# Methods

Projected reservoir system objectives of cumulative flood volume and reliability south of the San Joaquin Delta were evaluated for 3492 scenarios for the historical period (1951-2000 water years) up to 2100 in the future. These scenarios included a choice of 31 global circulation models (GCM) and 4 representative concentration pathways (RCP) that made up CMIP5 climate scenarios. Climate projections were then downscaled and adapted to a hydrologic simulation model to estimate system objectives. To estimate water demand, 36 different land use scenarios (LULC) were considered for each GCM/RCP pair. Finally, 30 year moving averages were considered across the dataset to reduce the effect of natural variability and noise.

To detect non-parametric significance, a one-sided Mann Whitney U-test was conducted progressively for each rolling window against the historical sample distribution. At p<0.05, it was said that a significant change in the system objective was detected with 95% confidence. A significant change is defined as the moment the tested window and the historical window are thought to be from different distributions. Furthermore, it was found that the ensuing results are not sensitive to the choice of window size in taking the moving averages. Scenarios that never detected a significant change in the projection window were deemed “no detect scenarios,” where detection is thought to possibly occur after the year 2100.

**Single Scenario Analysis**

The single scenario analysis sought to consider the first significant detection year across each of the 3492 scenarios, combinations of choices in GCM, RCP, and LULC, individually. The advantage of this methodology is that it provides a direct link between a specific choice in GCM, RCP, and LULC and an estimation of when significant detection occurs, which may provide insight in how these choices control results. The resulting distribution of first-detection years was then analyzed in total, including counts of “no detect scenarios.” Results sorted by GCM, RCP, or land use scenario choice. For each scenario type, distribution median, standard deviation, and sample size, were computed for every available choice. Pathways incurring a significant detection were also mapped to its actual objective severity at both the time of detection and at the end of the projection period.

**Multiple Scenario Analysis**

The multiple scenarios analysis was concerned with significance detection across the ensemble in timeseries. This analysis characterizes how the relative count of significant detection for each year, or the ratio of scenarios incurring a significant detection and those that did not changes with time. In essence, if each characterization of the future, every combination of scenarios, is equally likely to occur, the multiple scenario analysis represents a measure of detection probability with time within the context of the sample population of defined possible scenarios included in the analysis. It is important to note that every scenario and model choice only seeks to describe the future, thus outcomes for each scenario are possible, but the model ensemble does not represent a collection of all possible futures. Results were then sorted by GCM, RCP, and LULC’s, with relative counts computed relative to the scenarios within a set GCM, RCP, or LULC. Since detections climbed steadily with time, the distribution of relative counts at the end of the projection period (2098) was also considered.

**Sensitivity Analysis**

Since model scenarios show significant variability, it is interesting to characterize that variability with its input variables. The first, second, and total order global sensitivity of first detection years for choices in different GCM, LULC, or RCP’s was also formally computed using Sobol sensitivity analysis, providing a measure of how much variability in results are provided by each parameter both independently and through interactions with other parameters..