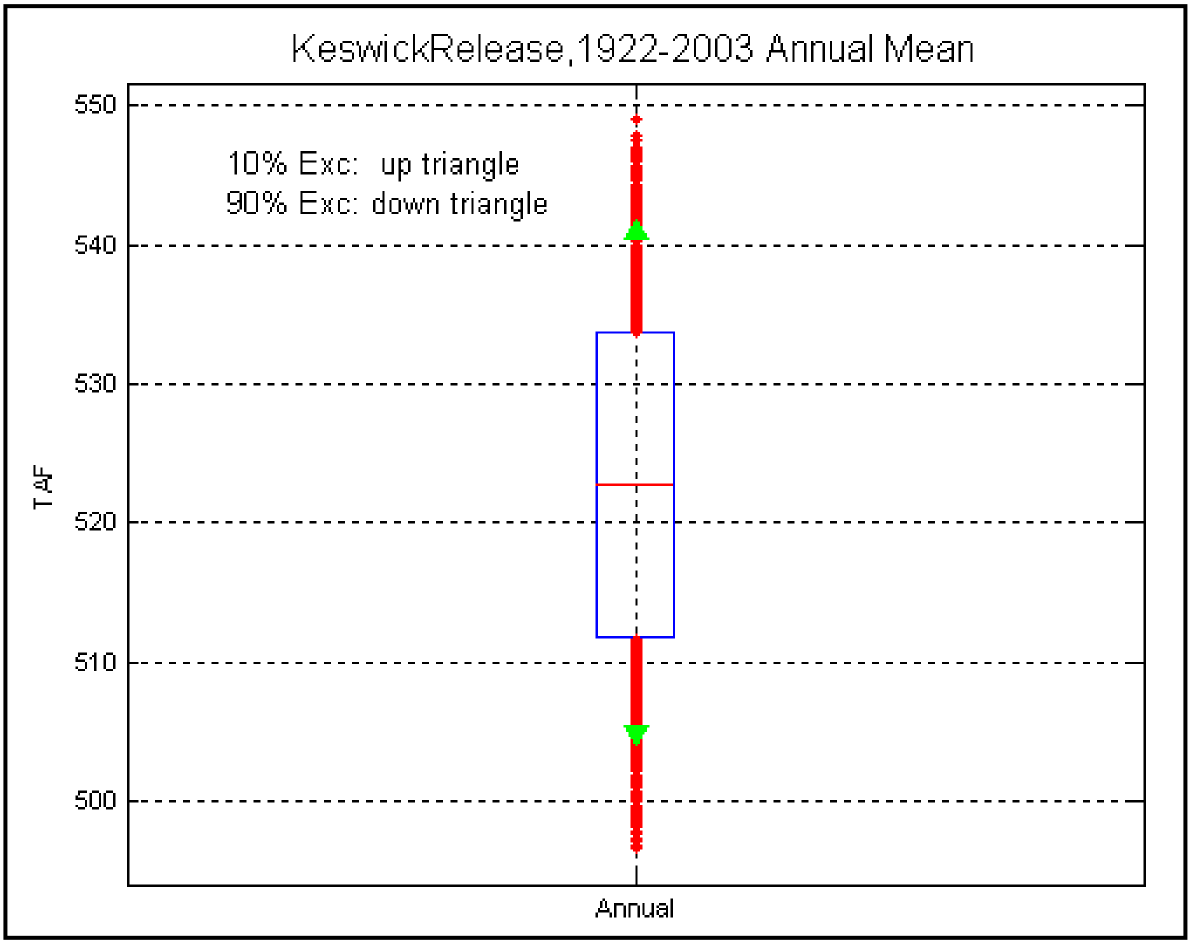

Figure 8. Standard Uncertainty Graphic: Performance metric uncertainty, annual absolute result

- **Type (5) Performance Metric Uncertainty – Monthly Change from Base:** Similar to plot type (3), but for “difference” results on monthly mean (i.e. scenario monthly mean minus base monthly mean) (e.g.,Figure 9).

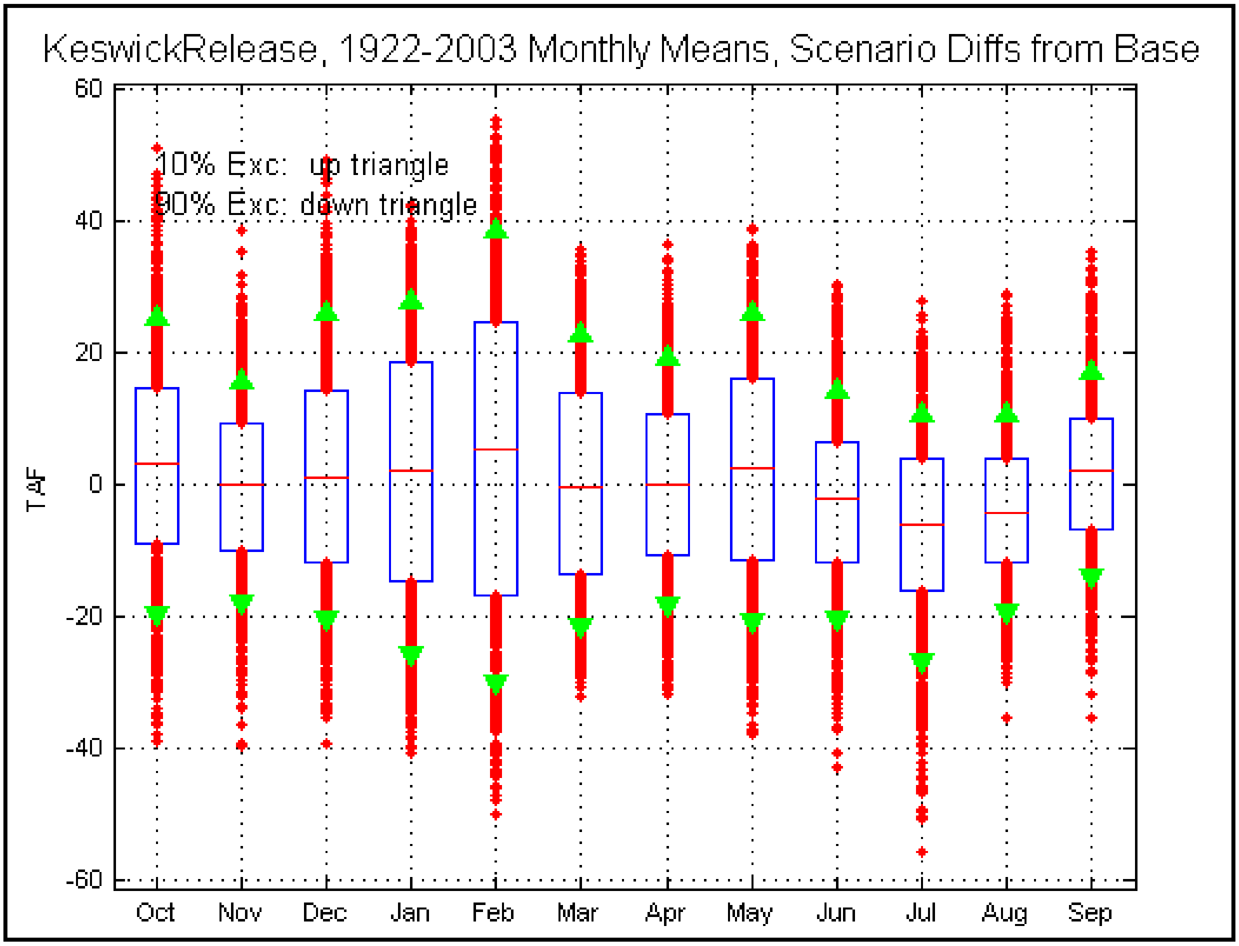

Figure 9. Standard Uncertainty Graphic: Performance metric uncertainty, monthly change from base

- **Type (6) Performance Metric Uncertainty – Annual Change from Base:** Similar to plot type (5), but for annual rather than monthly "difference" (e.g.,Figure 10).

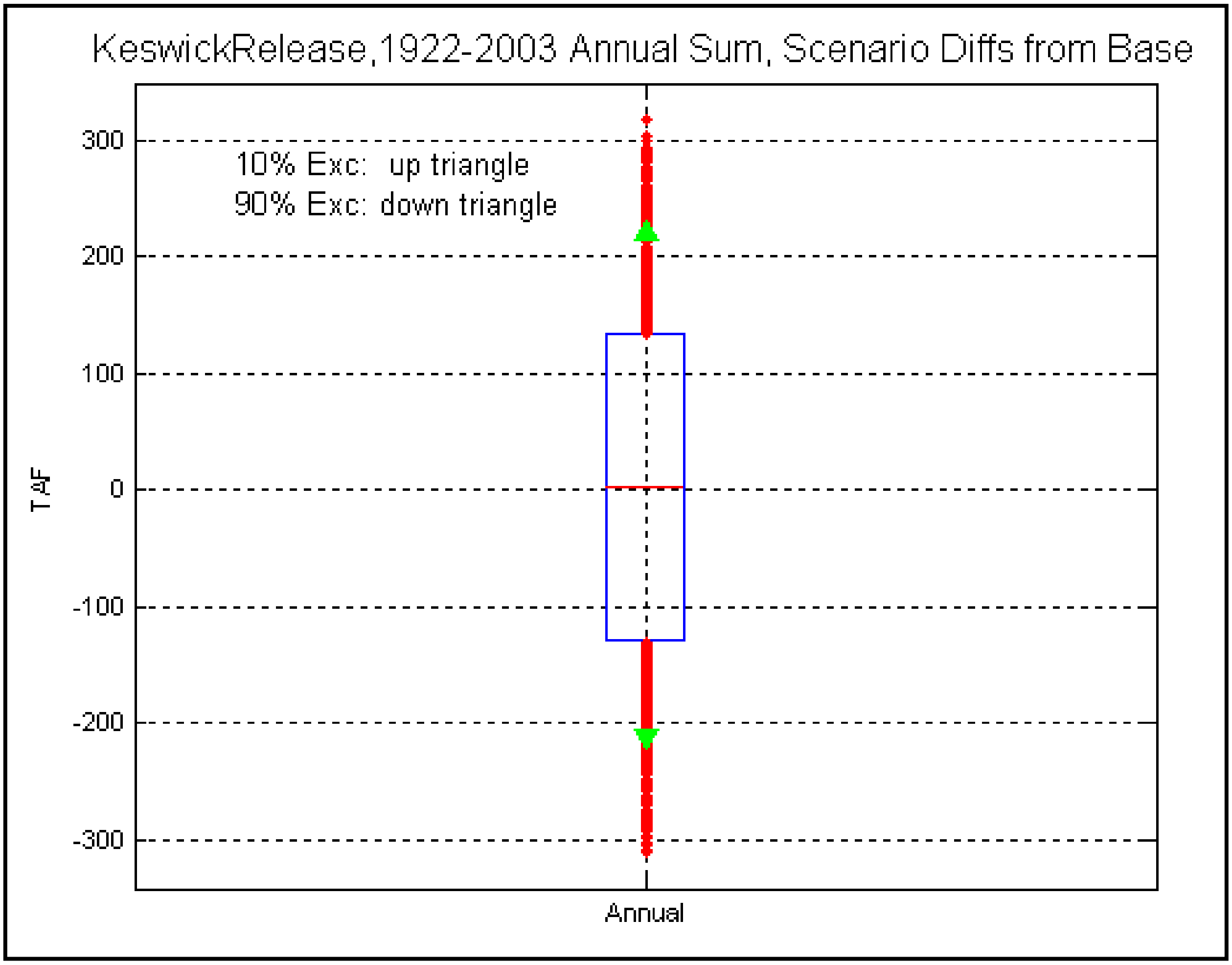

Figure 10. Standard Uncertainty Graphic: Performance metric uncertainty, annual change from base

Library of Results

Given the eight averaging periods considered, a total of 34 graphics were generated for each of the 46 model output variables (1 each for graphic types 1 and 2; and 8 each for graphic types 3-6). These graphics are catalogued in a directory tree and available electronically (Appendix X). The categories below organize the 34 figures for each output variable by the graphic types described above:

- Fig01 = Type (1)
- Fig02 = Type (2)
- Fig03-Fig06 = Types (3)-(6) for the WY1922-2003 averaging period

- Fig07-Fig10 = Types (3)-(6) for the WY1928-1934 averaging period
- Fig11-Fig14 = Types (3)-(6) for the WY1987-1992 averaging period
- Fig15-Fig18 = Types (3)-(6) for the SJR 60-20-20 Wet Years group
- Fig19-Fig22 = Types (3)-(6) for the SJR 60-20-20 Above Normal Years group
- Fig23-Fig26 = Types (3)-(6) for the SJR 60-20-20 Below Normal Years group
- Fig27-Fig30 = Types (3)-(6) for the SJR 60-20-20 Dry Years group
- Fig31-Fig34 = Types (3)-(6) for the SJR 60-20-20 Critical Years group

Key Findings

The reader is encouraged to evaluate results for specific output metrics and to develop individual impressions on the significance of base model uncertainty. Some general observations are offered here:

- As seen in the SJR uncertainty analysis, storage uncertainty builds in drier periods and is erased in wetter years when the reservoirs fill. This can be seen clearly in the time evolving plots for Oroville, Trinity, and Shasta north of the Delta, and in New Melones and Lake McClure in the San Joaquin basin. Folsom Reservoir, which exercises more of its conservation storage capacity on an annual basis, shows more uncertainty on the lower end of the storage envelope on a year to year basis.

- Monthly uncertainty in project exports is greatest in early fall and early summer, when operational flexibility is generally higher.

- Variation in Delta outflow requirement is entirely in February through June, indicating the dominant influence of the X2 standard adjustment. In future analysis, the scaling limits on this standard should probably not be set as high.

- For river flow variables, uncertainty is generally greatest during drier periods.

- Dry periods produce less uncertainty for CVP North of Delta deliveries and greater uncertainty for South of Delta deliveries to both CVP and SWP.

The utility of a planning model is often described in terms of its ability to capture the differences in operations between alternatives. In the case of the OCAP studies it is the ability of the model to capture the differences between existing level operations and those at a future level of development. The value of this information is potentially affected by any uncertainties attributed to model results due to uncertainties of a range of model inputs. Uncertainty analysis has been performed for a baseline CalSim-II study at both existing and future levels of development. If the differences between the two studies' uncertainty runs is comparable (i.e. no greater than) the difference between the actual base runs, it suggests that uncertainty in model output does not affect the value of the comparison between the existing and future model runs. An examination of the existing and future uncertainty results has found that this criteria is largely met.

References

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