Project #4703

Long Term Vulnerability Assessment and Adaptation Plan for the San Francisco Public Utilities Commission Water Enterprise – Phase I

Context

The San Francisco Water System Model (SFWSM) was developed to support the goal of the Long-Term Vulnerability Assessment (LTVA) of the Hetch Hetchy Regional water system managed by the San Francisco Public Utilities Commission (SFPUC). Although the LTVA was completed in 2021, SFPUC and the Hydrosystem Research Group (HRG) at the University of Massachusetts continued to enhance the SFWSM code to evaluate new alternative water supply options that SFPUC is considering for its asset portfolio.

In a recent 2024 modeling effort, an error in the SFWSM code was found. Upon investigation, the modeling team determined that this error did not affect the LTVA results, except for scenarios involving significant increases in instream-flow requirements (IFR). This is relevant for the environmental narratives NAE2.1 ('State-amended Water Quality Control Plan', or State-amended WQCP) and NAE2.2 ('Draft Tuolumne Voluntary Agreement', or Alternative SFPUC proposal also called as "Alternative proposal" hereafter).

The objectives of this errata are as follows:

- Detail the identified error in the SFWSM code and its resolution,
- Demonstrate that the LTVA results (excluding the results for NAE2.1 and NAE2.2) are not significantly affected by the error,
- Revise Section 5.3.2 of the LTVA report, which describes the results for NAE2.1 and NAE2.2,
- Update the last bullet point of Section ES4 ('Results') in the Executive Summary of the LTVA report. One additional bullet point was also added to the Section ES4.

Description of the SFWSM code error

During droughts, SFPUC may implement various measures to reduce deliveries to customers to mitigate severe water shortages. The SFWSM version that was utilized for the LTVA uses an index called Years of Remaining Supply (YRS) to decide on July 1st whether to ration deliveries. On July 1st, if the YRS index falls below certain predefined thresholds, the model will reduce system-wide delivery by either 10 or 20%. If rationing is triggered, it remains in effect for at least one year until a new assessment is made.

The YRS index is calculated as follows:

$$YRS = \frac{Total\ System\ Storage}{Expected\ System\ Demand}, \tag{1}$$

- **Total System Storage**: this includes the total volume of available water stored in the system reservoirs (including the Don Pedro water bank and the SFPUC storage account in the Westside groundwater basin in addition to surface reservoir storages).
- **Expected System Demand (ESD):** This comprises:
  - Expected supply to the SFPUC retail and wholesale customers for the upcoming year,
  - Expected total evaporation over the system reservoirs for the upcoming year,
  - Expected IFR loss for the upcoming year, which is the total IFRs not collected by a downstream reservoir. The IFR loss includes the IFR below Stone Dam, Crystal Springs Reservoir and Calaveras Reservoir. The SFPUC contribution to the IFR below Don Pedro Reservoir (released from water bank) is added to the calculation to the IFR loss under the narrative NAE2.1 and NAE2.2. Note that under the current FERC license and related agreements, SFPUC does not contribute water to the IFR below Don Pedro Reservoir because SFPUC compensates the irrigation districts financially to provide this contribution on its behalf.

To understand the error in the SFWSM code, it is crucial to note that during every simulated year, starting on July 1st, the model accumulates through time simulated daily values of reservoir evaporation and IFR loss. For example, at the end of the time step for July 1st, 2010, the variable holding the total IFR loss is the sum of the simulated IFR loss for that time step. By the end of the time step representing July 2nd, 2010, this variable includes the IFR loss for both July 1st and July 2nd, and this process continues until June 30th, 2011, for which the IFR loss variable equal to the sum of the IFR loss from July 1st, 2010 through June 30th, 2011.

In this example, the model was intended to reset the total IFR loss variable to zero on July 1st, 2011 after estimating the YRS index using equation 1, allowing it to accumulate the IFR loss for the upcoming year. However, the IFR loss was excluded from the ESD calculation, leading to an overestimation of the YRS index. This overestimation prevented the model from triggering rationing as it should have if the total IFR loss had been included in the YRS calculation. The error was corrected by ensuring the IFR loss is included in the ESD calculation.

Assessment of the effect of the identified model error on the LTVA results

Figure 1 depicts the three components of the ESD used in the YRS calculation before (left) and after (right) correction of the model error: IFR Loss (blue), reservoir evaporation (orange) and urban water supply (green). The results are presented for the range of rainfall scenarios used un the climate stress test, ranging from a 40% reduction to a 40% increase.

Under the current FERC license, which is the current IFR flow schedule used below Don Pedro Reservoir, the difference between the results before and after correction is minimal (i.e., compare the solid and dash black lines in Figure 1, top right). This is because the IFR loss contribution to the ESD is small. Therefore, omitting the IFR loss in the ESD calculation has little to no impact on the YRS value (Figure 2).

However, under the in-stream flow narrative NAE2.1 and NAE2.2, we have assumed that SFPUC contributes to the IFR below Don Pedro Reservoir, and this contribution is included in the IFR loss. The additional IFR resulting from the SFPUC contribution to the updated Don Pedro IFR is large, especially under NAE2.1 (see Figure 5-49 of the LTVA report; also reproduced further down in this errata). This means that excluding the IFR loss variable in the ESD calculation, and particularly the SFPUC's contribution to the IFR below Don Pedro Reservoir, leads to a significant overestimation of the YRS. This can be seen by comparing the simulated ESD (Figure 1) and YRS (Figure 2) after correction: (i.e., difference between dash and solid lines. Note that after correction under narrative NAE2.1 and NAE2.2, the absolute value of the urban water supply contribution to ESD (green) decreases, as the ESD value reflects the fact that deliveries are rationed. This is particularly evident with NAE2.1 after correction, as rationing is almost always active (see discussion below).

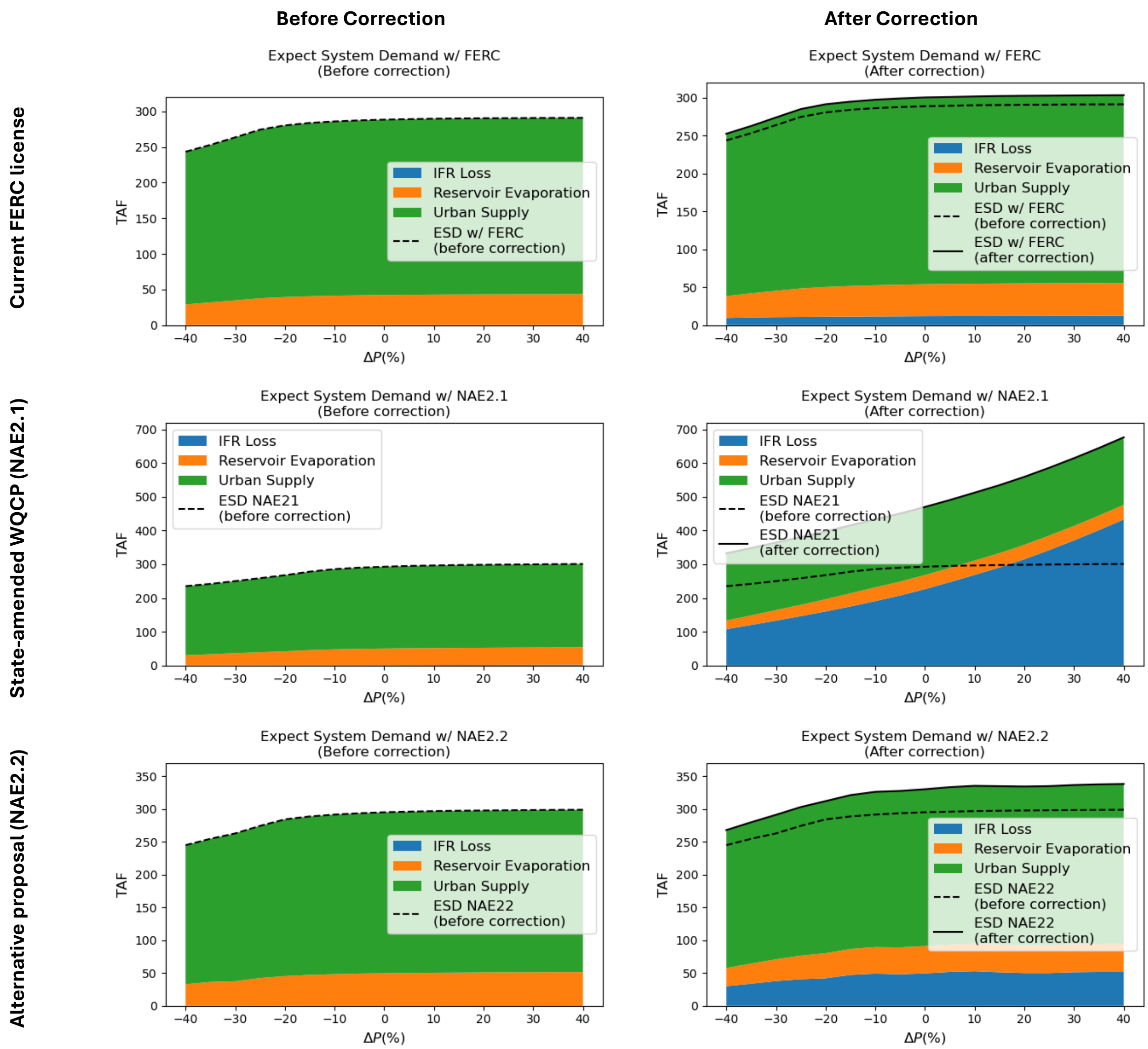

Figure 1 Components of the 'Expected System Demand' (ESD) variable used in the YRS calculation. The components before and after correction are shown in the left and right columns, respectively. The IFR loss is shown in blue, the reservoir evaporation in orange, and the urban water supply in green. The first row shows the results obtained under the current FERC agreement (which is used for most of the results obtained throughout the LTVA). The second and third rows show respectively the results obtained using the state-amended WQCP (i.e., NAE2.1) and the Alternative proposal (NAE2.2). The x-axis shows the range of rainfall scenarios for which the results are shown. Results are averaged across the ten realizations used in the climate stress test, and account for no temperature warming and the baseline urban demand scenario (i.e., 227 mgd). The dash and solid black lines show the ESD obtained prior and after correction, respectively. Note that the y-axis scale changes from one row to another.

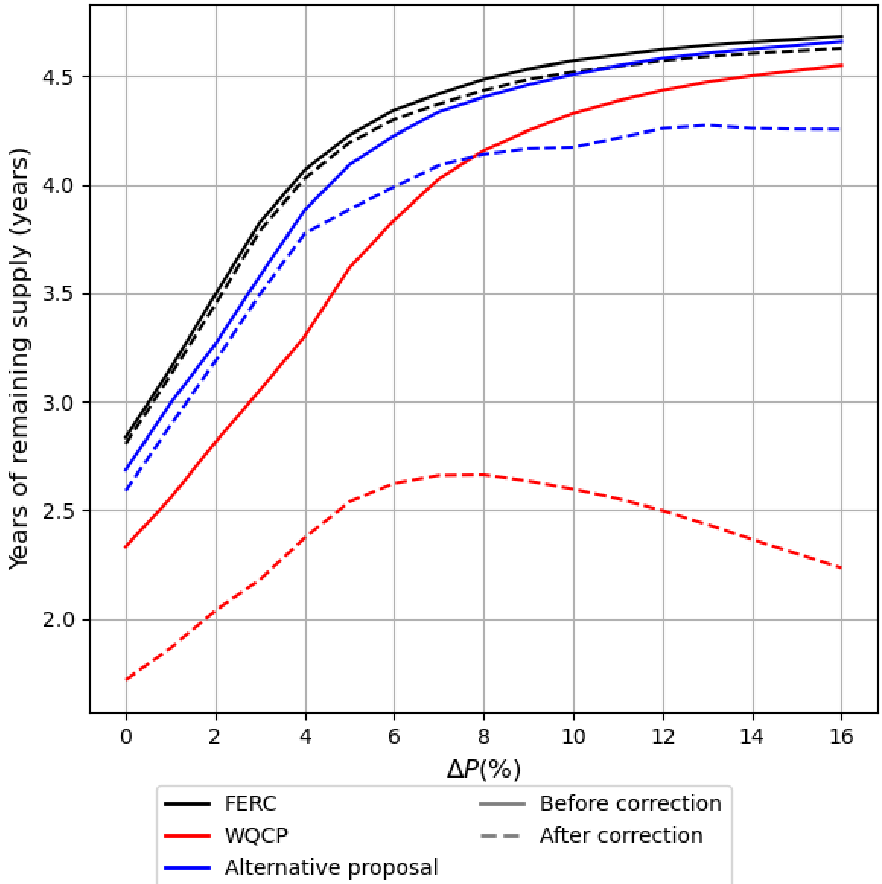

Figure 2. Influence of the modeling error on the estimate of average Years of Remaining Supply (YRS). The average YRS variable is shown for different IFR assumptions (current FERC license in black, the state-amended WQCP in red and the Alternative proposal in blue) and several rainfall scenarios (x-axis). The values shown in the figure are averages across the 10 stochastic realizations.

As illustrated in Figure 1, the identified model error impacts the value of the ESD. This miscalculation leads to errors in estimating the YRS index (Figure 2), and thus the frequency of rationing or reliability (i.e., defined as the frequency of years without rationing):

- **Current FERC license** (Figure 3): Under this assumption, the IFR loss is small as it only comes from the IFR below Calaveras and Crystal Springs Reservoirs. Its omission results in a slight overestimation of system reliability (i.e., underestimation of the frequency of rationing) as shown in Figure 3. For example, under current climate conditions (ΔP=0%), the error in reliability of the system is 0.2%, 0.6%, 1.4% and 1%, for the DB, D15, D30 and D45 demand scenarios, respectively.

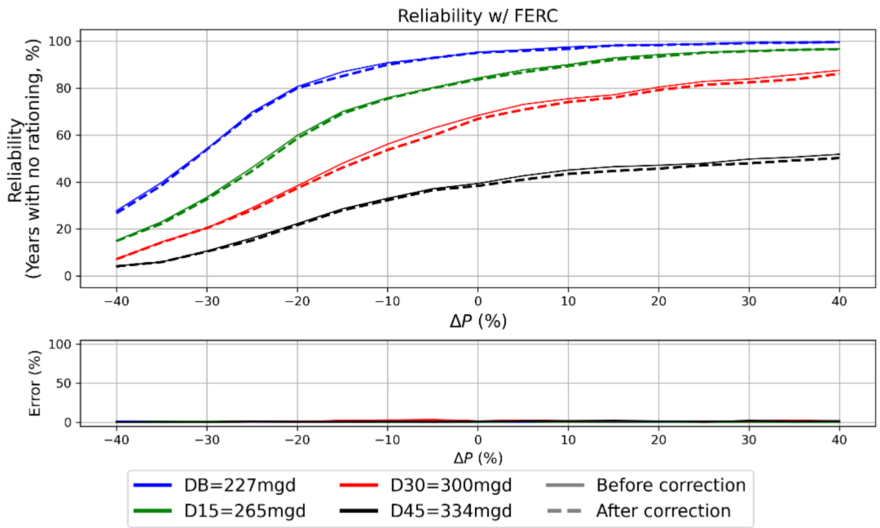

Figure 3. Top: Reliability (i.e., frequency of years with no rationing) obtained across a range of scenarios of change in rainfall (x-axis), demand scenarios (colors) and before and after correction of the model (solid and dash lines, respectively).

Bottom: Deviation between the simulated reliability before and after the model correction. The 'no warming temperature' scenario is used to generate these results.

- **State-amended WQCP (NAE2.1)** (Figure 4): For this scenario, which involves the largest increase in IFR below Don Pedro Reservoir, the error correction leads to a completely different outcome. The increase in IFR loss to the system is such that the system reliability never exceeds a few percentage points, whatever the climate or demand conditions. Note that the error increases with increased precipitation, as the state-amended WQCP IFR flow schedule (i.e., 40% of unimpaired flow at La Grange) is heavily influenced by precipitation over the basin (see Figure 5-49 from the LTVA report). Under current climate conditions, the error in reliability of the system is 89%, 91%, 91% and 91%, for the DB, D15, D30 and D45 demand scenarios, respectively.

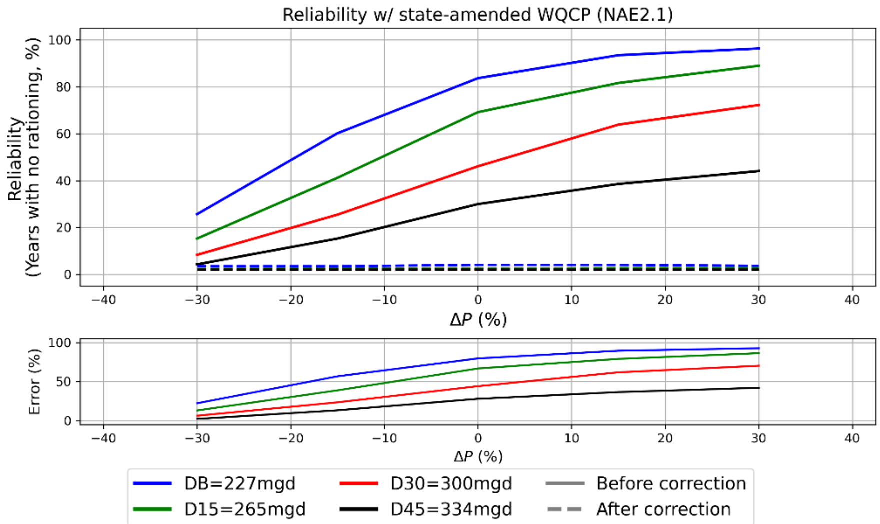

Figure 4. Same as Figure 3 but for the state-amended WQCP (NAE2.1) IFR schedule below Don Pedro Reservoir.

The significant drop in reliability following the introduction of the state-amended WQCP IFR highlights the SFWSM model's limitations when applied under conditions that are significantly different from those used for estimating its parameters. Model simulations that include the state-amended WQCP show that rationing is triggered (or maintained if already active) even during wet years with full storage (not shown). This occurs because the YRS function, which triggers rationing, includes the IFR demand. With the significant increase in IFR under NAE2.1, the overall YRS decreases. Figure 2 (dash red line) illustrates that the average YRS with the state-amended IFR does not exceed 2.7 years, regardless of precipitation conditions (note that the YRS threshold that triggers 20% rationing is 3.1 years (see Table 3.26 from the LTVA report). Further research is needed to define the necessary adjustment of the model parameters should the state-amended WQCP be implemented.

- **Alternative proposal (NAE2.2)** (Figure **5**): The error here is notable but not as severe as with NAE2.1. The reason is that the total volume of the Alternative proposal IFR is much less than the state-amended WQCP IFR, even at low levels of precipitation (see Figure 5-49 of the LTVA report). Although the error increases with precipitation, it is less pronounced because the Alternative proposal IFR flow schedule is much less sensitive to climate conditions (see Figure 5-49 from the LTVA report) than NAE2.1 is.

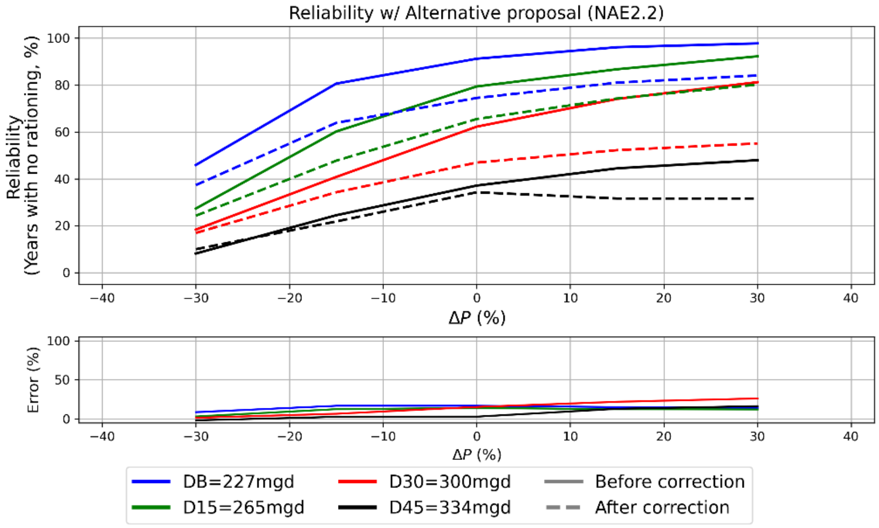

Figure 5. Same as Figure 33 but for the Alternative proposal (NAE2.2) IFR schedule below Don Pedro Reservoir.

In summary, the identified error has minimal to no effect on results using the baseline FERC assumption for the IFR below Don Pedro Reservoir. However, it caused significant misestimations of rationing under the state-amended WQCP (NAE2.1) and the Alternative proposal (NAE2.2) IFR flow schedules, leading to misrepresented system operations in the model. The impact of the error is much greater for the state-amended WQCP IFR flow schedule due to its large size when compared to the one described in the Alternative proposal.

Revision of Section 5.3.2 of the LTVA report

For convenience, all of Section 5.3.2 is reproduced below, including parts of the section that have not been altered following the correction of the error in the model.

5.3.2 New IFR below Don Pedro Dam (NAE2.1 and NAE2.2)

The state-amended Water Quality Control Plan (aka state-amended WQCP or NAE2.1) represents a very large increase over the existing IFR below Don Pedro, while the Alternative proposal (NAE2.2), while still much larger than the existing baseline IFR, is substantially lower (Figure 5-49). Noting that the baseline (existing) contribution to the release by SFPUC is 50 cfs from June through September, or about 4 TAF/year, the state-amended WQCP represents more than a 50-fold increase above the current baseline with no increase or decrease in historical precipitation. Meanwhile, the Alternative proposal represents only about a 10-fold increase. Importantly, the state-amended WQCP is more sensitive to precipitation than the Alternative proposal. In contrast, the Alternative proposal is far less sensitive to precipitation, with relatively modest changes in total annual environmental releases with changes in overall precipitation. It is also noted that spill from the Water Bank contributes to the IFR.

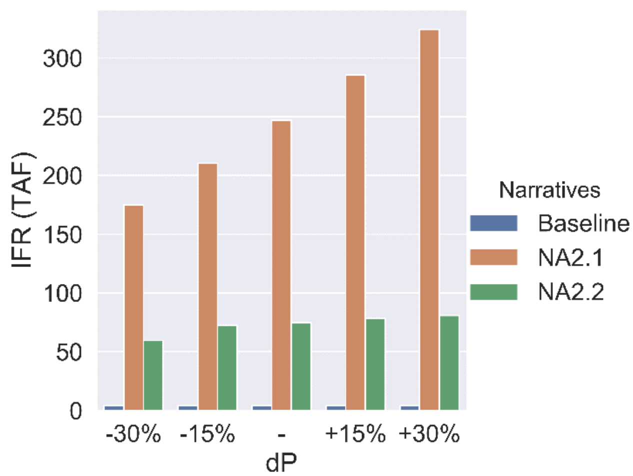

Figure 5-49. Annual IFR from Water Bank
NAE2.1 is the State-amended WQCP and NAE2.2 is the Alternative proposal.

To simplify the comparison between NAE2.1 and NAE2.2, only two demand scenarios (227 and 300 mgd) are represented in Figure 5-50 and Figure 5-51. Both state-amended WQCP (NAE2.1) and Alternative proposal (NAE2.2) lead to a significant decline in system performance, although the decrease in performance for NAE2.1 is much larger. Under NAE2.1, reliability falls below 5% across all climate conditions, even at the baseline demand scenario (227 mgd). For NAE2.2, the system reliability decreases by about 20% under baseline demand and current climate conditions. Even significant rainfall increases do not achieve the 90% reliability target. However, reliability does improve with increased rainfall under NAE2.2, as the NAE2.2 IFR does not continue to increase as precipitation increases, as it does in NAE2.1.

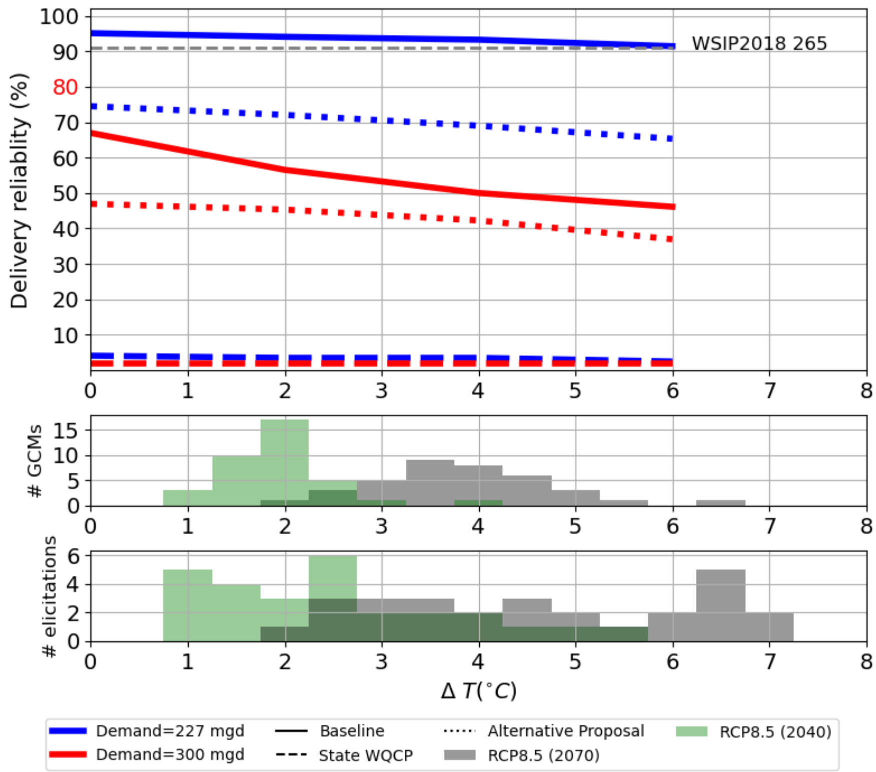

Figure 5-50. Water Delivery Reliability for the Reference, NAE2.1, and NAE2.2 Narratives across All Temperature (ΔT) Scenarios and a Subset of Two Demand Scenarios (227 mgd, Which Corresponds to Current SFPUC Demand, and 300 mg [+30%]).

The dash-grey line shows the reliability obtained from HHLSM WSIP 2018. The 90% reliability target is shown in red in the y-axis.

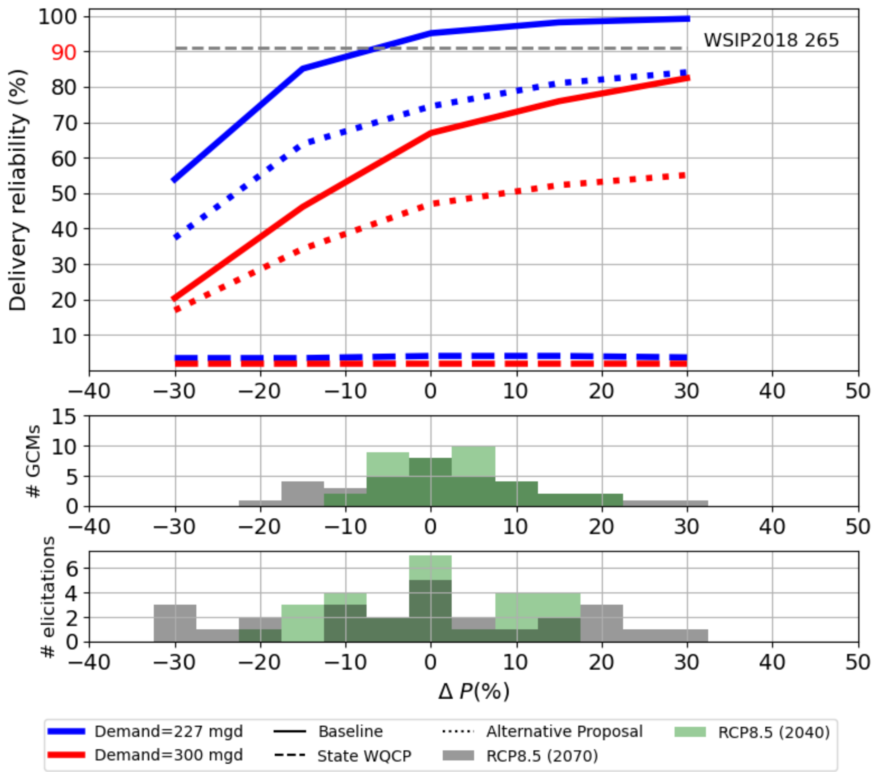

Figure 5-51. Water Delivery Reliability for the Reference, NAE2.1, and NAE2.2 Narratives across All Precipitation (ΔP) Scenarios and a Subset of Two Demand Scenarios (227 mgd, Which Corresponds to Current SFPUC Demand, and 300 mgd [+30%]).

The dash-grey lines show reliability obtained from the HHLSM WSIUP 2018. The 90% reliability target is shown in red in the y-axis.

In summary, both the state-amended WQCP and Alternative proposal significantly impact water delivery reliability, with the former having a much greater effect:

- Regardless of demand or climate scenarios, the state-amended WQCP results in consistent and steady rationing of water deliveries to customers.
- The state-amended WQCP's IFR flow schedule below Don Pedro Reservoir increases with rainfall more rapidly than additional supply would under those conditions, meaning increased rainfall does not benefit the system.
- Under current climate and demand conditions (227 mgd), the reliability of the Alternative proposal decreases significantly by about 20%, resulting in a reliability of approximately 75%, which is 15% points below the 90% target. The 75% reliability corresponds to the reliability level that would be obtained under the current FERC license with a reduction in average rainfall by 20%, a reduction level that appears unlikely based on the GCM projections. Some experts consider this reduction level a potential extreme scenario by 2070.
- The Alternative proposal is less sensitive to rainfall changes compared to the state-amended WQCP. While system reliability under this IFR schedule increases with rainfall, even substantial increases in rainfall do not raise reliability above the 90% target.
- The significant decreases in reliability under the state-amended WQCP's IFR (NAE2.1), and to a lesser extent under the Alternative proposal (NAE2.2), are due to the inclusion of large IFR volumes into the Years of Remaining Supply (YRS) metric used to trigger rationing. To better reflect system operations under these new conditions, either the YRS function or the YRS thresholds for triggering rationing could be adjusted. Although

more research is needed on this topic, an initial step could be to conduct a sensitivity analysis of system operations (e.g., frequency of rationing) in relation to the YRS thresholds. Lowering the YRS thresholds should reduce rationing. However, rationing would be triggered at lower storage levels, increasing the system's vulnerability to shorter-duration droughts to those it is currently vulnerable to.

Update the last bullet point of Section ES4

- The RWS is particularly vulnerable to the state-amended new IFR below Don Pedro Dam (State WQCP), which represents a huge reduction in water available. Under all demand and climate scenarios the system reliability, defined as frequency of years without rationing, remains below 5%.
- The RWS is also vulnerable to the draft Tuolumne voluntary agreement new IFR below Don Pedro Dam (Alternative proposal), which represents a large reduction in water available, although significantly less than for the state-amended WQCP proposal. The implementation of the Alternative proposal under current climate and demand conditions would reduce the system reliability to 75%, which corresponds to the effect of a reduction in average rainfall by 20% under the current FERC agreement.