Board of Directors

Brian Brennan, Director
Angelo Spandrio, Director
Pete Kaiser, Director

Neil Cole, Director
Richard Hajas, Director

CASITAS MUNICIPAL WATER DISTRICT
Meeting to be held at the

The meeting will be held via teleconference.
To attend the meeting please call (888) 788-0099 or (877) 853-5247
Enter Meeting ID: 931 3830 4875#
Passcode: 422578#

SPECIAL MEETING AGENDA

January 15, 2021 @ 2:00 PM

Right to be heard: Members of the public have a right to address the Board directly on any item of interest to the public which is within the subject matter jurisdiction of the Board. The request to be heard should be made immediately before the Board's consideration of the item. No action shall be taken on any item not appearing on the agenda unless the action is otherwise authorized by subdivision (b) of ¶54954.2 of the Government Code and except that members of a legislative body or its staff may briefly respond to statements made or questions posed by persons exercising their public testimony rights under section 54954.3 of the Government Code.

1. CALL TO ORDER

2. ROLL CALL

3. PUBLIC COMMENTS - Presentation on District related items that are not on the agenda - three minute limit.

4. ACTION ITEMS

   4.a. Discussion of the Hydrologic Modeling Assumptions related to the Comprehensive Water Resources Plan and provide direction to staff as appropriate.
   Memo_Board_CWRP_Jan15-2021_Revised-2.pdf
   ATT1_AppendixD_draft_CWRP_June2020_rev01 (32).pdf

ATT2_Supplemental Analysis TM 20210111.pdf

5. ADJOURNMENT

CASITAS MUNICIPAL WATER DISTRICT
MEMORANDUM

TO: BOARD OF DIRECTORS

FROM: MICHAEL FLOOD, GENERAL MANAGER

SUBJECT: DISCUSSION OF COMPREHENSIVE WATER RESOURCES PLAN

DATE: 01/15/21

RECOMMENDATION:

It is recommended the Board of Directors discuss hydrologic modeling assumptions related to the Comprehensive Water Resources Plan, and direct staff as appropriate.

BACKGROUND:

The Board of Directors authorized a consulting services agreement with Stantec in January 2019 to prepare the Comprehensive Water Resources Plan (CWRP).

The CRWP is a high-level strategic document to help guide water resources planning efforts. The plan assesses current water supplies against forecasted demand through the year 2040, and provides a recommended portfolio of projects to address anticipated water supply shortfalls caused by prolonged drought and climate change. The CWRP is anticipated to provide information for the next Urban Water Management Plan Update, which is a required document due to the State every five years. The next UWMP update is due in June 2021.

A planning level analysis of more than 30 different projects and programs were evaluated in the CWRP – including a range of desalination, recycled water, improvements to existing facilities, conservation, groundwater and surface water enhancement projects and programs – using technical, economic, environmental, and social criteria.

Key deliverables in the CWRP effort included the following:

- Early Action Plan
- Probabilistic Lake Casitas Yield Analysis
- Identification of Funding Alternatives
- Draft and Final Report

An overview of the draft CWRP was presented at a Board Workshop held on February 8, 2020, and the draft CWRP report was released for public review from June 26, 2020 through August 24, 2020. The draft report is found on the District's website: https://www.casitaswater.org/your-water/casitas-water-security.

Several public comments were received on the draft CWRP report, which were provided to the Board of Directors on September 23, 2020 and December 9, 2020. Based on review of the comments, staff recommends that a revised draft CWRP report be prepared.

On December 9, 2020, the Board of Directors discussed the need for additional Board meetings to discuss the goals of the Comprehensive Water Resources Plan. At their December 16, 2020 meeting, the Board directed staff to return with CWRP information related to Lake Casitas yield modeling scenarios. At their December 23, 2020 meeting, the Board authorized additional hydrologic analyses to be performed by Stantec.

DISCUSSION:

The Draft Comprehensive Water Plan:

The June 2020 Draft CWRP includes an extensive analysis of Lake Casitas operational yield scenarios, which are presented in Appendix D of the report (included as Attachment 1) and summarized as follows.

The Draft CWRP recommends a Lake Casitas operational yield of 10,660 acre-feet (AF) per year based on the following modeling assumptions:

- Safe Demand approach that models demand reductions in accordance with the District's Water Efficiency and Allocation Program
- Robles Diversion Efficiency of 70%
- Initial Lake Volume of 237,761 AF (full reservoir)
- Minimum Pool of 20,000 AF
- Re-sequenced hydrology for 100 alternate 74-year periods
- 95% Reliability Goal
- Climate change adjustment

With a Safe Yield approach (rather than Safe Demand) and all other things being equal, the Safe Yield of Lake Casitas would be 9,190 AFY.

Board Request for Additional Modeling Scenarios:

At their December 23, 2020 meeting, the Board authorized Stantec to perform additional modeling scenarios based on the following:

- Safe Yield approach that models a constant amount of water that can be withdrawn from the lake without dropping below assumed minimum pool based on historical hydrology
- Minimum Pool of 950 AF (equal to Dead Pool)
- Alternate Historical hydrology periods of 1945-2006 and 1957-2018

Stantec has completed their supplemental analysis which is included as Attachment 2. The safe yield analysis with historical hydrology was compared using a minimum pool of 20,000 AF and 950 AF. In addition, an analysis was prepared that compares initial storage as a full lake

(237,761 AF) versus current storage (95,000 AF) for various constant demand scenarios. The following is a summary of results and considerations:

- A Safe Yield based on the historical record is significantly greater than the probabilistic approach recommended in the Draft Comprehensive Water Resources Plan. Using the historical period of record is less conservative for planning purposes, since the majority (67%) of synthetic hydrologic traces, developed based on the statistics of the historical record, had a drier hydrology than the historical period of record (1945-2018).

- The critical historical period is 1945-1965 when using a Safe Yield approach, and the critical period shifts to 1998-2018 with a Safe Demand approach that models the WEAP.

- Demand management through the WEAP helps to stretch supplies during droughts and water shortage conditions. A Safe Yield approach does not account for the reduction in demand that occurs when WEAP policies are implemented, and that has occurred historically. Provided that an effective demand management plan is adopted to reduce water use as lake levels decline, a Safe Yield approach can be more conservative than a Safe Demand approach for planning purposes.

- Reducing the minimum allowable storage from 20,000 AF to Dead Pool increases the safe yield by 7 percent. A reduction in minimum allowable storage is less conservative since no storage would be reserved for planning contingency.

Safety Factor Consideration:

Staff recommends that a safety factor be included in the planning study, given that future available supplies could be less than assumed. The Draft CWRP took a more conservative approach to planning given the uncertainties related to future hydrologic variability and climate change.

If the Board decides to adopt criteria with more risk as described above, staff recommends the Board consider adding a safety factor to other planning criteria, such as future planned average demands. For example, future planned demands could be increased by 10-15 percent, adding a buffer to plan for additional supply and account for unknown factors, such as demands being higher or supplies being lower than originally assumed.

Annual Demand Consideration:

The Draft CWRP is based on a future average non-drought demand of 16,000 AFY for the Casitas System (which includes approximately 525 AFY added to the Ojai system), and a future average non-drought demand of 2,350 AFY for the Ojai system, for a total combined demand of 17,825 AFY (16,000 – 525 + 2350 = 17,825). These demands account for both customer uses and losses in the water delivery systems.

The Draft CWRP planned demands are approximately 10% less than previously planned long-term demands of 17,500 AFY for the Casitas system and 2,570 AFY for the Ojai system to reflect that the recent drought will likely result in some permanent savings in the long-term.

Water demands typically rebound after drought periods but do not fully return to pre-drought levels due material changes such as replacement of landscaping, irrigation systems, and appliances with more water-efficient devices.

Staff recommends that the planned long-term average demands remain as presented in the Draft CWRP, or slightly higher if other planning contingencies are removed. Prior to recent WEAP demand reductions, water demands from Lake Casitas ranged between 14,841 AFY (2011) to 20,402 AFY (2013), and averaged 17,509 AFY for the 5-year period from 2011-2015[1]. Historical demands for Casitas can vary significantly from year to year due to the needs of agricultural and resale customers; demands typically increase during dry periods and decrease during wet periods.

The planned average long-term demands reflect unrestricted demands during non-drought periods, and managed demand reductions would be implemented as lake levels decline according with the WEAP. The WEAP serves as a demand management tool to reduce demands during droughts, and it has been effective in doing so. The WEAP serves to comply with the State's requirements of having an adopted Water Shortage Contingency Plan, as outlined in the 2020 Urban Water Management Plan guidelines.

Request for Board Direction to Staff:

Staff is requesting direction from the Board related to the following planning criteria, as they relate to the level of acceptable risk for planning purposes. The following planning criteria are recommended to be revisited based on recent Board discussions:

Planning Criteria	**Willing to Accept Less Risk**	**Willing to Accept More Risk**
Operational Yield Approach	Safe Yield	Safe Demand
Minimum Lake Storage	Greater than 950 AF	950 AF (Dead Pool)
Future Hydrology	Re-sequenced Historical with Climate Change	Historical only
Reliability Goal	Greater than 90%	Less than 90%
Annual Demand	Greater than: 16,000 AFY for Casitas System 2,350 AFY for Ojai System	Less than: 16,000 AFY for Casitas System 2,350 AFY for Ojai System

A presentation will be provided during the Board meeting to review the modeling results and planning criteria.

[1] Data reported by calendar year.

Appendix D Draft Lake Casitas Water Supply Analysis Technical Memorandum

Comprehensive Water Resources Plan

June 8, 2020

Prepared for:

Casitas Municipal Water District

Prepared by:

Stantec Consulting Services Inc.

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Section 1 Introduction

This Technical Memorandum (TM) describes the water supply analysis performed for Lake Casitas as part of the Comprehensive Water Resources Plan (CWRP). It documents the updates made to a previous yield model for Lake Casitas, and presents results of applying the model to analyses of estimated water supply available from Lake Casitas under different future hydrology and operating conditions. This TM satisfies the requirements of Task 6.3 in the CWRP Scope of Work.

Section 2 Lake Casitas Yield Model

Lake Casitas is the primary source of water available to Casitas Municipal Water District (Casitas). Hence an estimate of the yield available from this source is critical to water resources decision-making by the Casitas staff and Board. A previously developed simulation model to estimate the safe yield of Lake Casitas was provided to Stantec as part of CWRP project, with the understanding it would be updated and improved to reflect current and potential future conditions and incorporate hydrologic uncertainty. This section describes the Lake Casitas Yield Model and the improvements made to it under the CWRP project.

2.1 Original Lake Casitas Yield Model

Casitas provided the Stantec consulting team with an Excel-based simulation model of Lake Casitas developed by staff in the early 2000s. The model consisted of several related files containing data and calculations. It is documented in the 2004 Water Supply and Use Status Report (CMWD 2004). The details of this previous documentation, which are also contained in an appendix to the current Casitas Municipal Water District Urban Water Management Plan (CWMD 2016), are not repeated here.

The original Lake Casitas Yield Model is a mass-balance model that tracks Lake inflows, outflows (including evaporation) and change in storage to simulate operations over historical hydrology conditions. Highlights of the model configuration and capabilities include:

Period of record in model provided by Casitas: 1945-1965; Period of record for most data supporting the model: 1945-1999.

- Surface inflows include streams that are directly tributary to the Lake and diversions from the Ventura River at the Robles Diversion Structure.
- Outflows include net evaporation (evaporation minus precipitation) and withdrawals to meet Casitas demands.
- Monthly simulation of reservoir operations using a maximum Lake capacity of 254,000 acre-feet (AF). Lake water surface area or elevation were not calculated in the model.
- Daily tracking of Ventura River extraction and accretion, and Robles Diversion Structure inflows.
- Monthly tracking of tributary inflows and Lake evaporation based on historical data.

- Identification of critical historical drought period (WY1945-WY1965).
- Robles Diversion simulated based on 1959 Operating Criteria and the Robles Biological Opinion (BO) in effect at the time.
- Comparison of Lake inflows while operating under the 1959 Operating Criteria, Biological Opinion, and Keinlen D20 Study Criteria (CMWD, 2004).

2.2 Lake Casitas Yield Model Improvements

In the course of updating the Lake Casitas Yield Model for use in the CWRP, several significant improvements were made to the model. These are described in this section.

2.2.1 Extension of Period of Record

The model period of record was extended to include all available years of historical hydrologic data at the time the CWRP was started. The full updated model period extends from 1944 to 2018 and includes the 1945 – 1965 data provided in the original model. The extension process consisted of updating model input data for historical direct tributary inflows to the Lake, Robles Diversion inflows, evaporation and precipitation, and Lake storage volumes for the period 1966-2018.

- Historical direct tributary inflows from 1966 - 2018 were provided by Casitas. These inflows were given as back-calculated values from historical water inventory data for Lake Casitas.
- Robles Diversion inflows were extended using historical hydrological information from USGS stream gages along tributaries to the Ventura River.
- Extraction and Accretion values within the Ventura River between streamgage locations and the Robles Diversion Structure were extended using a multiplier that varied by calendar month. This method was provided in the original model and outlined in the 2004 Water Supply and Use Status Report (CMWD 2004).
- Net evaporation values were extended using historical water inventory data provided by Casitas.

The original model used historical net evaporation volumes for each month of the reservoir simulation calculations. In the updated model this was changed so reservoir evaporation in each month is calculated dynamically based on the known (historical) net evaporation rate in feet in that month and the computed reservoir surface area as determined during the simulation for that month.

2.2.2 New Bathymetric Survey

A new bathymetric survey of Lake Casitas was performed in 2017. The updated data for lake volume, water surface elevation and water surface area were incorporated into the elevation-area-capacity table in the Lake Casitas Yield Model. The new survey resulted in a reduction in maximum Lake capacity from 254,000 acre-feet (AF) to 237,761 AF, which in turn resulted in a decrease in estimated yield from the Lake for the same hydrology and operating conditions.

2.2.3 Spillway Calculation

The original model only included the drought period of 1945 – 1965 in which lake volumes never reached the maximum capacity of 254,000 AF and lake levels were not above the elevation of the spillway crest. Throughout the extended period of record there were multiple periods of recovery when the lake levels would exceed the elevation of the spillway.

In order to refine the simulation of Lake operations during periods of high inflow when the Lake is full, a computation of spillway overflow based on historical records and the configuration of the spillway structure was added to the model. The new bathymetric survey of 2017 did not include elevation, area and capacity data above the spillway crest. In order to model high inflow when the lake is full and apply the derived spillway equation, the elevation-area-capacity (EAC) table from the new bathymetric survey was extended. Fitting a curve to the EAC table allowed Lake surface area and capacity values to be extrapolated beyond the elevation of the spillway crest.

Historical spillway flows were plotted against the height of flow over the spillway crest (H). A good-fit equation for the data was developed using an exponent of 1.5 on the height parameter H to be consistent with the form of the ogee crest spillway flow equation - $Q=CLH^{3/2}$. The resulting equation derived for flow over the Lake Casitas spillway is $Q=281*H^{3/2}$.

A monthly spill volume in AF was needed for the monthly Lake simulation performed by the Yield Model. Using the spillway outflow rate calculated based on the beginning-of-month height of the reservoir level over the spillway crest would overestimate the spillway outflow because absent new inflows the Lake level will fall and the spillway outflow will decline during the month. An adjustment was needed as a substitute for doing a daily diminishing head analysis since the Yield Model operates on only a monthly time step. Empirically it was found that multiplying the instantaneous flow rate corresponding to the Lake level at the beginning of the month by 10 provided good agreement with running a daily diminishing head simulation throughout the month. This compares to a conversion factor of 55 to convert cfs to a monthly flow volume. The resulting equation used in the updated model for monthly flow over the Lake Casitas spillway in months when the lake water surface elevation exceeds the spillway elevation is $\text{Volume} = 10 * 281 * H^{3/2}$.

2.2.4 Robles Diversion Operation

The Robles Diversion Structure diverts water from the Ventura River into the Robles Diversion Canal, which conveys the diverted water to Lake Casitas. The diversion system has a nominal capacity of 500 cfs. Environmental considerations and physical operating conditions govern operation of the diversion structure under different hydrologic situations. The Biological Opinion (BO) adopted in 2004 modified previous requirements for passage of flows for fish habitat. This was further modified during the recent drought to allow increased diversions to the Lake when storage levels in the Lake are low.

As part of the model upgrade, the functions used to simulate operation of the Robles Diversion Structure were modified to reflect the current operating rules. The operation of the diversion structure in the model followed the 2004 BO as follows.

- The Extraction and Accretion values are applied to historical hydrology based off the method outlined within the 2004 Water Supply and Use Status Report. This resulting flow rate is categorized as 'Available to Divert' at the Robles Diversion Structure.
- Within the Migration Period (Jan. 1st to June 30th) outlined in the BO, available flows above 30 cfs up to 500 cfs are diverted down the Robles Canal. Flows equal to and below 30 cfs bypass the diversion structure and are sent downstream.
- Outside of the migration period (July 1st to Dec. 31st), available flows over 20 cfs up to 500 cfs are diverted down the Robles Canal.
- Storm events within the Migration Period are categorized within the BO as available flows above 149 cfs, Following the peak storm event, flows above the thresholds as outlined in the applicable primary 12-day and secondary 10-day fish passage tables in the BO, up to 500 cfs, are diverted down the Robles Canal.

In addition to simulating the regulatory factors affecting operation of the diversion structure, the diversion efficiency based on physical and operational factors was added as model input. The original model did not account for the fact that actual historical diversions were generally less than the theoretical or legal diversion amounts allowed under the adopted operating rules. The relationship between theoretical and actual historical diversions was investigated by plotting the actual daily diversions against the theoretical diversion calculated based on the adopted operating rules. This data was plotted for two periods of record: 2004-2018 when the current BO governed operation of the structure, and 2017-2018 when Lake Casitas storage was low. Results are shown in **Figure 2-1** and **Figure 2-2**.

The figures show that on most days the actual recorded diversion is less than what the model would have predicted based on the legal operating rules. The difference could be attributed to clogging of the diversion structure with debris, poor water quality making it inadvisable to divert to the Lake, or other physical or administrative factors affecting operation of the structure. For the 2004-2018 period, the ratio of total historical to total modeled flows is 0.66. For the 2017-2018 period that ratio is 0.73. To accommodate the uncertainty in this important factor, the updated Lake Casitas Yield model allows the user to set this parameter for each simulation. Based on discussion with Casitas staff, a value of 0.70 (70%) was adopted for the Robles diversion efficiency factor when simulating typical operating conditions with the current diversion structure facility.

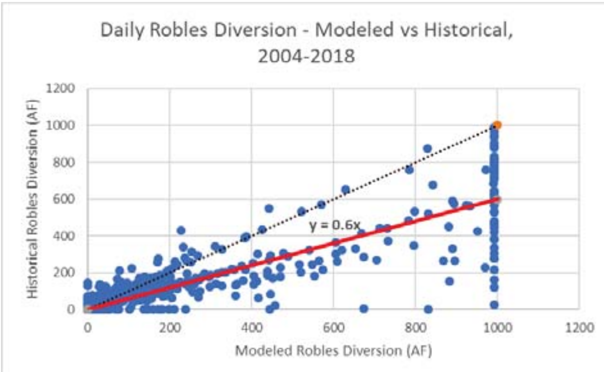

Figure 2-2 Daily Robles Diversion - Modeled vs Historical, 2004-2018

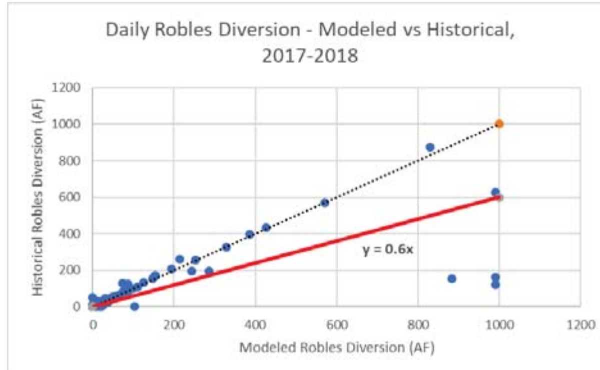

Figure 2-1 Daily Robles Diversion - Modeled vs Historical, 2017-2018

2.2.5 Minimum Allowable Storage

In previous applications of the Lake Casitas Yield Model, the safe yield was determined by finding the largest demand that could be met from the Lake based on drawing the lake level down to the dead pool elevation. The storage at this elevation is 950 AF, and represents the amount of water that cannot be released from the Lake using the normal outlet works. This would leave no buffer for emergencies or for droughts more severe than the drought in the historical record. In practice the Casitas managers would not want to draw the Lake down to the dead pool level, but would want to reserve water in storage for conditions outside the range used for prudent planning (e.g., more severe droughts, equipment failures). In addition, water quality is poor at very low lake levels and Casitas may not be able to treat water with its current water treatment facilities when water is pulled from the Lake when storage is very low. The amount of emergency storage appropriate for Casitas is a policy decision, as discussed below.

To accommodate this planning strategy, the updated Lake Casitas Yield Model allows the user to set a minimum allowable storage level to be used in safe yield simulations. Making this value a variable allows Casitas to test different minimum allowable storage levels and their impact on reservoir performance.

2.2.6 Effect of Model Upgrades

Figure 2-3 shows the effects on Lake Casitas safe yield estimates of the Yield Model improvements described above. Updating the elevation-area-capacity data, adding minimum allowable storage, incorporating the Robles Diversion Structure BO rules, and adjusting modeled Robles diversions for historical experience progressively reduced the Lake Casitas safe yield estimates. Overall these model changes resulted in a 17% reduction in the safe yield estimate for the historical hydrologic period. [Note: the version of the model used for the preliminary analyses described above was updated later in the study, giving slightly different results.]

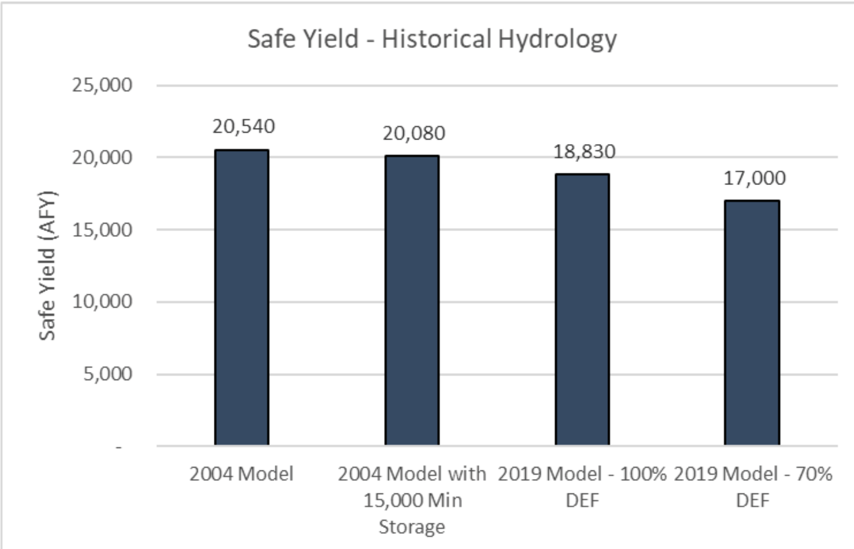

Figure 2-3 Effects of Model Improvements on Safe Yield Estimates

2.2.7 Water Efficiency and Allocation Program and the "Safe Demand" Concept

The original Lake Casitas Yield Model determined the safe yield for the Lake by allowing the user to iterate on the estimated annual demand on the Lake until the largest demand without drawing the Lake below the dead pool level was determined. This annual demand was distributed monthly based on percentages of total annual demands determined from historical water use data. The monthly percentages were applied in every year of the simulation. This approach does not account for the inherent variability in annual demand as a function of weather, economics, and other factors, but more importantly does not account for the impact of water conservation measures implemented by Casitas during years of drought. The updated Lake Casitas Yield Model incorporated changes to address the second factor but not the first. Future updates could link water demand to weather conditions (hot/dry, normal, cool/wet) as a further model refinement.

For the CWRP, the Lake Casitas Yield Model was updated to incorporate the effects of Casitas' policies for implementing demand management practices during periods of low Lake levels. The Casitas Water Efficiency and Allocation Program (WEAP) policy provides information to the Casitas Board in setting water use reduction goals during droughts and other water shortage periods. The policy is summarized in Table 6 in the WEAP report. It sets water allocations for Casitas customers based on usage records from 1989, and provides guidance for reducing water allocations based on Lake Casitas storage volumes. The policy was designed to use demand management as a strategy for managing through critical shortage periods, and assures that supplies are available to meet reduced demands throughout the critical period in the historical period of record (1945-2018).

Key values of Lake Casitas storage levels and demand thresholds incorporated in the current WEAP policy are summarized in **Table 2-1**, as defined in Table 6 in the WEAP report. In simplified form, the WEAP sets water reduction goals based on a starting water demand that is reduced by 20 percent from the 1989 system-wide water demand. Different water use categories were treated differently, but the overall effect was a reduction of about 20 percent. With this assumed system-wide demand (19,127 AFY), the demand reductions at different lake levels as described in WEAP Table 6 are capable of managing supply and demand through the historical critical period.

Table 2-1 WEAP Demand Reduction Targets

	Reservoir % Full		Reservoir Storage (AF)		Water Use Reduction Response Goal as a Percent of Current Water Allocation (Table 6) (1)	Water Demand Target Value Based on Percent Reduction from "80% of 1989" Water Allocation (AFY)
Stage Title	Minimum	Maximum	Minimum	Maximum		
Stage 1 - Water Conservation	50	100	118,881	237,761	100% (80% voluntary reduction) (2)	19,127
Stage 2 - Water Shortage Warning	40	50	95,104	118,881	80%	15,302
Stage 3 - Water Shortage Imminent	30	40	71,328	95,104	70%	13,389
Stage 4 - Severe Water Shortage	25	30	59,440	71,328	60%	11,476
Stage 5 - Critical Water Shortage	0	25	-	59,440	50%	9,564

(1) Values based on information from Table 6 in CMWD, 2018.
(2) 100% water use reduction goal was used in the model.

The WEAP policy provides guidance to the Board; it does not establish fixed operating rules. When simulating the impact of the WEAP policy, it was assumed that water customers would actually reduce their demands consistent with the targets in the policy. That is, if Lake Casitas storage was in the Stage 2 range at the beginning of a year in the simulation, a demand of 15,302 AFY was simulated for that year. In the recent drought in Southern California, Casitas' customers demonstrated the ability to meet or exceed the WEAP demand reduction targets. Some of the landscape changes and customer behavior changes made in response to the drought will be permanent and have lasting effects on reducing customer demand. In turn, achieving similar levels of demand reduction during future droughts may be more difficult because the "easy" savings have already been built into the system. Despite this difficulty, Casitas' staff felt comfortable in assuming for water supply planning purposes that the levels of demand reduction outlined in the current WEAP policy will be achievable in the future.

The Lake Casitas Yield Model used for the CWRP includes a toggle that allows the user to simulate safe yield in the traditional sense (constant demand for all periods of simulation) or what for this study is termed "safe demand", which includes demand reductions in accordance with the WEAP policy as described above. For Casitas' future water supply planning, the safe demand concept is more applicable because it is consistent with the WEAP policy adopted by the Board and with the behavior of Casitas' customers during the recent drought.

Section 3 Simulation of Net Evaporation

Evaporation loss is an important part of the water budget for Lake Casitas. The Casitas Water Resources Committee has asked several questions regarding how evaporation is accounted for in the Lake Casitas Yield Model. This section describes that process. More detail on evaporation data and modeling is provided in CWMD (2004).

As noted previously, the Yield Model simulates monthly operations of Lake Casitas. Evaporation losses are accounted for in a net evaporation term (evaporation – precipitation) that is estimated for each month of the 1945-2018 simulation period. When possible, historical evaporation and precipitation data for the years in the simulation period was used. Evaporation was based on the average of pan evaporation measurements for two evaporation pans at Lake Casitas, adjusted by a pan evaporation coefficient for each calendar month provided by the U.S. Bureau of Reclamation. Precipitation was based on the average of recorded rainfall at two rain gauges at Lake Casitas. When historical data was not available for evaporation precipitation, monthly averages for the period of record were used. The average annual evaporation rate for Lake Casitas is about 42 inches per year. It can vary substantially from year to year; for example, in 2018 the evaporation rate was 45.7 inches. The typical monthly distribution of annual evaporation is shown in **Table 3-1**.

Table 3-1 Distribution of Annual Evaporation by Month

Month	Fraction of Annual Evaporation
October	0.0712
November	0.0607
December	0.0609
January	0.0669
February	0.0450
March	0.0641
April	0.0759
May	0.0955
June	0.1099
July	0.1320
August	0.1204
September	0.0975
Total	**1.0**

The net evaporation rate in inches for each month in the 1945-2018 simulation period was calculated as evaporation minus precipitation for that month. This resulted in a unique net evaporation rate for each month in the simulation period. In some months rainfall exceeded the evaporation loss; in those cases the value of the net evaporation parameter in the Yield Model was negative.

The net evaporation loss in acre-feet from reservoir storage was calculated in the model for each month of the simulation by multiplying the net evaporation rate in feet by the reservoir surface area in acres. The surface area is a function of reservoir storage and lake level. As the reservoir level increases or decreases over time, the evaporation loss in volume reflects this change. For the same monthly net evaporation rate, reservoir losses are higher at higher storage levels and lower at lower storage levels because of the difference in reservoir surface area. This effect is shown conceptually in **Figure 3-1**.

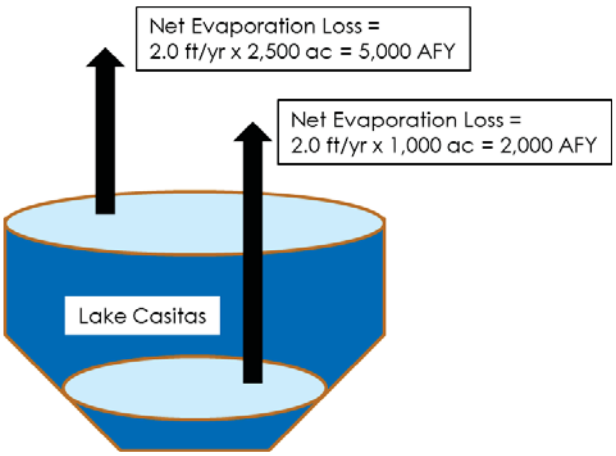

Figure 3-1 Effect of Reservoir Surface Area on Calculated Monthly Net Evaporation Loss

This effect is shown in the chart in **Figure 3-2**, which shows the primary reservoir inflows (tributary inflow and Robles Diversion inflow) and reservoir outflows (net evaporation and withdrawals to meet demands) for the 10 year simulation period from 1945-1954. It is evident that as the reservoir storage volume declines (and the reservoir surface area shrinks), the evaporation loss in acre-feet also tends to decline.

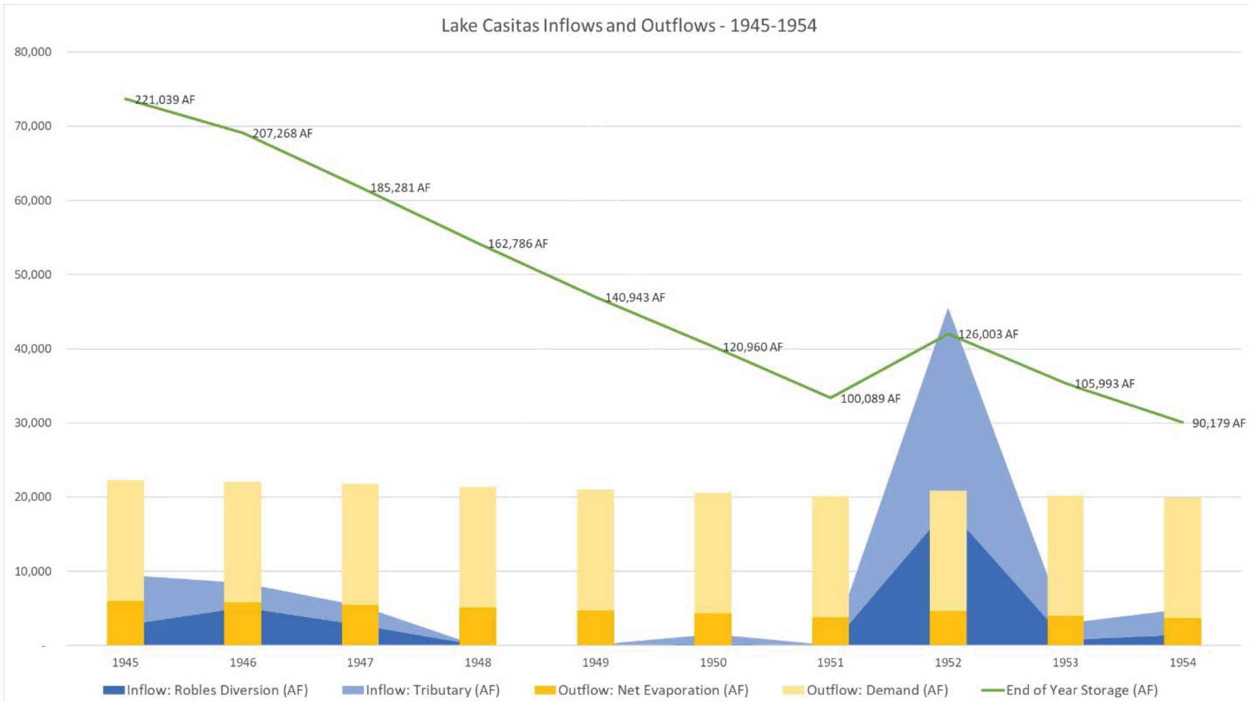

Figure 3-2 Sample Modeled Lake Casitas Inflows and Outflows, 1945-1954 Historical Hydrology

Section 4 Minimum Allowable Storage and Robles Diversion Sensitivity Analysis

Key modeling assumptions affecting safe yield and safe demand analyses include the minimum allowable storage in Lake Casitas and the effectiveness of the Robles Diversion Structure. The sensitivity of model results to those input parameters are described in this section.

As described previously, the minimum allowable storage is a policy decision based on the amount of emergency storage desired in Lake Casitas. As such the selection of the minimum allowable storage is affected by the Casitas Board's risk tolerance. A higher minimum allowable storage reduces the risk of impacts from unforeseen events, but reduces the amount of working storage to meet demands under normal conditions and thus results in a lower safe yield. Similarly, a lower minimum allowable storage increases the risk of impacts from unforeseen events but results in higher safe yield for normal operations. To test the sensitivity of Lake Casitas simulated yield to the minimum storage level, yield analyses were performed for minimum allowable storage values varying from 15,000 AF to 100,000 AF.

The Robles Diversion Structure is a critical facility in determining the Lake Casitas yield, since it controls the amount of water diverted into the Lake from the Ventura River. As described previously the amount of water diverted on a daily basis is governed by both physical and regulatory constraints. To account for the uncertainty in actual vs theoretical operations, the yield model has a parameter that allows the user to set the Robles diversion efficiency factor. An efficiency factor of 0.70 was adopted for all simulations of base conditions with the existing facility. To test the sensitivity of the Lake Casitas simulated yield to the Robles diversion efficiency factors, yield analyses were performed for efficiency factors varying from 0.6 to 1.0. All simulations were performed using historical hydrology and the full model period from 1945-2018.

The sensitivity analyses of minimum allowable storage and Robles diversion efficiency were combined into sets of yield model runs in which both parameters were varied over the stated ranges. The sensitivity analysis was performed for safe yield and safe demand assumptions. Results are shown in **Figures 4.1 – 4.3** and **Table 4-1** and **Table 4-2**.

The minimum allowable storage level has a substantial effect on safe yield and safe demand over the range of 15,000 AF to 100,000 AF. This is a large range, representing 6% to 42% of total available capacity. The safe yield varies by an average of 5,370 AFY over this range, and the safe demand varies by an average of 13,260 AFY over this range. The results are less sensitive to the Robles diversion efficiency factor. Over the range of 0.6 to 1.0 the safe yield varies by an average of 1,920 AFY and the safe demand varies by an average of 2,340 AFY.

Based on these results the Casitas staff felt comfortable with setting the Robles diversion efficiency factor at 0.70. The minimum allowable storage level was presented to the Board as a policy decision.

[Note: the model results described in this section are based on a previous version of the Yield Model which was changed slightly later in the study. The conclusions of this section are still valid.]

Table 4-1 Safe Yield Sensitivity Analysis of Minimum Allowable Storage and Robles Diversion Efficiency Factor

Lake Casitas Safe Yield (AFY)					
Minimum Allowable Storage (AF)	Robes Diversion Efficiency Factor				
	100%	90%	80%	70%	60%
15,000	18,830	18,230	17,625	17,000	16,400
30,000	17,875	17,260	16,660	16,050	15,450
50,000	16,620	16,010	15,400	14,800	14,175
75,000	15,075	14,460	13,850	13,250	12,650
100,000	13,050	12,700	12,350	11,750	11,140

Table 4-2 Safe Demand Sensitivity Analysis of Minimum Allowable Storage and Robles Diversion Efficiency Factor

Lake Casitas Safe Demand (AFY) – WEAP Policy Operation					
Minimum Allowable Storage (AF)	Robles Diversion Efficiency Factor				
	100%	90%	80%	70%	60%
15,000	27,150	26,325	25,500	24,775	24,025
30,000	24,650	23,910	23,160	22,450	21,700
50,000	21,015	20,600	20,225	19,650	18,425
75,000	16,300	15,900	15,325	14,550	13,810
100,000	13,250	12,875	12,530	12,050	11,400

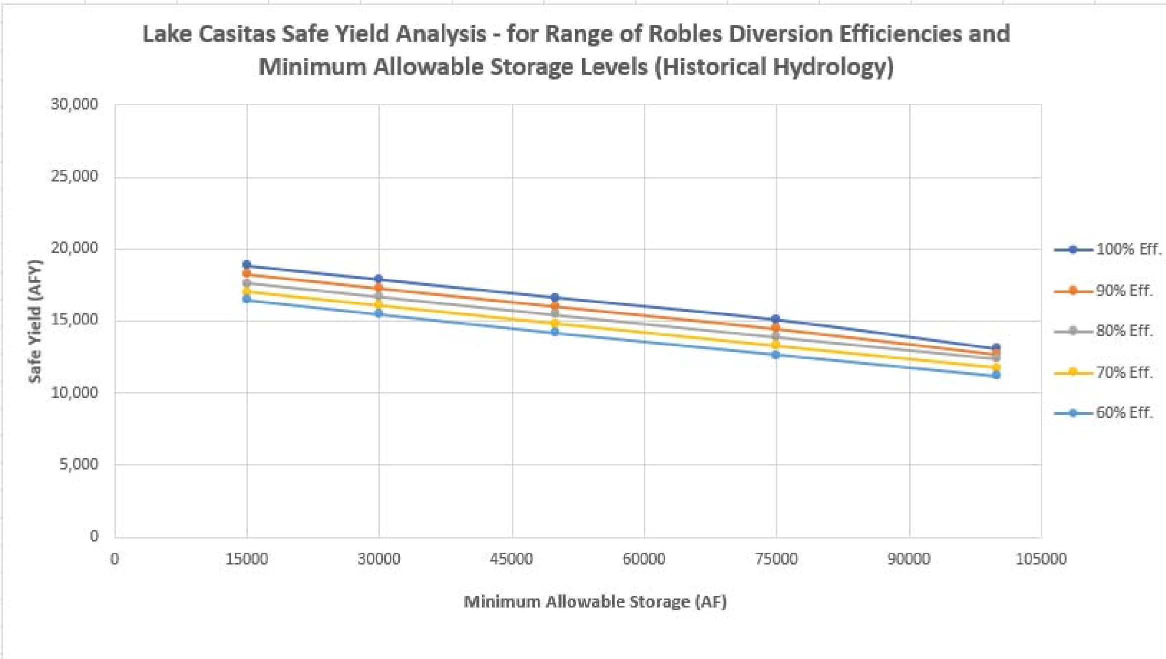

Figure 4-1 Lake Casitas Safe Yield for Range of Minimum Allowable Storage and Robles Diversion Efficiency

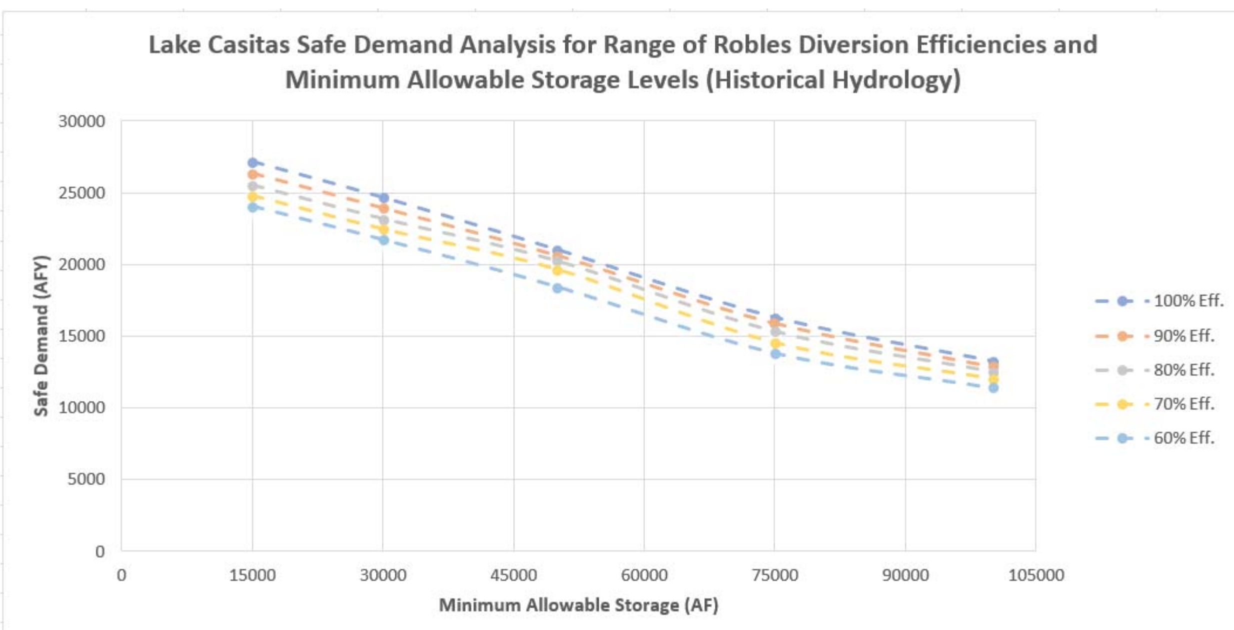

Figure 4-2 Lake Casitas Safe Demand for Range of Minimum Allowable Storage and Robles Diversion Efficiency

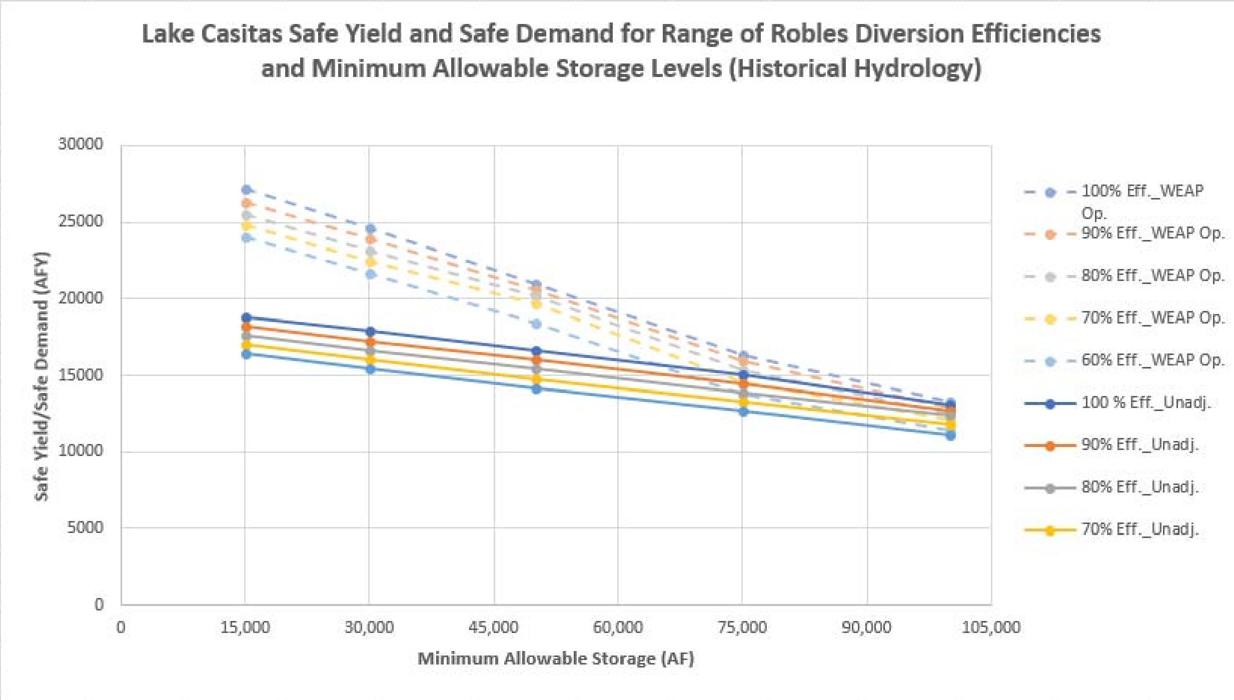

Figure 4-3 Lake Casitas Safe Yield and Safe Demand for Range of Minimum Allowable Storage and Robles Diversion Efficiency

Section 5 Analysis of Hydrologic Uncertainty

The previous Lake Casitas yield analyses – both those conducted with the original model and those performed with the new model as described in the foregoing sections – all used historical hydrology in the simulations. That includes historical data for direct inflows to Lake Casitas, flows in the Ventura River on which diversions at the Robles Diversion Structure were based, and net evaporation from the Lake. This type of analysis assumes historical hydrology will recur in the future in exactly the same sequence and magnitude. In fact, the one thing known about future hydrology is that it will not occur in the same sequence and magnitude as the historical record. Natural variability in climate, shifts in climate drivers such as ocean temperatures, and other factors all are responsible for affecting future hydrologic conditions.

Hydrologic variability is being addressed in long-range water supply plans being conducted by water utilities throughout the nation. For this study, hydrologic variability was incorporated into the Lake Casitas water supply analysis in two ways:

1. Natural variability was incorporated by generating 100 sequences of hydrologic model inputs with the same basic statistics as the historical record. Simulations based on selected sequences from this dataset were used to develop a probabilistic approach to estimating Lake Casitas yield.

2. Potential effects of climate change on temperature and precipitation were incorporated by reviewing published climate change studies and adjusting yield estimates to reflect likely future climate conditions.

Each of these modifications to Lake Casitas Yield Model inputs are described below.

5.1 Resequencing of Historical Hydrology

Natural hydrologic variability was incorporated into the Lake Casitas yield analysis by generating 100 hydrologic datasets (traces) derived from the historical dataset and having the same basic statistics (e.g., standard deviation and serial correlation of annual streamflows) as the historical record. This was accomplished in the following steps.

1. Resequencing was based on Ventura River streamflows upstream of the Robles Diversion Structure from the yield model. This was considered a more reliable dataset than the direct tributary inflows to the Lake, as aggregated model input data for the tributary inflow node was estimated by Casitas from 1983 to present. Annual streamflow volumes for the Ventura River upstream of the Robles Diversion Structure for the model period of record (1944-2018) were extracted from the Yield Model for use in the resequencing analysis.

2. Ventura River annual streamflows were input to a k-nearest neighbor (KNN) software routine to generate 100 similar sequences of annual Ventura River streamflows. In a KNN routine, a historical year is randomly selected as the first year in the new sequence. Using that first year's associated annual flow, remaining annual flows are ranked and weighted based on how close they are to the selected first year's annual flow. To determine the second year of the new KNN sequence, one of these weighted historical annual flows and its corresponding historical year is selected. This is akin to selecting one ping pong ball from a jar of ping pong balls, in which the number of balls representing a given year is based on the nearness of the annual flow in that year to the annual flow in the first year. The second year in the KNN sequence is then chosen to be the year after the selected historical year. This generates new streamflow sequences that reflect the persistence in the historical record (i.e., probability of a wet year following a wet year or a dry year following a dry year). The synthetic streamflow sequences generated by the KNN approach contain substantial variability, as shown in **Figure 5-1**.

3. The KNN methodology produced many hydrologic sequences with longer and deeper droughts than the critical drought in the historical period. Because the historical critical drought was 21 years long (1945-1965), the synthetic streamflow records were analyzed for 5-year, 10-year and 20-year moving average annual streamflow to assess their severity relative to the historical record. **Figure 5-2** shows a range of statistics for the synthetic hydrologic traces, and demonstrates the large number of traces with longer, deeper droughts than the historical critical period.

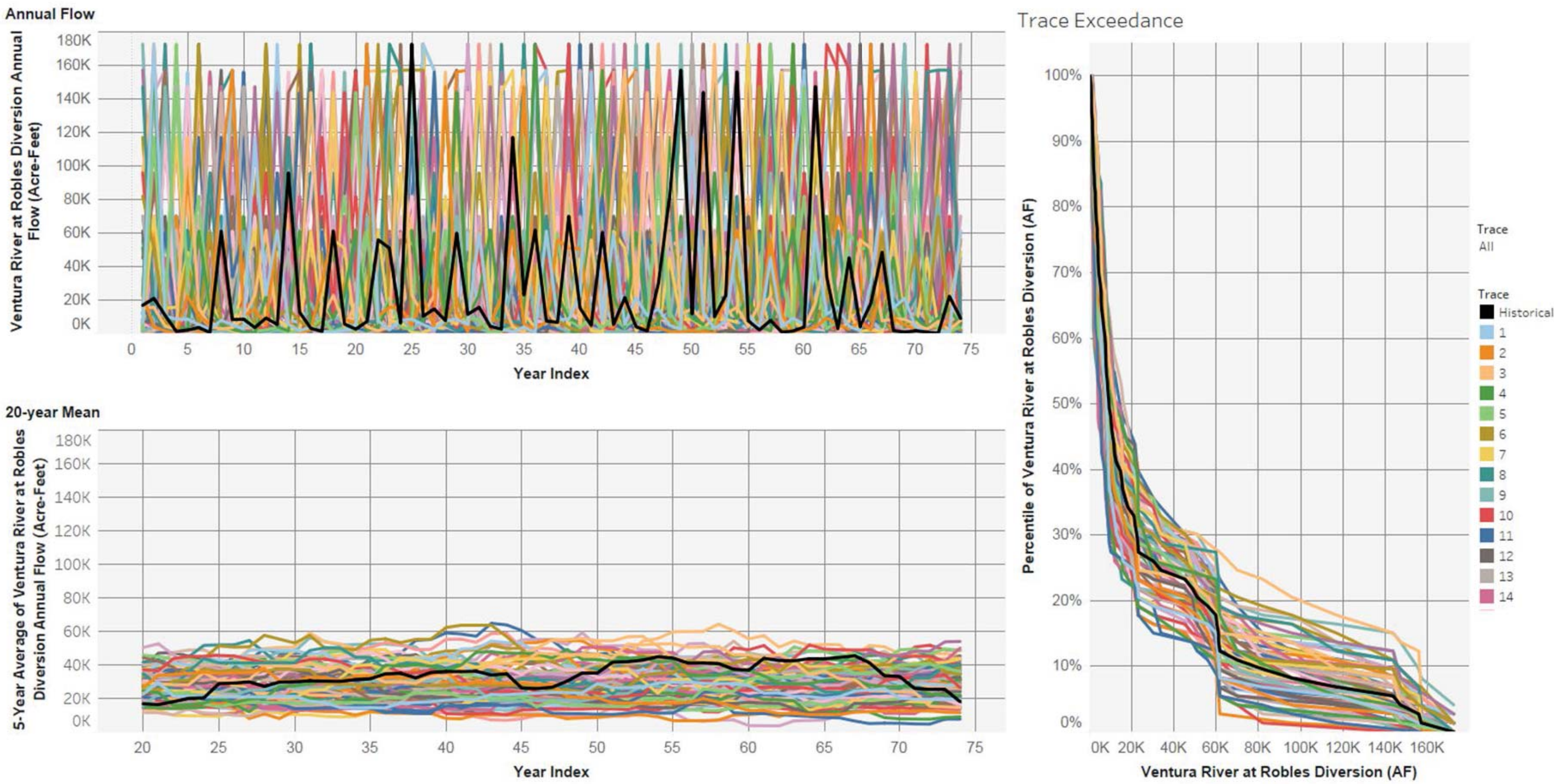

Figure 5-1 100 Hydrologic Traces for Ventura River Upstream of Robles Diversion

Note: Each color is a different hydrologic trace. The black trace is historical hydrology.

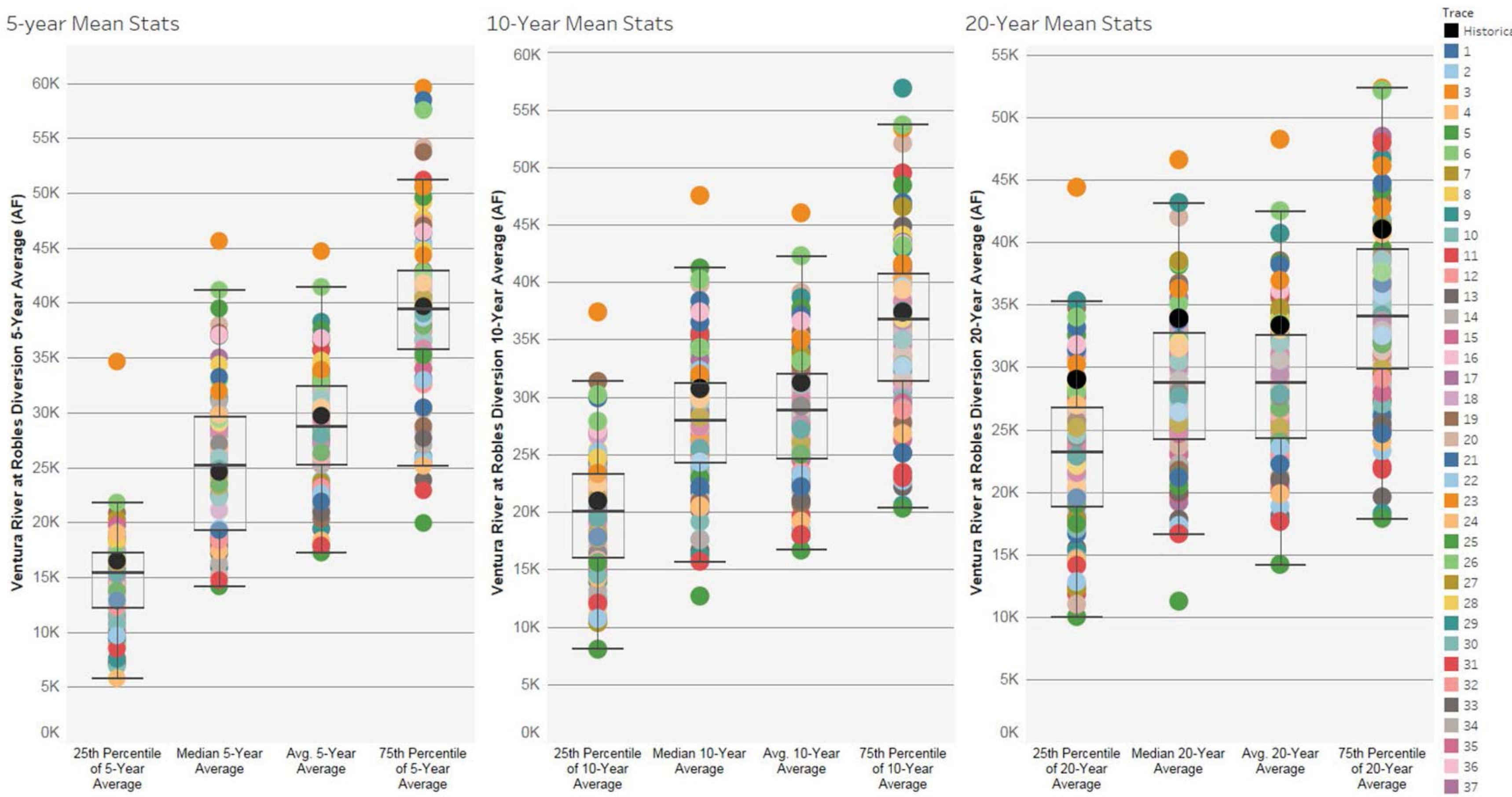

Figure 5-2 5-year, 10-year, and 20-year Moving Average Statistics for Ventura River Synthetic Streamflows

Note: Each colored dot represents one of the 100 synthetic streamflow records. The black dot is the historical record.

4. For each of the 100 resequenced Ventura River historical annual streamflows, the corresponding historical year was used as an index to resequence the other two Lake Casitas Yield Model inputs dependent on climate – the direct Lake inflows and Lake net evaporation. For example, in trace 1 the annual Ventura River streamflow selected for the first year in the sequence was the 1982 annual flow. To generate the other model inputs, the annual direct Lake inflow was taken from 1982 and annual net evaporation was taken from 1982. In this way the historical correlation between all the hydrologic inputs was preserved.

5. The Lake Casitas Yield Model simulates Lake operations on a monthly basis. To generate the monthly input for each synthetic sequence, the monthly data for the corresponding year in the resequencing process was taken from the historical database. For the example used in the previous step, the yield model input for the first year in the simulation of trace 1 was populated with the historical monthly streamflows from 1982 for the direct Lake inflow and net evaporation. Similarly, the historical daily Ventura River flows from 1982 were used to calculate the Robles diversion volumes for the first year in trace 1.

6. Because the safe yield and safe demand analyses involved iteration, selected traces from the set of 100 were used to test the process of performing the reliability analysis. The selected traces represented the full range of long-term average streamflow statistics shown in **Figure 4-2**. Twelve traces were selected, plus the historical record, for use in the yield reliability analysis. The moving average statistics for the 13 traces are shown in **Figure 5-3**.

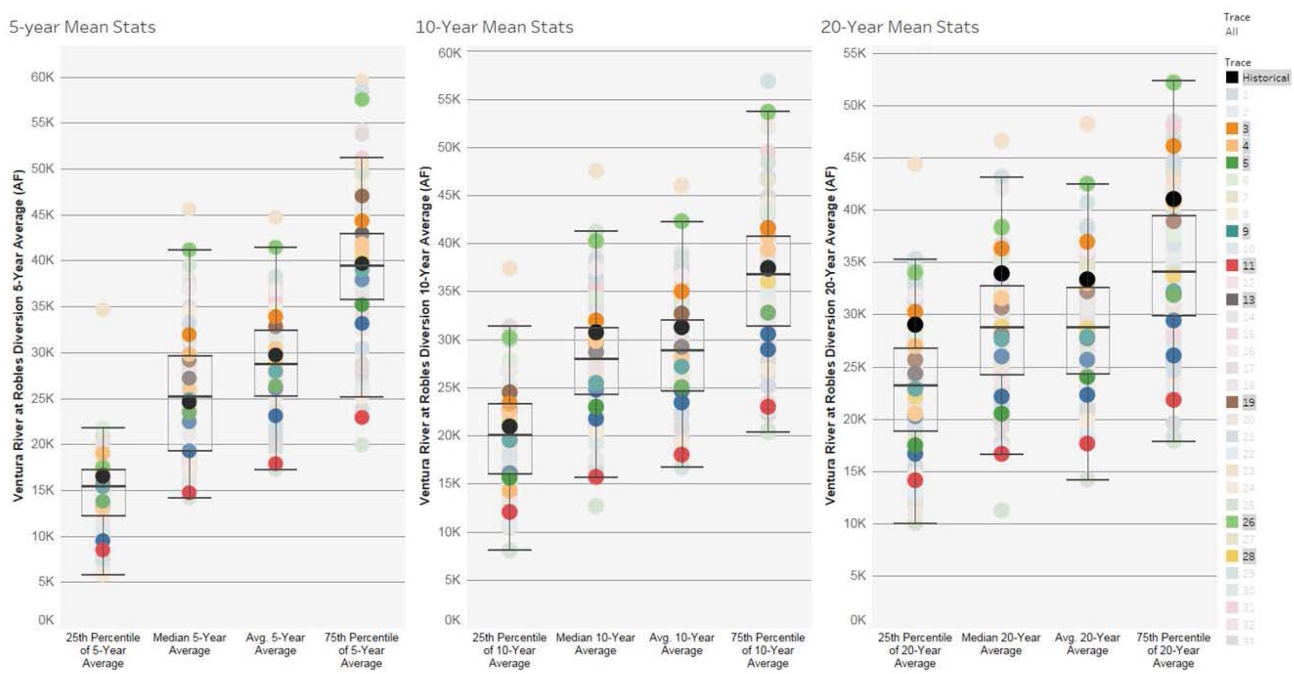

Figure 5-3 Moving Average Statistics for Traces Selected for Yield Reliability Analysis

5.2 Yield Reliability Analysis

The 100 resequenced hydrologic traces plus the historical hydrologic record were simulated in the Lake Casitas Yield Model to determine the corresponding safe yield and safe demand for each trace. Simulations used a minimum allowable storage of 20,000 AF and a Robles diversion efficiency factor of 0.70. The exceedance probability of each safe yield and safe demand result were computed and the results were plotted as shown in **Figure 5-4**. Polynomial equations were fitted to the probability distribution to estimate safe yields and safe demands for a range of exceedance probabilities.

Because the extreme tails of the distributions differed significantly from the bulk of the data, a sensitivity analysis was performed by excluding the upper and lower 10% of traces from the analysis and the results were replotted. The truncated safe yield and safe demand exceedance probability curves are shown in **Figure 5-5** and **Figure 5-6**. **Table 5-1** summarizes the safe yield and safe demand reliability results for the two datasets. Using the middle 80% of the traces provides a better polynomial fit to the data. However, because the primary interest of the CWRP is in the reliability of Lake Casitas yield during extreme dry periods (i.e., 90%-99% exceedance probability range), the analysis based on the full 100 traces was adopted for this study.

Table 5-1 Lake Casitas Safe Yield and Safe Demand Reliability Results

Exceedance Probability	Safe Yield – 100 Sequences (AFY)	Safe Yield – 80 Sequences (AFY)	Safe Demand – 100 Sequences (AFY	Safe Demand – 80 Sequences (AFY
0.10	19,265	18,409	26,115	24,714
0.25	18,015	17,232	24,512	23,535
0.50	15,498	15,270	20,851	20,878
0.75	12,440	13,308	15,952	17,359
0.90	10,346	12,130	12,419	14,833
0.95	9,605	11,738	11,142	13,922
0.99	8,996	11,424	10,085	13,168

Note: Simulations are based on 20,000 AF minimum allowable storage, 0.70 Robles diversion efficiency factor, and no climate change adjustment

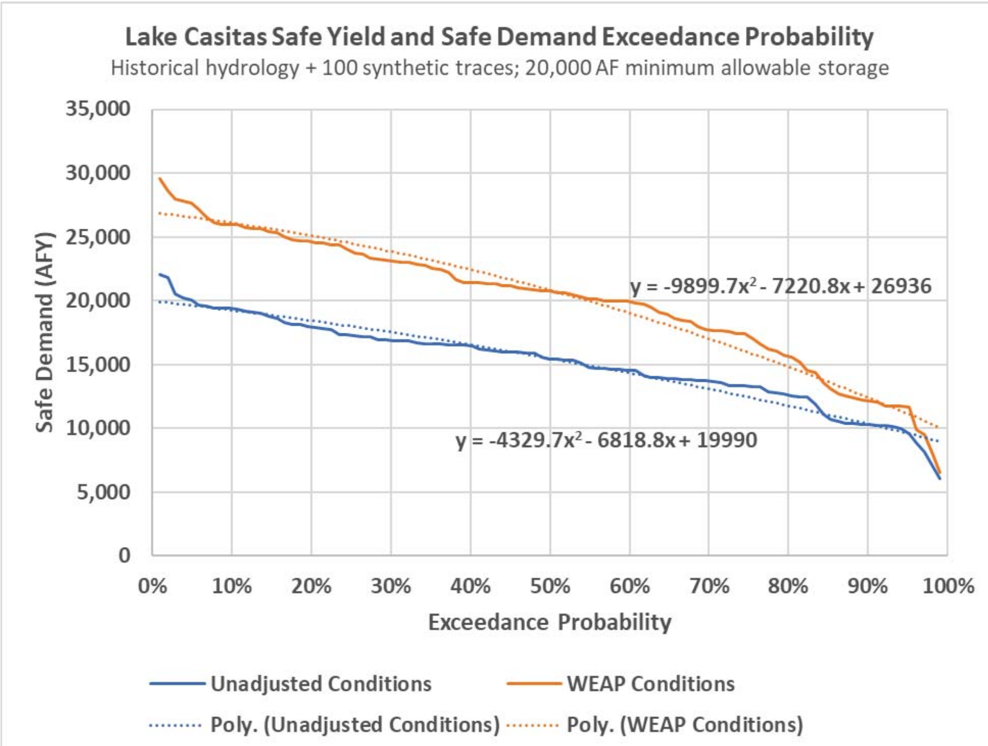

Figure 5-4 Safe Yield and Safe Demand Probability Based on 100 Synthetic Hydrologic Sequences

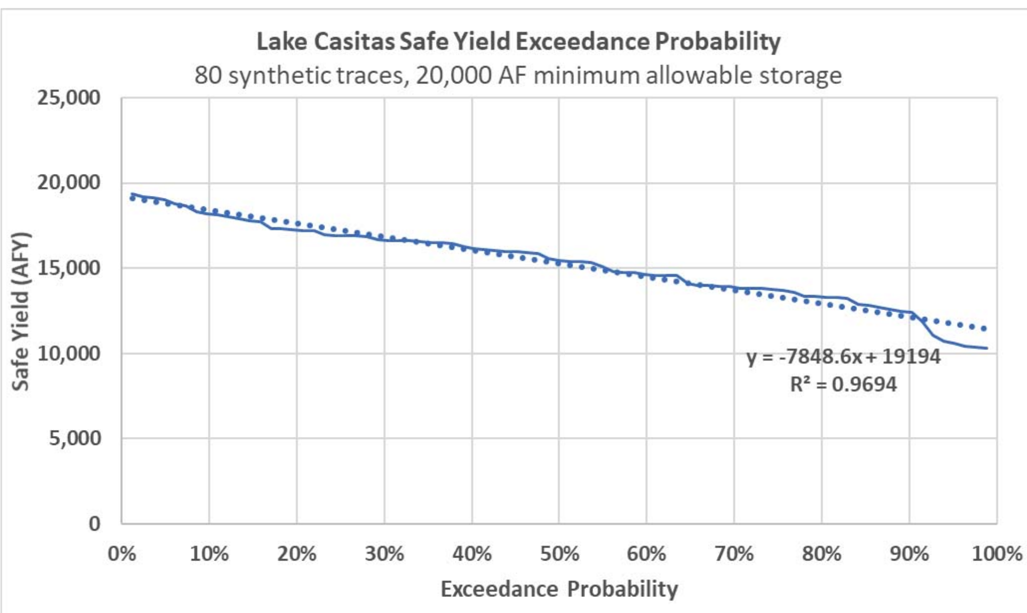

Figure 5-5 Safe Yield Probability Based on 80 Synthetic Hydrologic Sequences

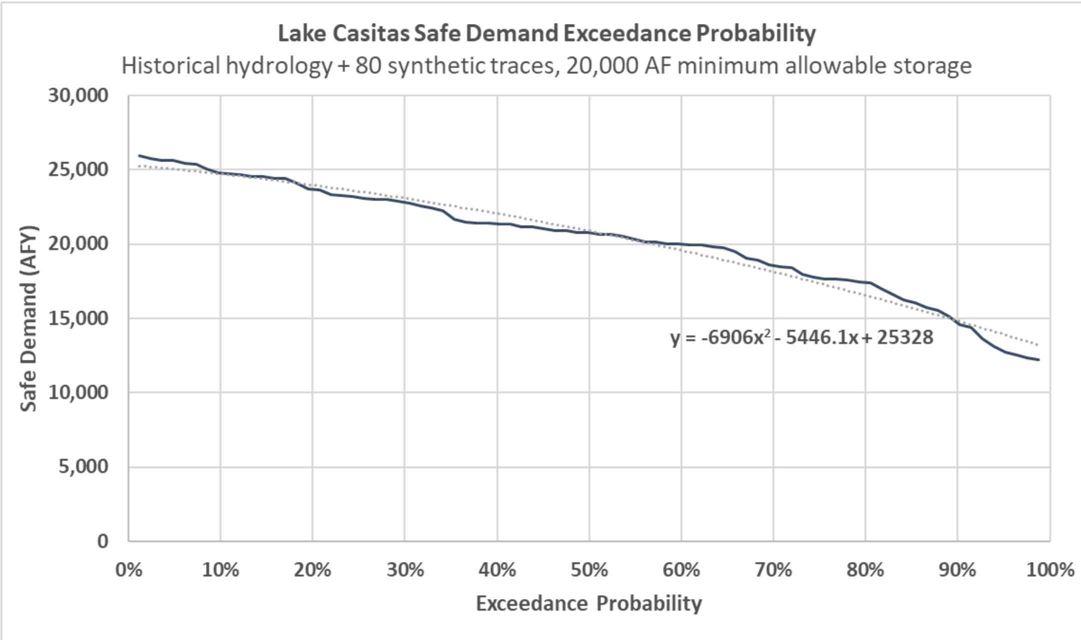

Figure 5-6 Safe Demand Probability Based on 80 Synthetic Hydrologic Sequences

5.3 Climate Change Analysis

The analysis of the effects of climate change on Lake Casitas hydrology was based on the findings of *Projected Changes in Ventura County Climate: 2021-2040, Western Regional Climate Center/Desert Research Institute and Watersheds Coalition of Ventura County, 2019.* This is considered to be the most reliable estimate of near-term climate change effects for the Casitas region. The study was supported by Casitas and other Ventura County agencies.

Primary findings as they relate to this study for the time period through 2040 are:

- Average temperatures will increase.
- Maximum temperatures will increase by 3-5 degrees.
- Average annual precipitation could increase or decrease; for this study it was assumed there would be no substantial change in annual precipitation.
- There will be more 3-4 more dry days per year, primarily in spring and fall.
- Precipitation intensity will increase. The wettest 5% of rainfall days will contribute 10% more of the total annual precipitation.
- Evapotranspiration will increase by 2.5 to 6.5 inches per year, with higher increases occurring in inland areas.

- Runoff production (conversion of rainfall to runoff) will decrease due to reduction in soil moisture associated with higher temperatures and greater evapotranspiration.

The Lake Casitas Yield Model simply simulates inflows, outflows and change in storage in Lake Casitas based on an assumed demand. Changes in temperature and precipitation could affect lake hydrology and demands on the Casitas system. Demands are varied in the safe yield and safe demand analysis to find the largest demand that can be met throughout the simulation period. For the safe demand and safe yield modeling analysis, climate effects on lake hydrology could captured in two ways: adjusted lake inflows and adjusted lake evaporation.

Potential climate effects could alter Lake inflows in three primary ways:

- Increase in Precipitation Intensity: Increase runoff from the top 5% of rainfall days without increasing mean annual rainfall
- Increase in Number of Dry Days: Increase the number of days when no runoff would occur
- Decrease in Soil Moisture: Reduce runoff from smaller storm events

The Lake Casitas Yield Model represents lake inflows in two time series: flow in the Ventura River at the Robles Diversion and direct inflow into the lake. Both time series would be affected by these changes. Increase in precipitation intensity would increase runoff, whereas the increase in number of dry days and reduction in soil moisture would decrease runoff. To properly investigate the impact of these climatological changes on watershed runoff, a rainfall-runoff model would be needed to simulate watershed response to changed meteorological inputs on a daily basis. Such a model was not available for the Casitas watershed and developing a model was beyond the scope of the CWRP. For purposes of this analysis, it was assumed the three climate factors affecting Lake inflows would compensate for each other with no appreciable impact on Lake yield.

The Lake Casitas Yield Model has monthly rates of evaporation that are applied to the computed lake surface area to calculate the volume of evaporation loss on a daily basis. The regional climate change assessment indicates that evapotranspiration will increase by 2.5 to 6.5 inches per year, with higher increases occurring in inland areas.

Table 5-2 summarizes the approach to the lake evaporation climate change adjustment. Two levels of climate change impact were considered – low climate change (LCC) impact corresponding to the lower end of the range of anticipated impacts by 2040, and high climate change (HCC) impact corresponding to the upper end of the range of anticipated impacts by 2040.

Table 5-2 Assumed Climate Change Effects on Lake Casitas Evaporation

Climate Change Impact	Modeling Approach	Magnitude of Change to Simulate Lower Climate Impact	Magnitude of Change to Simulate Higher Climate Impact
Increase in Evapotranspiration	Increase annual Lake Casitas evaporation, distributed monthly on a pro rata basis	3 inches/year	6 inches/year

Based on data from the Ventura County climate change study, annual evaporation at Lake Casitas could increase by about 3-6 inches depending on the climate scenario assumed. This effect was modeled using the following steps.

1. For LCC, assume annual evaporation rate increases by 3 inches. For HCC, assume annual evaporation rate increases by 6 inches.

2. Distribute the increase in annual evaporation across the 12 calendar months on a pro rata basis. For example, if the January evaporation rate represents 3 percent of the total annual evaporation rate, then for LCC the increase in evaporation rate would be 3 x 0.03 = 0.09 inches and for HCC the increase in evaporation rate would be 6 x 0.03 = 0.18 inches.

The Lake Casitas Yield Model was run in the safe yield mode (no demand reductions for the WEAP policy) for the two reduced evaporation scenarios using historical hydrology, a minimum allowable storage of 15,000 AF, and a Robles diversion efficiency factor of 0.70. The results are summarized in **Figure 5-6**. The Low Climate Change assumption of an increase in annual evaporation rate of 3 inches reduced the safe yield by 2.2%. The High Climate Change assumption of an increase in annual evaporation rate of 6 inches reduced the safe yield by 4.3%. These are relatively modest impacts over the 2040 planning horizon. For the CWRP it was decided to use the High Climate Change condition to be conservative. When appropriate, climate change adjustments to safe yield and safe demand estimates developed from the Lake Casitas Yield Model were made by reducing modeled values by 4.3%.

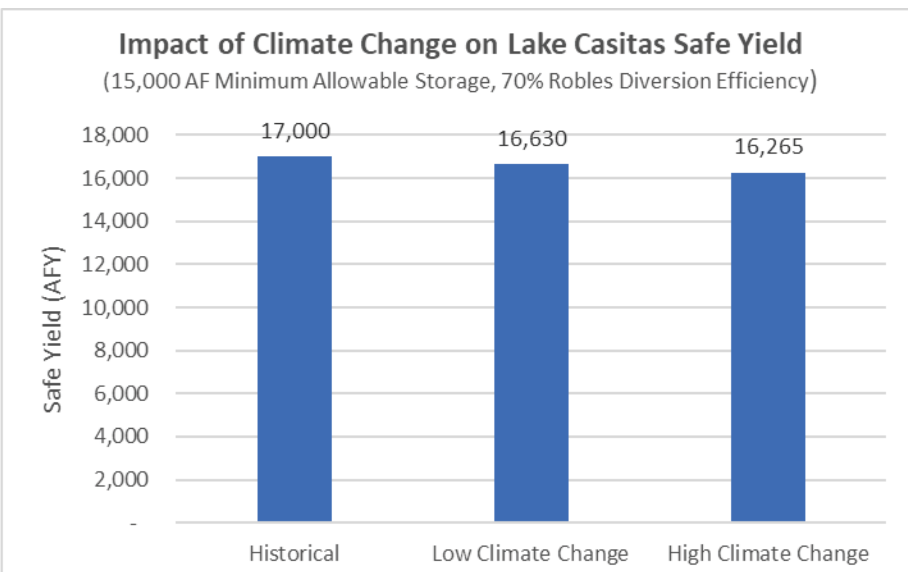

Figure 5-7 Impact of High Climate Change Assumptions on Lake Casitas Safe Yield

Section 6 Critical Period

Previous safe yield analyses with the original Lake Casitas Safe Yield Model using the historical period in the simulations found that the critical drought period occurred from 1945-1965. After making the adjustments to elevation-area-capacity table, the Robles Diversion Structure simulation, and the minimum allowable storage level, the critical drought period in the historical record was still the 1945-1965 period. This is shown in **Figure 6-1**.

However, when the demands on Lake Casitas were adjusted during the simulation to account for the effect of the WEAP policy, the critical period in the historical record became the 1998-2018 period that contains the recent severe drought. This is shown in **Figure 6-2**. If future hydrologic studies depend on the critical period, it is recommended that both the 1945-1965 and 1998-2018 periods be included in the analysis.

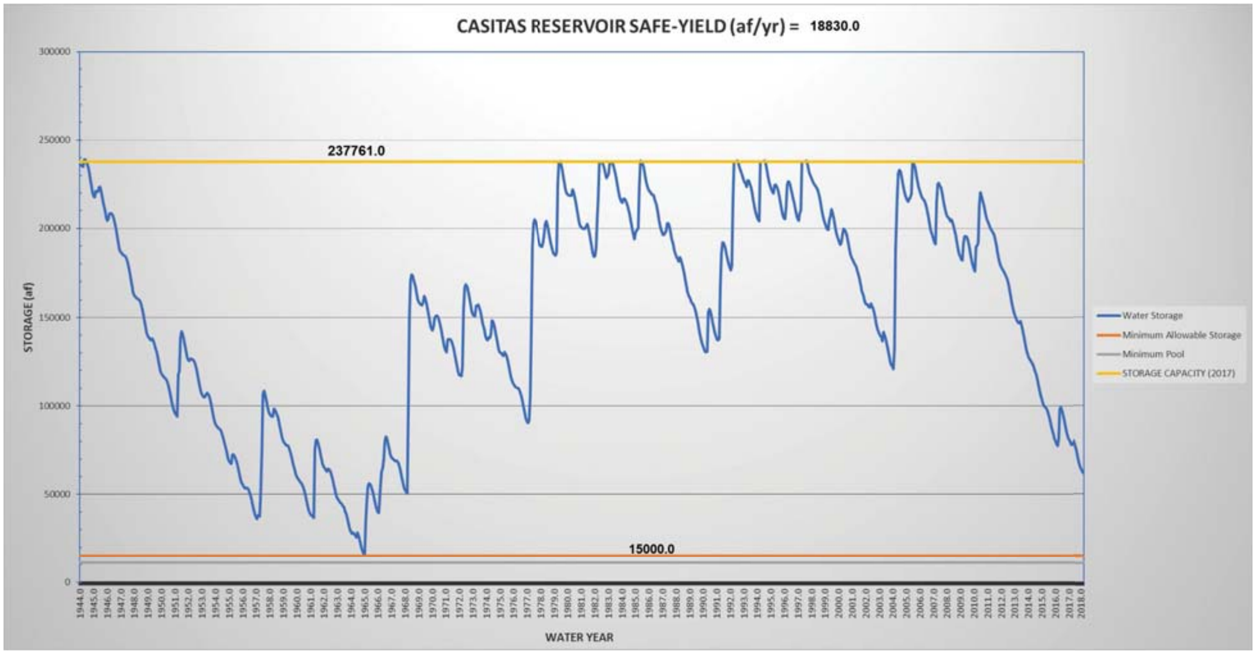

Figure 6-1 Simulated Lake Casitas Storage for Safe Yield with Constant Demand Throughout Simulation

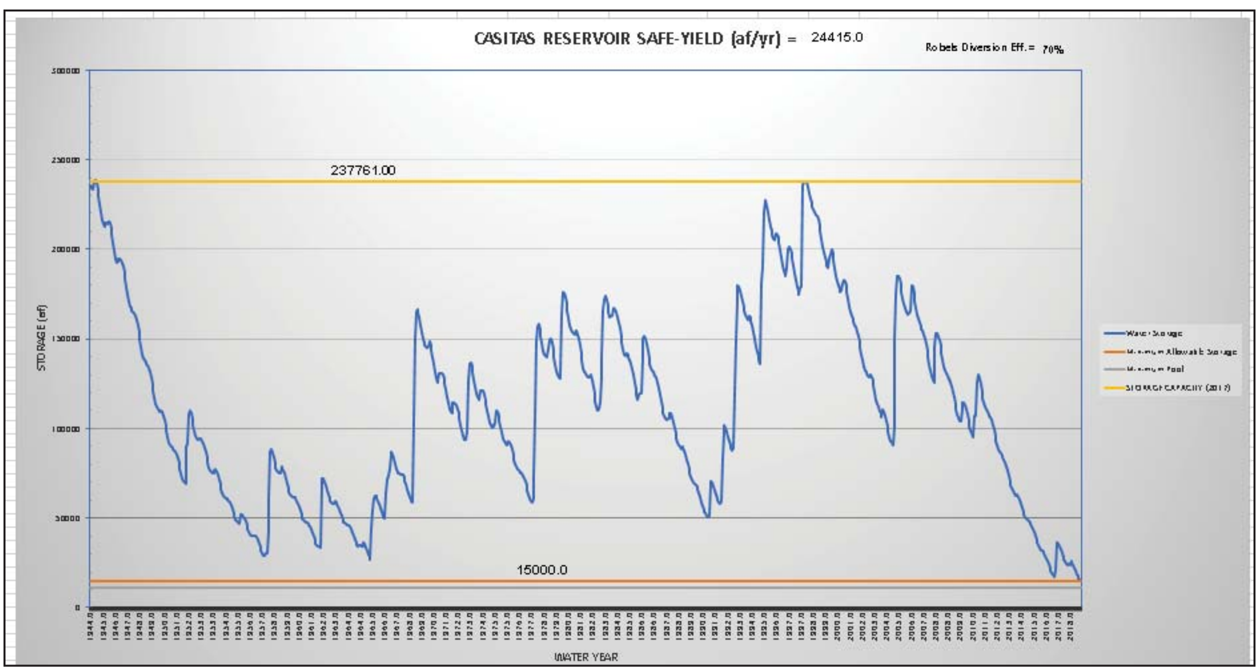

Figure 6-2 Simulated Lake Casitas Storage for Safe Yield with Demand Adjusted Based on WEAP Policy

Section 7 Minimum Allowable Storage Policy Development

Casitas staff and Water Resources Committee wanted to base the selection of the Lake Casitas minimum allowable storage on the ability to meet critical uses supplied by Lake Casitas. Critical uses are defined as uses that should be met even during emergency periods to meet health and safety obligations, contractual obligations, and regional economic goals. The minimum allowable storage was related to the number of years of critical use volume to be held in storage at all times for the safe yield and safe demand model simulations.

A proposed minimum allowable storage policy was developed by reviewing future water demand estimates for categories of Casitas customers and estimating the percentage of critical water use in each category. Three options were developed – upper bookend, lower bookend, and recommended value. Assumptions for each option were made for future water demand, the percentage of demand considered critical, the amount of water lost from the Lake due to net evaporation, and the number of years of critical use to be retained in storage. Assumptions were validated by Casitas staff.

Table 7-1 provides details on the calculations and assumptions made for each minimum allowable storage option. After reviewing this information, Casitas staff agreed that the recommended minimum allowable storage value of 20,000 AF would be presented to the Board as a policy to be considered.

Table 7-1 Minimum Allowable Storage Calculations

	Upper Bookend			Lower Bookend			Recommended A		
	Percent Critical Use	2040 Forecasted Water Use from Lake (AFY)	2040 Critical Use from Lake (AFY)	Percent Critical Use	2040 Forecasted Water Use from Lake (AFY)	2040 Critical Use from Lake (AFY)	Percent Critical Use	2040 Forecasted Water Use from Lake (AFY)	2040 Critical Use from Lake (AFY)
Retail Use	60%	3,000	1,800	50%	2,700	1,350	50%	2,700	1,350
Agricultural Use	70%	8,000	5,600	50%	7,200	3,600	50%	7,200	3,600
Contract Sales	100%	6,500	6,500	25%	5,850	1,463	50%	5,850	2,925
Total Use		17,500	13,900		15,750	6,413		15,750	7,875
Years of Critical Use in Emergency Storage			3.0			1.0			2.0
Emergency Storage (AF)			41,700			6,413			15,750
Net Evap Make-Up			2,000			0			1,400
Dead Pool (AF)			950			950			950
Minimum Allowable Storage (AF)			**44,650**			**7,363**			**18,100**
Recommended Value (AF)			**45,000**			**7,000**			**20,000**

Assumptions

Upper Bookend:	Percent Critical Use is very conservative
	2040 forecasted use is from 2016 UWMP without Ojai Valley demands met from wells
	3.0 years of critical use gets through 3 additional drought years with no backup supplies
	Net evaporation make-up volume assumes no natural inflow or Robles diversions
Lower Bookend:	Percent Critical Use is based on all users cutting back to WEAP levels
	2040 forecasted use assumes 10% permanent reduction from 2016 forecast values due to demand management
	50% of ag deliveries keeps trees alive but does not produce a harvest
	25% of contract deliveries assumes contract allocation is 50% per WEAP and contractors get 50% of that amount
	1.0 years of critical use in storage gets through one additional drought year with no backup supplies
	Net evaporation make-up volume assumes natural inflow is minimal but enough to compensate for evaporation losses
Recommended:	WEAP allocations for all customer classes
	10% reduced 2040 demand forecast for demand management is consistent with supply gap calculations
	2.0 years of critical use in storage gets through two additional drought years with no backup supplies
	Net evaporation make-up volume based on conservative assumption of no significant Lake inflow

Section 8 Results for Use in CWRP

As noted in previous sections, the Yield Model was updated during the course of the project to correct minor calculations and the application of the resequenced hydrologic data. This section presents results based on the final version of the model. The reliability analysis using all 100 synthetic hydrologic traces was used.

Based on the recommendation of staff and the Water Resources Committee, a minimum allowable storage level of 20,000 AF will be recommended to the Board for planning. **Figure 8-1** shows the exceedance probabilities for safe yield and safe demand modeling analyses based on that assumption and using the final version of the Yield Model. **Table 8-1** summarizes the results and provides the yield reliability values to be used in the CWRP. As an example of how the results in this table should be interpreted, the 95% safe demand reliability can be stated in words as follows:

There is a 95% chance that in the future Casitas will be able to safely support a demand of up to 10,660 AFY every year from Lake Casitas with existing supplies and infrastructure, 20,000 AF minimum allowable storage, and implementation of our current WEAP policy. There is a 5% chance that hydrology will be drier than expected and we will need to use our emergency storage pool at least once to meet the demand of 10,660 AFY.

Table 8-1 Lake Casitas Safe Yield and Safe Demand Reliability with Climate Adjustment for 20,000 AF Minimum Allowable Storage

Exceedance Probability (Reliability)	Safe Yield (AFY)	Safe Yield with Climate Adjustment (AFY)	Safe Demand (AFY)	Safe Demand with Climate Adjustment (AFY)
0.90	10,350	9,900	12,420	11,890
0.95	9,610	9,190	11,140	10,660
0.99	9,000	8,610	10,090	9,650

Note: Results based on 20,000 AF minimum allowable storage and 70% Robles diversion efficiency factor.

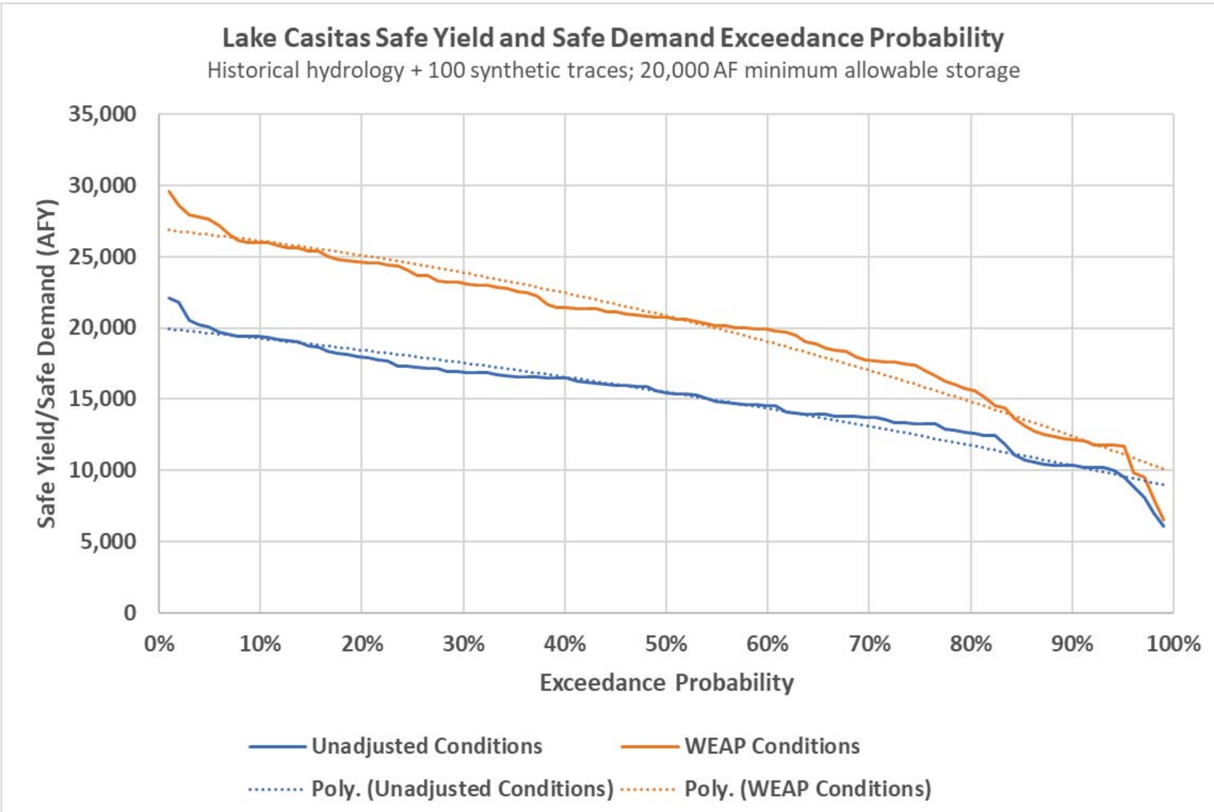

Figure 8-1 Exceedance Probability for Lake Casitas Safe Yield and Safe Demand Simulations With Synthetic Hydrology

The results summarized in **Table 8-1** demonstrate the significant benefits of the WEAP demand reduction policy in terms of managing and stretching existing water supplies. At the 95% reliability level with 20,000 AF minimum allowable storage, a base safe yield of 9,190 AFY can be delivered in every year. However, with implementation of the WEAP demand reduction targets during periods of low Lake levels, the safe demand with 95% reliability is 10,660 AFY. The difference – 1,570 AFY – is a measure of the benefit of Casitas' customers reducing their demands during drought periods. Without a commitment to implement water conservation measures during these periods, Casitas would have to acquire sufficient new water supplies to produce the equivalent of 1,570 AFY in additional yield.

Section 9 References

CMWD, 2004. Water Supply and Use Status Report, Casitas Municipal Water District, December 7, 2004.

CMWD, 2016. Final Urban Water Management Plan and Agricultural Water Management Plan, 2016 Update, prepared by Milner-Villa Consulting for Casitas Municipal Water District, June 2016.

CMWD, 2018. Water Efficiency and Allocation Program, Casitas Municipal Water District, May 9, 2018.

Western Regional Climate Center/Desert Research Institute and Watersheds Coalition of Ventura County, 2019. Projected Changes in Ventura County Climate: 2021-2040.

Stantec

Response to Request for Additional Lake Casitas Simulations for the CWRP

January 11, 2021

Prepared for:

Casitas Municipal Water District

Prepared by:

Stantec Consulting Services, Inc.

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Introduction

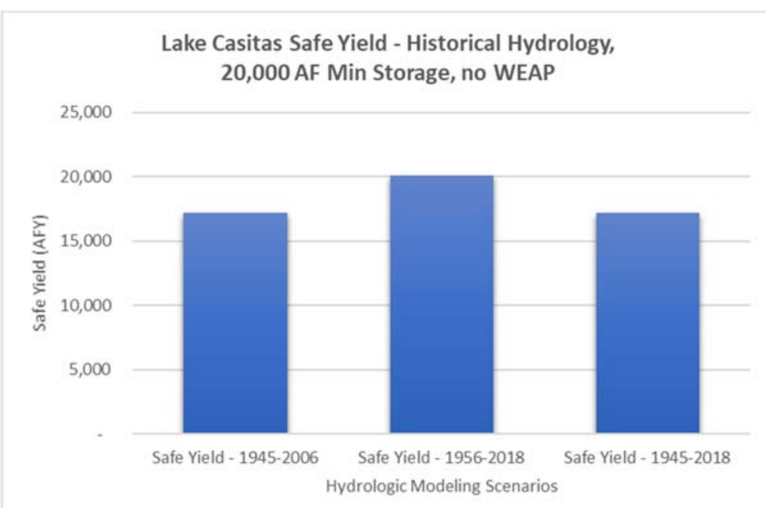
This technical memorandum presents results of additional Lake Casitas modeling analyses requested by Casitas on January 4, 2021. Three tasks were requested:

- Safe yield for historical hydrology and 20,000 AFY minimum allowable storage for three periods of record
- Safe yield for historical hydrology and no minimum allowable storage for three periods of record
- Lake performance for a range of constant demands

Results of these modeling analyses are presented below in tables, charts, and a brief list of observations, followed by a brief comparison of these results the Lake Casitas yield values adopted for the draft CWRP.

Task 1 – Safe Yield Analysis with Historical Hydrology, 20,000 AF Minimum Allowable Storage, No WEAP

Model Simulation Assumptions	Safe Yield: Historical Hydrology / 20,000 AF Min Storage / No WEAP		
Historical Hydrologic Period	**1945 - 2006**	**1956 - 2018**	**1945 - 2018**
Constant Demand (AFY)	Safe Yield	Safe Yield	Safe Yield
Initial Lake Volume (AF)	237,761	237,761	237,761
Minimum Allowable Storage (AF)	20,000	20,000	20,000
Robles Diversion Efficiency (%)	70%	70%	70%
Supplemental Water (AFY)	0	0	0
Climate Change Adjustment (%)	0	0	0
WEAP Demand Adjustment	No	No	No
Model Simulation Results			
Minimum Calculated Storage (AF)	20,042	20,074	20,042
Month/Year of Minimum Calculated Storage	Oct-65	Dec-18	Oct-65
Safe Yield (AFY)	**17,180**	**20,100**	**17,180**

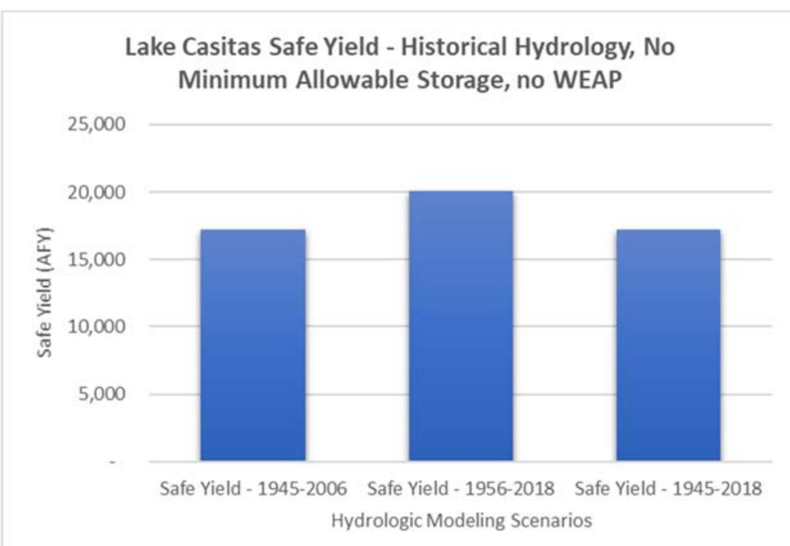


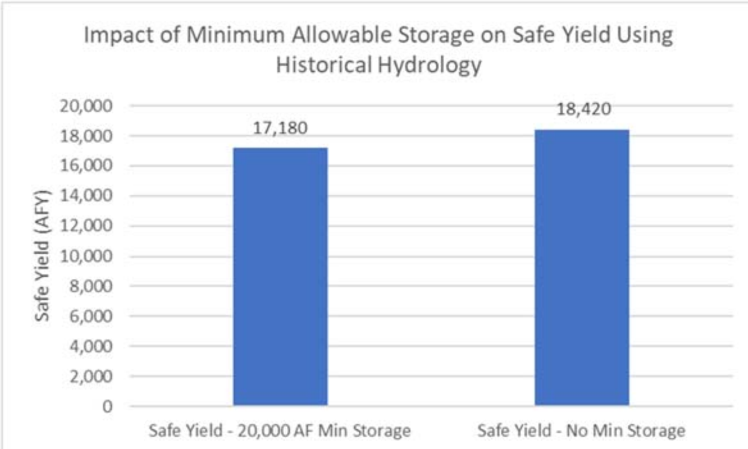
<u>Observations</u>

- Safe yield for the historical period is 17,180 AFY. This is greater than the 95% reliable safe yield of 9,190 AFY from the CWRP analysis using 100 resequenced hydrologic datasets to account for uncertainty, the updated Lake Casitas model (new Lake storage and operating assumptions) and a climate change adjustment. It is also greater than the 95% reliable safe demand of 10,660 AFY adopted in the draft CWRP based on the 100 resequenced hydrologic datasets, updated model, climate change adjustment, and WEAP adjustments to annual demand. See Appendix D, Table 8-1.
- Critical period is 1945-1965 without WEAP. CWRP analysis showed that with WEAP, the critical period shifts to 1998-2018 (see Appendix D, Section 6).

Task 2 – Safe Yield Analysis with Historical Hydrology, No Minimum Allowable Storage (Dead Pool), No WEAP

Model Simulation Assumptions	Safe Yield: Historical Hydrology / Dead Pool Min Storage / No WEAP		
Historical Hydrologic Period	**1945 - 2006**	**1956 - 2018**	**1945 - 2018**
Constant Demand (AFY)	Safe Yield	Safe Yield	Safe Yield
Initial Lake Volume (AF)	237,761	237,761	237,761
Minimum Allowable Storage (AF)	950	950	950
Robles Diversion Efficiency (%)	70%	70%	70%
Supplemental Water (AFY)	0	0	0
Climate Change Adjustment (%)	0%	0%	0%
WEAP Demand Adjustment	No	No	No
Model Simulation Results			
Minimum Calculated Storage (AF)	970	950	970
Month/Year of Minimum Calculated Storage	Oct-65	Dec-18	Oct-65
Safe Yield (AFY)	**18,420**	**21,253**	**18,420**





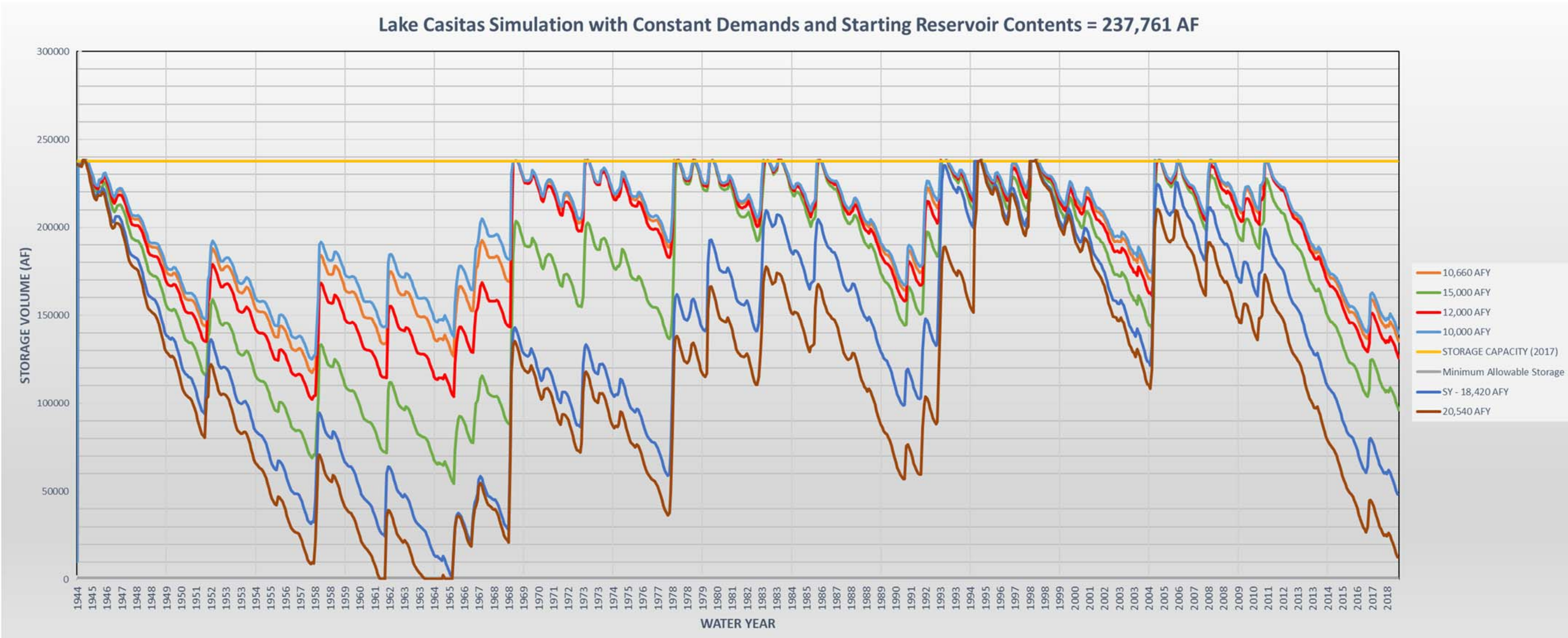
<u>Observations</u>

- Reducing minimum allowable storage from 20,000 AF to 950 AF (dead pool) increases safe yield by 1,240 AFY (7%) for simulation with historical hydrology and no WEAP.

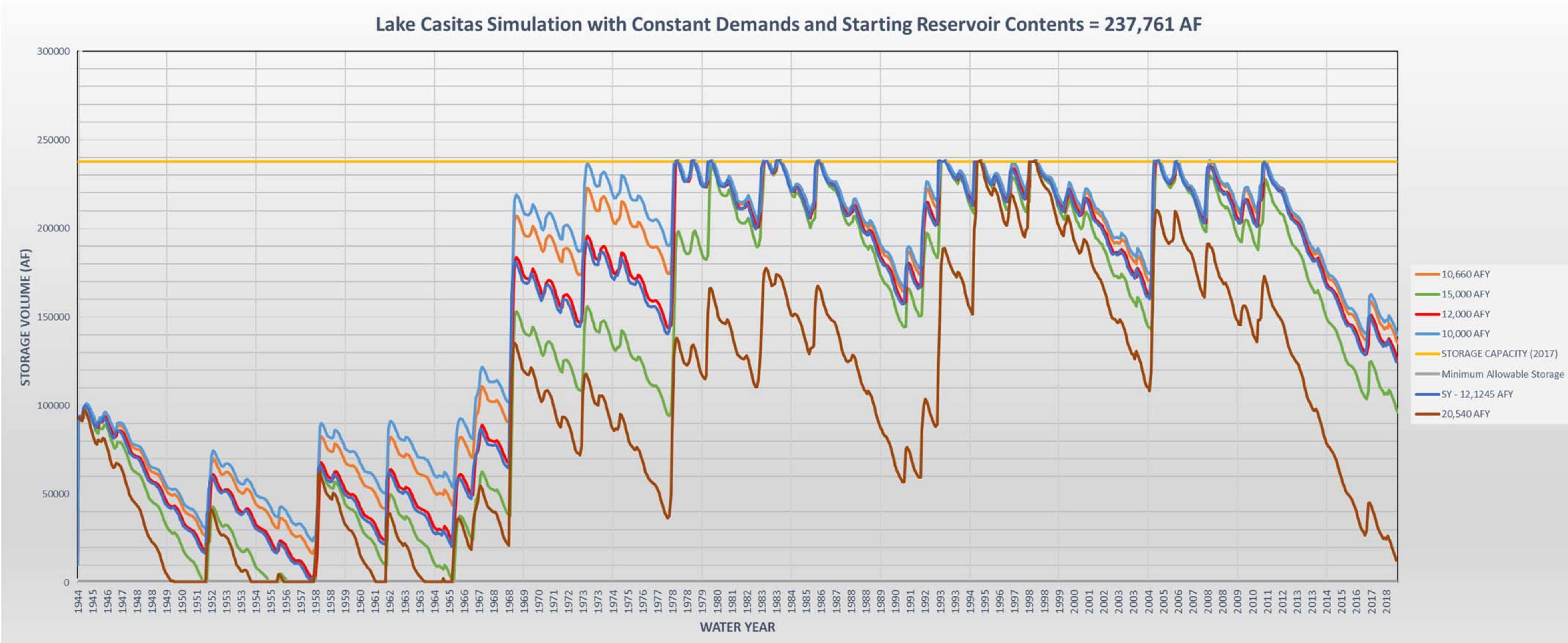
Task 3 – Lake Casitas Simulations with Historical Hydrology, Constant Demand Between 10,000 AFY and 15,000 AFY, No Minimum Allowable Storage, No WEAP

Model Simulation Assumptions	Constant Demand: Historical Hydrology / Initial Storage = Full / Climate Change Adj / No WEAP			Constant Demand: Historical Hydrology / Initial Storage = Current Condition / Climate Change Adj / No WEAP		
Historical Hydrologic Period	**1945 - 2018**	**1945 - 2018**	**1945 - 2018**	**1945 - 2018**	**1945 - 2018**	**1945 - 2018**
Constant Demand (AFY)	15,000	12,000	10,000	15,000	12,000	10,000
Initial Lake Volume (AF)	237,761	237,761	237,761	95,000	95,000	95,000
Minimum Allowable Storage (AF)	950	950	950	950	950	950
Robles Diversion Efficiency (%)	70%	70%	70%	70%	70%	70%
Supplemental Water (AFY)	0	0	0	0	0	0
Climate Change Adjustment (%)	4.3%	4.3%	4.3%	4.3%	4.3%	4.3%
WEAP Demand Adjustment	No	No	No	No	No	No
Model Simulation Results						
Minimum Calculated Storage (AF)	**54,541**	**102,323**	**124,892**	**0**	**2,466**	**23,692**
Month/Year of Minimum Calculated Storage	Oct-65	Nov-57	Nov-57	Jan-57	Nov-57	Nov-57
Safe Yield (AFY)	18,420	18,420	18,420	12,145	12,145	12,145

Starting Full



Starting at Current Storage



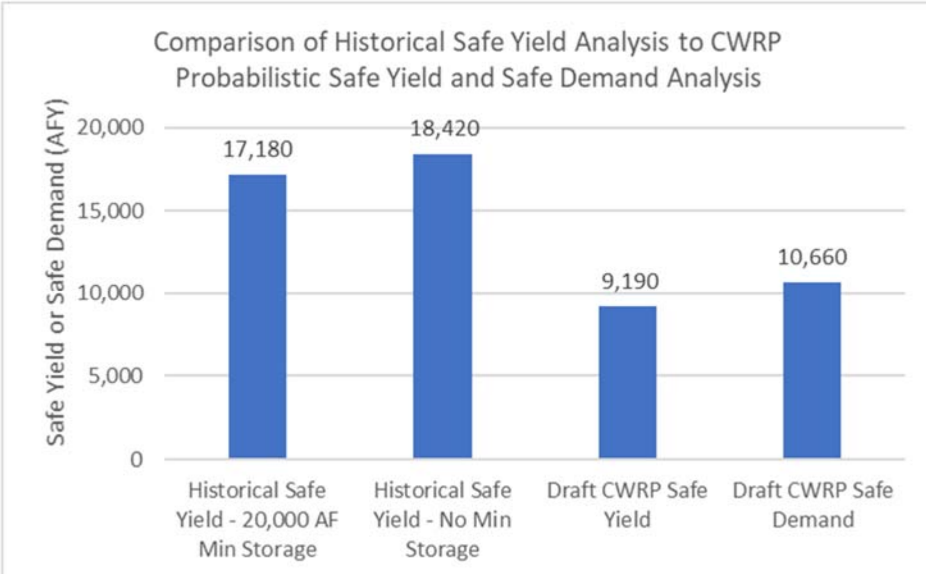
Observations

- We were requested to run this with the climate change adjustment. Because the methodology applies the climate change adjustment factor (4.3% reduction) to the computed safe yield or safe demand, climate change could not be factored into these simulations of Lake performance under specified demands and historical hydrology.
- Setting the starting Lake storage to current Lake contents (95,000 AF) significantly affects the reservoir performance based on the 1945-2018 period of record. A demand of over 12,145 AFY empties the Lake during the critical historical period without the WEAP.
- We also simulated the Lake performance with the safe yield estimate of 20,540 AFY from the 2004 analysis and original model, as shown in the plots. As expected, this causes the lake to go dry because: the new bathymetric survey shows less storage volume; the Robles diversion efficiency was calibrated to historical data; and the current Biological Opinion operations were included.

Comparison of Draft CWRP Analysis with Safe Yield Based on Historical Hydrology

Model Simulation Assumptions	Draft CWRP Safe Demand	Draft CWRP Safe Yield	Historical Safe Yield - 20,000 AF Min Storage	Historical Safe Yield - No Min Storage
Historical Hydrologic Period	1945-2018	1945-2018	1945 - 2018	1945 - 2018
Probabilistic Analysis (100 Traces)	Yes	Yes	No	No
Reliability	95%	95%	100%	100%
Constant Demand (AFY)	Safe Demand	Safe Yield	Safe Yield	Safe Yield
Initial Lake Volume (AF)	237,761	237,761	237,761	237,761
Minimum Allowable Storage (AF)	20,000	20,000	20,000	950
Robles Diversion Efficiency (%)	70%	70%	70%	70%
Supplemental Water (AFY)	0	0	0	0
Climate Change Adjustment (%)	4.3%	4.3%	0	0
WEAP Demand Adjustment	Yes	No	No	No

Model Simulation Results	Draft CWRP		Historical Safe Yield - 20,000 AF Min Storage	Historical Safe Yield - No Min Storage
Minimum Calculated Storage (AF)	20,000	20,000	20,042	970
Month/Year of Minimum Calculated Storage	Dec-18	Oct-65	Oct-65	Oct-65
Safe Yield (AFY)	NA	9,190	17,180	18,420
Safe Demand (AFY)	10,660	NA	NA	NA



<u>Observations</u>

- Incorporating the effects of natural hydrologic variability and climate change significantly reduce the estimated Lake Casitas safe yield compared to assuming historical hydrology repeats.
- Accounting for the benefit of customer conservation in accordance with the WEAP increases safe yield from 9,190 AFY to 10,660 AFY (16% increase) in the CWRP analysis.

General Conclusions and Considerations

- The critical period in the historical record is 1945-1965 when WEAP demand reductions are not considered. With WEAP, the critical period is 1998-2018 (see Appendix D, Section 6.0).
- Safe yield based on the historical record and an initially full lake is significantly greater than the 95% reliable safe yield based on the probabilistic approach used in the CWRP (18,240 AFY compared to 9,190 AFY), assuming the lake starts full.
- If the simulation using historical hydrology from 1945-2018 starts with the lake at the current storage volume of 95,000 AF (40% of capacity), the safe yield with no WEAP is 12,125 AFY. This is 34% less than if the lake were full today and represents a significant risk of requiring additional management strategies in the future.
- The 2004 safe yield analysis estimated a safe yield of 20,540 AFY using historical hydrology, a critical period of 1945-1965, no minimum allowable storage, and no WEAP. The revised safe yield estimate of 18,250 AFY under those assumptions is lower due to the revised total lake storage volume and changes to simulation of the Robles Diversion and the Biological Opinion.
- Using historical hydrology only assumes the future will repeat the past and does not account for hydrologic/climatic uncertainty and the possibility of more severe droughts. Statistical analysis showed there is a 67% chance future hydrology could be drier than historical hydrology just based on natural variability. Using historical hydrology only for planning is not a conservative assumption.
- Not considering the influence of the WEAP on customer water demand behavior is a conservative assumption, since actual experience with the WEAP shows customers reduce their demands when required by the policy.
- Adopting a minimum allowable storage of 20,000 AF versus dead pool has minor impact on the safe yield (7% reduction) for historical hydrology and no WEAP. The impact with WEAP is more

significant, as shown by other CWRP analyses, because the WEAP forces significant demand reductions at the lowest lake storage volumes.