Appendix 28A Climate Change

1 Introduction

This document summarizes the development of the 2035 CT and WSIP 2070 boundary conditions for the CalSim II model. For more details regarding the development of the 2035 CT and WSIP 2070 boundary conditions, please review the Final Environmental Impact Report for Long-Term Operation of the California State Water Project (SWP LTO FEIR), Appendix F: Part 2: Attachment 1 Climate Change Projections Development (DWR, 2020) and Water Storage Investment Program (WSIP) Technical Reference Document Appendix A: Climate Change and Sea-Level Rise (CWC, 2016), respectively.

2 Historical Observed Meteorological Data

Livneh et al. (2013) daily historical meteorology data at 1/16th degree (~6 km) (~3.75 miles) spatial resolution over the period 1915 through 2011 was used to develop historical VIC simulation and future climate change scenarios based on quantile mapping approach. These historical data were adjusted based on PRISM data (Daly et al., 1994) to correct biases found in the pre-1950 period. These datasets have already been reviewed under the Sacramento – San Joaquin River Basins Study, Central Valley Flood Protection Plan (CVFPP) 2017 Update, and Water Storage Investment Program (WSIP).

3 Future Climate Change Scenarios

The climate change scenarios centered around 2035 (2020-2049) and WSIP 2070 were developed with the ensemble informed climate change scenarios method, using the 20 Coupled Model Intercomparison Project 5 (CMIP5) global climate model projections. With the ensemble informed climate change scenarios method, historical temperature and precipitation were adjusted with quantile mapping based on the selected global climate model projections to represent future conditions.

These projections were downscaled using the localized constructed analog (LOCA) method at 1/16th degree (approximately 6 kilometers [km], or approximately 3.75 miles) spatial resolution (Pierce et al., 2014). The LOCA method is a statistical scheme that uses future climate projections combined with historical analog events to produce daily downscaled precipitation, and maximum and minimum temperature time series data. Further details on the LOCA downscaling can be found in WSIP Technical Reference Document Appendix A (CWC, 2016).

The 20 CMIP5 global climate projections were selected by the California Department of Water Resources (DWR) Climate Change Technical Advisory Group (CCTAG) as the most appropriate projections for California water resources evaluation and planning (DWR CCTAG, 2015). The climate model projections were generated with two emission scenarios, one optimistic (Representative Concentration Pathway [RCP] 4.5) and one pessimistic (RCP 8.5), identified by the IPCC for the Fifth Assessment Report (AR5) (IPCC, 2013).

More details regarding the global climate model projections, predicted changes to temperature, and predicted changes to precipitation are provided in SWP LTO FEIR, Appendix F: Part 2: Attachment 1 Climate Change Projections Development (DWR, 2020) and WSIP Technical Reference Document Appendix A (CWC, 2016).

4 VIC Model Simulations

DWR generated historical and projected surface runoff and baseflow at 1/16th degree (approximately 6 km, or 3.75 miles) by inputting historical and projected meteorological data into the VIC model. The VIC Model (Liang et al., 1994, 1996; Nijssen et al., 1997) simulates land-surface-atmosphere exchanges of moisture and energy at each model grid cell. The VIC Model incorporates spatially distributed parameters describing topography, soils, land use, and vegetation classes.

DWR utilized the VIC model to generate the 2035 CT and WSIP 2070 climate inputs, as described below. VIC simulated surface runoff and baseflow were used to produce routed streamflows at several locations in the Sacramento and San Joaquin River Basin. Further details on the VIC model and routing model can be found in WSIP Technical Reference Document Appendix A (CWC, 2016).

5 Sea Level Rise

For a climate centered around year 2035, 15 cm of sea level rise (SLR) was assumed. 15 cm reflects median projected SLR at 2035 according to the latest Ocean Protection Council Sea-Level Rise Guidance released in 2018 (OPC, 2018).

For the WSIP 2070 hydrology (centered on 2070), 45 cm of SLR was assumed. Details regarding the assumptions for 45 cm of SLR are provided in the WSIP Technical Reference Document Appendix A (CWC 2016).

6 CalSim II Inputs Preparation

Climate and sea-level change are incorporated into CalSim II in two ways: changes to the input hydrology, and changes to the flow-salinity relationship in the Delta due to SLR.

The following methods were used to calculate projected CalSim II inflow data:

6.1 2035 CT

- For larger and smaller watersheds, simulated changes in streamflows (simulated future streamflows divided by historical simulated streamflows) were applied to the CalSim II inflows. These fractional changes were first applied for every month of the 82-year period consistent with the VIC Model simulated patterns. A second order correction was then applied to confirm that the annual shifts in runoff at each location were consistent with that generated from the VIC Model. Similarly, fractional changes were also used to simulate change in precipitation and temperature as needed for forecasting and operational assumptions used in CalSim II.
- For larger watersheds where streamflows are heavily impaired, a process was implemented by calculating historical impairment based on observed data and adding that impairment back onto the VIC Model simulated flows at a location upstream of the impairment. This approach is consistent with the approach used in the WSIP CalSim II modeling under future conditions.
- Water year types and other indices used in system operation decisions by CalSim II were regenerated using adjusted flows, precipitation, or temperature as needed in their respective methods.
- SLR effects on the flow-salinity response in CalSim II were incorporated by a separate Artificial Neural Network (ANN) for future climate condition.
- SLR effects were used in the regression equations to estimate the flow split between the Sacramento River and Georgiana Slough at times when the Delta Cross Channel (DCC) is open or closed.

6.2 WSIP 2070

- For larger watersheds, which constitute the majority of the total inflow volume in the system, CalSim II inflows were replaced with projected runoff obtained from the VIC Model.
- For smaller watersheds, for which using direct runoff from the VIC Model was not possible, simulated changes in streamflows (simulated future streamflows divided by historical simulated streamflows) were applied to the CalSim II inflows. These fractional changes were first applied for every month of the 82-year period consistent with the VIC Model simulated patterns. A second order correction was then applied to confirm that the annual shifts in runoff at each location were consistent with that generated from the VIC Model. Similarly, fractional changes were also used to simulate change in precipitation and temperature as needed for forecasting and operational assumptions used in CalSim II.
- For larger watersheds where streamflows are heavily impaired, a process was implemented by calculating historical impairment based on observed data and adding that impairment back onto the VIC Model simulated flows at a location upstream of the impairment. This approach is consistent with the approach used in the WSIP CalSim II modeling under future conditions.

- Water year types and other indices used in system operation decisions by CalSim II were regenerated using adjusted flows, precipitation, or temperature as needed in their respective methods.
- SLR effects on the flow-salinity response in CalSim II were incorporated by a separate Artificial Neural Network (ANN) for future climate condition.
- SLR effects were used in the regression equations to estimate the flow split between the Sacramento River and Georgiana Slough at times when the Delta Cross Channel (DCC) is open or closed.

More details regarding the development of the CalSim II inputs are provided in SWP LTO FEIR, Appendix F: Part 2: Attachment 1 Climate Change Projections Development (DWR, 2020) and WSIP Technical Reference, Appendix A: Climate Change and Sea-Level Rise (CWC, 2016).

7 Summary of Future Climate Hydrology

Projected changes in the Eight River Index (8RI), Sacramento Valley Four Rivers Index (SAC-4), San Juaquin Valley Four Rivers Index (SJR-4), and runoff at each of the eight major rivers for 2035 CT and WSIP 2070 are provided in Figure 1. In both climate conditions, 8RI runoff changes are dominated by the increase in runoff in the Sacramento Valley. Increase to runoff in the Sacramento Valley is greater than increases to runoff in the San Joaquin Valley under both future climate conditions. Runoff increases in all major basins at both future climate conditions except for the San Joaquin River basin, where runoff decreases by about 1 percent at 2035 CT. Increases to runoff under WSIP 2070 climate condition are greater than increases to runoff under 2035 CT, in most basins, except in the Yuba River, American River, and Stanislaus River basins. Generally, in reviewing basins from North to South, relative changes to runoff decrease, as evapotranspiration losses overcome precipitation increases.

Long-term average monthly flows of SAC-4 and SJR-4 are presented in Figures 2 and 3, respectively. As compared to historical runoff, 2035 CT and WSIP 2070 SAC-4 peak runoff increases and shifts from March to February. Winter runoff, when the peak flow on the seasonal pattern occurs, increases by 13 percent in March to 24 percent in January under 2035 CT conditions. Winter runoff increases even more under WSIP 2070, long-term average runoff increases by 18 percent in March to 47 percent in January. Increase in runoff and shift in peak timing are a result of increased precipitation and temperature, respectively. Total annual SAC-4 runoff increases by roughly 3 percent under 2035 CT and 5 percent under WSIP 2070, as noted in Figure 1. Under 2035 CT conditions, SJR-4 peak runoff volume and timing remain similar to historical runoff. However, under 2035 CT conditions, Winter runoff increases by up to 43 percent (in January) and Summer runoff decreases by up to 49 percent (in July). Under WSIP 2070 conditions, SJR-4 peak runoff volume decreases as compared to historical runoff while timing remains similar. Winter runoff increases by up to 91 percent (in January) and Summer runoff decreases by up to 71 percent (in July) under WSIP 2070 conditions. Increased Winter temperatures lead to a higher portion of precipitation that directly results in runoff, as opposed to snowpack. Similarly, with decreased snowpack, runoff during the Summer, when the majority of runoff is snowmelt, decreases. The seasonal changes result in a total annual SJR-4 runoff increase of 1 percent and about 3 percent under 2035 CT and WSIP 2070 conditions, respectively (Figure 1).

To summarize operational response to 2035 CT and WSIP 2070 climate conditions, figures of Delta inflow, outflow and exports are provided (Figures 4 through 6). In these figures, CalSim II results from the No Action Alternative at historical and future conditions are provided. NAA 051422 represents historical conditions; 2035 CT NAA 062122 represents 2035 CT conditions; and WSIP 2070 NAA 062122 represents 2070 conditions. As a result of increased runoff during the Winter months (January through March), Delta inflow increases by 14 to 18 percent and 22 to 31 percent under 2035 CT and WSIP 2070 conditions, respectively. Then, Delta inflow decreases by 7 to 19 percent and 7 to 29 percent under 2035 CT and WSIP 2070 conditions, respectively, in the Spring and Summer (May through September) due to reduced runoff. With these seasonal changes to 2035 CT and WSIP 2070 conditions, annual average Delta inflow increases by 4 percent and 7 percent, respectively. With the exception of Summer months, Delta outflow patterns are consistent with Delta inflow patterns (Figure 5). To compensate for the reduction of Delta inflow, under 2035 CT and WSIP 2070 conditions exports are reduced by 13 percent and 22 percent, respectively, during the Summer (Figure 6). These Summer reductions lead to a 7 percent (340 TAF) and 13 percent (650 TAF) decrease in annual exports at 2035 CT and WSIP 2070 conditions, respectively. It should be noted that Delta inflow and total exports reflect combined operations of the CVP and SWP. Review of individual projects may show deviations in operational discretion (e.g., balancing exports and reservoir storage). Yet, the overall trend remains; at future2035 CT climate conditions, reservoirs are more likely subject to spill during the winter, reduced runoff decreases reservoir storage and release in the Spring and Summer. Exports are reduced to compensate for reduced reservoir releases in the Spring and Summer.

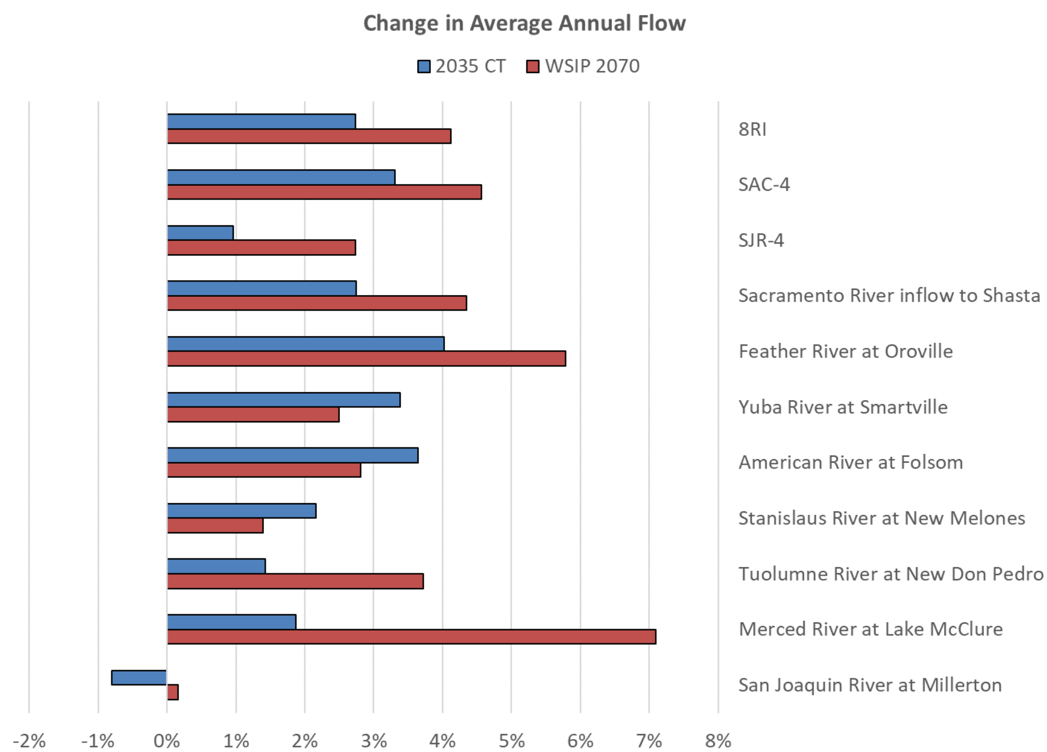

Figure 1. Relative Change in Average Annual Flow

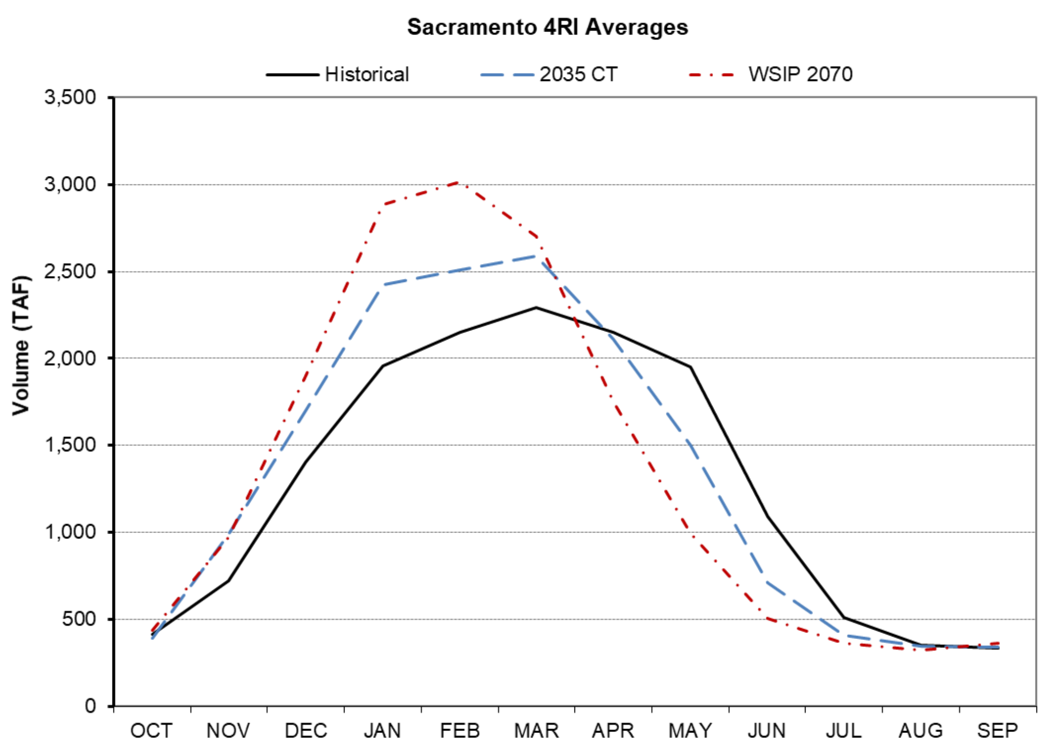

Figure 2. Monthly Pattern of Sacramento Valley Runoff

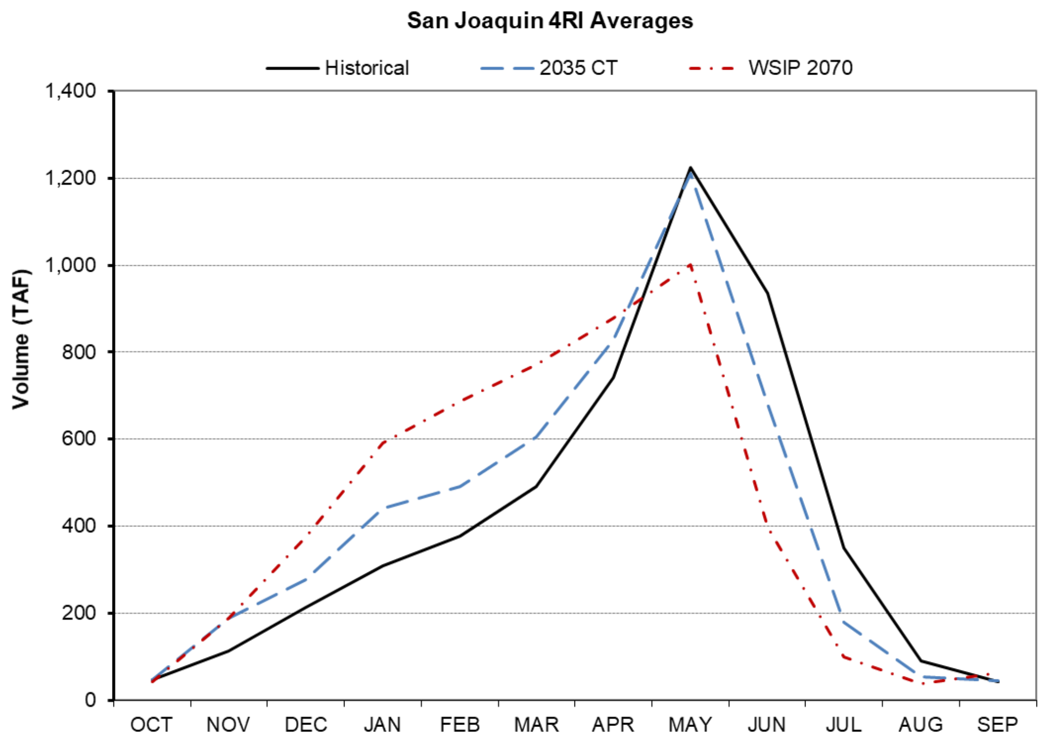

Figure 3. Monthly Pattern of San Joaquin Valley Runoff

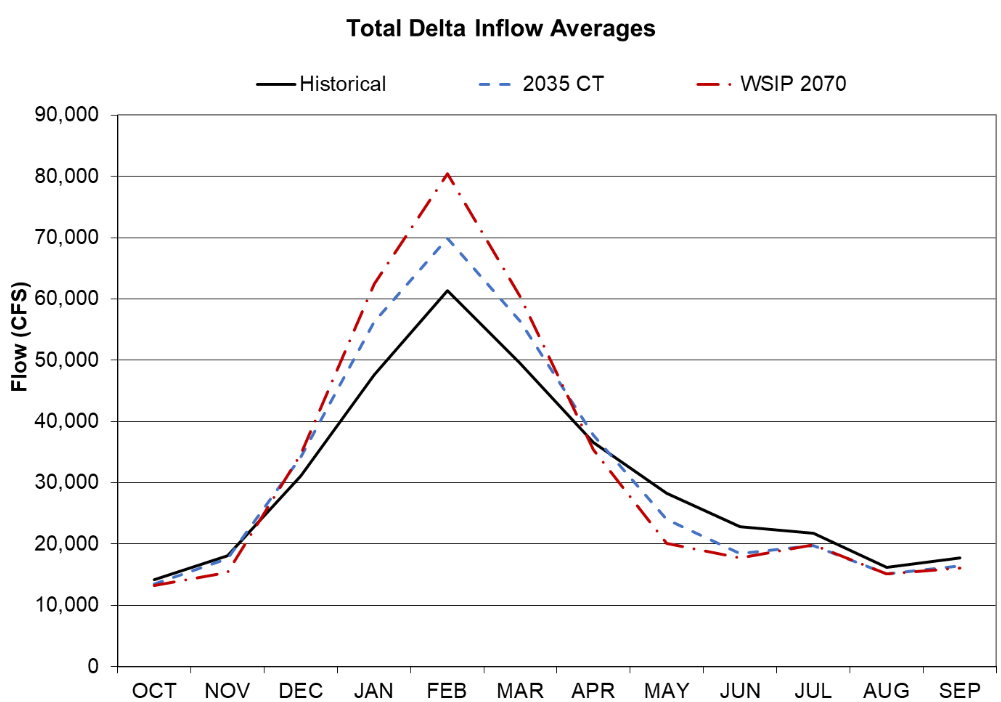

Figure 4. Monthly Pattern of Total Delta Inflow

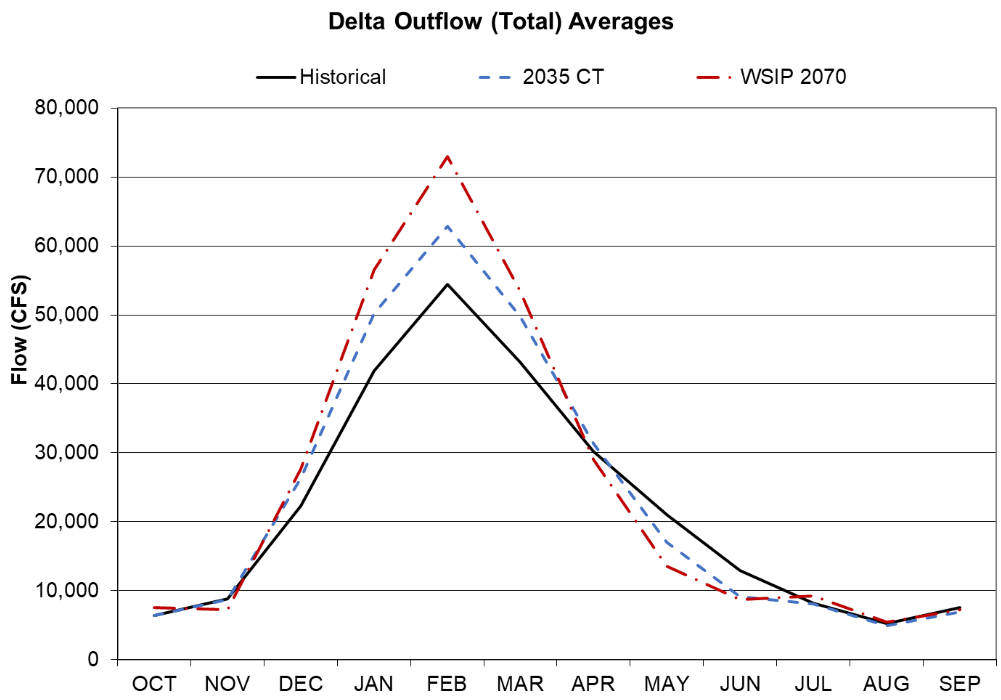

Figure 5. Monthly Pattern of Total Delta Outflow

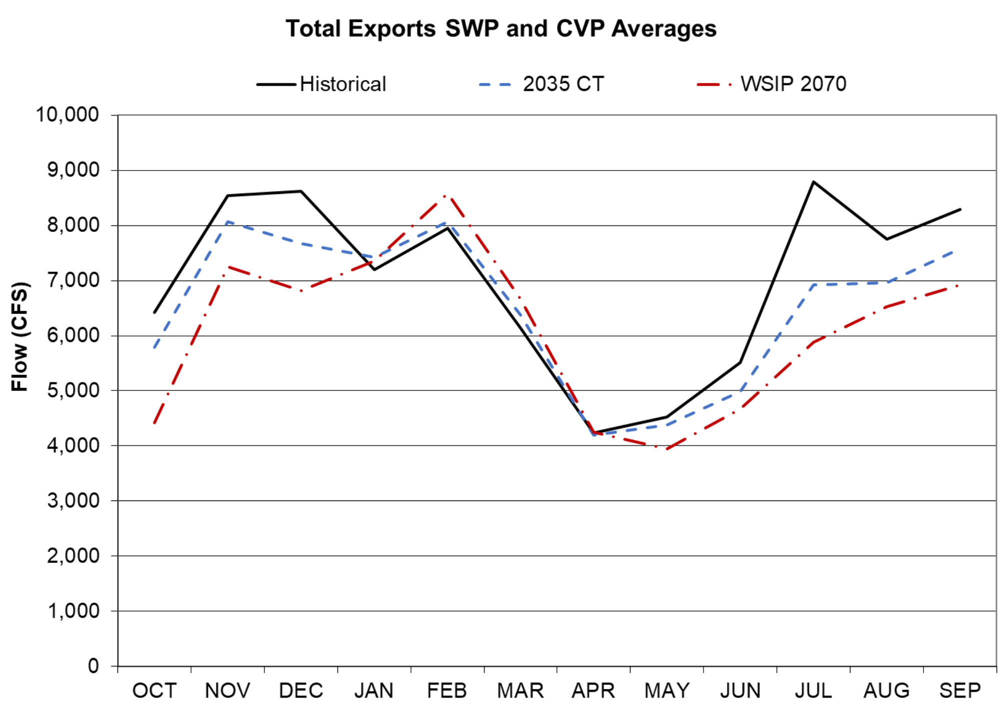

Figure 6. Monthly Pattern of Total Delta Exports

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