Revised Work Plan for Near-Term Quantitative Support of Integrated Scenario Analysis for the 2009 California Water Plan Update

MWH

Stockholm Environment Institute

RAND Corporation

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Abbreviations and Acronyms

Bay-Delta	San Francisco Bay-Sacramento-San Joaquin Delta
BOD	biochemical oxygen demand
CAT	Climate Action Team
CEC	California Energy Commission
CMIP3	Coupled Model Intercomparison Project Phase 3
COA	Coordinated Operations Agreement
CVP	Central Valley Project
CVPIA	Central Valley Project Improvement Act
CWP	California Water Plan
D-1641	SWRCB Water Right Decision 1641
DFG	Department of Fish and Game
DO	dissolved oxygen
DWR	California Department of Water Resources
EI	export/inflow
ET	evapotranspiration
GCM	global circulation models
IEUA	Inland Empire Utilities Agency
NCAR	National Center for Atmospheric Research
PPIC	Public Policy Institute of California
ppt	parts per thousand
RDM	Robust decision-making
SEI	Stockholm Environment Institute
SLR	sea level rise
SWAN	Statewide Water Analysis Network
SWP	State Water Project
TAG	Technical Advisory Committee
UC Santa Barbara	University of California, Santa Barbara
USACE	U.S. Army Corps of Engineers
WEAP	Water Evaluation and Planning

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1.0 BACKGROUND AND PURPOSE

In fall 2007, MWH, the Stockholm Environment Institute (SEI) - U.S. Center, and RAND Corporation (RAND) provided a proposal to the California Department of Water Resources (DWR) for developing a quantitative scenario analysis of water supply options under uncertainty for the California Water Plan (CWP) 2009 Update This proposal was presented at several public forums, was revised in response to stakeholder comments, and was accepted and funded by DWR. This document presents a revised work plan based on the proposal to be undertaken by the Project Team (MWH, SEI, and RAND).

This work plan has been prepared in response to growing interest within both DWR and the water stakeholder community to use integrated scenario analysis as a foundation for the CWP Update. This represents a departure from the supply gap (or shortage) analysis used in most previous water plans. Under supply gap analysis, planners projected water demand into the future based on a single set of assumptions, and then calculated a supply gap by comparing this projection to an assessment of currently available water supplies. Supply gap analysis did not typically consider uncertainty in the underlying assumptions about water demand growth or supply availability. It also did not explicitly weigh the advantages and disadvantages of various management response packages available to expand water supply or moderate water demand, such as increasing surface storage, reusing wastewater, conjunctively managing surface supplies and groundwater basins, increasing water use efficiency, and desalinating seawater.

In response to these shortcomings, the CWP 2005 Update moved away from supply gap analysis and toward integrated scenario analysis by prominently featuring future demand uncertainty and multi-component water management response packages as key elements of the water plan. The CWP 2005 Update presented a graphical framework that described what DWR considered to be the key components of integrated scenario analysis. This framework, presented in Figure 1, includes three tiers. The top tier corresponds to the input data and assumptions. These include assumptions about demand drivers (e.g., population growth), geophysical parameters (e.g., climate change impact on the spatial and temporal patterns that characterize flow in California's rivers and streams), and water management objectives (e.g. future instream flow regimes designed to protect aquatic ecosystems). There is uncertainty in projecting the future water management landscape in California. Integrated scenario analysis endeavors to capture this uncertainty by defining scenarios based on the range of plausible demand drivers, geophysical states, and objectives. Scenario definition begins at the top tier of the framework.

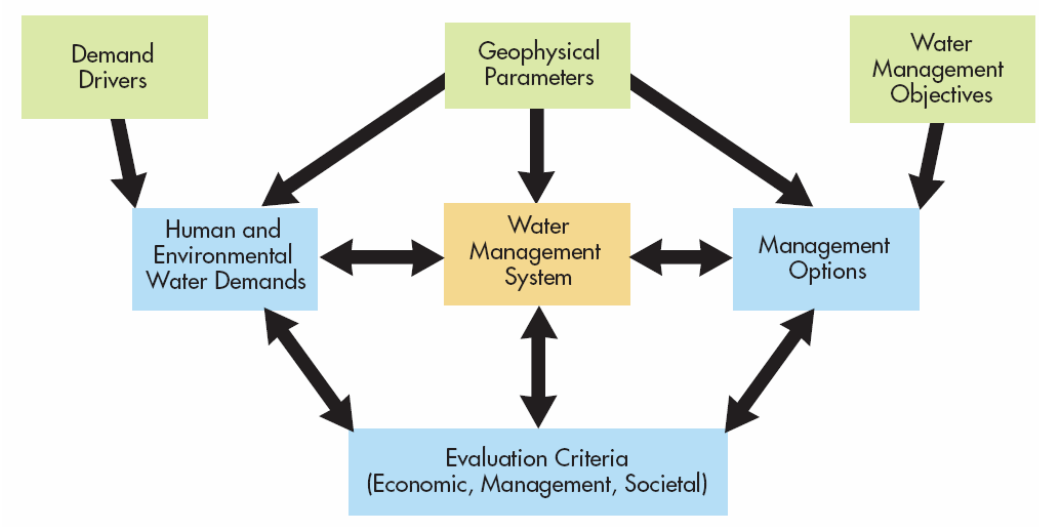


Figure 1: Useful Integrated Scenario Analysis Framework from the CWP 2005 Update

Having allowed for a range of scenarios at the top tier, the framework moves to the second tier, which is where the primary analysis occurs. At the second tier, the balance between different future levels of human and environmental water demand and different response packages (comprising individual management options) can be assessed within the context of the California water management system. A computer simulation model is used at this point because it is not possible to experiment directly with climate, infrastructure, water rights and contracts, and the regulations that define the California water system.

Once a suitable analytical platform is selected, it should produce results that can, on the third tier of the framework, be evaluated with respect to a range of evaluation criteria defined by stakeholders and decision-makers. While different stakeholders may place more or less importance on any one evaluation criterion, if the range of criteria is wide enough, each stakeholder should be able to assess whether a particular response package evaluated against a specific scenario represents an improvement for their particular constituency. It is at this third level that negotiation and decision-making occurs.

Because this transition to integrated scenario analysis represented a substantial departure from the supply gap analysis used in earlier CWP updates, DWR was not fully able to implement the framework in Figure 1 as part of the CWP 2005 Update. That document focused largely on identifying important demand drivers and developing a small set of scenarios (three) with respect to human and environmental water demands. While a list of management options was elaborated, they were not linked to the demand scenarios through a model of the water management system. This work plan will help DWR make substantial progress toward fully implementing the integrated scenario analysis framework in the CWP 2009 Update.

2.0 RELATED STUDIES

This work plan builds on collaborations, analyses, and studies performed by DWR and its consultants related to integrated scenarios analysis and the development of analytical tools. This section of the work plan traces some of the important aspects of these interactions over the past 5 years and other interactions in which DWR has been engaged. The section culminates in the justification of the use of the Water Evaluation And Planning (WEAP) modeling platform to be deployed in analysis for the CWP 2009 Update.

2.1 CWP 2005 UPDATE

An early informal collaboration took place between DWR water planning staff and RAND as part of RAND's multiyear National Science Foundation study on decision-making under uncertainty. As a first step, RAND personnel worked with DWR to develop a simple statewide water demand model. Although not originally intended to inform the CWP 2005 Update, the model was selected by DWR to quantify three narrative demand scenarios that had been developed for the CWP 2005 Update (Groves et al. 2005). These scenarios of water demand were viewed as helpful by the CWP advisory committee but were also critiqued for treating supply scenarios and management responses as independent.

2.2 SOUTHERN CALIFORNIA SCENARIO ANALYSIS

After the release of the CWP 2005 Update, RAND and researchers from University of California, Santa Barbara (UC Santa Barbara), continued to develop the scenario model to support analysis designed to identify robust water management strategies for California water planners (Wilkinson and Groves 2006). In this application, which was included by DWR as a case study for its new Statewide Water Analysis Network (SWAN), a first step was taken in integrating water demand and supply scenarios with management responses in a single annual water demand/water supply ledger. Although the underlying model was simplistic and devoid of detailed physical elements, participants in several Southern California workshops in fall 2005 found the integration useful for extracting value from the demand scenarios. A major conclusion of the work, however, was that an improved physical representation of hydrology and the actual water management system would be useful, even for high-level scenario planning.

2.3 WEAP APPLICATION - SACRAMENTO RIVER HYDROLOGIC REGION

Independent of the interaction between DWR and RAND, the SEI and the National Center for Atmospheric Research (NCAR) collaborated to develop an analytical framework for integrating climate change into water management planning. This project used the WEAP water resource systems modeling platform. SEI had been developing the WEAP software for over a decade as a tool with which integrated scenarios of water demand and water supply management could be simulated, typically using historical hydrologic observations as input. In this project, SEI nested WEAP's water management logic within a rainfall runoff model of the terrestrial components of

the hydrologic cycle, and ran the model using climate inputs. This enhancement was critical as the assumption that historical hydrologic patterns will recur is no longer valid under climate change. The enhanced tool was used to develop a WEAP application of the Sacramento River Hydrologic Region (Purkey et al. 2007; Yates et al. 2005a; Yates et al. 2005b). The model was subsequently included by DWR as a SWAN case study in which verification of the model's simulated mass balances and the addition of a Sacramento-San Joaquin Delta (Delta) salinity module were undertaken.

2.4 INLAND EMPIRE UTILITIES AGENCY STUDIES

Based on the utility of WEAP as a tool for climate change analysis, RAND adopted the model as a platform for analysis of Southern California's Inland Empire Utilities Agency (IEUA) water management. In this study, RAND partnered with scientists from NCAR to develop projections of future local weather patterns (to 2040) reflective of a wide range of plausible climate change outcomes, as estimated by 21 climate models (Tebaldi et al. 2005; Yates et al. 2003). Subsequently, RAND developed a WEAP application of the IEUA service area to generate integrated demand and supply scenarios reflective of various water management options. RAND used WEAP together with exploratory modeling software to evaluate the performance of a variety of water management strategies across hundreds of climate scenarios. RAND's scenario methodology suggested strategies that were robust to uncertainties about climate change and other management uncertainties. RAND presented results in three workshops in fall 2006 and one in fall 2007 (Groves et al. 2008a; Groves et al. 2008b). Several DWR staff members participated in these workshops as part of the SWAN case study process. A key finding from the work is that integrated scenario analysis was very effective at informing decision-makers about climate change and other challenges posed by uncertain future conditions, and about choices among management strategies.

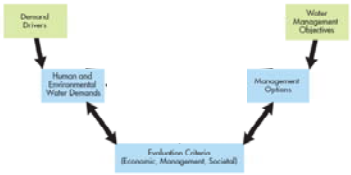
2.5 CALSIM DEVELOPMENT

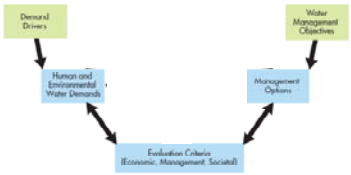
MWH and SEI have been involved in the development and enhancement of CalSim, the principal water planning model used by DWR. MWH is assisting DWR develop the next generation of the model (CalSim-III) that contains a more detailed spatial representation of California's water system and integrates simulation of both surface water and groundwater. While CalSim was not selected as an engine for scenario analysis in the CWP 2005 Update, largely because of its dense model structure and long setup and run times, the model contains a very detailed representation Central Valley Project (CVP) and State Water Project (SWP) operations that could be mined to assemble a screening model to more appropriately represent the water management system at the heart of statewide water management in California. This has been the primary motivation for the development of CalLite, a simplified version of the model that may provide a platform for statewide integration of the regional analysis in the CWP Update.

The studies described above addressed different aspects of the integrated scenario analysis framework depicted in Figure 1. The CWP 2005 Update presented several demand scenarios and a list of management options, but did not integrate them. The Southern California Scenario Project integrated scenarios of supply and demand, but did so without a detailed representation of the actual water system. The Sacramento River Hydrologic Region WEAP application developed a moderately detailed and realistic systems representation of demand and supply under climate change, but did not explore a wide range of management options. Finally, the IEUA WEAP application reflected all elements of the system, but simplified the representation of hydrology and of the water system itself. Table 1 summarizes the contrasting characteristics of each of these studies. The last rows of Table 1 correspond to the CWP 2009 Update as described in this work plan.

DWR and Water Plan Update stakeholders are currently evaluating options for developing long-term quantitative analysis for future water plan updates. Notably, DWR has discussed with other potential partners Shared Vision Planning as a promising procedural structure for CWP Update process (see www.SharedVisionPlanning.us). Shared Vision Planning is a facilitated collaborative process that engages a range of stakeholders in all levels of the integrated scenario analysis framework in Figure 1, starting from the definition of analytical assumptions and the crafting of scenario storylines, continuing through the selection, development, and deployment of a modeling framework, and terminating with the evaluation of alternatives using a broadly subscribed set of performance metrics. Recent literature (Call 2001; Gregory and Failing 2002) suggests that Shared Vision Planning can be an effective strategy for creating consensus among a disparate group of stakeholders involved in water resources policy-setting and decision-making.

Table 1: Evaluation of Previous Studies with Respect to Integrated Scenario Analysis Framework

	Scenario Framework	Geographic Domain	Level of Integration	Level of System Detail	Climate/Hydrology
CWP 2005 Update		Statewide, by Hydrologic Region	No integration between demand scenarios and management options	Coarse demand factor representation; management options derived from other studies	Annual data for past hydrology (water portfolios), no climate or hydrologic signal in scenarios
Southern California Scenario Analysis		Southern California; demand by county, supply by region	Arithmetic combination of supply and demand; factor changes to baseline estimates	Coarse demand factor representation; management options derived from other studies and related to supply and demand projections	Annual projections of supply and demand; no inter-annual variability; no climate signal
WEAP Application Sacramento River Hydrologic Region		Sacramento Basin, including Bay-Delta and Trinity Diversion	Full integration with demand and supply elements interacting dynamically during simulation	Full system detail with all critical system components represented explicitly	Monthly precipitation, temperature, humidity, wind speed; rainfall/snowmelt simulation; water quality simulation.
IEUA Studies		Inland Empire Utilities Agency service area	Integrated supply and demand and long-term water management plans	Aggregated representation of large system components	Monthly precipitation, temperature, humidity, wind speed; rainfall/snowmelt simulation; parameterizations of effects on imports.

CWP 2009 Update		California by Hydrologic Region (10)	Arithmetic combination of supply and demand; factor changes to baseline estimates	Coarse demand factor representation; management options derived from other studies and related to supply and demand projections	Monthly projections of demand. Irrigation demand driven by monthly HR-averaged weather time series; Annual projections of supply.
		Sacramento and San Joaquin River Hydrologic Regions	Full integration with demand and supply elements interacting dynamically during simulation, including long-term water management strategies	Full system detail with all critical system components represented explicitly	Monthly precipitation, temperature, humidity, wind speed; rainfall/snowmelt simulation; water quality simulation.

Key:
Bay-Delta = San Francisco Bay/Sacramento-San Joaquin Delta
CWP = California Water Plan
IEUA = Inland Empire Utilities Agency

Shared Vision Planning is an attractive prospect, given DWR's experience in moving towards an integrated scenario analysis framework in the CWP 2005 Update. That transition was complicated because the analytical framework that DWR proposed to represent the California water management systems, a loosely integrated collection of models developed by DWR for other purposes, was not universally endorsed by the stakeholders involved in the CWP update process. The lack of consensus on this central element of integrated scenario analysis prevented those working on the update from implementing the framework shown in Figure 1 in its entirety. There is legitimate optimism that if the entire integrated scenario analysis framework could be placed within a Shared Visioning Planning process, a consensus would emerge around input assumptions, models, and performance metrics, thereby increasing the credibility and, hence, the utility, of the CWP 2009 Update.

This expectation shapes DWR's current conversation around Shared Vision Planning, which is pointing to the collaborative definition of an appropriate integrated scenario analysis framework for the coming CWP 2009 Update, with full implementation of the framework being realized only in the CWP 2014 Update. As part of the development of an integrated scenario analysis framework, one activity that will be undertaken for the CWP 2009 Update is an inventory of all planning work that is currently underway at regional and system-wide levels to identifying promising methodologies and highlight key planning challenges and management opportunities.

There is also, however, the expectation from both the stakeholder community and DWR management that in addition to a long-term strategy for integrated scenario analysis, substantive progress should be made in developing analytic scenario results for the CWP 2009 Update. This work plan will conduct near-term analysis for the CWP 2009 Update that builds on the other studies in Table 1, and will provide relevant findings and lessons learned for future water plans. This work plan focuses on demonstrating that integrated scenario analysis for several planning areas within California in the CWP 2009 Update provide a useful Shared Vision Planning laboratory for defining the elements of any ultimate integrated scenario analysis process.

It is not easy to imagine how the Shared Vision Planning process would guide stakeholders through these steps entirely in the abstract, absent any model through which the concepts of scenarios and performance metrics could be explored. Therefore, this work plan will use WEAP to develop in a timely manner a useful representation of the California water system. This will be accomplished by leveraging all of the work already produced as part of the CWP 2005 Update and SWAN collaborations between DWR and its consultants.

3.0 APPROACH

The WEAP system is a comprehensive, fully integrated water basin analysis tool. It is a simulation model that includes a robust and flexible representation of water demands from all sectors, and flexible, programmable operating rules for infrastructure elements such as reservoirs, canals, and hydropower projects. Additionally, WEAP has watershed rainfall-runoff modeling capabilities that allow all portions of the water infrastructure and water demands to be dynamically nested within the underlying hydrological processes. In effect, it allows the modeler to analyze how specific configurations of infrastructure, operating rules, and priorities will affect water uses as diverse as instream flows, agricultural irrigation, and municipal water supply under the umbrella of input weather data and physical watershed conditions. This makes the WEAP system ideally suited for studies of the impacts of climate change.

WEAP will be used to support two complementary analyses for the CWP 2009 Update. The first analysis, led by DWR staff, will use WEAP to develop a low-resolution regional demand and supply balance representation for each of the 10 hydrologic regions in California. The second, led by the consulting team will develop a more detailed hydrologic representation of the Sacramento and San Joaquin River hydrologic regions to evaluate integrated demand and supply scenarios.

3.1 HYDROLOGIC REGION WEAP ANALYSIS

For the statewide hydrologic region level analysis, indoor urban demand will be represented in a manner similar to that used for the CWP 2005 Update. Outdoor urban and agricultural water demand will be estimated based on evapotranspiration (ET) requirements and irrigation patterns for prescribed monthly sequences of weather for stylized watershed areas. Monthly available supply by hydrologic region will be based largely on inventories of available supplies and projections from the region's major water suppliers. Due to the coarse nature of this analysis, only a rough comparison of the independent projections of demand to supply will be able to be performed. DWR staff members are exploring ways in which to consider the water management response packages developed by the CWP advisory committee in this analysis. The remainder of this work plan addresses the second, more detailed WEAP analysis.

3.2 SACRAMENTO AND SAN JOAQUIN RIVER REGION WEAP ANALYSIS

For a more detailed analysis of a portion of California, the WEAP modeling tool will be employed to simulate and evaluate more refined integrated water management scenarios for 2 of the 10 California Hydrologic Regions – the Sacramento River and San Joaquin River hydrologic regions. This integrated model will then be used to: (1) quantify the small set of handcrafted narrative scenarios developed by the CWP Update staff and advisory committee; and (2) generate a larger ensemble of plausible scenarios to systematically evaluate the performance of various regional water management response packages in the face of a number of critical uncertainties, including climate change. Work will pursue the following specific objectives:

1. Develop a modeling framework that can demonstrate the entire integrated scenario analysis framework envisioned in Figure 1 for two key hydrologic regions in California — Sacramento River and San Joaquin River.
2. Use this framework to assess the full spectrum of uncertainties that confront water planning in California, including global climate change, land use and demographic changes, and others.
3. Evaluate the results of these analyses against an appropriate set of performance metrics, including performance during drought periods as well as across the entire simulation period, and over a wide range of plausible future conditions.
4. Develop a strategy to evaluate the most promising regional water management strategies using a version of CalSim or CalLite so that insights gained through integrated scenario analysis at the regional level can inform DWR's principal planning model for the California water system.
5. Offer insights to a parallel Shared Vision Planning process that will establish a more definitive strategy for integrated scenario analysis for use in the CWP 2014 Update, and beyond.

Achievement of these objectives will contribute substantially to the continued evolution of the CWP update, leading to a comprehensive integrated scenario analysis approach.

3.2.1 WEAP Representation of the Hydrologic System

The WEAP application of the Sacramento River and San Joaquin River hydrologic regions will be developed at a suitable spatial scale to capture the major hydrologic flows, represent major demographic and land use trends, and evaluate the effects of water management responses. In general, the model is organized by DWR planning areas – there are 11 planning areas in the Sacramento River hydrologic region and 10 in the San Joaquin River hydrologic region. For the 4 planning areas covering the southern Cascade and northern and central Sierra Nevada mountain ranges, the planning areas are further disaggregated along watershed boundaries and elevation bands to reflect major reservoir operations and elevation-dependent hydrologic processes. For the remaining 17 planning areas, located primarily on the floor of the Central Valley, water demands and water supplies are specified at the planning area level, and only disaggregated as deemed necessary to properly reflect usage of different supplies or to evaluate important scenarios or response packages. Table 2 indicates the level of model disaggregation.

Table 2. Central Valley Planning Area Model Disaggregation

Hydrologic Region	Planning Area	Disaggregation by Watershed	Disaggregation by Demand Area
Sacramento River	501 – Shasta – Pit	Pit River Upper Sacramento River	None
	502 – Upper Northwest Valley	Cottonwood Creek Thomes/ Elder Creeks Stony Creek	None
	503 – Lower Northwest Valley	None	503_North – Sacramento River/Clear Creek Diverters 503_South – Sacramento River/Thomes/Stony Creek Diverters
	504 – Northeast Valley	Cow Creek Battle Creek Antelope/Mill/Deer Creeks Chico Creek	None
	505 – Southwest	Cache Creek Putah Creek	None
	506 – Colusa Basin	None	506_East – CVP Settlement Contractors 506_East – CVP Agricultural Contractors
	507 – Butte-Sutter-Yuba	Butte Creek	507_East – Feather/Yuba River Diverters 507_West – Sacramento River Diverters
	508 – Southeast	Feather River Yuba River Bear River American River	508_North – Feather River Diverters 509_South – Bear/Yuba River Diverters
	509 – Central Basin West	None	None
	510 – Sacramento Delta	None	None
	511 – Central Basin East	None	None

Table 2. Central Valley Planning Area Model Disaggregation (Continued)

Hydrologic Region	Planning Area	Disaggregation by Watershed	Disaggregation by Demand Area
San Joaquin River	601 – Upper West Side Uplands	None	None
	602 – San Joaquin Delta	None	602_North – Delta Service Area 602_South – DMC diverters
	603 – Eastern Valley Floor	None	603_North – Mokelumne River Diverters 603_South – Stanislaus/Calaveras River Diverters
	604 – Sierra Foothills	Cosumnes River Mokelumne River Calaveras River Stanislaus River Tuolumne River	None
	605 – West Side Uplands	None	None
	606 – Valley West Side	None	606_North – DMC Diverters 606_South – DMC /Mendota Pool Diverters
	607 – Upper Valley East Side	None	None
	608 – Middle Valley East Side	None	None
	609 – Lower Valley East Side	None	609_North – Merced River Diverters
	610 – East Side Uplands	Merced River Chowchilla/Fresno River San Joaquin River	609_South – Madera Canal/Fresno River Diverters
Tulare Lake	702 – San Luis West Side	None	None

Key:
CVP = Central Valley Project
DMC = Delta-Mendota Canal

The WEAP model will simulate the period 2005 to 2050 using a monthly time step. Historical monthly meteorological conditions from 1970 to 2005 and a current level of development (e.g., 2005) will be used to calibrate the model.

The following subsections describe how the WEAP model will treat climate change, droughts, flooding, water quality, environmental flows, and Delta export operations.

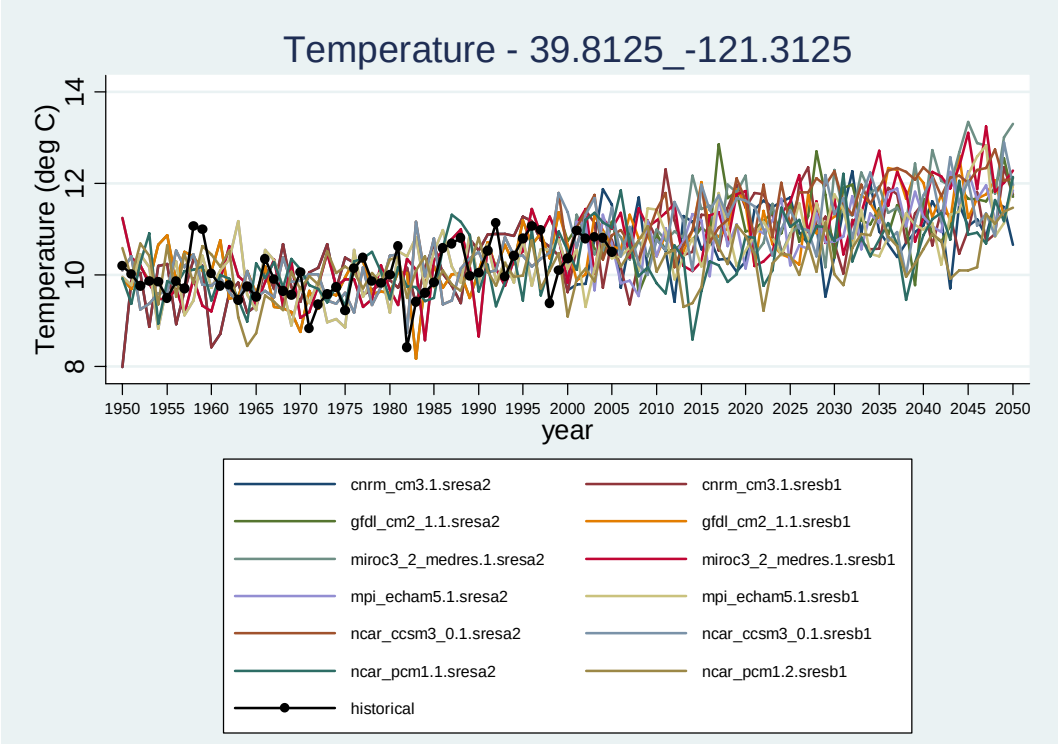
3.2.2 Climate Change

Changes in regional meteorological conditions due to global climate change will impact water demands and water supplies in California. Although there is no consensus on the precise nature of these changes, atmosphere-ocean global circulation models (GCM) have been used to develop many estimates of plausible future temperature and precipitation patterns on a coarse grid over California. These results have been "downscaled" to a smaller scale to remove systematic biases and provide estimates that are relevant at the regional and local scales.

The World Climate Research Programme's Coupled Model Intercomparison Project Phase 3 (CMIP3) multimodel dataset provides downscaled temperature and precipitation projections on a 1/8th-degree (approximately 7-mile) grid for 16 GCMs that were run under three global greenhouse gas emissions scenarios that represent the likely range of greenhouse gas emissions scenarios.[1] This dataset includes the 12 specific climate scenarios (6 models and 2 emissions scenarios) specified by the California Climate Action Team (CAT) on behalf of the California Energy Commission (CEC), and these data have been used as the foundation of numerous climate change impacts studies in California.

As an example, Figure 2 show the downscaled 12 CEC projections of annually averaged temperature and annual precipitation for a single grid box overlaying the Bucks Lake snow survey site in the Feather River Basin from 1950 to 2050. The black line indicates the actual average historical conditions for the same region from 1950 to 2050. Options for developing suitable estimates of relative humidity and wind speed for each of the CEC temperature and precipitation projections will be evaluated.

[1] The downscaled CMIP3 dataset is available at http://gdo-dcp.ucllnl.org/downscaled_cmip3_projections/.



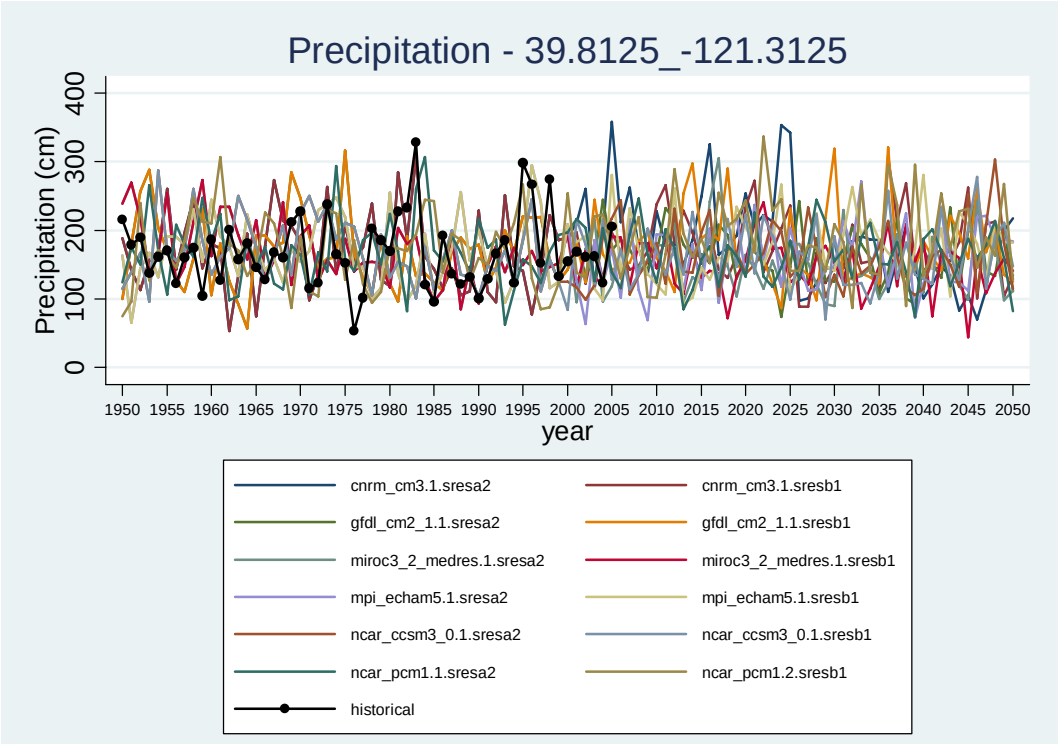


Figure 2. Annual Average Temperature and Precipitation and Bucks Lake Snow Survey Site, Feather River Basin

To evaluate how these plausible sequences of weather will impact conditions the Sacramento River and San Joaquin River hydrologic regions, watershed (aka catchment) objects[2] will be defined in the WEAP model corresponding to agricultural, urban, and other non-irrigated lands for each planning area (see Table 2). For each watershed object, WEAP evaluates the hydrologic response to individual sequences of temperature, precipitation, relative humidity, and wind speed. The rainfall runoff model embedded in WEAP partitions precipitation (and applied water) into ET, runoff, and groundwater percolation. Climate impacts that can be evaluated include the following:

- Crop irrigation demands, based on imposed weather sequences, ET requirements, irrigation schedules, and cropping patterns
- Temperature-dependent snow accumulation and melt processes
- River flows and groundwater percolation reflecting precipitation patterns and snow accumulation and melt for each imposed weather sequence

In addition to the 12 CEC climate projections, the WEAP modeling system can be used to evaluate the larger set of climate projections included in the CMIP3 dataset or other synthetic weather sequences.

Climate change will also lead to global sea-level rise, which will impact California coastal regions and the San Francisco Bay-Sacramento-San Joaquin Delta (Bay-Delta). The Sacramento River and San Joaquin River WEAP model will consider how sea level rise will impact Delta water salinity as defined in the water quality section below.

3.2.3 Droughts

Past CWP updates evaluated the impact of future drought upon California's water demand and supply by estimating how the future water system would respond to repeats of historical drought periods. These analyses did not explicitly consider sequences of hydrology, instead they estimated how a repeat of single or multi-year historical hydrologic conditions would impact supplies and demand. As described in Section 3.2.2, however, the CWP 2009 Update will evaluate the water system under projected future conditions as characterized by GCMs. This approach thus does not directly support an analysis of historical drought periods equivalent to past Water Plans.

Instead, the WEAP analysis will address drought first by reporting how the system is simulated to perform during drought periods that are present in the GCM-derived hydrologic sequences. As each GCM-derived hydrologic sequence is unique, the timing, duration, and severity of droughts will differ across the different hydrologic scenarios. This analysis thus will provide an aggregated look at how the system responds during the drier period during the future.

[2] Watershed objects are defined by area land cover, soil type, and other parameters.

Next, to establish more consistency in evaluation of drought, we will modify each GCM-derived hydrologic sequence to include drought conditions of historic magnitude at the 2020 and 2040 time horizons. This analysis will provide information that is more comparable to drought analyses done in past CWPs and Urban Water Management Plans.

Other synthetic drought sequences of interest for each of the GCM-derived hydrologic sequences may be evaluated, depending on budget.

3.2.4 Flooding

The WEAP model calculates monthly stream flows based on watershed inflows defined by imposed monthly weather sequences, and other management objects such as reservoirs and diversions. Characteristics of reservoir and conveyance objects partly determine the magnitude of flood releases and any conveyance capacity exceedence (suggestive of flooding). Flood triggers programmed into WEAP will determine the distribution of flood flows between rivers and bypasses. U.S. Army Corps of Engineers (USACE) flood control diagrams for major on-stream reservoirs in the Sacramento River and San Joaquin River hydrologic regions will be used to develop a representation of the baseline management strategy within the WEAP model.

Because the WEAP model will use a monthly time step, treatment of flooding issues will be limited to coarse parameterizations of flooding propensity under monthly flow volumes. As a first step to integrating flood analysis into the CWP scenario analysis, the modeling team will develop heuristic relationships between: (1) monthly flows through critical river reaches and conveyance facilities (including bypasses); and (2) propensity for flooding in these areas. Historical data and scenario-specific estimates will be used for this evaluation. The effect that alternative flood control rules have on flooding propensity will be evaluated under the different future scenarios.

3.2.5 Water Quality

The in-stream water quality analysis capabilities within WEAP include:

- Simple mixing and conservative behavior or first-order decay
- Built-in biochemical oxygen demand (BOD), temperature, and dissolved oxygen (DO) models
- Linkages to the US EPA river and stream water quality model, Qual2K
- Call to external models (DLL) to calculate water quality using user-defined routines

Analysis of the Sacramento River and San Joaquin River hydrologic regions focuses on Delta salinity. Water quality in the San Joaquin River will not be modeled.

To address Delta salinity, the WEAP model currently is linked to the G-mod regression model, which calculates Delta outflow required to meet Delta salinity standards. The G-mod equations,

however, are currently developed under current sea level conditions. Options are being investigated for updating these relationships to pertain to sea level rise (SLR) conditions, or incorporating the Delta ANN model developed for CalSim. The ANN model has been trained to handle four sea level rise scenarios (1-foot SLR, 2-foot SLR, 1-foot SLR + 4-inch amplitude and 2-foot SLR +4-inch amplitude).

In addition to setting flow requirements to meet Delta salinity standards, WEAP sets a Delta outflow standard to maintain the position of the 2 parts per thousand bottom isohaline, X2, which is applied as a habitat indicator for the Delta. For this, WEAP uses the Kimmerer-Monismith equation to compute the required net Delta outflow, based upon the position of X2 in the previous month. The Delta outflow standard, described below, outflow to meet X2 standard, and outflow to meet Delta salinity standards together determine outflow requirements for the Delta.

3.2.6 Environmental Flows

WEAP can consider specific river flow requirements for water quality, fish and wildlife, navigation, recreation, downstream, and other requirements through the specification of a flow requirement object associated with points on a river or diversion. Flow requirements are treated as a demand and are satisfied in accordance with the user-defined priority structure. WEAP can also consider wetland demands using agricultural watershed routines designed to estimate irrigation demand for rice fields.

The WEAP model will be used to evaluate the major river flows in the Sacramento River and San Joaquin River hydrologic regions on a monthly basis for each scenario. Flow requirements will be evaluated for a variety of locations, including the environmental sites considered in the CWP 2005 Update (Rosekrans and Hayden 2003) and flow recommendations contained in the May 2008 Department of Fish and Game (DFG) report “Recommendations to the State Water Resources Control Board.” The WEAP model will also include a schedule of minimum Delta outflow requirements to support and protect estuarine habitat for anadromous fish and other estuarine-dependent species. These flow requirements vary seasonally and are adjusted depending on year-type.

3.2.7 Delta Export Operations

Exports from the Delta at the Banks (SWP) and Jones (CVP) pumping plants are controlled by many regulatory rules and operational objectives. The regulatory rules include export restrictions during critical migration periods for anadromous fish called for under Section 3406b(2) of the Central Valley Project Improvement Act (CVPIA) and limits on total exports based on the 3-day running average Delta inflow called for under D-1641 (herein referred to as the export/inflow, or EI ratio). The operational objectives include delivery allocations to SWP and CVP contractors and sharing surplus and deficit flows within the Delta by the two projects under the Coordinated Operations Agreement (COA). The WEAP application developed for the Sacramento and San Joaquin hydrologic regions will include representations of regulatory

guidelines that restrict Delta exports during periods deemed critical for supporting aquatic ecosystems and operational objectives that limit exports during dry periods when water supplies are insufficient to satisfy all consumptive water demands within the system.

The regulatory guidelines restricting Delta exports will include aspects of the standards mentioned above. While the model will not perform a full accounting of b(2) operations, rules will be developed that curtail Delta exports during the critical April through May pulse period. An enhancement to the WEAP model will be added that will enable the user to develop expressions that constrain system operations based on current system conditions. In this way, limits on Delta exports will be implemented using the EI ratio schedule called for under D-1641.

The intent is to build enough detail in the Delta to perform strategic scenario analysis for the Water Plan, but this will not be sufficient for detailed analysis of Delta alternatives. As part of the proposed work plan, linkages of WEAP to CalSim and CalLite will be explored to permit more detailed analysis of the Delta and CVP and SWP systems operations.

Inter-annual variability in water supply motivates many of the reservoir operating rules. These rules are intended to secure water for dry years by balancing current water demands against carryover storage for delivery in subsequent years. Currently, the WEAP model contains routines for tracking water year-types using the Sacramento Valley Index, the Eight River Index, and the Shasta Index. These routines are used within the model to adjust environmental flow requirements, but are not implemented to guide curtailment of deliveries to CVP and SWP water contractors. That is, the model does not calculate annual allocations for the two projects. Instead, the WEAP model imposes limits on the amount of water that can be released from reservoirs. When storage drops below certain thresholds (i.e., into the buffer storage zone) reservoir releases are limited to a fraction (or buffer coefficient) of remaining active storage. This limits the amount of surface water available that can be diverted from rivers and, ultimately, pumped from the Delta. Buffer storages and buffer coefficients will be used to curtail Delta exports during dry periods.

As previously mentioned, the Sacramento-San Joaquin WEAP application will be developed to evaluate water supply and demand conditions for each of the planning areas within the two hydrologic regions. Therefore, the analysis will focus on water deliveries to different water use sectors (i.e., domestic, agriculture, and environment) at the planning area level, but will not distinguish between all of the various users within a sector. The model will, however, represent the major infrastructural components that influence the distribution of water through the system. Therefore, many of the principal water users will be explicitly represented. For example, the main service areas of the Delta-Mendota Canal and the California Aqueduct will be modeled as distinct demand areas because the magnitude and seasonal pattern of their demands affect Delta export and San Luis reservoir operations. However, for reporting purposes, the aggregate of deliveries to water use sectors will be considered within each planning area, and not to each project. This obviates the need to consider sharing of surplus Delta flows between the projects

under COA. For sharing responsibility to satisfy Delta standards, the buffer coefficients will be used to train the model.

3.3 MODEL CALIBRATION

The WEAP models will be calibrated using several types of historical data. Hydrologic flows (both natural and impaired) will be evaluated from 1970 to 2005 using historical monthly climate forcing data from the Maurer dataset (2002). The models will be calibrated and validated to observed streamflow for the major tributaries, flows along the Sacramento and San Joaquin rivers, diversions to the major water uses, Delta outflows, reservoir storages, and water supply allocations (groundwater vs. surface water to meet demands in different water year-types). Calibration of the hydrologic response of "rim-flow" tributaries with inflows to major reservoirs will include, among others, flows into Shasta Lake, Lake Oroville, and Folsom Lake in the Sacramento River hydrologic region, and inflows to New Melones Reservoir, New Don Pedro Reservoir, Lake McClure and Millerton Lake in the San Joaquin River hydrologic region. Since the model will include a representation of the major alluvial groundwater systems in the Sacramento and San Joaquin Rivers, which represent a major source of supply, the ability of the groundwater models to estimate both general amounts of use under average and drought conditions will be calibrated, as well as evaluate how closely WEAP can match relative regional groundwater table fluctuations.

Simulated streamflow will be calibrated and validated against historical observations using a classical split-sample procedure using the model independent, non-linear parameter estimation software PEST (Doherty 2002). PEST will be used to automatically adjust a set of scaling parameters such as soil water capacity, hydraulic conductivity, and snowmelt thresholds to better match simulated and observed flows.

For the period for which DWR has compiled water portfolio data (1998 through 2005), the WEAP-projected demand will be calibrated to estimated demands contained in the portfolio dataset. Outdoor urban and agricultural irrigation demand will be calibrated by adjusting soil and crop-specific parameters so that annually estimated applied water use closely matches the portfolio data estimates in terms of both total annual volume and depth applied to each use type (e.g., depth of applied water for turf, rice, orchards, etc., should closely reflect observed application). Urban indoor demand by sector (single-family, multifamily, commercial, and industrial) will be calibrated by adjusting per-user water-intensity factors for the calibration period.

3.4 UNCERTAINTY ANALYSIS AND EVALUATION OF RESPONSE PACKAGES

DWR and the 2005 CWP advisory committee elected to move towards a scenario approach to reflect uncertainty in both its projections of future water management conditions, and to evaluate water management response packages. This proposal builds on the accomplishments of the 2005 CWP towards this goal.

There are significant uncertainties about future drivers of water management conditions. Therefore, evaluating how well different response packages perform requires decision-making methodologies that accommodate the incomplete understanding of how future conditions may unfold.

Robust decision-making (RDM) will be used to evaluate a wide range of different response packages for California water management. RDM is an iterative, analytic approach to decision-making, useful when the future is highly uncertain (Lempert et al. 2006; Lempert et al. 2003). When the future cannot be easily characterized by statistical or probabilistic means, RDM seeks to identify robust strategies, i.e., those that are relatively insensitive to assumptions about the future. A robust response package for California, for example, would be one that performs well despite uncertainties about future hydrologic conditions, as influenced by climate change.

RDM uses computer simulation models to develop a large number of scenarios, reflecting possible future conditions. It then evaluates different management strategies against the many scenarios. Although some strategies are likely to be more robust than others, even these strategies will not perform well under all reasonable assumptions about the future.

RDM then uses statistical tools to identify the key vulnerabilities of the promising strategies (Groves and Lempert 2007), from which new hedging strategies can be developed. For example, an RDM analysis may determine that a particular set of climate conditions, combined with specific regulatory developments, would severely hamper the ability of the SWP to reliably meet its delivery objectives. This information could suggest a particular contingency arrangement along with some new facilities that would hedge against this important vulnerability at a reasonable cost.

These revised robust strategies are then reevaluated against the large set of scenarios to test their performance against many plausible conditions. In the end, robust strategies will likely have some vulnerability. Interactive visualizations are used to communicate key remaining trade-offs that decision-makers must face when choosing a final plan. Decision-makers are therefore presented with a concise set of scenarios and robust strategies and performance trade-offs necessary to assist in making a decision.

This approach has been successfully implemented in a variety of decision contexts (Groves and Lempert 2007; Lempert and Collins 2007; Lempert and Popper 2005; Lempert and Schlesinger 2000; Park and Lempert 1998, Groves et al. 2008a; Groves et al. 2008b).

Figure 3 illustrates the basic flow of an RDM analysis. As is common to any decision analysis, RDM begins by identifying the objective and project criteria (Step 1). It then focuses on key parameters, whose values are uncertain and cannot be represented with probabilities (Step 2), and defining management alternatives to consider (Step 3). It next uses simulation models to develop large ensembles of cases, each simulation representing a specific management strategy played out in a specific plausible future (Step 4). These simulations then support interactive sensitivity analyses, often with decision-makers and stakeholders (Step 5). This “what if”

analysis often leads to suggestions for additional revisions and refinements to the model (Step 6). The refined model then is reevaluated over many scenarios and used to support a statistical vulnerability analysis (Step 7). This analysis identifies those conditions or assumptions to which the particular management plans are sensitive. These “vulnerabilities” provide valuable insight and help identify robust alternatives, and the analysis repeats (Step 8). Successive iterations of this process often reveal increasingly robust alternatives. The last analytic step consists of identifying and displaying the key tradeoffs among the various robust alternatives against the different performance criteria (Step 9). Some analyses also evaluate alternative weightings of the performance metrics. The last step presents these tradeoffs to the decision-makers (Step 10). At this point, the decision-makers can identify the best options contingent on their concerns over the remaining vulnerabilities and weightings of the metrics.

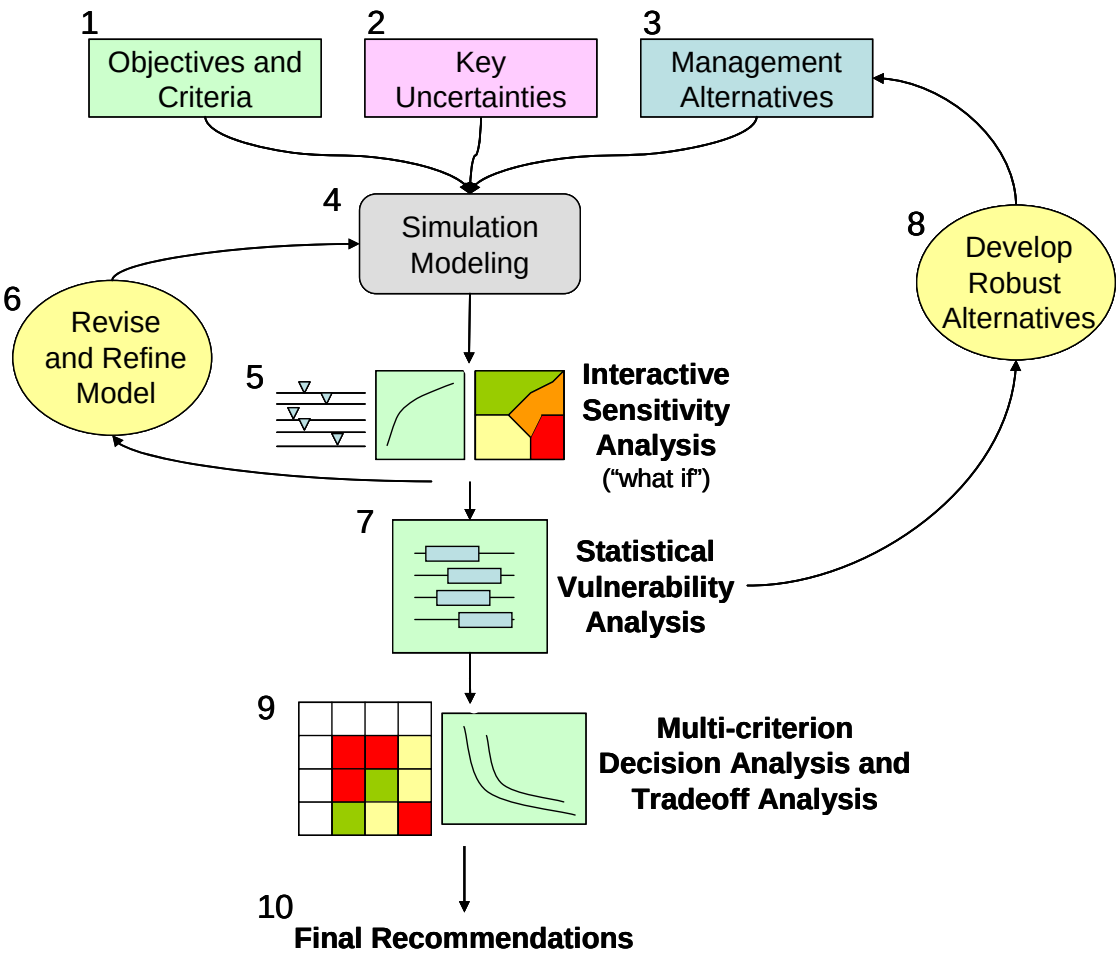


Figure 3. Robust Decision Making Analysis Flow

A preliminary summary of the scenario analysis that this project will support for the CWP 2009 Update is presented in Table 3. The table includes key uncertainties around exogenous factors (X), response package levers that can be manipulated by water managers (L), performance metrics (M), and interrelationships (R) that would be evaluated in the WEAP model. This XLMR framework is useful for organizing the major elements of a quantitative scenario-based decision analysis (see Chapter 4, Lempert et al. 2003). Table 3 calls out likely key themes of the CWP 2009 Update: climate change, efforts to reduce stress on the Delta, managing uncertainty and risk, sustainability, and flood management.

Table 3: Preliminary Scope of Proposed Scenario Analysis Using the XLRM Framework

Uncertainties/Planning Assumptions (X)	Response Packages (L)
• Temperature trends and variability • Precipitation trends and variability • Population growth • Naturally occurring conservation • Land use policy • Land cover change • Delta pumping rules and restrictions • Energy prices	• Current management • Currently planned regional development • New surface storage • New conveyance • Desalination (for HR analysis) • Accelerated conjunctive use • Accelerated wastewater reuse • Accelerated urban water use efficiency • Innovative water transfer markets • Increased stormwater capture • Adjusted flood reservation rules • New instream flow requirements
WEAP Model Relationships (R)	**Performance Measures (M)**
• Soil-moisture model connected to groundwater nodes • Indoor demand based on households and sector-specific drivers • Outdoor demand based on monthly temperature and precipitation and land use • Reservoir, CVP, and SWP Operations Delta model (CLARIFY THIS)	• Annual demand by region • Annual available supply by region • Water supply reliability by demand region • Average difference between demands and available supply (annual and averaged over years) • Supply, demand, and reliability during drought period • Patterns of critical environmental flows • Frequency/magnitude of spills

Key:
CVP = Central Valley Project
Delta = Sacramento-San Joaquin Delta
HR = hydrologic region
SWP = State Water Project

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4.0 WORK PLAN

The approach for integrated scenario analysis will be implemented via the following 15 tasks.

Task 1: Project management

This task will cover ongoing activities related to the overall management of the technical activities described in the tasks below.

Task 2: Coordinate with the CWP 2009 Update and other planning processes

This task represents periodic interaction and coordination with the California Water Plan advisory committee, SWAN, DWR Climate Technical Advisory Committee (TAG), and other statewide planning processes, including the ongoing CEC Climate Change investigations.

Task 3: Finalize project scope and work plan

This revised project scope and work plan document serves as the completion of Task 3.

Task 4: Enhance the WEAP modeling environment

This task will modify the WEAP software to support the proposed integrated scenario analysis. This will involve enhancements to facilitate implementation of scenario-based model logic, and to facilitate scenario experimentation by stakeholders. Specifically, SEI will modify the definition of new variables in the Key Assumptions so that they can be defined as arrays for which a series of values can be read in from external databases, or modified through a series of "scenario wizards." The expression-building functionality of WEAP will also be expanded to allow operation on these arrays through a range of index-based computations. Further, SEI will develop an easy-to-use scenario interface development wizard that will allow the user to bring critical scenario, inputs and outputs onto a control panel so that in running a scenario the user could avoid making specific changes to the underlying model database and sorting through the voluminous output associated with a particular WEAP run. As part of the proposed project, SEI will make the modified version of WEAP available for use, free of charge, by all stakeholders in the CWP 2009 Update process.

Task 5: Translate narrative scenario elements into model-appropriate logic and representations

This task will build on recent work of DWR staff and CWP advisory committee members in developing narrative scenario factors and water management responses for the Water Plan. The project team will work with DWR staff to determine which uncertain scenario factors and water management actions can and should be reflected in the WEAP modeling application. The project team will also work with the CWP advisory committee to finalize the metrics that will be calculated by the WEAP model and reported in the Water Plan. Together, this information will provide the needed elements of the XLRM framework to structure the scenario analysis.

Task 6: Develop ranges of model parameters to be evaluated in the scenario analysis

Once the key uncertain factors and management response actions are identified, the project team will work with DWR staff, the SWAN, and others to identify suitable ranges of values for model parameters to be evaluated in the scenario analysis. For example, the project team will consult recent population projections by the California Department of Finance and recent population scenario analysis by the Public Policy Institute of California (PPIC) to develop a plausible range of population growth values.

Scenarios of monthly temperature and precipitation will be derived from global climate model projections. The project will use down-scaled GCM simulation data from the World Climate Research Programme's CMIP3 multimodel dataset. This dataset includes over 100 different simulations from 16 global models evaluated for 3 global emissions scenarios on an 1/8th degree grid. The project team will initially use 12 specific simulations for each watershed object in the WEAP model, corresponding to 6 models and 2 emissions scenarios that were selected by the California CAT to serve as common climate scenarios for use in California climate impacts assessments.[3] These 12 simulations will provide an initial range of climate conditions to be evaluated in the analysis.

Task 7: Revise Sacramento River model to correspond with the proposed planning area structure

As part of previous work in the Sacramento River Hydrologic Region, a highly refined WEAP application was developed that captures much of the system detail in this part of California (Yates et al. 2007). This WEAP model of the Sacramento River Hydrologic Region represents water balances at a scale that is finer than that of an individual planning area. In this Task, the Sacramento River model will be revised to evaluate water mass balance primarily at the planning area level. For some regions, the planning areas will be further disaggregated to represent important elevation changes or water management characteristics (see discussion in Section 3). Specifically, the consolidated planning areas located in the Sierra Nevada Mountains will be disaggregated sufficiently to capture the hydrologic variability associated with the primary water storage infrastructure in the region. Planning areas on the valley floor portion of the model will be preserved to the maximum extent possible as the control volume for analysis.

Task 8: Expand the model to include the San Joaquin Hydrologic Region under the proposed planning area structure

Concurrent with revising the Sacramento River model in Task 7, a similar model of the adjacent San Joaquin River hydrologic region will be developed. This expansion with allow a complete representation of the Delta source area in WEAP, which should in turn allow consideration of issues related to the sustainability of the Delta. The basic approach to developing this portion of the model will parallel that applied in the Sacramento River hydrologic region. Agricultural

[3] More information on the CAT climate scenarios can be found at: http://meteora.ucsd.edu/cap/scen08_data.html.

model "templates" will be developed for both the Sacramento and San Joaquin valleys, making use of DWR datasets of crop water use, available for both hydrologic regions and the planning areas for 1998 through 2003. These templates will be the building blocks from which regional agricultural demands and responses will be represented. Land-use and land cover datasets and publicly available datasets will be used to distinguish water use types (agricultural, environmental, including instream flows, wild and scenic river flows, wildlife refuges, and municipal and industrial). Once the component pieces are in place, an integrated Sacramento - San Joaquin WEAP application will be assembled that will include the major reservoirs and planning areas.

Task 9: Calibrate and validate the models

To ensure that the WEAP applications of the Sacramento River and San Joaquin River hydrologic regions adequately represent hydrologic response to climate inputs, the model will be incrementally calibrated and validated (as discussed in Section 3.2). First to be calibrated will be the largely unregulated watersheds where there are good estimates of the naturalized inflows. Next to be calibrated will be irrigation and indoor water use by planning area. Last to be calibrated will be the impaired flows, reflecting reservoir operations, instream flow requirements, Delta exports, and diversions to agricultural and urban demands.

Task 10: Support DWR in implementing high-level scenario analysis for the 10 hydrologic regions using WEAP

This task represents the most direct continuation of the activities undertaken as part of the CWP 2005 Update and subsequent activity within DWR. This task will cover continued analytical and methodological support to DWR, through refinement and improvement of this low-resolution regional analysis for each of the 10 hydrologic regions. For this task, the project team will assist DWR in implementing a low-resolution WEAP representation of water demand and supply for each hydrologic region. This effort will build on the scenario work of the CWP 2005 Update by using the CMIP3 climate dataset to evaluate different scenarios of hydrologic-region-level average climate-driven agriculture and outdoor urban irrigation demand.

Task 11: Define the experimental design for evaluating response packages under a range of scenarios

For this task, the project team, in consultation with DWR and SWAN, will develop the experimental design for evaluating response packages under a wide range of scenarios. A set of common scenarios will be defined that reflect uncertainties in both future climate and also other management conditions (e.g., the "Xs" in the XLRM table above). It is anticipated that for each combination of non-climatic uncertainty factors, each of the 12 CEC climate scenarios will be evaluated. Therefore, if 10 combinations of non-climate factors are defined, a total of 120 scenarios would be evaluated. Included among these scenarios will be representations of the three narrative scenarios developed by the CWP advisory committee and DWR staff. Each response package will then be evaluated against each scenario.

Task 12: Evaluate water management response packages for different scenarios

For this task, the WEAP applications developed in Tasks 7 and 8 will be exercised to evaluate how various response packages will perform under different scenarios. These scenarios will reflect plausible changes in climate as reflected in the data obtained and adapted in Task 5; demand drivers such as population, naturally occurring conservation, and development patterns; and others. This will occur by first evaluating a set of response packages for the small set of handcrafted narrative scenarios developed by the CWP advisory committee. The results from this limited set of runs can then be displayed using standard scenario planning tables and graphics. Next, a much larger set of scenarios will be evaluated following the systematic experimental design (developed in Task 11) to span the space of plausible conditions. RDM methods will be used to characterize the conditions in which each response package performs well and poorly. This information can then be used to define a smaller set of policy-relevant scenarios that can be described in greater detail and highlighted in the CWP Update 2009.

Task 13: Develop a plan to link regional analysis output to system-wide analytical tools such as CalSim or CalLite

CalSim and CalLite, system-wide models that simulate the operation of the CVP and SWP, are accounting tools that make storage release and delivery decisions on a monthly time step. All water supplies and water demands are preprocessed and used as model input. These models do not simulate climate-driven hydrology, or climate-driven demands, nor do they have embedded agricultural and urban demand modules. Under this task, a strategy for mapping water supply and water demand scenarios developed for the CWP 2009 Update into inputs for CalSim and/or CalLite will be developed. Recommendations will be offered for how climate-driven demands and management responses could be preprocessed and simulated in these system-wide models. Based on this strategy, a limited set of scenarios will be modeled to demonstrate system-wide effects, and the integration of local and regional scale planning efforts at a larger, statewide scale.

Task 14: Train interested stakeholders in use of WEAP

Two training sessions will be held on WEAP and its use as part of a RDM process to enable stakeholders to work with DWR and its consultants in the development of the proposed analytical tools. The training course will be designed to build technical proficiency in the use of WEAP by introducing trainees to key features of WEAP through supervised exploration of the software. The training exercises will highlight features of WEAP using the application developed for the Sacramento and San Joaquin hydrologic regions and will include a discussion on how to make use of available data to conduct scenario analyses.

Task 15: Documentation

At the conclusion of the project, the project team will work with DWR staff to prepare a technical appendix for the CWP Update 2009 on all work completed under this project. At the request of DWR, the project team may also be involved in the preparation of text and graphics

for the main body of the document. As the extent of involvement in the development of the CWP Update document is unclear, the budget included covers the requirements for the technical appendix alone.

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5.0 SCHEDULE

The entire project described here will be implemented in three phases, as shown in Table 4 and Table 5.

Table 4: Schedule of Work Phases

Phase	Tasks	Period of Performance
1	Analysis scoping, model development and calibration – Tasks 1-10	May 2008 – November 2008
2	Implement scenario and RDM analysis / begin integration with CALSIM / training – Tasks 11-14	December 2008 – April 2009
3	Final documentation – Task 15	April 2009 – September 2009

Table 5: Schedule of Work Tasks

		2008								2009								
		M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S
		Phase 1						Phase 2						Phase 3				
Task 1	Project management	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Task 2	Coordinate with CWP 2009 update	■				■				■				■				■
Task 3	Finalize scope and work plan				■	■												
Task 4	Enhance WEAP						■	■										
Task 5	Translate narrative scenarios					■	■											
Task 6	Develop parameter ranges					■	■											
Task 7	Revise Sacramento River model	■	■	■	■	■												
Task 8	Develop San Joaquin River model	■	■	■	■	■												
Task 9	Calibration and validation						■											
Task 10	Support DWR HR-level analysis	■	■	■	■	■	■	■	■	■	■	■						
Task 11	Experimental design								■									
Task 12	Scenario analysis								■	■	■	■						
Task 13	Statewide integration									■	■	■						
Task 14	WEAP training							■				■						
Task 15	Documentation												■	■	■	■	■	■

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