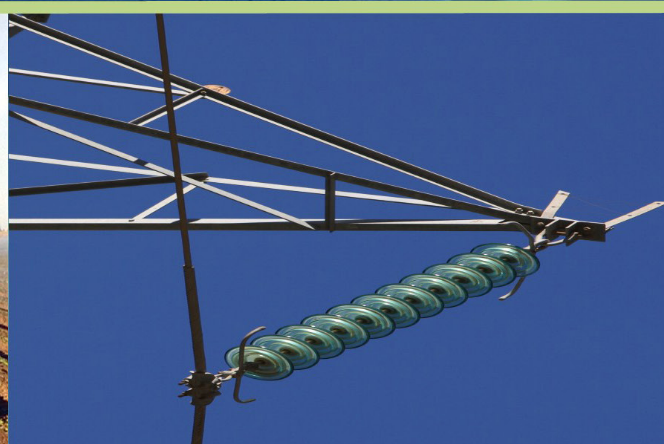
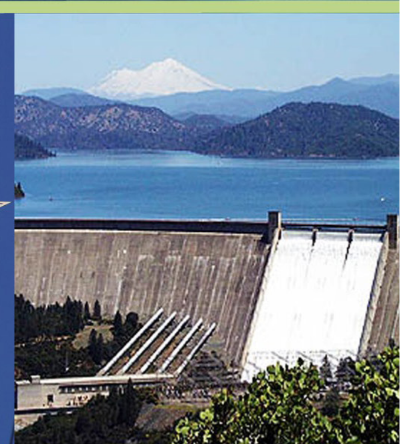
RECLAMATION

Managing Water in the West

Final Report

Central Valley Project Integrated Resource Plan





U.S. Department of the Interior
Bureau of Reclamation
Mid-Pacific Region

November 2014

Mission Statements

The mission of the Department of the Interior is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to Indian Tribes and our commitments to island communities.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

RECLAMATION

Managing Water in the West

Final Report

Central Valley Project Integrated Resource Plan

Prepared for Reclamation by CH2M HILL under
Contract No. R11PD2025

BY

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EXECUTIVE SUMMARY

Background

Over the past several decades, the Central Valley Project (CVP) has been confronted with a wide range of water resource management challenges that have put increasing pressure on the water supplies available to meet CVP contractor's needs. The Central Valley Project Integrated Resource Plan (CVP IRP) study continued the long-range planning activities of the Central Valley Project Yield Feasibility Investigation by addressing future uncertainties in climate as well as changing socioeconomic conditions. To better understand future challenges, the CVP IRP study focuses on providing more comprehensive assessments of potential climatic and socioeconomic uncertainties on key CVP management objectives for the entire CVP Service Area and each of the CVP Divisions.

The CVP IRP study also explored various portfolios of systemwide and local water management actions that might be employed to address some of the potential twenty-first century challenges. These portfolios of actions were evaluated against key CVP performance criteria to compare their potential effectiveness under a broad range of future socioeconomic-climate uncertainties, and to identify tradeoffs among various delivery reliability, water quality, environmental, hydropower, and urban and agricultural economic performance characteristics.

Study Approach

The CVP IRP study employed a scenario-based analytical approach to assess potential impacts as well as to evaluate the effectiveness of potential water management actions under a range of potential future uncertainties. The analytical approach involved using the Water Evaluation and Planning model of the Central Valley (WEAP-CV) and the CVP IRP CalLite model in an integrated manner. The role of each model in the approach is shown on Figure ES-1. The WEAP-CV model was used to generate hydrology information and demand information, which were then used as inputs to the CVP IRP CalLite model. The CVP IRP CalLite model simulated State Water Project (SWP) and CVP operations, with explicit representations of the SWP and CVP storage operations and delivery allocation decisions, and Bay-Delta regulatory requirements. It was also used to simulate changes to the system resulting from potential local and systemwide water management actions. Additional performance assessment tools were also applied to analyze urban and agricultural economics, water quality, hydropower generation, and greenhouse gas (GHG) emissions throughout the CVP Service Area.

Future Uncertainty and Scenario Development

A suite of scenarios was developed for the CVP IRP to account for a range of uncertainty in future conditions. These scenarios reflect the following conditions:

- Three future socioeconomic conditions
- Six future climate conditions, including one reflecting historical conditions without climate changes and five reflecting climate change conditions

These three socioeconomic futures and six climate futures were combined to form the suite of 18 future scenarios. Each scenario was analyzed for the period from October 2011 through September 2099 using a transient approach in which the climate and socioeconomic factors gradually changed as the simulation moved through time.

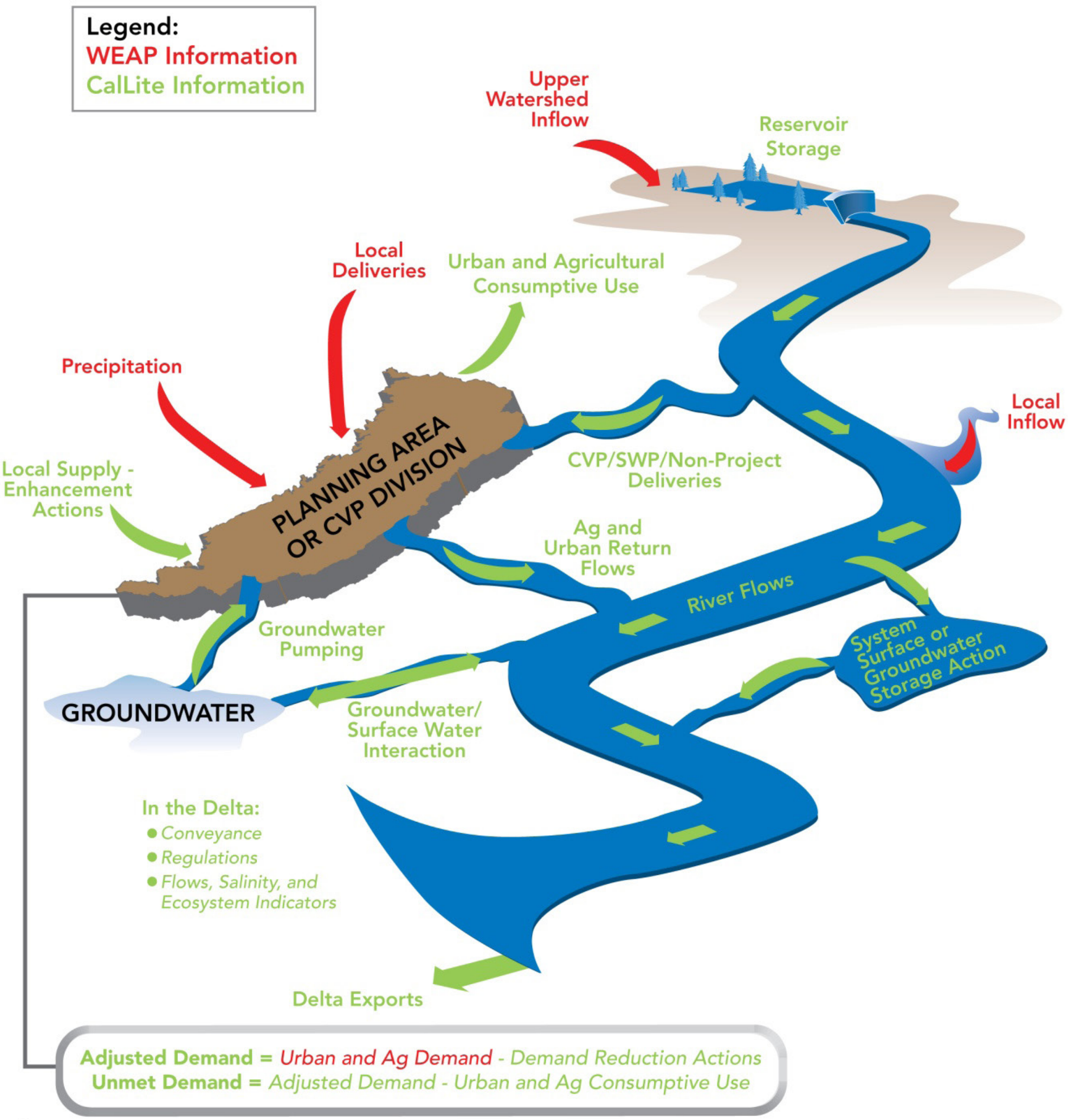

Figure ES-1. WEAP-CV/CalLite Integrated Analytical Approach

The CVP IRP used the following three socioeconomic future scenarios developed for the *California Water Plan Update 2009*: [2]

- Current Trends (CT), which assumed that recent trends will to continue into the future
- Slow Growth (SG), which assumed that future development is less resource-intensive than under recent conditions
- Expansive Growth (EG), which assumed that future development is more resource-intensive than under recent conditions

Population and land use projections were developed for each scenario for the period from 2010 through 2100. The projected statewide population under each scenario is shown on Figure ES-2.

2 California Department of Water Resources (DWR). 2009a. California Water Plan Update 2009. Bulletin 160-09. Sacramento, California.

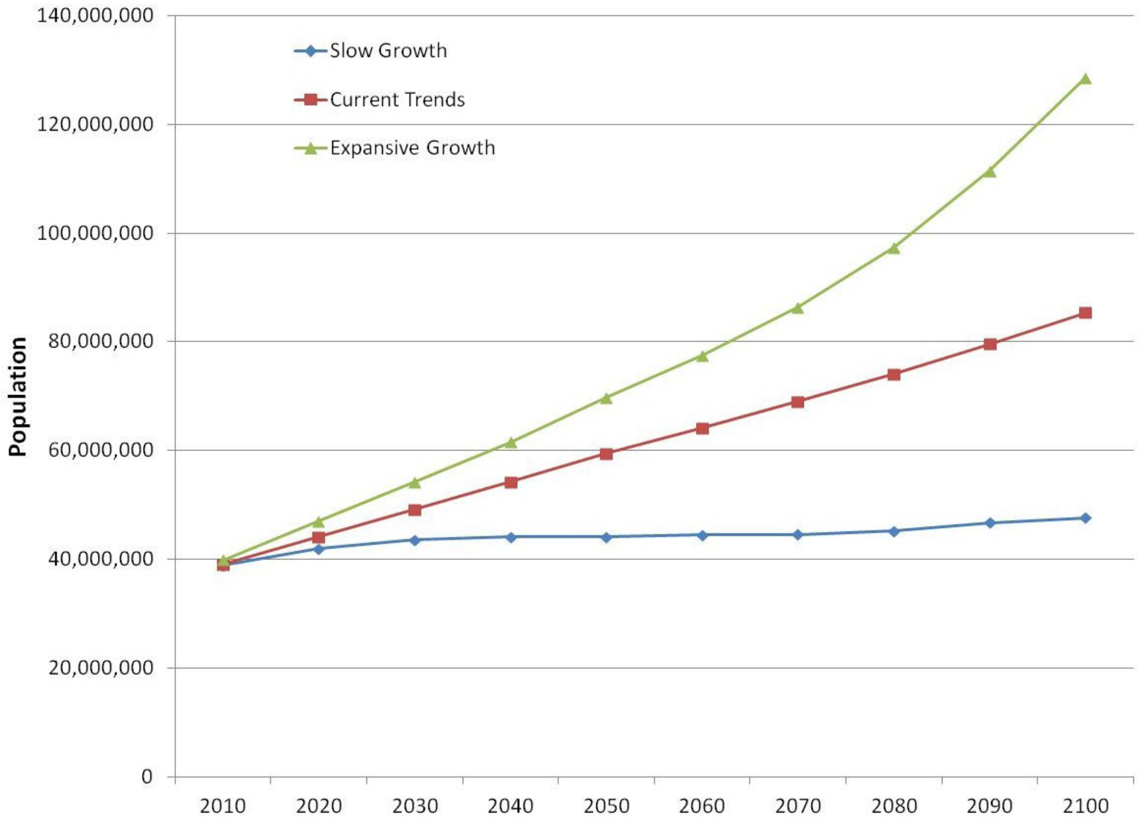

Figure ES-2. Statewide Population Projections under Each Scenario

The CVP IRP climate projections were developed using an approach similar to that used for the Bay Delta Conservation Plan. The five future climate sequences were developed using a multi-model hybrid delta ensemble approach in which the ensemble of future climate change projections was broken into regions representing future climate uncertainties ranging from (Q1) drier, less warming (relative to median); (Q2) drier, more warming; (Q3) wetter, more warming; and (Q4) wetter, less warming scenarios than captured by the ensemble median (Q5). The inter-annual variability in the temperature and precipitation projections was developed using the observed natural variability sequence (1915–2003) and the projected climate changes. Each climate future was characterized by changes in precipitation and temperature at locations where WEAP-CV inputs occurred. As an example, Figures ES-3 and ES-4 show the projected changes in temperature and precipitation for each climate scenario relative to conditions with no climate change in the American River Basin. The temperature and precipitation projections for each scenario generated a range of hydrologic responses, water demands, and sea level rise projections that drove the CVP IRP models.

Water Supply and Demand Projections

Projected water supplies and water demands varied significantly across the range of future scenarios. In general, differences in water supplies among the different socioeconomic scenarios were small. However, there were substantial differences in runoff among the different climate scenarios. Figures ES-5 and ES-6 show the annual time series of surface water runoff in the Sacramento River system upstream of Hood and in the San Joaquin River system upstream of Vernalis in each climate scenario for water years 2012 through 2099. Figures ES-7 and ES-8 show the change in each climate scenario relative to the Baseline. Average annual runoff under the no climate change condition was about 20.5 million acre-feet per year (MAF/year) in the Sacramento River system and about 6.7 MAF/year in the San Joaquin River system, for a total of 27.2 MAF/

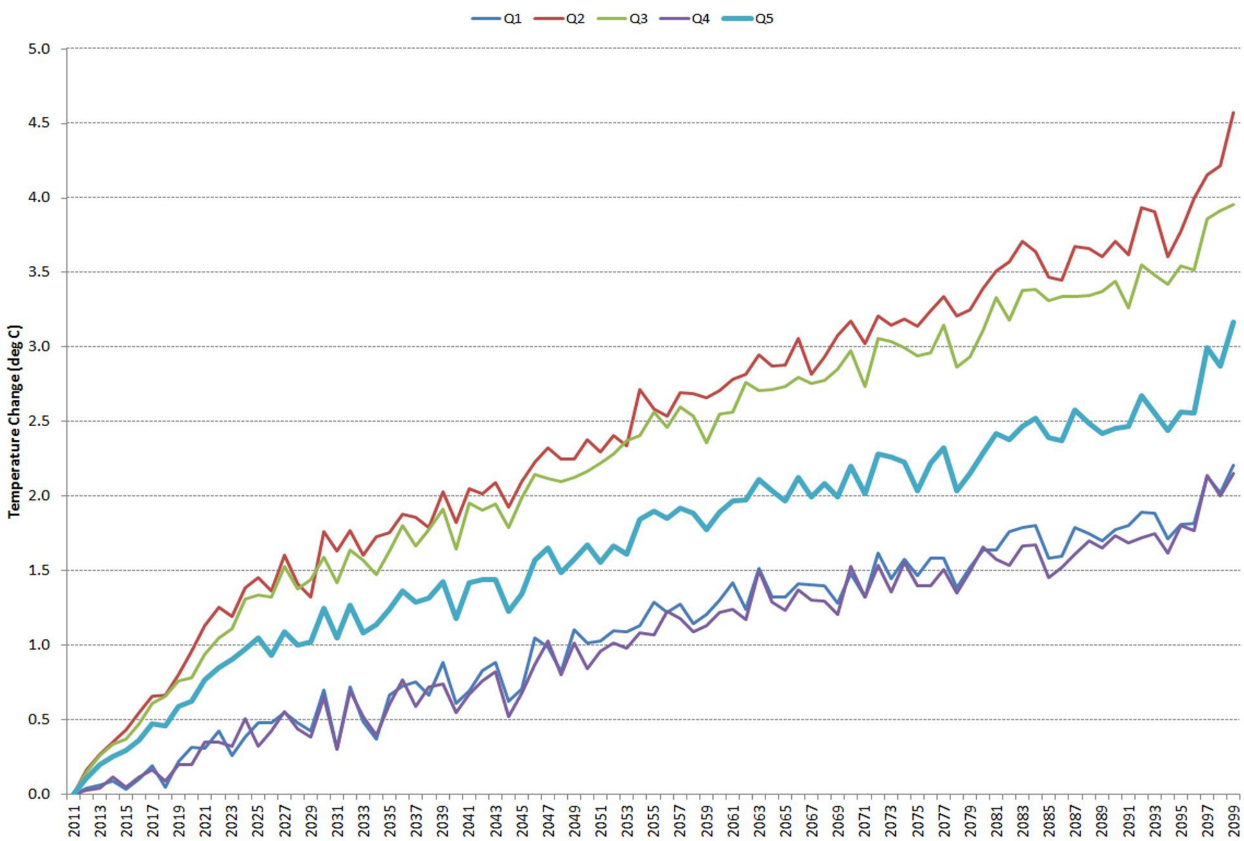

Figure ES-3. Projected Changes in Temperature in Ensemble-Informed Transient Climate Scenarios for a Representative Grid Cell in the American River Basin (Example)

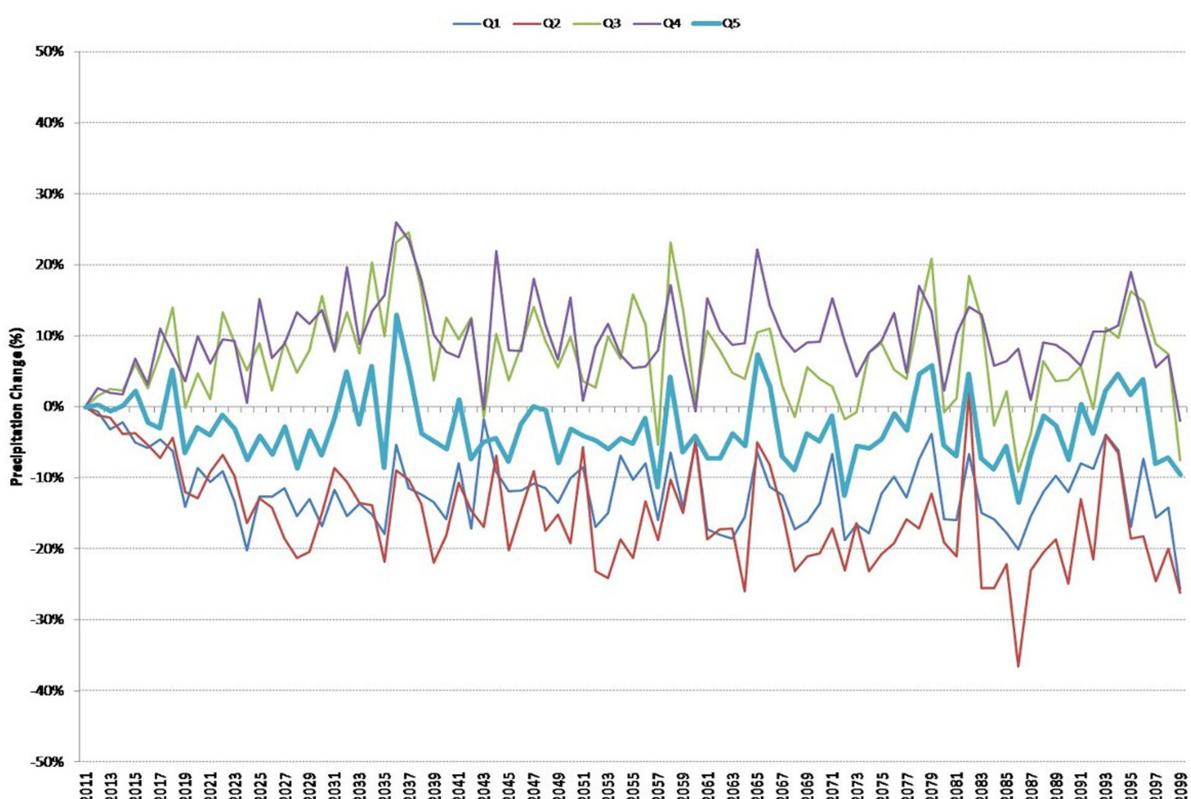

Figure ES-4. Projected Changes in Precipitation in Ensemble-Informed Transient Climate Scenarios for a Representative Grid Cell in the American River Basin (Example)

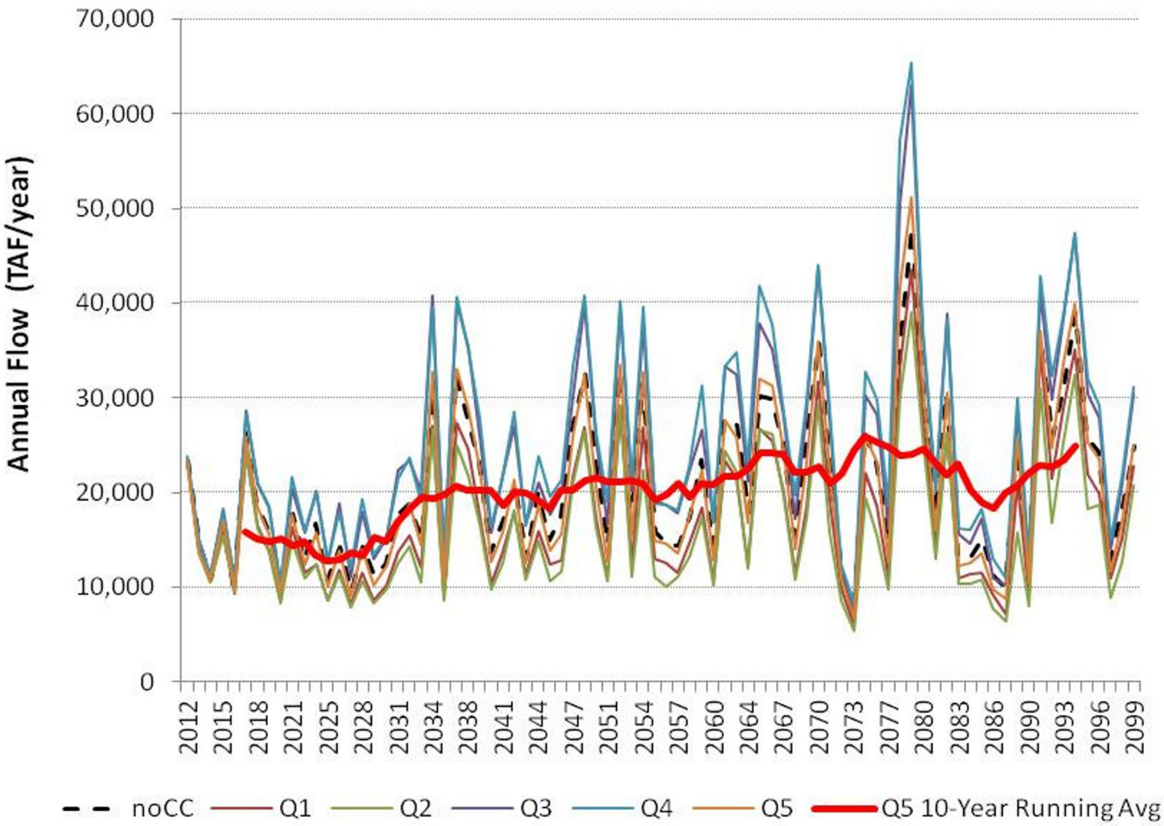

Figure ES-5. Annual Time Series of Runoff in the Sacramento River System in Each Climate Scenario

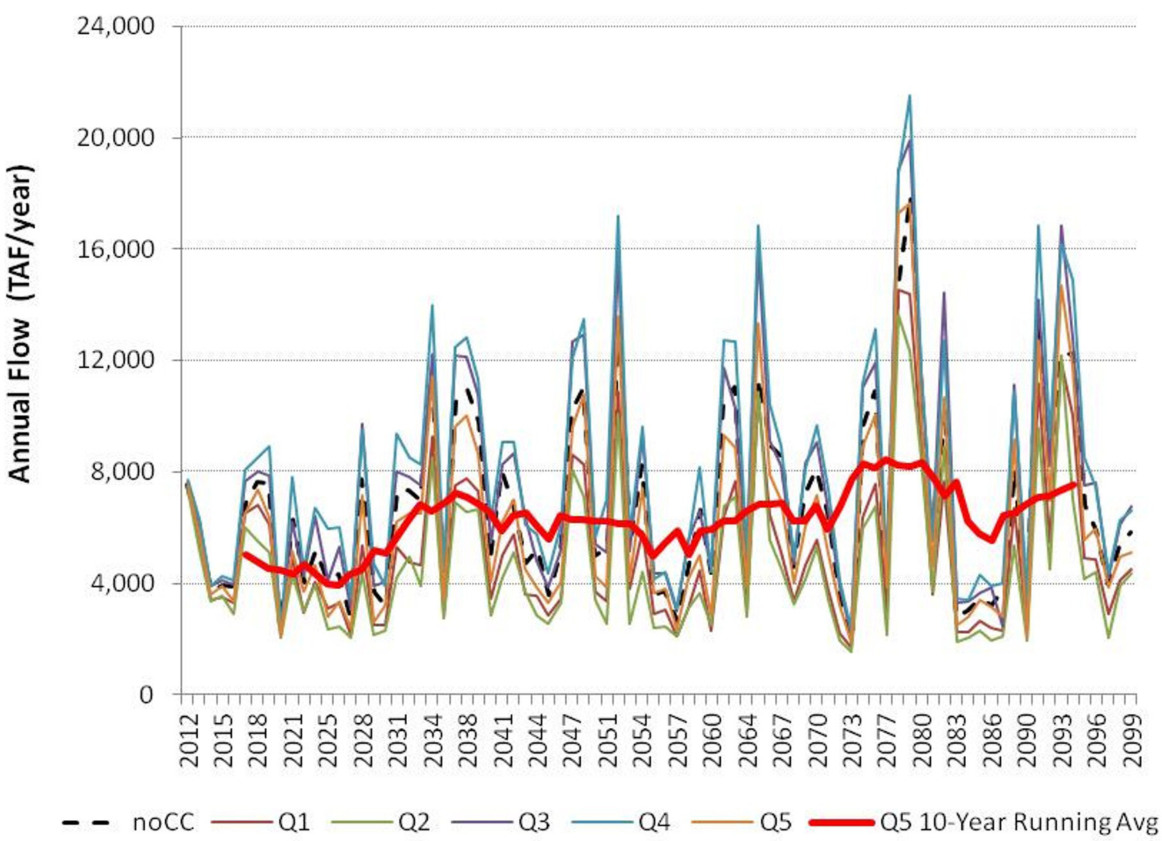

Figure ES-6. Annual Time Series of Runoff in the San Joaquin River System in Each Climate Scenario

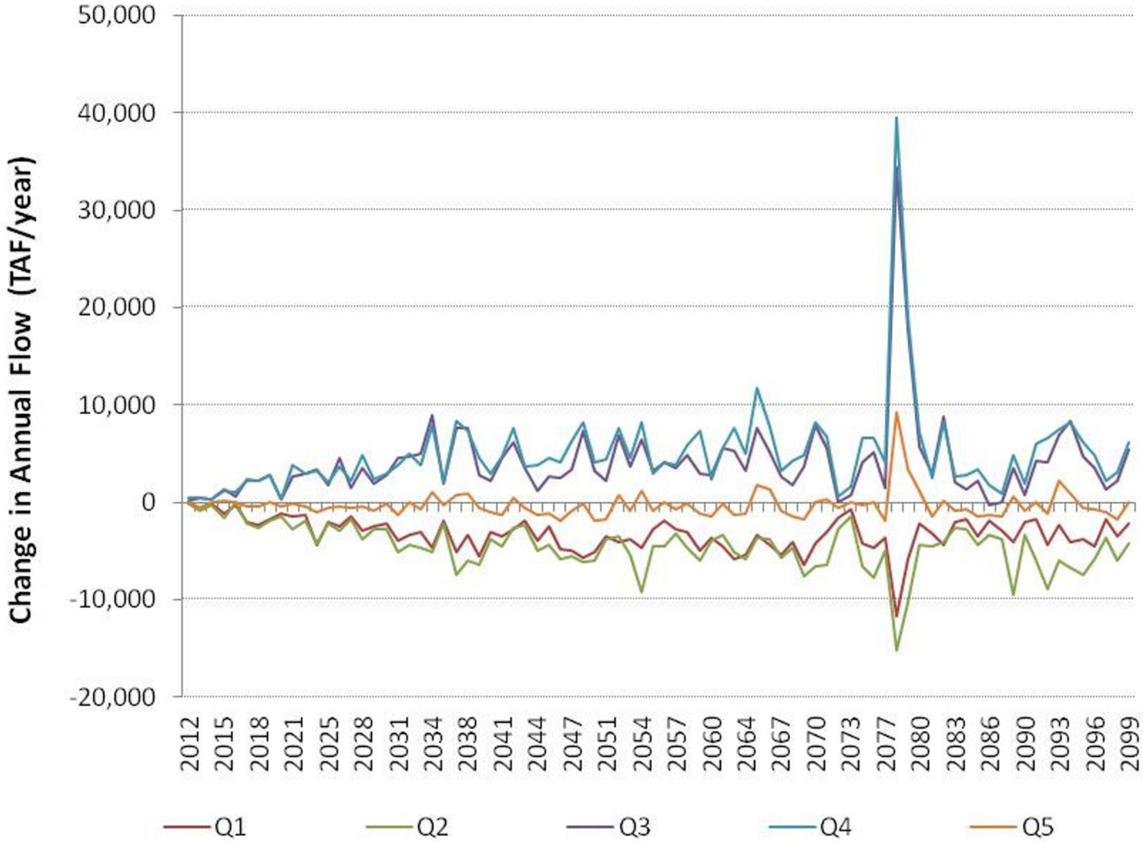

Figure ES-7. Change in Annual Runoff in the Sacramento River by Climate Scenario Relative to the Baseline

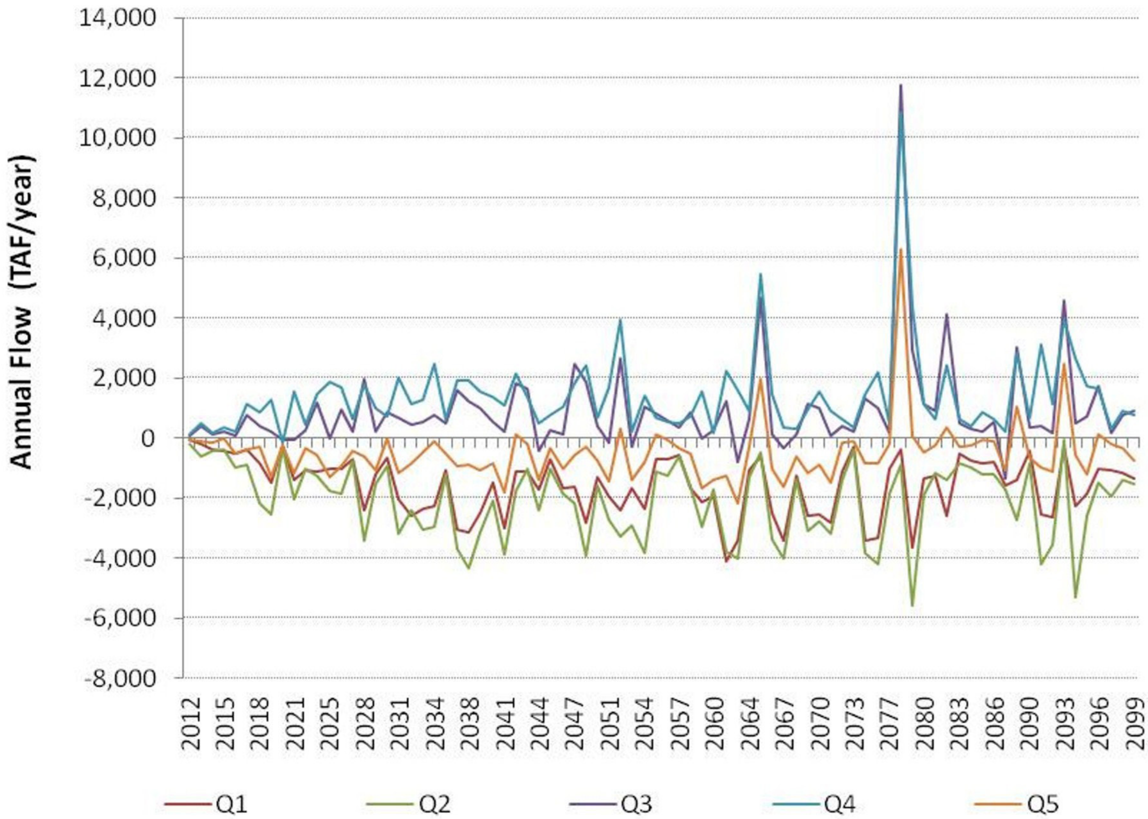

Figure ES-8. Change in Annual Runoff in the San Joaquin River by Climate Scenario Relative to the Baseline

year. Average annual runoff across the future climate scenarios for the two systems ranged from a low of about 20.7 MAF/year in the driest scenario (Q2) to a high of about 33.3 MAF/year in the wettest scenario (Q4). The mid-range scenario (Q5) resulted in 26.4 MAF/year. Figures ES-5 and ES-6 also show the 10-year running average for the mid-level (Q5) scenario. As demonstrated by the Q5 scenario running averages, there was a general trend of increasing flow on both river systems through the twenty-first century. These future time series reflected the similar inter-annual variability as the historical period because of the methodology used in developing the projections, with extended drought periods of lower runoff values from 2025–2030 (corresponding to the 1929–1934 dry period) and from 2083–2088 (corresponding to the 1987–1992 drought), and a very substantial dry period from 2072–2073 (corresponding to the 1976–1977 low precipitation years). However, as can be observed on the figures, the magnitude of the events differs from historical conditions.

Figures ES-9 and ES-10 show the average runoff in each month in the Sacramento River and San Joaquin River systems for each climate scenario for the entire simulation period from 2012 through 2099. Each basin has a different monthly pattern reflecting the difference in hydroclimate and terrestrial conditions within the basin. In each basin, the climate scenarios exhibited a similar pattern to the no climate change scenario, but with a shift in runoff from the spring months to the winter months. This projected shift occurred because higher temperatures during winter cause earlier snowmelt runoff. The shift in timing increased during the latter part of the century when the temperature changes were the greatest.

Water demands differed across both climate and socioeconomic scenarios. Figure ES-11 presents the annual time series of projected total agricultural demands within the CVP Service Area for the 18 socioeconomic-climate scenarios. Agricultural demands were projected to increase in the early to middle twenty-first century primarily because of rising temperatures and increasing

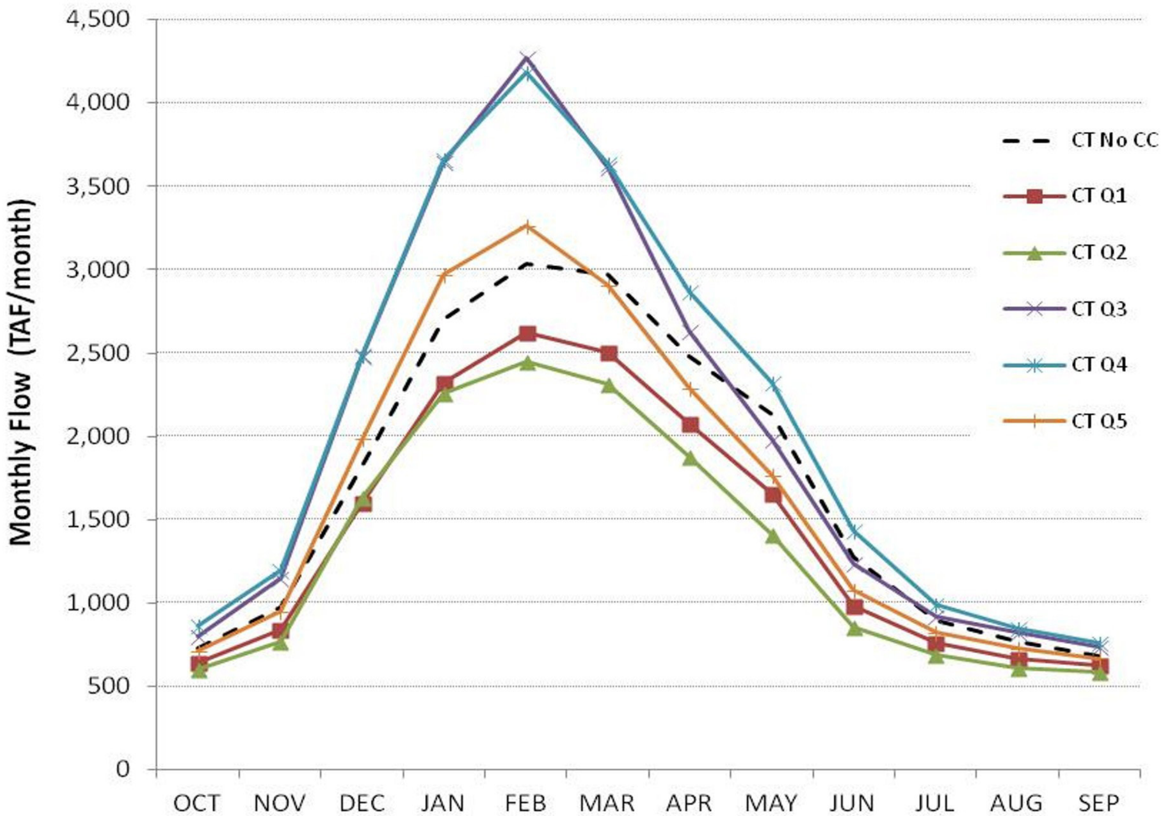

Figure ES-9. Average Runoff in Each Month in the Sacramento River System in Each Climate Scenario

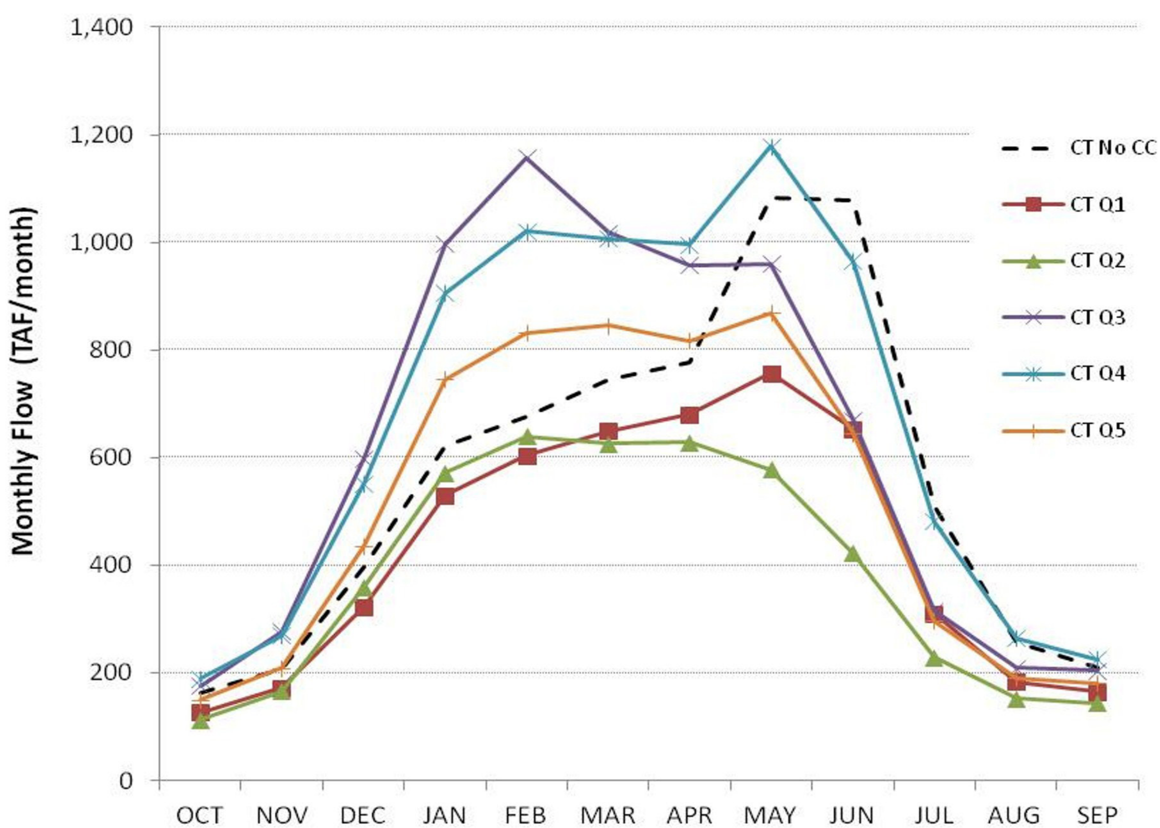

Figure ES-10. Average Runoff in Each Month in the San Joaquin River System in Each Climate Scenario

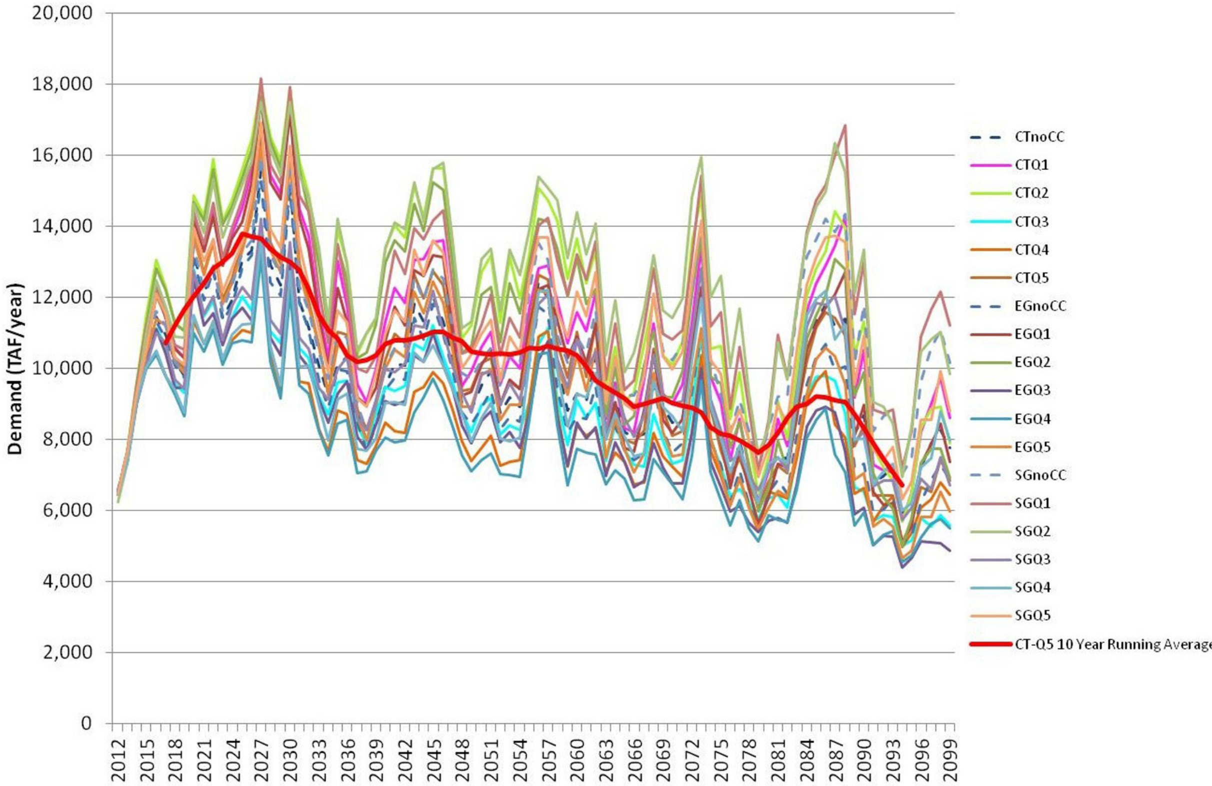

Figure ES-11. Annual Time Series of Agricultural Applied Water Demand in the CVP Service Area in Each Scenario

evapotranspiration (ET) (caused largely by increasing vapor pressure deficits). However, in the latter half of the twenty-first century, the agricultural demands were projected to decrease primarily because of the effects of a reduction in agricultural irrigated acreage. A decline in the ET of some agricultural crops currently being grown in the Central Valley also contributed to the reduction in demands related to projected increases in carbon dioxide concentrations and decreases in solar radiation. A shortening of the growth period for annual crops due to increasing temperatures also contributed to reduced ET. The average simulated total CVP Service Area agricultural demand decreased from a range of about 9.1–10.9 million acre-feet (MAF) during the 2012–2020 period to a range of about 5.1–10.1 MAF in the 2090–2099 period. Over the entire twenty-first century, these demands ranged from a minimum of 4.4 MAF to a maximum of 18.2 MAF.

In contrast to the agricultural demands, urban demands in the CVP Service Area were strongly correlated with the socioeconomic scenarios and showed only slight variations with changing short term climate variability and longer-term climatic trends. Figure ES-12 presents the annual time series of projected total urban demands within the CVP Service Area for the 18 socioeconomic-climate scenarios. Because the urban demands were driven largely by population, they tended to change steadily over time with the growth in population and expansion in commercial activities. Urban demand was only slightly changed under Slow Growth conditions but did increase significantly under the Current Trends and Expansive Growth scenarios. By the end of the twenty-first century, the overall average of all the socioeconomic-climate scenarios' urban demands in the CVP Service Areas was 2.7 MAF and ranged from 1.2 MAF (Slow Growth) to 4.1 MAF (Expansive Growth).

Baseline Unmet Demands in the CVP Service Area

A comparison of supplies and demands within the CVP Service Area revealed the extent of estimated unmet demands facing the CVP across the range of scenarios. Over the twenty-first century, average annual unmet demands ranged from 2.7 to 8.2 MAF/year across the range of socioeconomic-climate scenarios. The unmet demands occurred

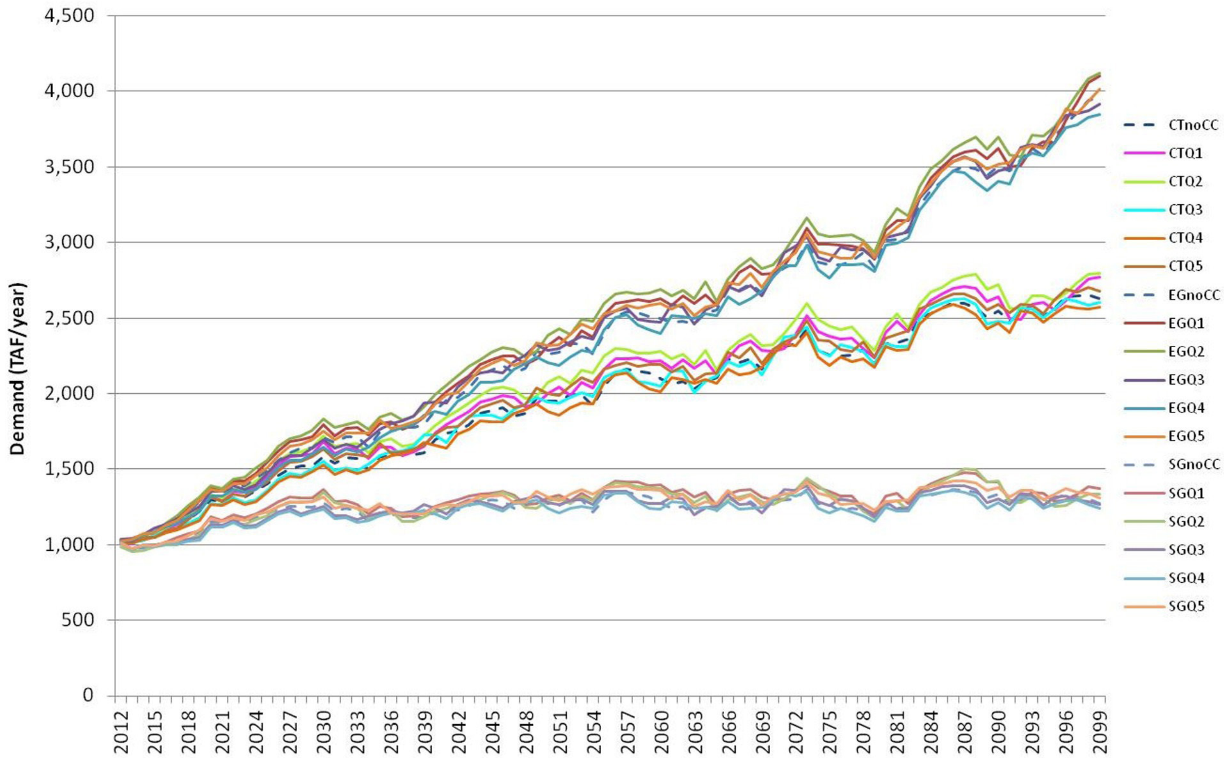

Figure ES-12. Annual Urban Applied Water Demand in the CVP Service Area in Each Scenario

predominantly in the South-of-Delta Divisions (Delta, San Felipe, West San Joaquin, and Friant). Figures ES-13 through ES-16 present annual time series of groundwater, surface water, local project supplies, and unmet demands in the CVP Service Area for four socioeconomic-climate scenarios, selected to represent the median, upper, and lower range of potential future impacts and a reasonable range of future uncertainties:

- Current Trends with no climate change (CT-noCC)
- Current Trends with median future temperature and precipitation change (CT Q5)
- Expansive Growth with higher temperature and lower precipitation changes (EG-Q2)
- Slow Growth with lower temperature and higher precipitation changes (SG Q4)

All four scenarios showed similar year-to-year variability, with demands increasing and surface water supplies decreasing during dry periods, and the opposite occurring in wetter years. The largest unmet demands occurred in the warmer-drier scenario (EG-Q2) and the least in the less warm-wetter climate scenario (SG-Q4). Overall, the central tendency (CT-Q5) unmet demands tended to be slightly greater than those in the no climate change scenario (CT-noCC).

Analysis of Water Management Actions

The CVP IRP's approach for analysis of water management actions explored combinations of potential water management actions grouped into portfolios designed to achieve particular objectives. These portfolios were designed around different themes, and analyzed by simulating each one with the suite of 18 socioeconomic-climate scenarios.

The following four portfolios of water management actions were analyzed using the CVP IRP modeling tools:

- Portfolio A: Aggressive Local Actions
- Portfolio C: Delta Conveyance and North-of-Delta Storage
- Portfolio D: Delta Conveyance and South-of-Delta Storage

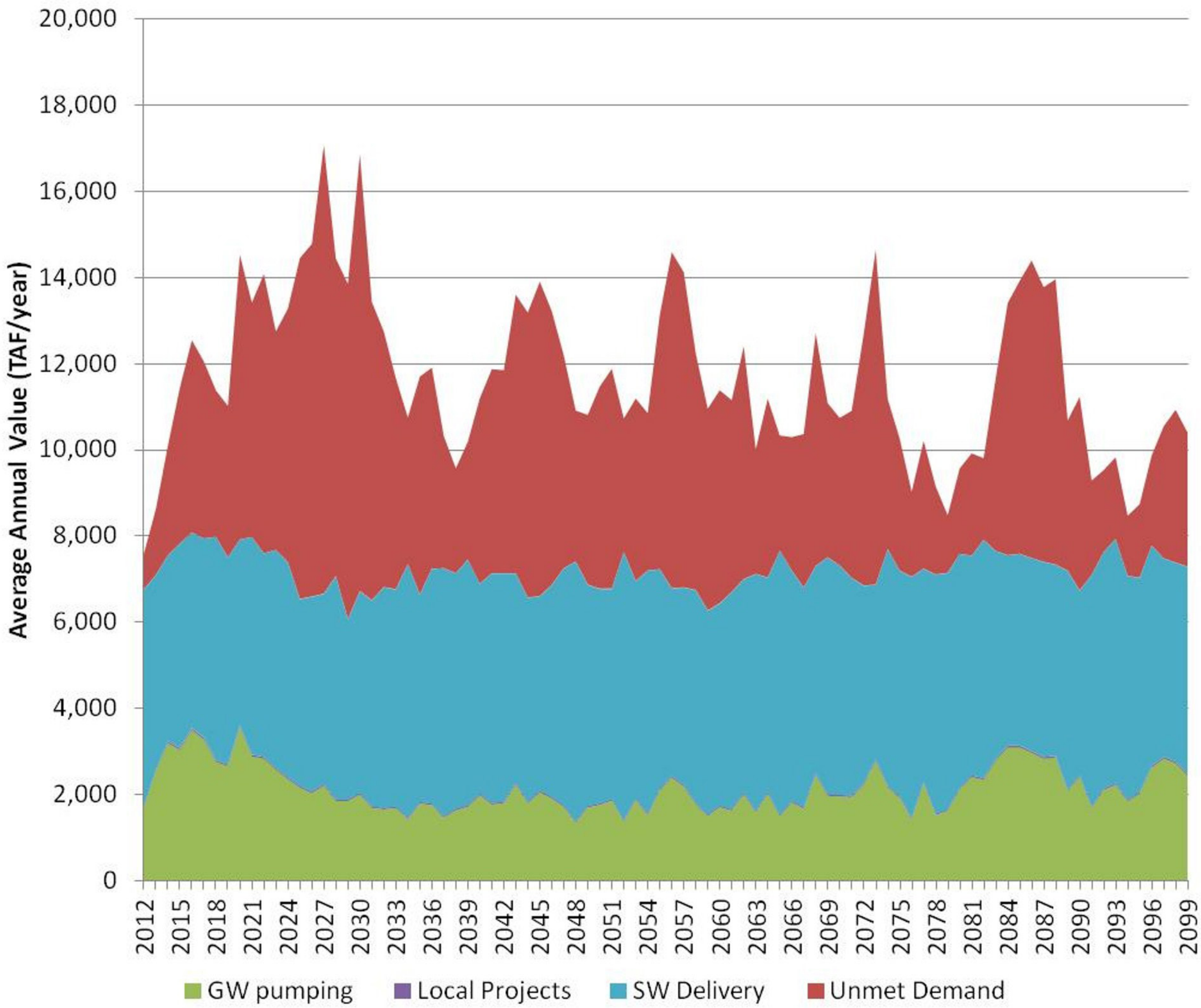

Figure ES-13. Annual Time Series of Supplies and Unmet Demand in the CVP Service Area in the CT-noCC Scenario

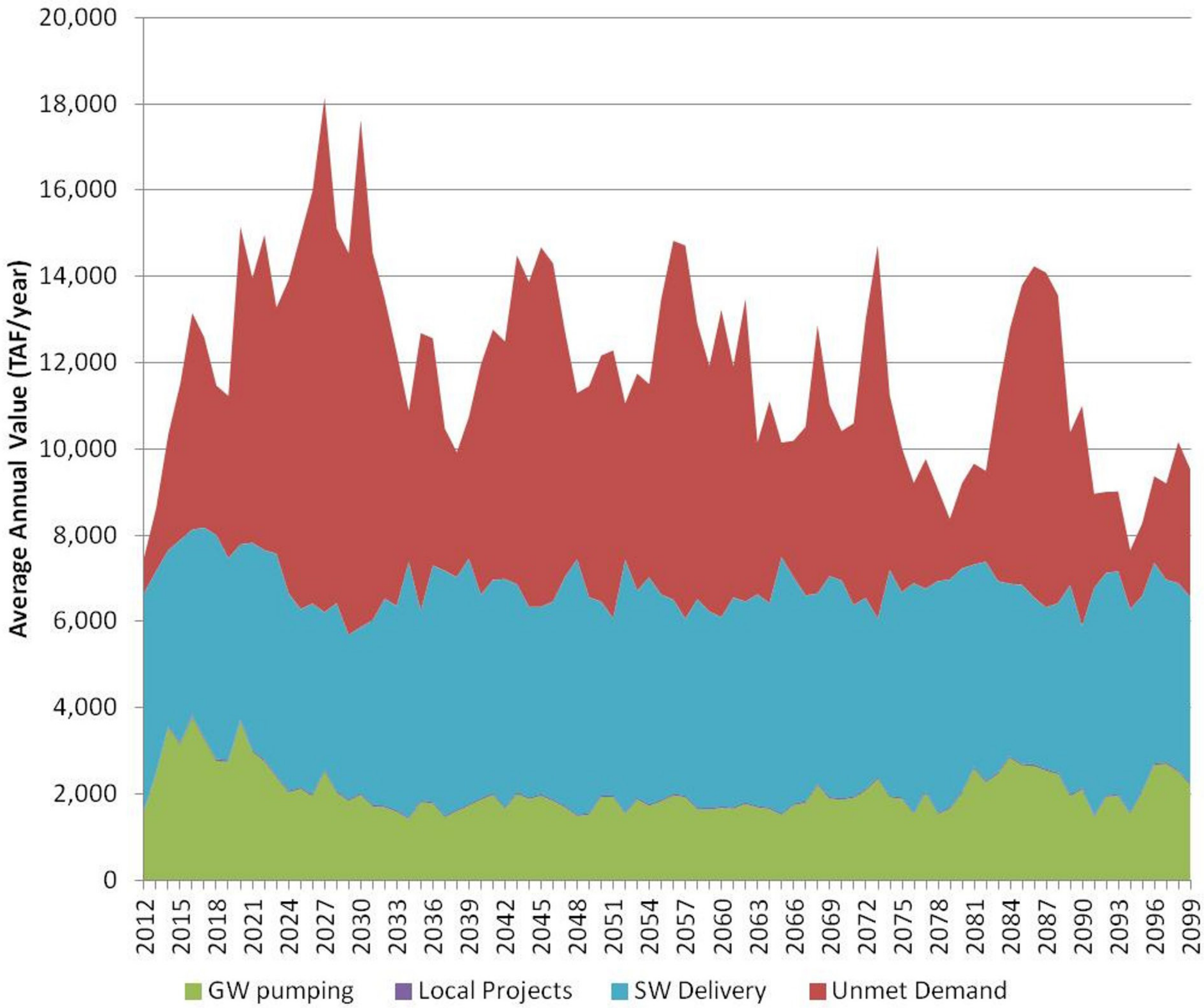

Figure ES-14. Annual Time Series of Supplies and Unmet Demand in the CVP Service Area in the CT-Q5 Scenario

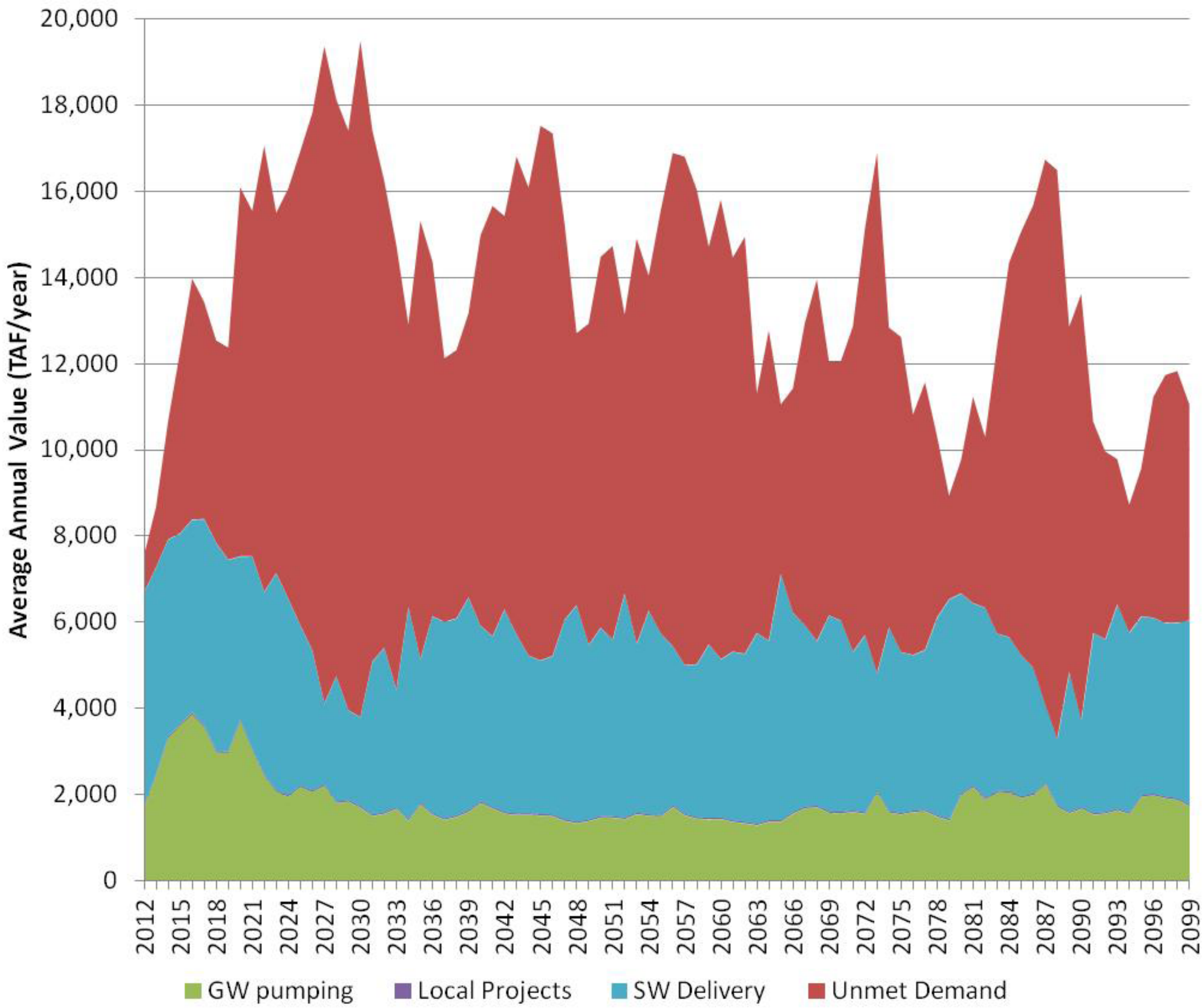

Figure ES-15. Annual Time Series of Supplies and Unmet Demand in the CVP Service Area in the EG-Q2 Scenario

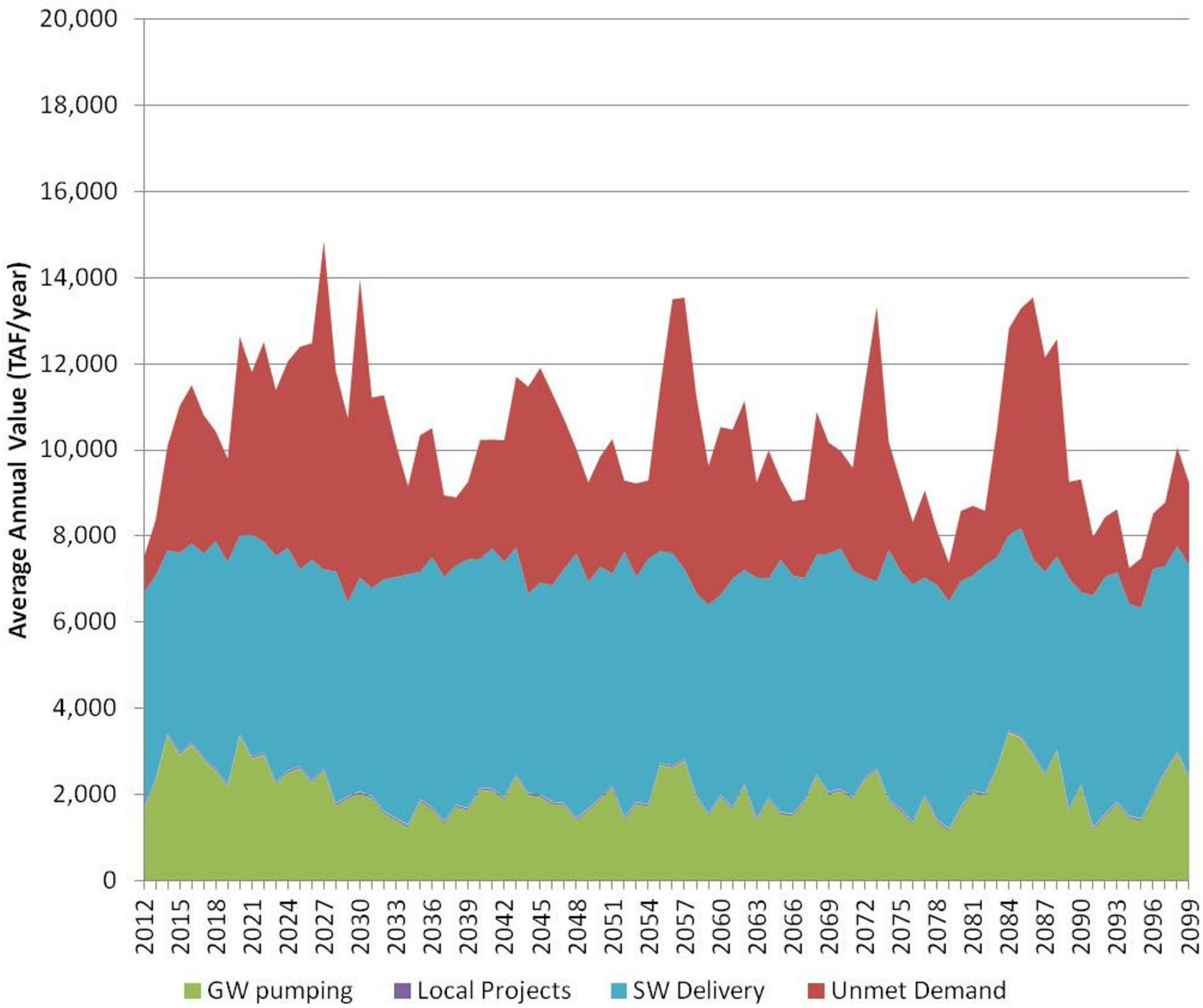

Figure ES-16. Annual Time Series of Supplies and Unmet Demand in the CVP Service Area in the SG-Q4 Scenario

- Portfolio E: Aggressive Local Actions, Enhanced Environmental Flows, and North-of-Delta Storage

(An additional portfolio, Portfolio B focusing on North-of-Delta Storage projects, was also analyzed but is not included in this summary section because those actions are included in the composite Portfolios C and E). The actions that are included in each of these portfolios are shown in Table ES-1.

The sections below compare the results of each portfolio of actions for a range of different performance metrics. To give an overview of the range of results associated with the different socioeconomic-climate scenarios, model results are shown for the same four scenarios for which unmet demand results were shown above:

- Current Trends with no climate change (CT-noCC)
- Current Trends with median temperature change and median precipitation future climate (CT-Q5)
- Expansive Growth with higher temperature change and lower precipitation future climate (EG-Q2)
- Slow Growth with lower temperature change and higher precipitation future climate (SG-Q4)

Unmet Demands in the CVP Service Area

Figure ES-17 shows the average annual unmet demand in the CVP Service Area and in each portfolio. All four portfolios resulted in significant reductions in unmet demands in each socioeconomic-climate scenario. Aggressive local demand reduction and local supply enhancement actions resulted in the greatest reductions in unmet

Table ES-1. Simulation Suites and Assumptions Included in Each Portfolio

	Portfolio A	Portfolio C	Portfolio D	Portfolio E
Baseline Assumptions	X	X	X	X
Local Actions				
Modest Ag and M&I Conservation	X	X	X	X
Municipal Recycling and Desalination				X
Aggressive Ag and M&I Conservation				X
Systemwide Actions				
Delta Conveyance		X	X	
Shasta Lake Enlargement		X		X
North-of-Delta Offstream Storage		X		X
South-of-Delta SW or GW Storage			X	
Enhanced Environmental Flows				X

Notes:
GW = groundwater
M&I = municipal and industrial
SW = surface water

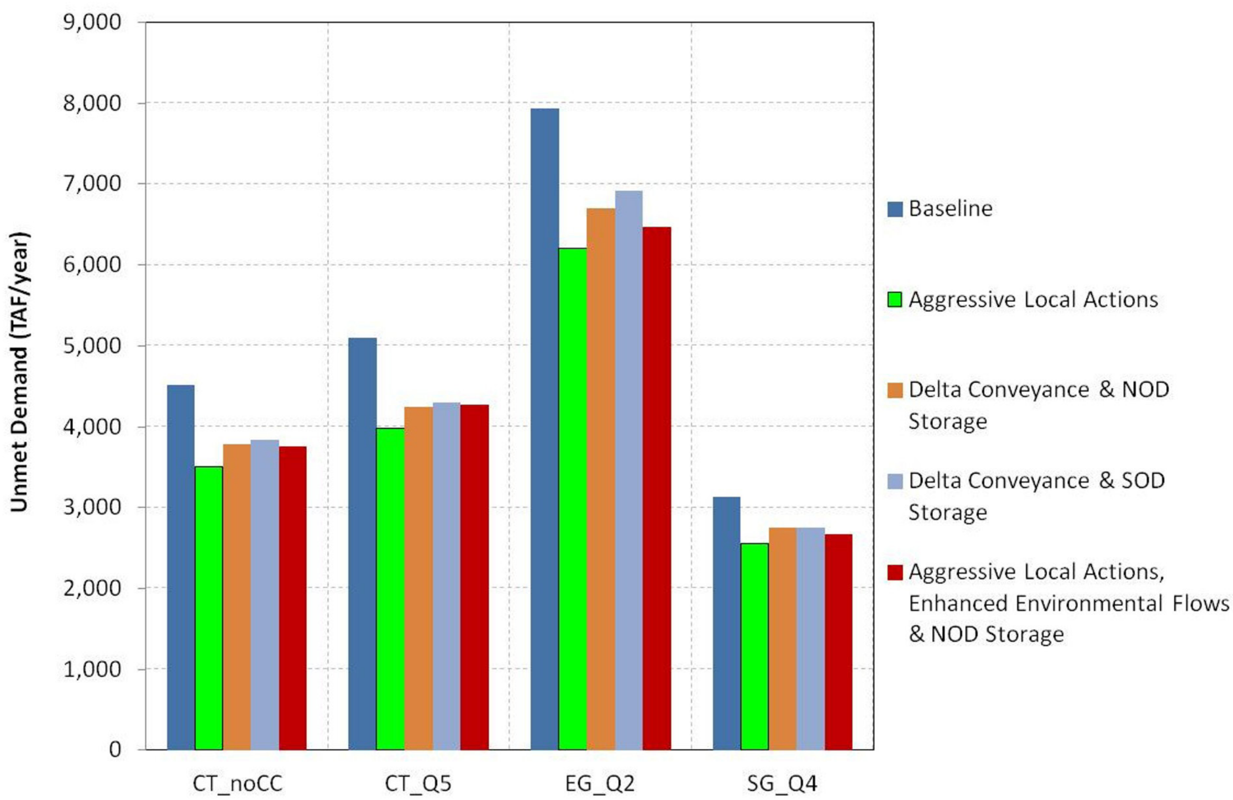

Figure ES-17. Average Annual Unmet Demand in the CVP Service Area by Portfolio demands among the portfolios. By contrast, the portfolios that included Delta conveyance with only modest demand-reduction actions had greater unmet demands than the two portfolios with aggressive demand reductions despite having greater increases in CVP deliveries relative to the Baseline.

Delta Exports and Delta Outflow

Figures ES-18 and ES-19 show the average annual Delta exports and Delta outflow in the Baseline and in each portfolio. In the Baseline and in all portfolios, both Delta exports and Delta outflow were greatest in the wettest scenario (SG Q4) and the lowest in the driest scenario (EG-Q2). Delta exports in CT-Q5 were modestly lower than in the CT-noCC scenario. Among the portfolios, implementation of local demand-reduction and supply-enhancement actions resulted in small increases in both Delta exports and Delta outflow relative to the Baseline. Adding enhanced environmental flows and North-of-Delta storage in addition to these aggressive local actions resulted in an increase in Delta outflow and a significant reduction in Delta exports. By contrast, both portfolios that include Delta conveyance showed increases in Delta exports and reductions in Delta outflow relative to the Baseline.

Delta Salinity

Figure ES-20 shows the average X2 position from February through June in the Baseline and in each portfolio. In the Baseline as well as all the portfolios, the X2 position was greater in all three climate scenarios than in CT-noCC, reflecting the effects of sea level rise and seasonal shifts in runoff. Among the scenarios with climate change, the X2 position was greatest (farthest eastward from the Golden Gate) in the driest scenario (EG-Q2) and the smallest in the wettest scenario (SG Q4). Among the portfolios, implementation of aggressive local demand-reduction and supply-enhancement actions resulted in a very little change in X2 position, consistent with the small changes in Delta exports and Delta outflows. Adding enhanced environmental flows and North-of-Delta storage in addition to these aggressive local actions resulted in a westward change in X2 position of about 3 kilometers. By contrast, both portfolios that include Delta conveyance showed an eastward change in X2 position of about 2 kilometers relative to the Baseline.

Water Temperature

The CVP IRP analyzed changes in water temperatures in the Sacramento and San Joaquin River in each of the portfolios. All of the portfolios showed only small changes in water temperatures relative to the Baseline in both the Sacramento and San Joaquin Rivers. As an example, Figure ES-21 shows the change in mean daily temperature from July through September in the Sacramento River at Jelly's Ferry in each portfolio relative to the Baseline. The largest reductions in mean daily water temperatures of 0.2–0.8 degrees Fahrenheit occurred in the Delta Conveyance and North-of-Delta Storage Portfolio, where temperatures were reduced because of increased storage levels in Lake Shasta. By contrast, Lake Shasta storage levels were reduced with enhanced environmental flow requirements, resulting in a small increase in water temperatures on the Sacramento River.

Hydropower Generation and Greenhouse Gas Emissions

Figures ES-22 and ES-23 show the average annual change in net hydropower generation and GHG emissions (that is, increases in GHG emissions in the SWP system and reductions in potential GHG offsets in the CVP system) for the CVP and SWP systems in each portfolio relative to the Baseline. Among the portfolios, implementation of aggressive local demand-reduction and supply-enhancement actions resulted in a small decrease in net hydropower generation and a small increase in GHG emissions relative to the Baseline due to the small increase in Delta exports in that portfolio. Both portfolios that include Delta conveyance showed reductions in net hydropower generation due to additional conveyance operations and increases in GHG emissions relative to the Baseline due to the substantial increases in SWP power consumption with increased Delta exports. By contrast, the Enhanced Environmental Flow Portfolio showed increases in net hydropower generation and reductions in GHG emissions due to the reductions in SWP power consumption with decreased Delta exports.

Economic Benefits

The CVP IRP analyzed changes in urban and agricultural economic outputs and in salinity management costs throughout the CVP Service

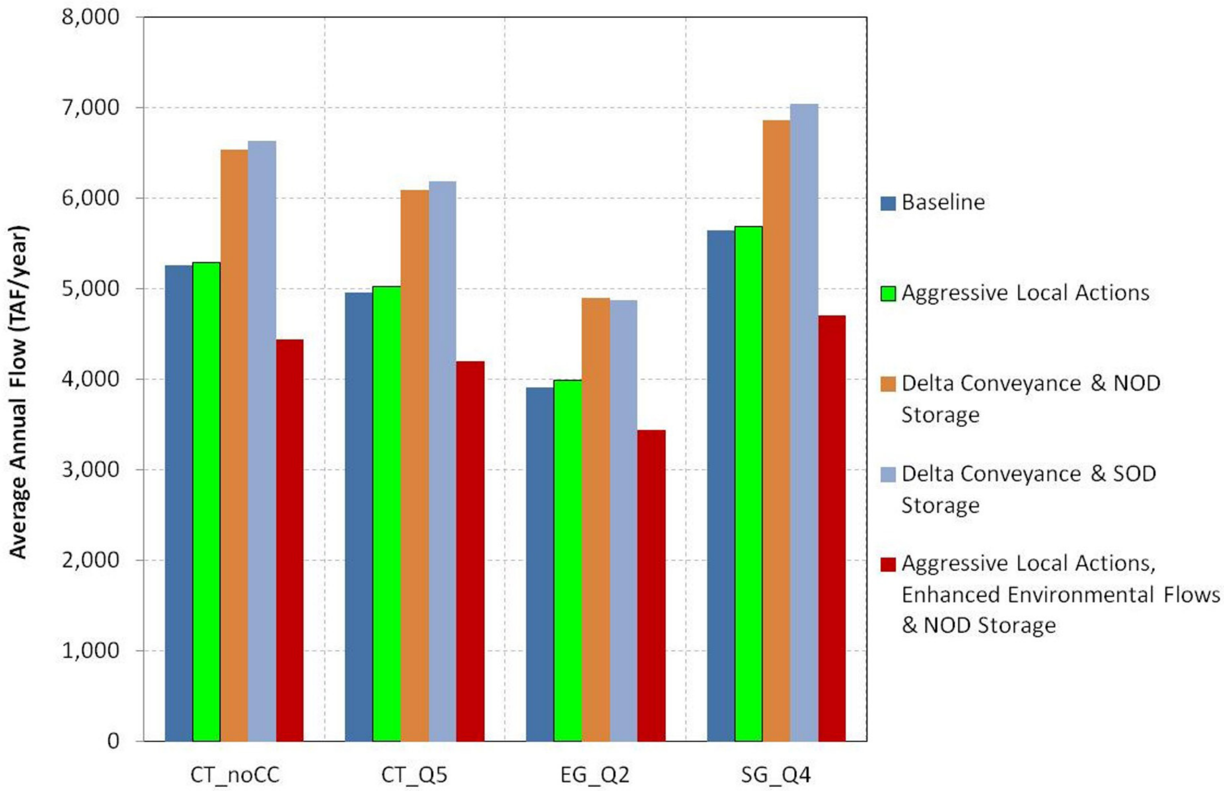

Figure ES-18. Average Annual Total Delta Exports by Portfolio

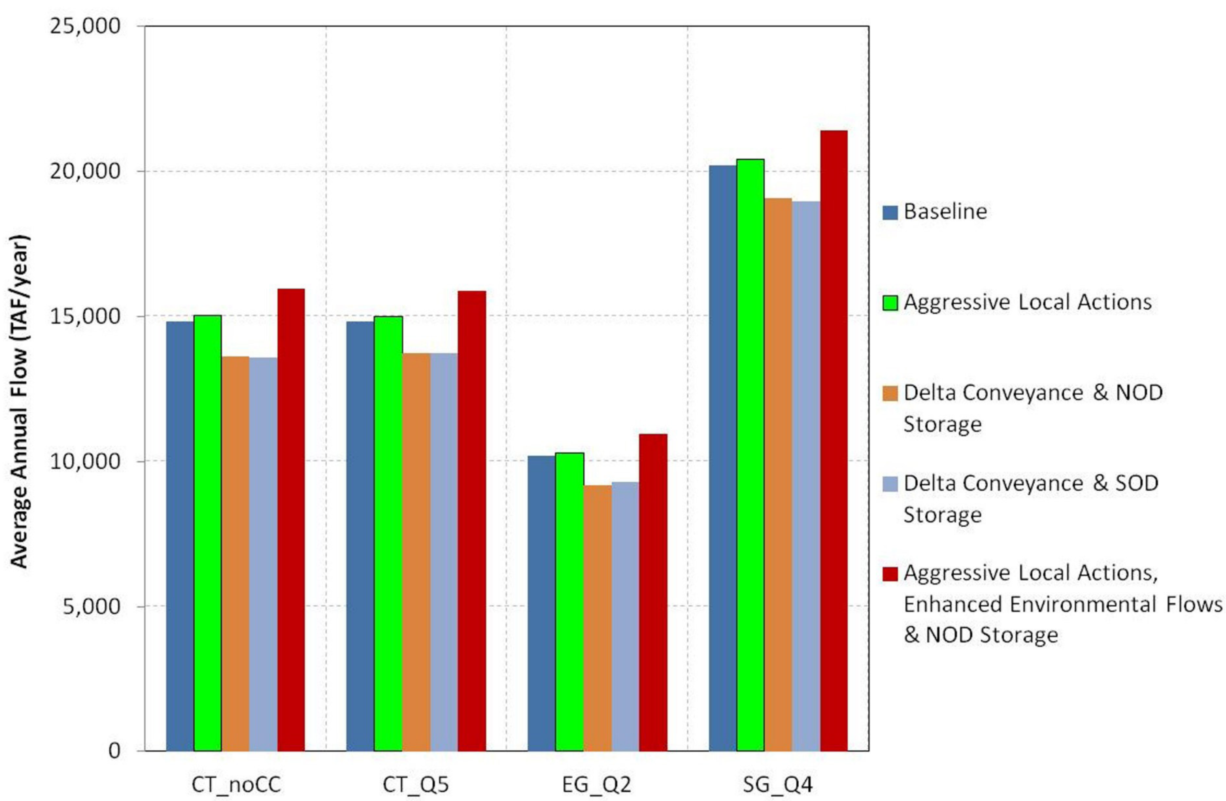

Figure ES-19. Average Annual Total Delta Exports by Portfolio

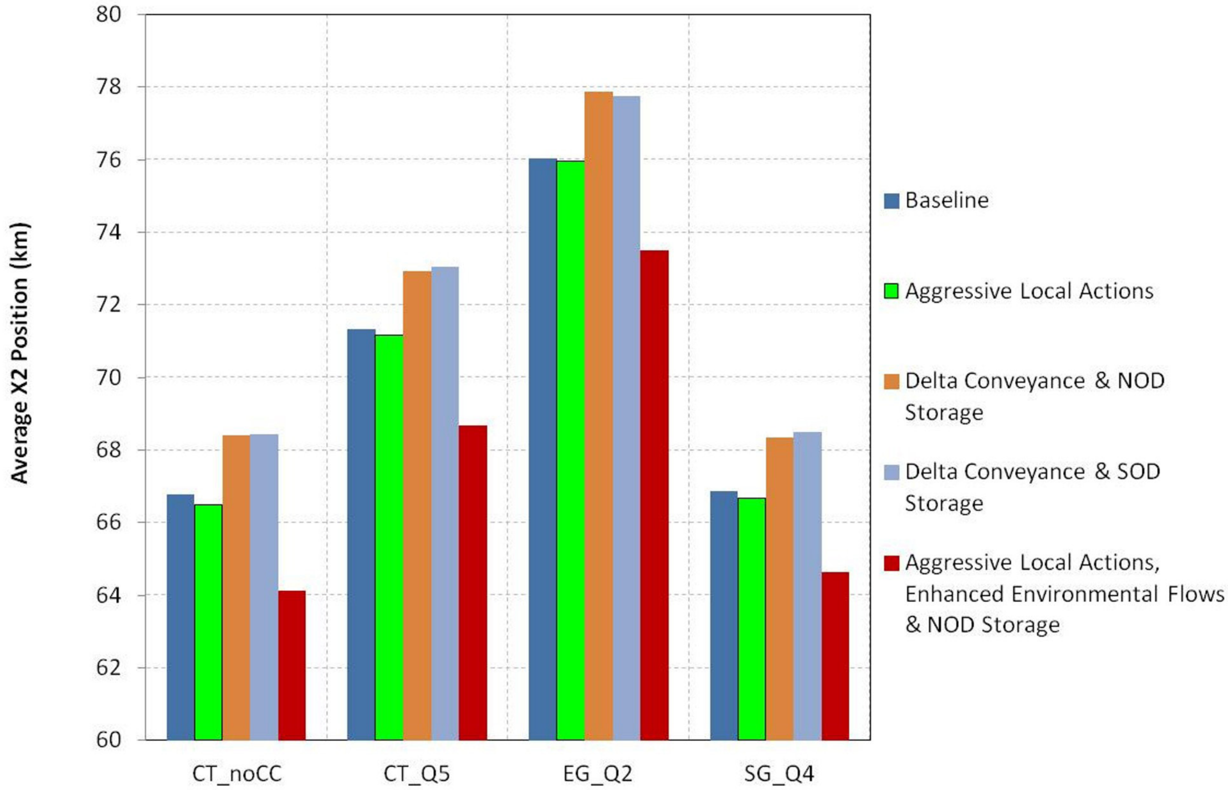

Figure ES-20. Average Annual February-to-June X2 Position by Portfolio

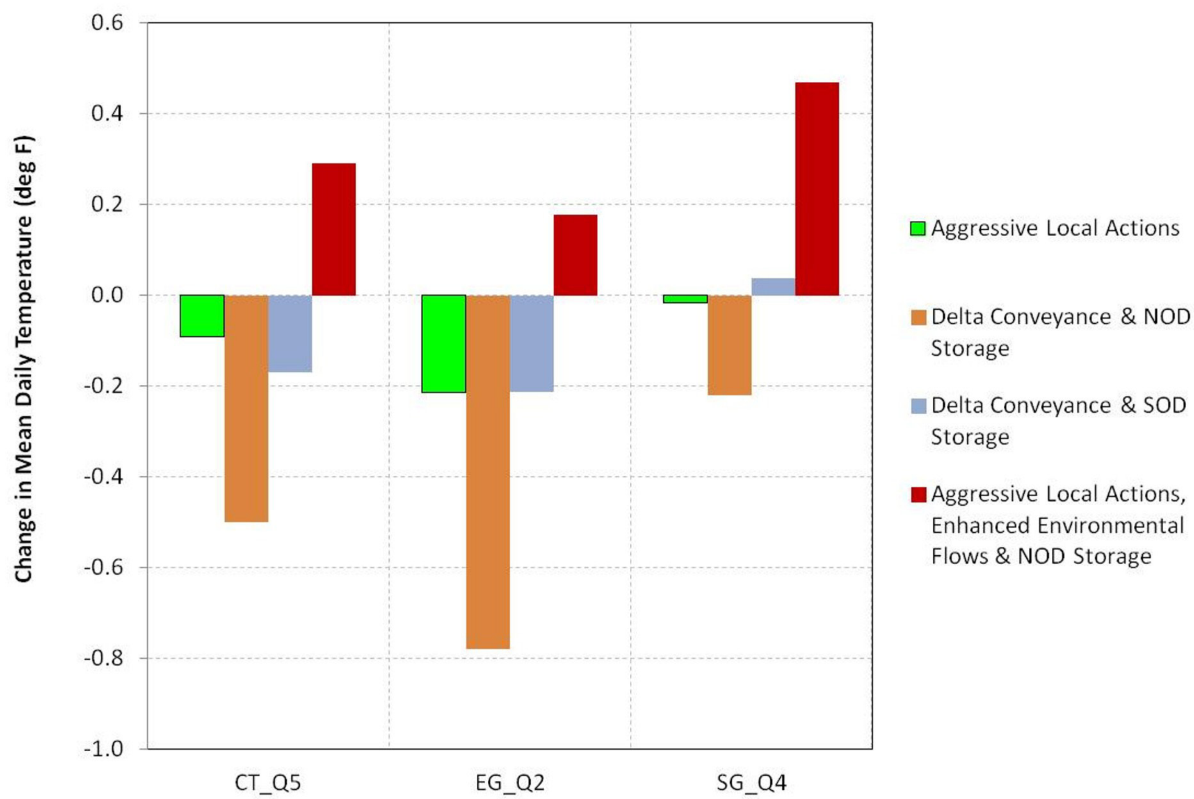

Figure ES-21. Change in Mean Daily Temperature on Sacramento River at Jelly's Ferry from July to September in Each Portfolio Relative to the Baseline

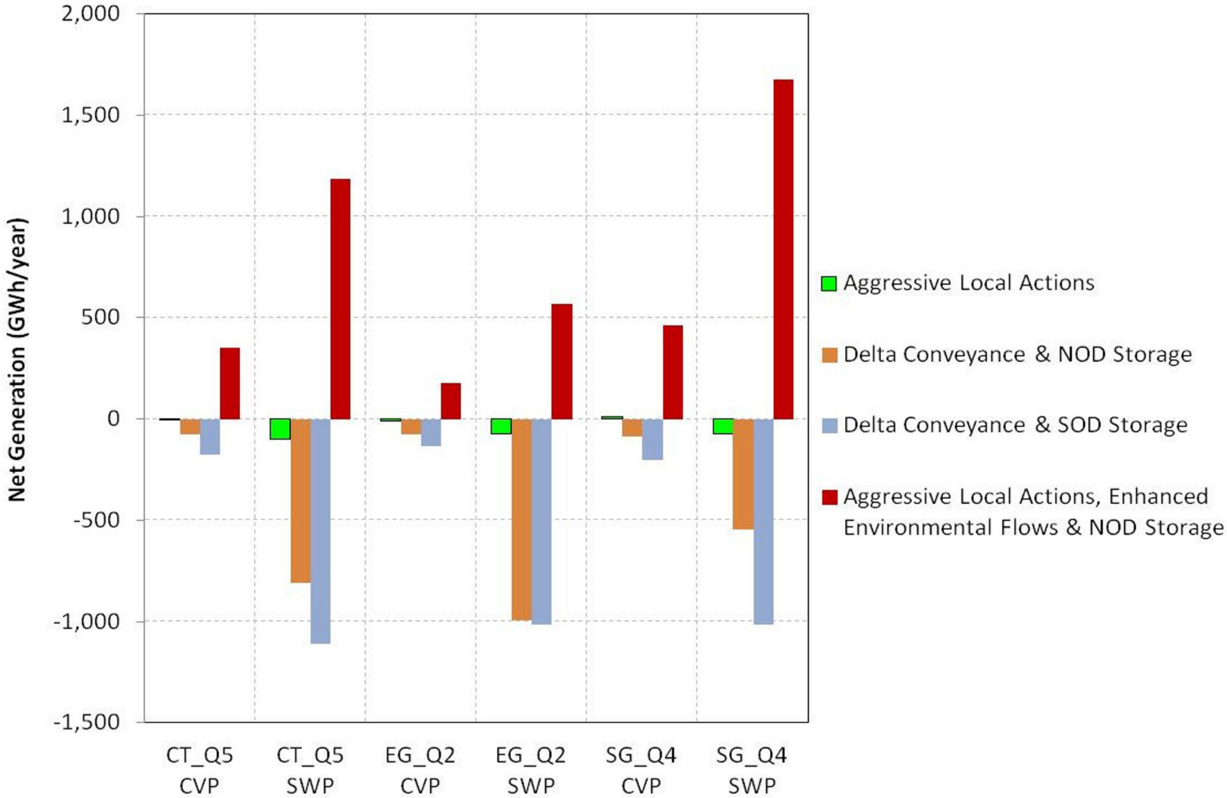

Figure ES-22. Change in Net Generation in CVP and SWP Facilities in Each Portfolio Relative to the Baseline

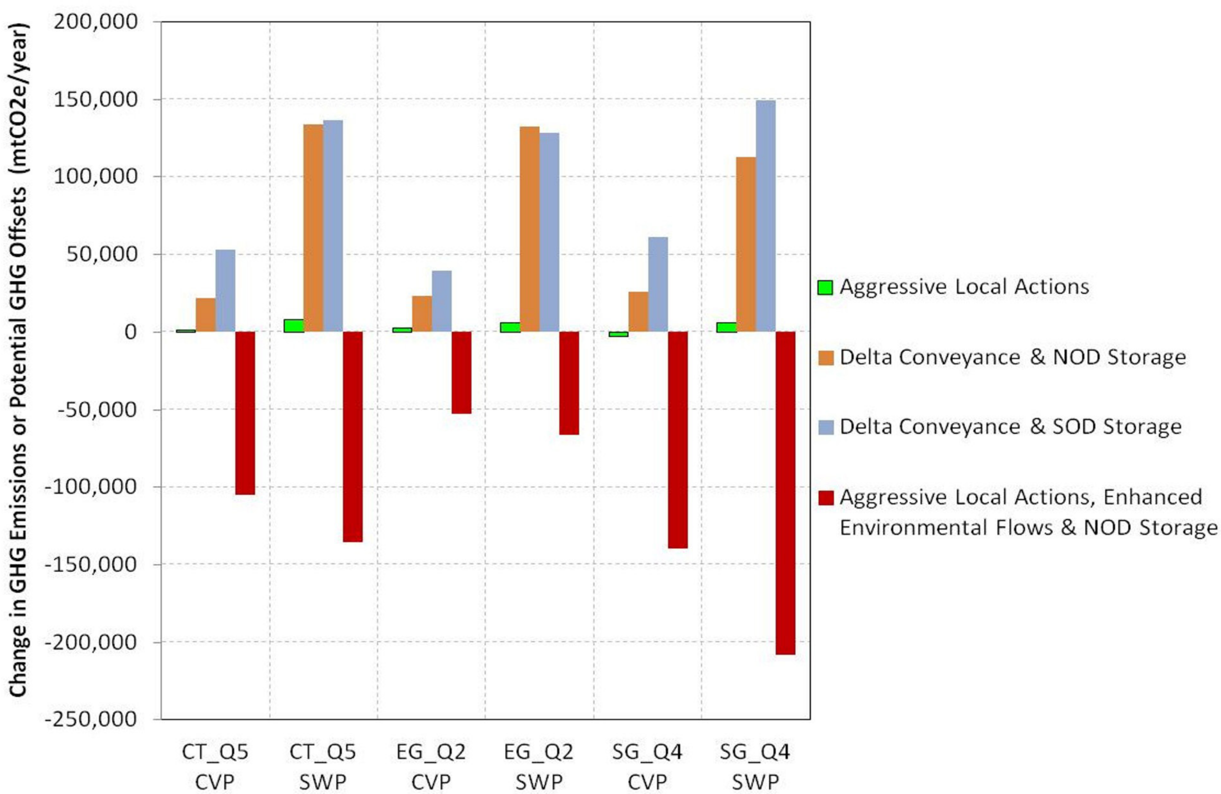

Figure ES-23. Change in GHG Emissions in CVP and SWP Facilities in Each Portfolio Relative to the Baseline

Area at three points in time to show the effects of changing socioeconomic conditions at different times in the twenty-first century. Note that the costs of implementing each action were not computed for the CVP IRP and, therefore, it is not possible to compare the potential economic benefits with the costs of each action. However, the economic results still provided useful information regarding the potential benefits associated with each portfolio. Figure ES-24 shows the change in average annual benefit in each portfolio relative to the Baseline for the CT-Q5, EG-Q2, and SG-Q4 scenarios in 2025, 2055, and 2085. Economic benefits from other resources such as those related to fisheries, ocean, and ecological resources were not evaluated in this study. Both portfolios that include Delta conveyance showed increased economic benefits relative to the Baseline, with the greatest benefits occurring near the end of the century in 2085 in the EG-Q2 scenario. The average annual net benefit in EG-Q2 was about $600 million/year in both Delta conveyance portfolios in 2085. By contrast, the portfolio that includes enhanced environmental flows showed decreased economic benefits of up to $350 million/year in 2085 relative to the Baseline.

Portfolio Tradeoffs

The results of portfolio performance assessments above were compared to evaluate tradeoffs among the portfolios. However, it should be noted that other potentially significant impacts such as the costs of implementing these portfolios were not evaluated.

- Portfolio A: Aggressive Local Reduction and Supply Enhancements
  - Portfolio A would provide reductions in unmet demands in the CVP Service Area, with little change in the other performance metrics as compared to the Baseline.
- Portfolio C: Delta Conveyance and North-of-Delta Storage
  - Portfolio C would provide increases in Delta exports, reductions in unmet demands in the CVP Service Area (though less than in Portfolio A), increased economic benefits, and a modest improvement in river water temperatures. However, these benefits would come with reduced Delta outflow, increased salinity in the Delta, reduced net hydropower generation, and increased GHG emissions.
- Portfolio D: Delta Conveyance and South-of-Delta Storage
  - Portfolio D would provide similar benefits and impacts to Portfolio C, with the exception that smaller water temperature benefits on the upper Sacramento River would be realized.
- Portfolio E: Aggressive Local Actions, Enhanced Environmental Flows, and North-of-Delta Storage
  - Portfolio E would provide increases in Delta outflow, improvements in Delta salinity, reductions in unmet demands in the CVP Service Area (though less than in Portfolio A), increased net hydropower generation, and reduced GHG emissions. These benefits would come with reduced Delta exports and reduced economic benefits.

Study Limitations and Next Steps

The CVP IRP study provides new valuable information for long-range planning purposes regarding the impacts of future climatic and socioeconomic uncertainties on the CVP Service Area and its Divisions. The CVP IRP study also examines the potential benefits and tradeoffs among several portfolios of water management actions, addressing some identified challenges confronting the CVP in the twenty-first century. However, there are limitations that should be kept in mind when evaluating the results of these analyses.

- The CVP IRP study was a screening-level analysis that simulated the most important components of the CVP water management system by using simplified representations of the CVP, SWP, and local project operations within the Central Valley. In addition, although the scope of the analysis covered supplies and demands within the CVP Service Area, the effects of potential actions on SWP and non-project contractor’s

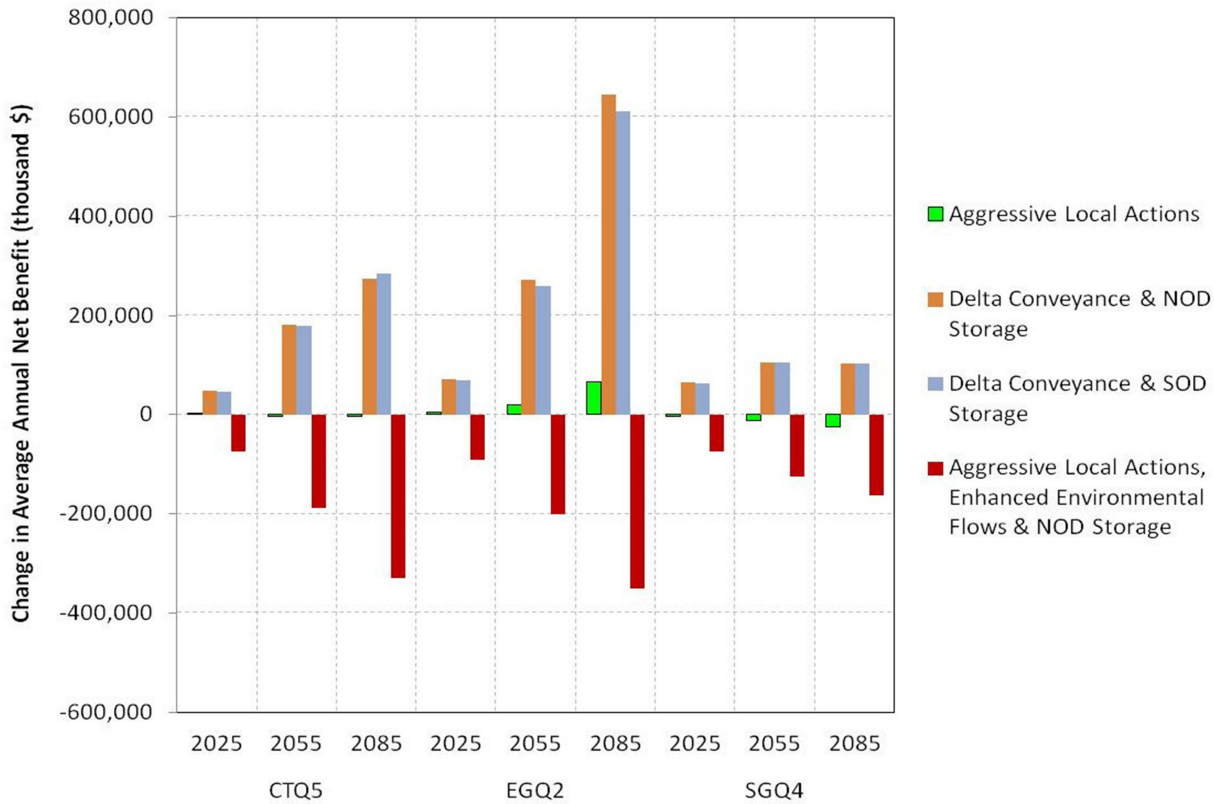

Figure ES-24. Change in Average Annual Agricultural and Urban Economic Benefit in the CVP Service Area in Each Portfolio Relative to the Baseline

unmet demands were not analyzed. Future studies should consider addressing regions served by the water users as part of the analysis.

- The analyses used WEAP-CV and CVP IRP CalLite, which are simplified models in which much of the complexity of the system has been aggregated as compared to more complex models such as CALSIM II. CVP IRP CalLite captured the most prominent aspects of the Central Valley hydrology and system operations, but simulated hydrology and water management within specific sub-basins has limited detail. Therefore, the model did not simulate some aspects of CVP operations such as Cross Valley Canal deliveries or Central Valley Project Improvement Act (b)(2) operations. In addition, the model included simplified representations of some of the water management actions as compared to CALSIM II.
- The CVP IRP's approach to characterizing future uncertainties used only three socioeconomic and five ensemble-informed hydroclimate projections, each of which was developed using only one historical time series to represent climate variability. A more comprehensive analysis could include other means of characterizing future uncertainties such as paleoclimate, more refined socioeconomic information, and multiple sequences of climate variability. The approach for developing projected agricultural demands was also limited to a few major crops at only four locations in the Central Valley and employed estimates of meteorological conditions rather than bias-corrected spatially downscaled Global Climate Model outputs directly corresponding to projected temperature changes.
- Although the analytical approach addressed a broad range of performance metrics related to the Central Valley water management system, it did not address some aspects of California water management that could be considered important metrics for assessment of impacts and development of robust adaptation strategies. In particular,

the costs of implementing each action were not considered in the CVP IRP analysis, and additional analysis methods could be included to consider other aspects such as ecological resources, flood control, and recreation.

- The CVP IRP study was only able to analyze a limited number of potential water management actions. This allowed for only a limited assessment of tradeoffs to be performed among different portfolios of actions. However, the analytical approach is capable of assessing a much broader range of potential actions and portfolios. The selection of portfolio actions in future studies should include interactions with stakeholder groups to obtain additional information regarding the effectiveness, efficiency, and acceptability of potential water management actions. In addition, considerations such as permitting and timing should be considered in the screening of potential actions.

Despite these limitations, the CVP IRP study provides a solid foundation for future screening-level analyses of the Central Valley water management system. However, the limitations identified here provide opportunities for additional improvements in the analytical approach, which could be pursued as part of future long-term Bureau of Reclamation planning activities.

ACRONYMS AND ABBREVIATIONS

°F	degrees Fahrenheit
°C	degrees Centigrade
ANN	artificial neural network (model)
Banks PP	H. O. Banks Pumping Plant
BDCP	Bay Delta Conservation Plan
CCF	Clifton Court Forebay
CCWD	Contra Costa Water District
CDF	cumulative distribution function
cfs	cubic feet per second
CIMIS	California Irrigation Management Information System
cm	centimeter
CO_2	carbon dioxide
COA	Coordinated Operations Agreement
CT	Current Trends
CT-noCC	Current Trends no climate change
CT-Q5	Current Trends – central tendency
CVP IRP	Central Valley Project Integrated Resource Plan
CVP	Central Valley Project
CVPIA	Central Valley Project Improvement Act
CWP	California Water Plan Update 2009
DOF	California Department of Finance
DSAT	Decision Support and Analysis Tool
DWR	California Department of Water Resources
EEF	Enhanced Environmental Flow
EG	Expansive Growth
EG-Q2	Expansive Growth – warmer and drier
ET	evapotranspiration
GC	Glenn-Colusa
GCID	Glenn-Colusa Irrigation District
GHG	greenhouse gas
GIS	Geographic Information System
GW	groundwater
GWh/year	gigawatt hours per year
IF	isolated facility
IPCC	Intergovernmental Panel on Climate Change
Jones PP	C. W. Jones Pumping Plant

km	kilometers
kPa	kilo pascals
LAWS	Land Atmosphere Water Simulator (model)
LCPSIM	Least-Cost Planning Simulation Model
LOD	level of development
M&I	municipal and indutrial
MAF	million acre-feet
MAF/year	million acre-feet per year
MJ/m2	mega-joules per square meter
$mTCO_2e$	metric tons of CO_2 equivalents
NODOS	North-of-Delta Offstream Storage
OMWEM	Other Municipal Water Economics Model
PPIC	Public Policy Institute of California
ppm	parts per million
Q1	drier, less warming
Q2	drier, more warming
Q3	wetter, more warming
Q4	wetter, less warming
Q5	ensemble median
Reclamation	Bureau of Reclamation
Rs	solar radiation
SBA	South Bay Aqueduct
SBWQM	South Bay Water Quality Model
SG	Slow Growth
SG-Q4	Slow Growth – less warming and wetter
SJRWQM	San Joaquin River Water Quality Model
SRWQM	Sacramento River Water Quality Model
SLWRI	Shasta Lake Water Resources Investigation
State	State of California
SW	surface water
SWAP	Statewide Agricultural Production (model)
SWP	State Water Project
TAF/year	thousand acre-feet per year
TC	Tehama-Colusa
Tdew	dew point temperature
Tmax	maximum temperature
Tmin	minimum temperature
VPD	vapor pressure deficit
WEAP-CV	Water Evaluation and Planning model of the Central Valley
X2	2 parts per thousand salinity concentration