Appendix 25B
Effects of Climate Change through 2100

Line items and numbers identified or noted as “No Action Alternative” represent the “Existing Conditions/No Project/No Action Condition” (described in Chapter 2 Alternatives Analysis). Table numbering may not be consecutive for all appendixes.”

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APPENDIX 25B
Effects of Climate Change through 2100

25B.1 Introduction

The surface water resources impact analyses presented in Chapter 6 Surface Water Resources evaluated conditions under Alternatives A through D as compared to the Existing Conditions/No Project/No Action Condition without consideration for climate change and sea level rise. Appendix 25A Climate Change and Sea Level Rise Sensitivity Analysis presented a sensitivity analysis with a range of climate change and sea level rise assumptions that included increased air temperatures from warm to hot and increased and decreased precipitation as compared to current conditions. The climate change projections were based on 112 climate projections developed by the United Nations Intergovernmental Panel on Climate Change (IPCC). The climate change projections presented in Appendix 25A were developed in 2010 to be used with the CALSIM II 2010 version to evaluate changes that would occur through 2060.

Since 2010, the climate change projections have continued to evolve. The 2016 Sacramento and San Joaquin Rivers Basin Study (2016 Basin Study) (Reclamation, 2016) incorporated climate change projections based on a wider range of global climate model simulations than those used in the CALSIM II model runs presented in Appendix 25A. In this appendix, results from the 2016 Basin Study were used to assist in evaluating the range of water supply conditions that could occur in California through 2099, and were also compared to changes in water supply conditions presented in Appendix 25A.

25B.2 Basis of Climate Change Projections for this EIR/EIS

As referenced above, a sensitivity analysis using a range of climate change projections was presented in Appendix 25A Climate Change and Sea Level Rise Sensitivity Analysis to provide a context for consideration of uncertainty and anticipated trends due to climate change throughout the planning horizon. The sensitivity analysis included several climate change scenarios for 2060 conditions. As described in Appendix 25A, these climate change scenarios were based upon 112 climate projections developed using 16 global climate models (GCM) and a range of emission scenarios used by the Intergovernmental Panel on Climate Change (IPCC). The projections were grouped into five ensembles, including “drier, less warming” (Q1), “drier, more warming” (Q2), “wetter, more warming” (Q3), “wetter, less warming” (Q4), and an ensemble bounded by the 25th and 75th percentile joint temperature and precipitation change within Q1 through Q4 (Q5) all assuming a sea level rise of 15 centimeters (cm) (approximately 18 inches). The projections used in the sensitivity analyses presented in Appendix 25A included Q2 “drier, more warming”; Q4 “wetter, less warming”; and Q5 (median conditions).

25B.2.1 Summary of Climate Change Projections for the No Project/No Action Condition in 2060

Application of these climate change projections on future projections result in the following assumptions for the No Project/No Action Condition in 2060 as compared to current conditions:

- Increased runoff in late winter/early spring and reduced runoff in late spring and summer
- Reduced snowpack; and therefore, the inflows to the reservoirs are reduced in the late spring and early summer

- Decreased reservoir storage conditions in summer and fall because of reduced spring and summer inflows from snowmelt and increased use of stored water to maintain minimum downstream flows and temperatures for aquatic resources and Delta salinity requirements
- Increased salinity in the Delta due to decreases in Delta inflow and sea level rise, specifically in dry and critical dry year conditions with limited stored water availability to be released to maintain Delta salinity for SWP and CVP operations
- Reduced water supply availability for SWP and CVP water contractors due to reduced reservoir storage

25B.2.2 Summary of Climate Change Projections for Alternatives A through D as Compared to the No Project/No Action Condition in 2060

The potential effects of climate change on implementation of Alternatives A through D as compared to the No Project/No Action Condition are presented in Appendix 25A. The CALSIM II model runs for this analysis included the Q2, Q4, and Q5 climate change and sea level rise assumptions for the Existing Conditions/No Project/No Action Condition in 2060, and all alternatives in comparison to the Existing Conditions/No Project/No Action Condition in 2060. The summary results, which include the comparison of the current Existing Conditions/No Project/No Action Condition and proposed alternatives for reference, are identified below:

- **Trinity Lake Storage**
  - *Without climate change and sea level rise – similar conditions under Alternatives A through D as compared to the Existing Conditions/No Project/No Action Condition*
  - Under Q5 (median) climate change projections – reduced storage in all but wet water year types of up to 7 percent under Alternatives A through D as compared to the No Project/No Action Condition
  - Under Q2 (drier, more warming) climate change projections - similar conditions under Alternatives A through D as compared to the No Project/No Action Condition
  - Under Q4 (wetter, less warming) climate change projections – increased storage in all water year types of 30 to 200 percent under Alternatives A through D as compared to the No Project/No Action Condition
- **Shasta Lake Storage**
  - *Without climate change and sea level rise – increased storage in dry and critical dry water years of up to 14 percent under Alternatives A through D as compared to the Existing Conditions/No Project/No Action Condition*
  - Under Q5 (median) climate change projections –reduced storage in dry and critical dry water years of 6 to 9 percent under Alternatives A, C, and D as compared to the No Project/No Action Condition; and similar conditions under Alternative B as compared to the No Project/No Action Condition
  - Under Q2 (drier, more warming) climate change projections - increased storage in all water year types of 7 to 10 percent under Alternatives A through D as compared to the No Project/No Action Condition

- Under Q4 (wetter, less warming) climate change projections – increased storage in all water year types of 20 to 200 percent under Alternatives A through D as compared to the No Project/No Action Condition

- **Lake Oroville Storage**
  - *Without climate change and sea level rise – similar conditions under Alternatives A through D as compared to the Existing Conditions/No Project/No Action Condition*
  - Under Q5 (median) climate change projections – reduced storage in all water year types of 10 to 14 percent under Alternatives A and D as compared to the No Project/No Action Condition
  - Under Q2 (drier, more warming) climate change projections - increased storage in all water year types of 6 to 8 percent under Alternatives A, B, and D as compared to the No Project/No Action Condition; and similar conditions under Alternative B as compared to the No Project/No Action Condition
  - Under Q4 (wetter, less warming) climate change projections – increased storage in all water year types of 30 to 45 percent under Alternatives A through D as compared to the No Project/No Action Condition

- **Folsom Lake Storage**
  - *Without climate change and sea level rise – increased storage in below normal and dry water year types of 6 to 12 percent under Alternatives A through D as compared to the Existing Conditions/No Project/No Action Condition*
  - Under Q5 (median) climate change projections – reduced storage in above normal, below normal, dry, and critical dry water year types of 8 to 15 percent under Alternatives A and D as compared to the No Project/No Action Condition
  - Under Q2 (drier, more warming) climate change projections - increased storage in all water year types of 8 to 20 percent under Alternatives A through D as compared to the No Project/No Action Condition
  - Under Q4 (wetter, less warming) climate change projections – increased storage in all water year types of 30 to 150 percent under Alternatives A through D as compared to the No Project/No Action Condition

- **Sacramento River Delta Flows**
  - *Without climate change and sea level rise – similar flows in wet, above normal, and critical water year types ; and increased flows during the summer in below normal and dry water year types of 7 to 13 percent and reduced flows during the winter in below normal and dry water year types of 7 to 10 percent under Alternatives A through D as compared to the Existing Conditions/No Project/No Action Condition*
  - Under Q5 (median) climate change projections – increased flows during the summer in all water year types of 6 to 18 percent; and reduced flows during the winter in below normal and dry water year types and during the spring in wet water year types of 6 to 9 percent under Alternatives A and D as compared to the No Project/No Action Condition
  - Under Q2 (drier, more warming) and Q4 (wetter, less warming) climate change projections - increased flows during the summer in below normal, dry, and critical dry water year types of 9 to 80 percent; and reduced flows during the winter in below normal and dry water year types of 6 to 10 percent under Alternatives A through D as compared to the No Project/No Action Condition

- Under climate change projections – increased flows in all months of all water year types of 30 to 150 percent under Alternatives A through D as compared to the No Project/No Action Condition

- **Delta Outflow**
  - *Without climate change and sea level rise – reduced outflows during the winter in below normal, dry, and critical dry water years of 7 to 10 percent; and increased outflows during summer and fall months in above normal, below normal, dry, and critical dry water years of 6 to 25 percent under Alternatives A through D as compared to the Existing Conditions/No Project/No Action Condition*
  - Under Q5 (median) climate change projections – reduced outflows during the winter in below normal, dry, and critical dry water years of 6 to 10 percent; and increased outflows during the summer months in all water years and during the spring and winter in below normal, dry, and critical dry water years of 6 to 30 percent under Alternatives A and D as compared to the No Project/No Action Condition
  - Under Q2 (drier, more warming) climate change projections – reduced outflows during the winter in above normal, below normal, dry, and critical dry water years of 6 to 10 percent; and increased outflows during the summer in above normal, below normal, and dry water years of 6 to 10 percent under Alternatives A through D as compared to the No Project/No Action Condition
  - Under Q4 (wetter, less warming) climate change projections – increased outflows during all seasons and in all water year types of 10 to 75 percent under Alternatives A through D as compared to the No Project/No Action Condition

- **SWP and CVP Exports**
  - *Without climate change and sea level rise – SWP and CVP exports would be similar in wet, above normal, and dry water years; and increased during critical dry water years by 8 to 10 percent under Alternatives A through D as compared to the Existing Conditions/No Project/No Action Condition*
  - Under Q5 (median) climate change projections – SWP and CVP exports would be similar under Alternatives A and D as compared to the No Project/No Action Condition
  - Under Q2 (drier, more warming) climate change projections – SWP and CVP exports would be similar in wet, above normal, and below normal water years; increased in dry and critical dry water years by 7 to 16 percent under Alternatives A through D as compared to the No Project/No Action Condition
  - Under Q4 (wetter, less warming) climate change projections – SWP and CVP exports would be increased in all water years by 20 to 70 percent under Alternatives A through D as compared to the No Project/No Action Condition

25B.3 Climate Change Projections in the Sacramento and San Joaquin Rivers Basin Study

The 2016 Basin Study incorporated climate change projections based on a wider range of global climate model simulations than the climate change projections developed in 2010. The 2016 Basin Study climate projections were based on a set of global climate change models and greenhouse gas emission scenarios selected by the California Department of Water Resources (DWR) Climate Change Technical Advisory Group (CCTAG). The 2016 Basin Plan utilized 12 climate change projections from the CCTAG projections downscaled for major regions throughout California to develop transient annual climate scenarios for 2012 through 2099. The precipitation and temperature results from the climate change projections also were used to develop runoff projections for major watersheds in California. Annual projected changes in land use and other socioeconomic factors that affect water demands also were developed for 2012 through 2099. This information was used as input to the Water Evaluation and Planning Model (WEAP) model to develop climate-based runoff projections for major watersheds. A model interface was developed to integrate the WEAP model to the CalLite model.

Five statistically representative climate scenarios were developed using a transient ensemble-informed approach, including:

- Median projection based upon a central tendency (CEN)
- Drier, less warming (WD)
- Drier, more warming (HD)
- Wetter, more warming (HW)
- Wetter, less warming (WW)

25B.3.1 Climate Change Model Assumptions for 2016 Basin Study

During the initial phase of the Basin Study, the climate change methodology used for the Study was similar to that used in this EIR/EIS. It was based upon the Coupled Model Intercomparison Project Phase 3 (CMIP3) (Reclamation, 2016). For the final 2016 Basin Study, the Coupled Model Intercomparison Project Phase 5 (CMIP5) simulations were used based upon more recent climate model data from the IPCC. The updated model data were developed based upon revised emissions scenarios with Representative Concentration Pathways (RCPs) defined by specific emission trajectories and radiative forcing (a measure of the influence of a factor in influencing the balance of incoming and outgoing energy in the Earth and atmosphere system). The updated RCPs were based upon future GHG emission assumptions related to fossil fuel use, regional political and social conditions, technologies, populations, and governance decisions.

The updated emissions scenarios were used to develop the five climate scenarios (CEN, WD, HD, HW, WW) by development of projections from an ensemble of downscaled climate model projections and compared to a sequence of observed meteorology using a quantile method (a method to divide values with a range of probabilities into groups with equal probabilities). Projected temperature and precipitation patterns for selected 30-year future climatological periods were compared to a historical reference period to calculate the quantitative changes. The changes in temperature and precipitation were compared to historical observed meteorological patterns using a quantile method which transformed the historical records into a modified sequence of temperature and precipitation conditions with future climate change assumptions. The resultant daily time series of temperature and precipitation incorporated the natural variability observed in the historic record with statistical shifts that reflected changes in climate projections, including the mean and the range of values, associated with the downscaled climate projections. Because the sequence of future climate variability (wet/dry periods) is not defined, the transient ensemble informed method could be applied with any sequence of an observational, paleo-reconstructed, or synthetic "stationary" climate record. In addition to the five climate scenarios, twelve individual downscaled GCM projections were selected from six different GCMs, two different emission scenarios, and one reference climate scenario with historical climate.

25B.3.2 Comparison of Climate Change Conditions between CMIP3 and CMIP5

The 2016 Basin Study found that for the CEN climate change scenario, warming occurred in a similar manner for the California and Nevada overall, with increased warming in the inland valleys and mountain ridges under CMIP5 as compared to CMIP3 (Reclamation, 2016). The CEN scenario results indicated that under air temperatures in the Central Valley would increase by 1.8 to 2.0 degrees centigrade by 2070 under both CMIP3 and CMIP5. Projected temperatures between the two models were similar showing an increase of 2.7 to 2.8 degrees by 2099 under CMIP5; and by 2.5 to 2.6 degrees under CMIP3.

Projections for precipitation varied between the CMIP3 and CMIP5 projections. By 2070, the CMIP3 projections indicated a precipitation increase of 0.4 percent in the Sacramento Valley region; and a decrease of 2.6 and 5.2 percent in the northern San Joaquin Valley and the Tulare Lake portion of the San Joaquin Valley, respectively. For the same period of projection, the CMIP5 model results indicated that by 2070, precipitation would increase by 2.1 and 0.8 percent in the Sacramento Valley and northern San Joaquin Valley; and decrease by 5.2 percent in the Tulare Lake portion of the San Joaquin Valley.

The projections for 2099 indicated that under CMIP3, precipitation would increase by 0.8 percent in the Sacramento Valley region; and decrease by 1.5 and 4.5 percent in the northern San Joaquin Valley and the Tulare Lake portion of the San Joaquin Valley, respectively. The CMIP5 projections for 2099 indicated that precipitation would increase by 3.9 and 2.5 percent in the Sacramento Valley and northern San Joaquin Valley; and decrease by 1.5 percent in the Tulare Lake portion of the San Joaquin Valley.

The CMIP5 projections were used in the 2016 Basin Study and applied to develop the downscaled climate projections that reflect a broader degree of warming due to the increased number of climate change model inputs.

25B.3.3 Findings of the 2016 Basin Study Climate Change Analysis

The 2016 Basin Study used a modeling approach that included changes in land use and water demands throughout California that could occur from 2012 through 2099 which is different than the CALSIM II model runs presented in this EIR/EIS. The CALSIM II model analyses generally assumed full use of water rights, including SWP and CVP water supplies, from the Sacramento and San Joaquin rivers by 2030. The CALSIM II model analyses did not consider further changes in land use or water demands, or other sources of water (e.g., conservation, water recycling, desalination, water transfers); and therefore, the CALSIM II model did not need to analyze the use of need for development of water supplies due to changes in land use or water demands. However, in the 2016 Basin Study, the WEAP model and the CalLite model were used to consider changes in the need for additional SWP and CVP and non-SWP/CVP water supplies throughout California; as well as changes in reservoir storage and stream flows. Therefore, the results of the WEAP and CalLite models used in the 2016 Basin Study are not directly comparable to the results from the CALSIM II models presented in Appendix 25A Climate Change and Sea Level Rise Sensitivity Analysis. However, the results from the 2016 Basin Study have been used to understand potential changes by 2100 with the updated climate change assumptions as compared to the results presented in Appendix 25A.

The 2016 Basin Study considered three development scenarios: Current Trends (based upon historical population growth and urban density), Expansive Growth (based upon higher population growth and lower urban density than Current Trends), and Slow Growth (based upon lower population growth and higher urban density than Current Trends). Because this EIR/EIS only evaluates growth projections based upon recent land use plans and other master plans, the results from the 2016 Basin Study considered in this analysis are based upon the Current Trends scenario used in the 2016 Basin Study. However, it should be understood that the 2016 Basin Study addressed future water demands that would occur due to growth through 2099. The CALSIM II model runs used in this EIR/EIS assumed that SWP, CVP, and water rights water deliveries in the Sacramento and San Joaquin rivers watersheds would be fully delivered by 2030; and that additional water supplies would occur from other sources that were not simulated in the CALSIM II model (e.g., conservation, water recycling, desalination, and water transfers).

The 2016 Basin Study also did not specifically analyze deliveries to SWP and CVP water users, which are analyzed in this EIR/EIS. The 2016 Basin Study analyzed "unmet water demands" as a measure of water supply availability.

The results of the analyses presented in the 2016 Basin Study for the period of 2015 through 2099 indicated that reservoir storage was higher under wetter climate scenarios and lower under drier climate scenarios. With respect to stream flows and unmet water demands, the 2016 Basin Study indicated the following in comparison to the 2016 Basin Study's Reference-No-Climate-Change scenario:

- **Sacramento River Flows**
  - Average annual flows under the CEN climate change scenario were approximately 2.9 percent higher than under the 2016 Basin Study Reference-No-Climate-Change scenario
  - Average annual flows under the WD and HD climate change scenarios were approximately 15 to 16 percent lower than under the 2016 Basin Study Reference-No-Climate-Change scenario
  - Average annual flows under the HW and WW climate change scenarios were up to 26 percent higher than under the 2016 Basin Study Reference-No-Climate-Change scenario
- **San Joaquin River Flows**
  - Average annual flows under the CEN climate change scenario were approximately 0.2 percent lower than under the Reference-No-Climate-Change scenario
  - Average annual flows under the WD and HD climate change scenarios were approximately 20 to 23 percent lower than under the 2016 Basin Study Reference-No-Climate-Change scenario
  - Average annual flows under the HW and WW climate change scenarios were 26 to 30 percent higher than under the 2016 Basin Study Reference-No-Climate-Change scenario
- **Unmet Water Demands in the Central Valley with the Current Trend Projections**
  - Projected unmet water demands under the 2016 Basin Study Reference-No-Climate-Change scenario ranged from 7,353 to 8,146 acre-feet/year from 2015 to 2099
  - Projected unmet water demands under the CEN climate change scenario were similar as under the 2016 Basin Study Reference-No-Climate-Change scenario and ranged from 7,470 to 8.478 acre-feet/year from 2015 to 2099
  - Projected unmet water demands under the WD climate change scenario were greater than under the 2016 Basin Study Reference-No-Climate-Change scenario and ranged from 8,666 to 9.350 acre-feet/year from 2015 to 2099
  - Projected unmet water demands under the HD climate change scenarios were greater than under the 2016 Basin Study Reference-No-Climate-Change scenario and ranged from 8,753 to 9,853 acre-feet/year from 2015 to 2099

- Projected unmet water demands under the HW climate change scenario were lower than under the 2016 Basin Study Reference-No-Climate-Change scenario and ranged from 6,290 to 7,810 acre-feet/year from 2015 to 2099
- Projected unmet water demands under the WW climate change scenario were lower than under the 2016 Basin Study Reference-No-Climate-Change scenario and ranged from 6,168 to 7,221 acre-feet/year from 2015 to 2099

25B.4 Summary of the Comparison of the Climate Change Findings of this EIR/EIS and the 2016 Basin Study

Overall the findings of both this EIR/EIS (as presented in Appendix 25A Climate Change and Sea Level Rise Sensitivity Analysis) and the 2016 Basin Study are similar in that reservoir storage and stream flows are projected to be increased under assumed wetter climate change scenarios and lower under drier climate change scenarios. Due to the differences in assumptions in the model assumptions between the two studies (e.g., the focus of the CALSIM II model on SWP and CVP water deliveries as compared to the focus of the 2016 Basin Study on all water supplies and the ability to meet all water demands), it is not appropriate to use the updated climate change model assumptions to calculate potential changes in the results presented in Appendix 25A.

As described above, the CMIP5 projections anticipate higher air temperatures and increased precipitation in the Sacramento Valley (where the SWP Lake Oroville and most of the CVP reservoirs are located) as compared to the CMIP3 projections used as the basis for the climate change analysis presented in Appendix 25A. Therefore, it is possible that the incremental changes in stream flows and Delta outflows projected in Appendix 25A under Alternatives A through D as compared to the Existing Conditions/No Project/No Action Condition could increase if the updated climate change assumptions were used in the CALSIM II model simulations presented in Appendix 25A.

25B.5 References

Bureau of Reclamation (Reclamation). 2016. Sacramento and San Joaquin Rivers Basin Study Technical Report. March.