Chapter Four

Environmental Consequences

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4.1 Introduction

Chapter 4 presents the probable consequences (impacts or effects) of each of the alternatives on the environmental resources described in Chapter 3. The potential effects of each action alternative compared to the No Action Alternative are presented for each potentially affected resource in this chapter, in the same order as described in Chapter 3.

The methodology and technical assumptions used to analyze the potential impacts to the Colorado River system (e.g., reservoir elevations, releases, and flows) is described in Section 4.2. Additional methodologies and assumptions used to analyze specific resources are described in the appropriate resource section.

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4.2 Methodology

Hydrologic modeling of the Colorado River system was conducted to determine the potential hydrologic effects of the alternatives. The modeling provided projections of potential future Colorado River system conditions (e.g., reservoir elevations, reservoir releases, river flows) for comparison of those conditions under the No Action Alternative to conditions under each action alternative. Due to the uncertainty with regard to future inflows into the system, multiple simulations were performed in order to quantify the uncertainties of future conditions and the modeling results are typically expressed in probabilistic terms.

The hydrologic modeling also provided the basis for the analysis of the potential effects of each alternative on other environmental resources such as recreation, biology, energy, etc. The potential effects to specific resource issues are identified and analyzed for each action alternative and again, compared to the potential effects to that resource issue under the No Action Alternative. These comparisons are typically expressed in terms of the incremental differences in probabilities (or projected circumstances associated with a given probability) between the No Action Alternative and the action alternatives.

This section provides an overview of the hydrologic modeling system. Further detail is also provided in Appendix A. For some resource analyses, additional modeling using other techniques was needed to analyze the potential effects to particular resource issues. In most of these cases, the output from the hydrologic modeling was used as input to these other models. The methodologies used for the additional modeling are described in each respective resource section.

4.2.1 Alternatives Modeled

As discussed in Chapter 2, five alternatives are considered in this Draft EIS: No Action, Basin States, Conservation Before Shortage, Water Supply, and Reservoir Storage. Each alternative includes specific assumptions with regard to the four operational elements of the proposed federal action: Shortage Guidelines, Coordinated Reservoir Operations, Storage and Delivery of Conserved Water, and Interim Surplus Guidelines. Additional details with respect to the modeling assumptions used to represent each alternative is presented in this section and in Appendix A.

4.2.2 Period of Analysis

This Draft EIS addresses guidelines that would be in effect for the period between 2008 to 2026 for Lower Basin reservoir operations and the coordinated operations of Lake Powell and Lake Mead. All action alternatives are assumed to revert back to the assumptions used to represent the No Action Alternative beginning in 2027. Due to the potential for hydrologic effects of the action alternatives beyond the 19-year interim period, the hydrologic modeling for all alternatives extends through 2060.

4.2.3 Model Description

Future Colorado River system conditions under the No Action Alternative and the action alternatives were simulated using the Colorado River Simulation System (CRSS). The model framework used for this process is a commercial river modeling software called RiverWare™. RiverWare™ is a generalized river basin modeling software package developed by the University of Colorado through a cooperative process with Reclamation and the Tennessee Valley Authority. CRSS was originally developed by Reclamation in the early 1970s and was implemented in RiverWare™ in 1996. River operation parameters modeled and analyzed in CRSS include the water entering the river system, storage in system reservoirs, releases from storage, river flows, and the water demands of and deliveries to water users in the Basin States and Mexico.

The water supply used as input to the model consisted of the historic record of natural flow in the river system over the 99-year period from 1906 through 2004 from 29 individual inflow points (or nodes) on the system. The future Colorado River water demands were based on demand and depletion projections prepared by the Basin States. Depletions are defined as diversions from the river less return flow credits, where applicable. The operation of the mainstream reservoirs including Lake Powell and Lake Mead is provided as a set of operating rules which describe how water is released and delivered under various hydrologic conditions. Further explanation of the model and operating rules is provided in Appendix A.

4.2.4 Computational Procedures and Future Hydrology

The model was used to simulate the future operational conditions of the Colorado River system on a monthly time-step for the period 2008 through 2060. Output data included reservoir elevations and storages, releases from the dams, hydroelectric energy generation, salinity concentration, flows at various points along the system, and diversions to and return flows from various water users. The input data for the model included monthly natural inflows, various physical process parameters (such as the evaporation rates for each reservoir), initial reservoir conditions, and the diversion and depletion schedules for entities in the Basin States and Mexico. The common and specific operating rules were also input for each alternative analyzed.

Despite the differences in the operating rules under the No Action Alternative and each action alternative, the future conditions of the Colorado River system (especially water levels at Lake Mead and Lake Powell) are most sensitive to future inflows. As discussed in Section 3.3, observations over the period of historical record (1906 through present) show that inflow into the system has been highly variable from year to year, and over decades. Although the model does not project future inflows, it can be used to analyze a range of possible future inflows and to quantify the probability of particular events (e.g., lake elevations levels being below or above certain levels).

Although several methods are available for projecting the range of possible future inflows, Reclamation utilized the existing historical record of natural flows to create a number of different hydrologic sequences using a technique for sampling from the historical record known as the Indexed Sequential Method (ISM) (USBR 1985; Ouarda et. al. 1997). These sequences were used to perform a series of simulations and the output was analyzed to quantify the uncertainty due to hydrologic variability for each variable of interest.

Each future inflow scenario was generated by "cycling" through the historical natural flow record. For example, assuming a 99-year historical record (1906 through 2004) and that the model projects 53 years into the future (2008 through 2060), the first inflow sequence would be comprised of the series of historical natural flows from 1906 through 1958; the second inflow sequence would utilize the series of historical natural flows from 1907 through 1959; the last sequence would utilize the series of historical natural flows beginning in 2004, with historical natural flows from 1906 through 1957 appended to the end to form a complete (53-year) sequence. The result of ISM is a set of 99 separate simulations (referred to as "traces") for each alternative that is analyzed. This enables an analysis of the respective criteria over a broad range of possible future hydrologic conditions using standard statistical techniques, discussed below.

4.2.5 Post-processing and Interpretation Procedures

The physical, biological, and socioeconomic analyses in this Draft EIS required the sorting and arranging of various types of model output data into tabulations or plots of specific operational conditions or parameters at various locations on the system. This was done through the use of statistical methods and other numerical analyses.

The hydrologic model generated data on a monthly time step for over 300 points (or nodes) on the river system. Furthermore, through the use of ISM, the model generated 99 possible outcomes for each node for each month over the time period 2008 through 2060. These very large data sets generated for each alternative can be visualized as three-dimensional data "cubes" with the axes of time, space (or node) and trace (or outcome for each future hydrology). The data were aggregated to reduce the volume of data and to facilitate comparison of the alternatives. The type of aggregation varies depending upon the needs of the particular resource analysis. The post-processing techniques used for this Draft EIS fall into two basic categories: those that aggregate in time, space or both, and those that aggregate the 99 possible outcomes.

For aggregation of data in time and space, simple techniques were employed. For example, deliveries of Colorado River water to all California diversion nodes in the model were summed to produce the total delivery to the state for each calendar year. Similarly, lake elevations were chosen on an annual basis (i.e., end of December) to show long-term lake level trends as opposed to short-term fluctuations. In other analyses, since the interim criteria period is 2008 through 2026, those analyses found it important to aggregate the data over that period of time and compared the aggregation over the remaining years (2027 through 2060). The particular aggregation used is noted in the methodology section for each resource, where applicable.

Once the appropriate temporal and spatial aggregation was chosen, standard statistical techniques were used to analyze the 99 possible outcomes for a fixed time or particular temporal span. Statistics that were generated included the mean, standard deviation, and percentiles.

Percentiles were determined by simply ranking the outcomes at each time (from highest to lowest) and determining the value at the specified percentile. For example, if end-of-calendar year Lake Mead elevations are ranked for each year, the 50th percentile (median) outcome for a given year is the elevation for which half of the values are below and half are above that elevation. Similarly, the 10th percentile value is the elevation for which ten percent of the values are lower and 90 percent are higher. This statistical method is used to view the results of all hydrologic sequences in a compact manner yet maintains the variability at high, medium, and low reservoir levels that may be lost by averaging the results of all traces. Several presentations of the ranked data are then possible. For example, a graph (or table) may be produced that is used to compare the 90th percentile, 50th percentile, and 10th percentile outcomes from 2008 through 2060 for the No Action Alternative and the action alternatives. It should be noted that a statistic such as the 10th percentile is not the result of any one hydrologic trace (i.e., no historical sequence produced the 10th percentile). Such a statistic provides information with regard to the probability (e.g., a 10 percent probability) of the variable of interest being at or below the 10th percentile value in a specified year; however, the statistic cannot be used to understand the probability of remaining at that value in subsequent years.

4.2.6 Model Uncertainty

The CRSS model does not project future inflows, but rather relies on the historic record to analyze a range of possible future inflows. For this reason, projections of future reservoir elevations are probabilistic, based on the 99-year historic record. The historic record includes periods of extreme drought and periods with above average flow, allowing analysis of the proposed federal action under a wide range of future flow conditions. However, 99-year record period is a relatively short time frame, and it is possible that future flows may include periods of wet or dry conditions that are outside of all the possible sequences seen in the historical record. Use of the historic record also cannot reflect potential future climate changes.

Reclamation has several on-going research and development programs to investigate alternative methods for generating ranges of possible future inflows on the Colorado River, including stochastic hydrology methods and paleo-reconstruction methods (reconstruction of historical inflows from analysis of tree-rings). A hydrologic sensitivity analysis was performed using three distinct methods for generating future inflows and is presented in Appendix N.

Model output is also sensitive to input diversion and depletion schedules. The best available data for future diversions and depletions were input to CRSS. Actual future depletion schedules, especially when simulating system conditions far into the future (beyond about 20 years from the present) may differ.

Finally, all models are sensitive to the quality of the data available as input information. For example, water flows are based upon the data from gages which have uncertainties associated with their measurements. These uncertainties limit the accuracy of any model that uses that data, even though that is generally the best available information.

4.2.7 Modeling Assumptions Common to All Alternatives

In addition to the specific operating rules necessary to model each of the alternatives (discussed in Chapter 2, Appendix A, and in the following section), the modeling of river system operations also requires certain assumptions about various aspects of water delivery and system operations that are common to all alternatives.

Assumptions common to all alternatives:

- All simulations were performed with a start year of 2008 and a simulation length of 53 years (2008 through 2060);

- Each action alternative was assumed to be in effect for the interim period which extends from 2008 through 2026. After 2026, the operating rules for all action alternatives revert to the rules of the No Action Alternative;

- The initial conditions for the Upper Basin and Lower Basin reservoirs reflect the 2007 end-of-calendar year (EOCY) elevations as projected by the August 2006 24-Month Study. The Lake Powell and Lake Mead starting conditions (initial elevations) in the model were 3,614.80 and 1,116.53 feet msl, respectively. Initial conditions for all reservoirs are detailed in Appendix A;

- Future hydrology was generated from the 99-year (1906 through 2004) historic record of calculated natural flows at 29 separate inflow points in the Colorado River watershed using the ISM. Ninety-nine simulations were performed for each alternative;

- The current Upper Basin reservoir operating rules, with the exception of Lake Powell, are identical under all alternatives. Under the action alternatives, the operation of Lake Powell reflects the coordinated operations strategy of each respective alternative during the Interim Period;

- Future water demands for Upper Division water users are based on depletion projections prepared by the Upper Division states in coordination with the Upper Colorado River Commission and Reclamation and published in the SIA Final EIS (Volume II, Appendix G). These depletion schedules are provided in Appendix C to this Draft EIS;

- The Lake Mead flood control procedures are always in effect;

- Except during flood control, Lake Mead is operated to meet downstream demands under the water supply condition (Normal, Surplus, or Shortage condition) in effect in a particular year;

- Future water demands for Lower Division water users are based on depletion projections prepared by the Lower Division states and published in the SIA Final EIS (Volume II, Appendix G) with some exceptions. The depletion schedules under

Normal conditions for IID, CVWD, and MWD are those specified in the Colorado River Water Delivery Agreement and include accelerated Inadvertent Overrun paybacks through 2004 and any subsequent changes in payback schedules. The depletion schedules for all Arizona users were provided by the Arizona Department of Water Resources for this EIS effort. These depletion schedules are provided in Appendix D to this Draft EIS;

- If the Lake Mead elevation falls below 1,000 feet msl, the delivery to SNWA is reduced to zero. This reflects the limitations of the SNWA intakes which are used to pump water from Lake Mead;
- Lake Mohave and Lake Havasu are operated in accordance with their existing rule curves;
- Water deliveries to Mexico are pursuant to the requirements of the 1944 Treaty. This provides annual deliveries of 1.5 maf to Mexico and up to 1.7 maf during Lake Mead flood control release conditions;
- Mexico's principal diversion is at Morelos Diversion Dam where most of its Colorado River apportionment of 1.5 maf is diverted. In practice, up to 140 kafy is delivered to Mexico near the SIB. The model, however, extends to just south of the NIB to include the Morelos Diversion Dam and accounts for the entire 1944 Treaty delivery at that point;
- For 2008 and 2009, the model sets the delivery schedule to Mexico at the NIB to 1.577 mafy. The additional 77 kafy reflects the average over-deliveries to Mexico for the period 1964 through 2005 (excluding years when there were flood control releases on the Colorado mainstream or Gila River);
- Beginning in 2010, the proposed Drop 2 Reservoir is assumed to be in operation and to conserve an average of 69 kafy, reducing the average over-delivery to Mexico from 77 kafy to 8 kafy;
- The bypass of return flows from the Welton-Mohawk Irrigation and Drainage District to the Cienega de Santa Clara in Mexico is assumed to be 109 kafy (the historical average for the period 1990 through 2005) and are not counted as part of the 1944 Treaty delivery;
- Except under the Conservation Before Shortage Alternative, replacement of the bypassed water is not assumed to occur in the future. The United States recognizes that it has an obligation to replace, as appropriate, the bypass flows and the assumptions made herein, for modeling purposes; do not necessarily represent the policy that Reclamation will adopt for replacement of bypass flows. The assumptions made with respect to modeling the bypass flows are intended only to provide a thorough and comprehensive accounting of the Lower Basin water supply. The

United States is exploring options for replacement of the bypass flows, including options that would not require operation of the Yuma Desalting Plant; and

- For modeling purposes, the Yuma Desalting Plant is not assumed to operate over the modeling period.

Assumptions with regard to the reduction of deliveries to the Lower Division states and Mexico are as described below.

4.2.7.1 Shortage Sharing Assumptions

A summary of the modeling assumptions with respect to the reduction of deliveries to the Lower Division states and Mexico was provided in Section 2.2. These modeling assumptions are identical in all alternatives and are explained further in this section. Shortage-sharing assumptions within a particular state are detailed in Section 4.4 and in Appendix A.

It was assumed that shortages would be allocated to each Lower Division state and Mexico based on percentages of the total Lower Basin shortage being applied. Two sets of percentages were assumed depending upon the amount of total Lower Basin shortage to be applied. Shortages less than or equal to the magnitude that would cause Arizona 4th priority uses to be reduced to zero are termed “Stage 1” shortages. This magnitude is dependent upon the scheduled depletions for the Arizona 4th priority users (post September 30, 1968 contractors, including the CAP), which vary over the period of analysis. In a “Stage 2” shortage, additional shortages above that magnitude are applied.

In order to assess the potential effects of the alternatives, it was assumed that Mexico would share proportionately in Lower Basin shortages. Allocation of Colorado River water to Mexico is governed by the 1944 Treaty. The proposed federal action is for the purpose of adopting additional operational strategies to improve the Department’s annual management and operation of key Colorado River reservoirs for an interim period through 2026. However, in order to assess the potential effects of the proposed federal action in this Draft EIS, certain modeling assumptions are used that display projected water deliveries to Mexico. Reclamation’s modeling assumptions are not intended to constitute an interpretation or application of the 1944 Treaty or to represent current or future United States policy regarding deliveries to Mexico. The United States will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Treaty with Mexico through the IBWC in consultation with the Department of State.

The shortage-sharing percentages were computed as follows:

Stage 1 Shortage Sharing Modeling Assumptions. Shortages are first imposed under Stage 1 and would be applied to the most junior users within Arizona (those with post-1968 water rights, i.e., 4th and 5th priority rights within Arizona), Nevada and Mexico. Stage 1 shortages continue until the deliveries to the post-1968 water rights holders in Arizona (including the CAP) are reduced to zero. The maximum amount of Stage 1 shortages during the period of analysis is dependent on the scheduled depletions for the post-1968 water rights holders and decreases in time (2008 through 2060) from approximately 1.8 maf to 1.7 maf.

The assumed Stage 1 shortage sharing percentages are explained in Table 4.2-1.

Table 4.2-1
Modeling Assumptions for Distribution of Stage 1 Shortages[1]

Entity	Percentage of Stage 1 Shortage	Calculation
Arizona[2]	80	▪ Computed assuming that Arizona takes the remaining amount of shortage after Nevada and Mexico take their respective shares ▪ Calculated as: 1.0 – 0.1667 – 0.0333 = 0.80 or 80.0 percent
California	0	▪ Does not receive shortage under Stage 1
Nevada	3.33	▪ Computed as a ratio of Nevada's allotment to the total allotments of the Lower Division states and Mexico ▪ Calculated as: 0.3 maf / 9.0 maf – 0.0333 or 3.33 percent
Mexico	16.67	▪ Computed as a ratio of Mexico's allotment to the total allotments of the Lower Division states and Mexico ▪ Calculated as: 1.5 maf / 9.0 maf = 0.1667 or 16.67 percent

1. *These modeling assumptions do not reflect policy decisions and are not intended to constitute an interpretation or application of the 1944 Treaty. They have been developed for comparison of the alternatives.*
2. *Within the CAP, Ak-Chin and Salt River Pima-Maricopa Indian Community tribes have pre-1968 contracts for the delivery of 72 kaf that is not reduced until a Stage 2 Shortage is applied.*

Stage 2 Shortage Sharing Modeling Assumptions. After deliveries to the 4th and 5th priority rights within Arizona are reduced to zero, it is assumed that any additional delivery reductions would be distributed to Arizona, California, Nevada, and Mexico. The assumed Stage 2 shortage sharing percentages are explained in Table 4.2-2. Under a Stage 2 Shortage, the total Lower Basin shortage is the sum of the computed Stage 1 and Stage 2 shortage amounts.

Table 4.2-2
Modeling Assumptions for Distribution of Stage 2 Shortages[1]

Entity	Percentage of Stage 2 Shortage	Calculation
Arizona	15-20	▪ The percentage changes as Arizona's 4th priority use schedule changes and ranges between 15 and 20 percent ▪ Computed as a ratio of Arizona's allotment less the amount of shortage applied to Arizona under Stage 1, to the total allotments of the Lower Division states and Mexico less the total amount shorted to users under Stage 1 ▪ Calculated as: (2.8 – Arizona Stage 1 shortage) / (9.0 – total Stage 1 shortage)
California	60-65	▪ California shortage sharing percentage changes as Arizona's 4th priority use schedule changes and ranges between 60 and 65 percent ▪ Computed assuming that California takes the remaining amount of the additional shortage ▪ Calculated as: 1.0 – 0.1667 – 0.0333 – Arizona's Stage 2 percentage expressed as a fraction

Table 4.2-2
Modeling Assumptions for Distribution of Stage 2 Shortages[1]

Entity	Percentage of Stage 2 Shortage	Calculation
Nevada	3.33	▪ Computed as a ratio of Nevada's allotment less the amount of shortage applied to Nevada under Stage 1, to the total allotments of the Lower Division states and Mexico less the amount shorted to users under Stage 1 ▪ Calculated as: (0.3 – Nevada Stage 1 shortage) / (9.0 – total Stage 1 shortage) = 0.0333 or 3.33 percent
Mexico	16.67	▪ Computed as a ratio of Mexico's allotment less the amount of shortage applied to Mexico under Stage 1, to the total allotments of the Lower Division states and Mexico less the total amount shorted to users under Stage 1 ▪ Calculated as: (1.5 – Mexico Stage 1 shortage) / (9.0 – total Stage 1 shortage) = 0.1667 or 16.67 percent

1. These modeling assumptions do not reflect policy decisions and are not intended to constitute an interpretation or application of the 1944 Treaty. They have been developed for comparison of the alternatives.

4.2.8 Modeling Assumptions Specific to Alternatives

Each alternative includes specific assumptions with regard to the four operational elements of the proposed federal action. Assumptions with regard to Shortage Guidelines, Coordinated Reservoir Operations, and the ISG were presented in Chapter 2 and are detailed in Appendix A. In this section, the assumptions with regard to the Storage and Delivery of Conserved Water element are summarized. Details of these assumptions are presented in Appendix M.

Modeling Assumptions Regarding Storage and Delivery of Conserved Water. The general concept of a storage and delivery mechanism is that water users could conserve system water or non-system water and store that water in Lake Mead to be delivered in later years, subject to specified losses.

Three alternatives assume some form of a storage and delivery mechanism (Basin States Alternative, Conservation Before Shortage Alternative, and Reservoir Storage Alternative). Each alternative specifies the maximum amount of storage credits that can be created during any year, the maximum amount of storage credits that may be recovered during any year, and the maximum cumulative amount of storage credits that can be available at any one time (Tables 2.3-2, 2.4 1, and 2.6-1). These volume limitations are recognized in the model as are other rules that specify under which water supply conditions conserved system or non-system water may be delivered or stored.

Under all three alternatives, it is assumed that specific losses would be applied to the conserved water that is stored in Lake Mead, including a one-time system assessment, and yearly evaporation losses. At the time the storage credits are created, the entity that generates the storage credits is required to dedicate a percent of the storage credits to the system, defined as a system assessment, on a one-time basis to provide a water supply benefit to the system. For the Basin States Alternative and the Conservation Before Shortage Alternative, the system assessment is assumed to be five percent. For the Reservoir Storage Alternative, the system assessment is assumed to be ten percent. Additionally, storage credits are subject to annual evaporation losses which are assumed to be three percent per year during each year the conserved water remains in storage in Lake Mead. The exception to this is during Shortage conditions, when no evaporation loss is applied.

At this time, it is unknown which entities might participate in a Lake Mead mechanism that allows the storage and delivery of conserved system and non-system water. Furthermore, the timing and magnitude of the storage and delivery of conserved water is unknown. However, modeling assumptions with respect to the entities that might participate and their respective level of participation were needed to enable the evaluation of the mechanism and its potential effects on environmental resources, particularly to reservoir storage and river flows below Lake Mead.

Table 4.2-3 summarizes the modeling assumptions with regard to the entities that were assumed to participate under each alternative, the activities undertaken to generate storage credits, and the water supply conditions under which storage and delivery of storage credits could occur. Appendix M further describes these and other key modeling assumptions. The proposed federal action is for the purpose of adopting additional operational strategies to improve the Department's annual management and operation of key Colorado River reservoirs. However, in order to assess the potential effects of the proposed federal action in this Draft EIS, certain modeling assumptions are used that display projected water deliveries to Mexico. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Treaty or to represent current or future United States policy regarding deliveries to Mexico. The United States will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Treaty with Mexico through the IBWC in consultation with the Department of State [1].

Under the Conservation Before Shortage Alternative, extraordinary conservation is assumed to occur during voluntary shortage conditions but not during involuntary shortage conditions.

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[1] Notwithstanding the lack of an existing mechanism to implement such modeling assumptions, Reclamation utilized these assumptions for a number of reasons, including the following: (1) a larger volume of potential storage in Lake Mead is identified and the associated impacts are thereby analyzed; (2) the maximum potential changes to river flows below Hoover Dam are identified and the associated impacts analyzed; (3) the assignment of water conservation amounts to entities in the Lower Basin states in excess of amounts currently requested by each state is avoided; and (4) a program of potential future cooperation between the United States and Mexico is identified.

Table 4.2-3
Modeling Assumptions for Storage and Delivery of Conserved System and Non-System Water

		BS, CBS & RS [1]						CBS & RS	CBS	RS
		California	Arizona	Nevada				Mexico	Federal	Federal
Water Supply Condition		Extraordinary Conservation	Extraordinary Conservation	Tributary Conservation	Groundwater	Desalinization	Drop 2 Reservoir [4]	Extraordinary Conservation	Extraordinary Conservation	Extraordinary Conservation
Flood Control Surplus	Store	No	No	No	No	No	No	No	No	No
	Deliver	No	No	No	No	No	No	No	No	No
Quantified (70R) Surplus	Store	No	No	Yes	No	Yes	Yes	Yes	Yes	Yes
	Deliver	No	No	No	No	Yes	Yes	Yes	Yes	Yes
Full Domestic Surplus	Store	No	No	Yes	No	Yes	Yes	Yes	Yes	Yes
	Deliver	No	No	Yes	No	Yes	Yes	Yes	Yes	Yes
Normal	Store	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Deliver	Yes	yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Shortage (involuntary and voluntary)	Store	No	No	Yes	Yes	Yes	No	No	No [5]	Yes
	Deliver	No	No	Yes	Yes	Yes	No	No	No	Yes
System Assessment		Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes
Period of Activity		2006-2026	2017-2026	2009-2060	2009-2060	2020-2060	Temporary	2008-2026	2008-2026	2008-2026

Notes:

1. *BS = Basin States Alternative, CBS = Conservation Before Shortage Alternative, RS = Reservoir Storage Alternative*
2. *yes = activity assumed to occur*
3. *no = activity assumed to not occur*
4. *Beginning in 2012, Nevada is assumed to receive 40 kafy of the water conserved by the Drop 2 Reservoir during Normal and Surplus years until a total of 300 kaf has been credited to Nevada. Thereafter, water conserved by the Drop 2 Reservoir is assumed to be system water.*
5. *Under the Conservation Before Shortage Alternative, extraordinary conservation is assumed to be undertaken by the federal government during voluntary shortage conditions but not during involuntary shortage conditions*
6. *These modeling assumptions do not reflect policy decisions and are not intended to constitute an interpretation or application of the 1944 Treaty. They have been developed for comparison of the alternatives..*

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4.3 Hydrologic Resources

This section identifies the potential effects on hydrologic resources that may occur as a result of implementing the No Action Alternative and the action alternatives.

4.3.1 Methodology

The methodology used to analyze the potential impacts of the alternatives to reservoir storage, reservoir releases, and the corresponding changes in river flows downstream of the reservoirs is described in Section 4.2.

As noted in Section 4.2, the CRSS model is a monthly time-step model and output for simulated water system conditions, such as reservoir elevations or releases, can be provided on monthly and annual bases. The data and output used in the impact analysis may vary depending on the specific issue being addressed. An example of the different months considered in the analyses follows:

Lake Powell

- **March:** representative of months (or period) with seasonal low Lake Powell elevations;
- **July:** representative of months (or period) with seasonal high Lake Powell concentration of visitors; and
- **September:** month representing End-of-Water Year, used for water accounting and reporting in Upper Basin.

Lake Mead

- **July:** representative of months (or period) with seasonal low Lake Mead elevations; and
- **December:** month representing End-of-Calendar Year, used for water accounting and reporting in Lower Basin.

The specific data and output used in the different resource analyses are presented in this chapter.

4.3.1.1 Methodology Used To Estimate a Range of Daily Glen Canyon Dam Releases

The observed CRSS model output for six annual Lake Powell release volumes were used to estimate the monthly volumes that would be seen under water year release volumes that were less than, equal to, and greater than 8.23 maf. These annual release volumes consisted of 7.00, 7.48, 7.80, 8.23, 9.00, and 9.50 mafy, corresponding to the Glen Canyon Dam release volumes observed under the modeled alternatives. For each month corresponding to each one of these annual flow volumes, the average, maximum, and minimum daily flow volumes were then calculated using the allowable daily fluctuation parameters specified in the 1996 Glen Canyon ROD. It is recognized that monthly and daily flow patterns observed in the different release years could potentially deviate somewhat from the flow values and patterns calculated using this approach although they would most likely be very close to the calculated value. It is also noted that the release patterns for the 7.0 maf release are not as consistent because the monthly volumes would be affected by balancing of Lake Powell and Lake Mead storage. When balancing takes place, monthly release volumes shift as forecasted inflow shifts, resulting in more than one possible pattern for the 7.0 maf release years.

4.3.1.2 Methodology Used To Estimate the Effect on Groundwater

The annual median elevation of the water surface in the Colorado River has been used as an indicator of groundwater elevations adjacent to the Colorado River within the potentially affected river reaches. This is due to the slow movement of groundwater and the time required for the decline in the groundwater table to stabilize at a decline equal to that of the river (LCR MSCP BA, Appendix J and Appendix K). The methodology used to analyze the potential effects to groundwater followed the methodology established in the LCR MSCP analysis.

4.3.2 Lake Powell and Glen Canyon Dam

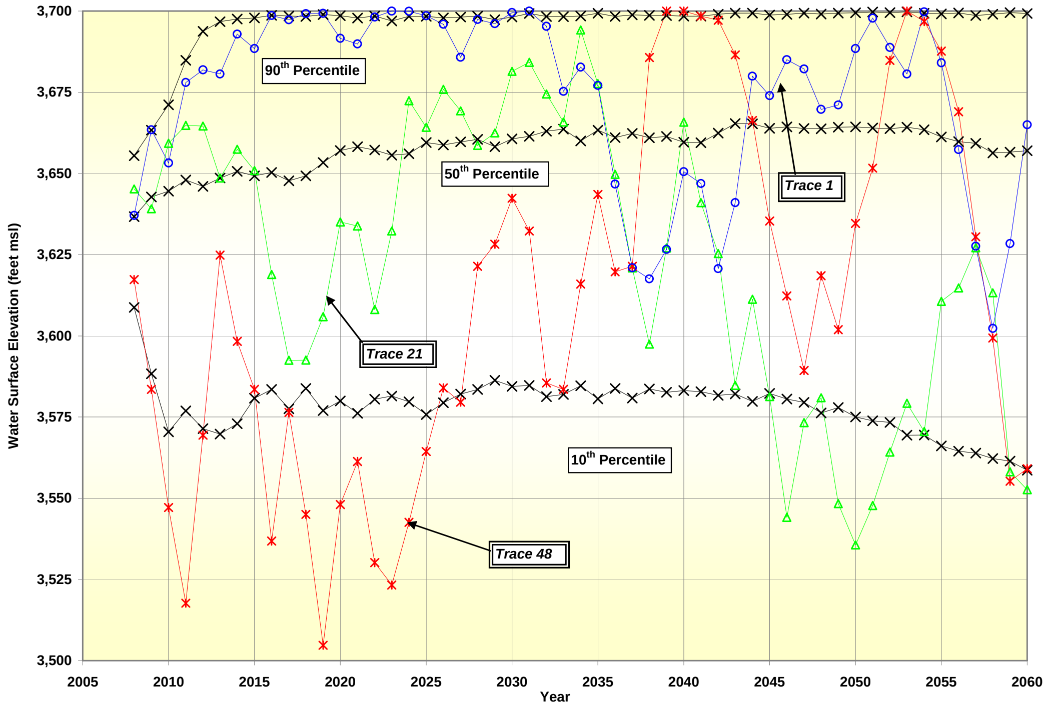
As noted in Section 3.3, future elevations of Lake Powell are expected to be within the range of historic water levels. However, each action alternative may alter the probability (when compared to the No Action Alternative) that the reservoir may be at a given elevation in the future.

Under the No Action Alternative, the elevation of Lake Powell is projected to fluctuate between full and lower levels during the period of analysis (2008 through 2060). Figure 4.3-1 illustrates the range of water levels by three lines, labeled 90^{th} percentile, 50^{th} percentile and 10^{th} percentile. The 50^{th} percentile line shows the modeled median elevation for each future year. The median elevation gradually increases from about 3,640 feet msl to about 3,660 feet msl in the year 2060. The 10^{th} percentile line shows that the elevation would gradually decline from about 3,610 feet msl to about 3,560 feet msl.

It should be noted that the Lake Powell elevations depicted in Figures 4.3-1 and 4.3-2 are for modeled lake water levels at the end of July. The Lake Powell water level generally reaches its seasonal high in July whereas the seasonal lows generally occur in March.

Three distinct traces were added to Figure 4.3-1 to illustrate what was actually simulated under the various traces and respective hydrologic sequences and to highlight that the 90^{th}, 50^{th}, and 10^{th} percentile lines do not represent actual traces, but rather the ranking of each year's data from the 99 traces for the conditions modeled. The traces also illustrate the variability among the different traces and that the reservoir levels could temporarily decline below the 10^{th} percentile line. Trace 1 represents the hydrologic sequence that begins in year 1906. Trace 21 represents the hydrologic sequence that begins in year 1926. Trace 48 represents the hydrologic sequence that begins in year 1953.

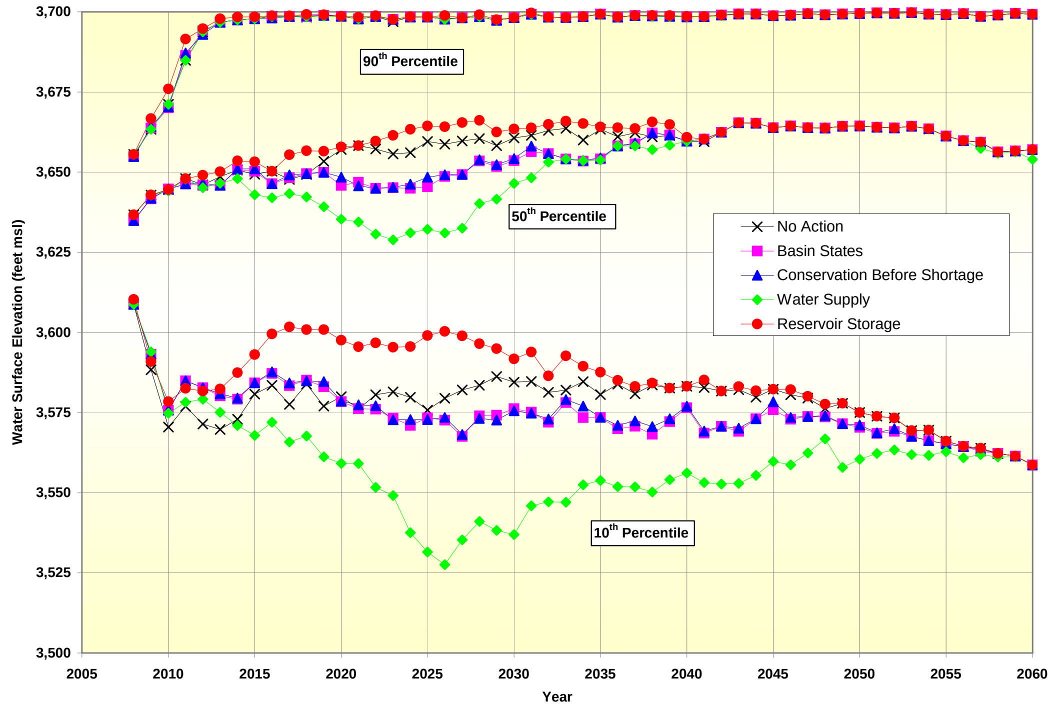
Figure 4.3-1
Lake Powell End-of-July Elevations Under the No Action Alternative
90th, 50th and 10th Percentile Values



In Figure 4.3-1, the 90th and 10th percentile lines bracket the range where 80 percent of the water levels simulated for the No Action Alternative occurred. The highs and lows shown on the three traces would likely be temporary conditions. The reservoir level would tend to fluctuate in the range through multi-year periods of above-average and below average inflows. Neither the timing of water level variations, nor the length of time the water level would remain high or low can be predicted. These events would depend on the future variation in basin runoff conditions.

Figure 4.3-2 presents a comparison of the 90't'h, 50th, and 10th percentile values obtained for the No Action Alternative to those of the action alternatives. This figure is best used for comparing the relative differences in the general lake level trends that result from the simulation of the different alternatives.

Figure 4.3-2
Lake Powell End-of-July Elevations
Comparison of Action Alternatives to No Action Alternative
90th, 50th, and 10th Percentile Values



As illustrated in Figure 4.3-2, the 90th percentile results were nearly identical for all of the alternatives. For the 50th and the 10th percentile results, the Reservoir Storage Alternative had the highest Lake Powell water levels and the Water Supply Alternative had the lowest water levels. The water levels under the Basin States Alternative and the Conservation Before Shortage Alternative were similar and were generally lower than those under the No Action Alternative.

Table 4.3-1 provides a summary of the data illustrated in Figure 4.3-2, which is the 90th percentile, median (50th percentile) and 10th percentile values of the alternatives compared to those of the No Action Alternative. The values presented in this table include those for years 2026 and 2060 only. Results for the 90th percentile show that Lake Powell elevations under the action alternatives were almost the same as those under the No Action Alternative. For the 50th percentile, the water levels under the Water Supply, Basin States, and Conservation Before Shortage Alternatives were lower than those under the No Action Alternative during 2026, but were almost the same by 2060. The 10th percentile trend was very similar to the 50th percentile trend.

Table 4.3-1
Lake Powell End-of-July Elevations (feet msl)
Comparison of Action Alternatives to No Action Alternative
90th, 50th, and 10th Percentile Values

Alternative	Year 2026			Year 2060		
	90th Percentile	50th Percentile	10th Percentile	90th Percentile	50th Percentile	10th Percentile
No Action	3,697.90	3,658.75	3,579.43	3,699.27	3,656.99	3,558.63
Basin States	3,697.71	3,648.61	3,572.63	3,699.27	3,656.99	3,558.63
Conservation Before Shortage	3,697.74	3,649.20	3,573.50	3,699.27	3,656.99	3,558.63
Water Supply	3,697.64	3,631.02	3,527.55	3,699.27	3,654.00	3,558.63
Reservoir Storage	3,698.85	3,664.17	3,600.29	3,699.27	3,656.99	3,558.63

When the Lake Powell water level is at or exceeds 3,695 feet msl, the reservoir is considered to be essentially full. Figure 4.3-3 shows the frequency that future Lake Powell End-of-July elevations would exceed elevation 3,695 feet msl under the No Action Alternative and the action alternatives. This type of figure is best used to compare the likelihood that the Lake Powell elevations would be at or above the noted elevation (3,695 feet msl in this example) under an action alternative as compared to the No Action Alternative. Figure 4.3-3 illustrates that the percent of values that were above elevation 3,695 feet msl under the action alternatives were similar to the No Action Alternative throughout the period of analysis. The exception to this is the Reservoir Storage Alternative which provides slightly higher exceedence values than the No Action Alternative between years 2010 through 2033. This means that the Lake Powell elevations would generally tend to be higher under the Reservoir Storage Alternative, as compared to the No Action Alternative.

As summarized in Table 4.3-2, the exceedence values under the Basin States, Conservation Before Shortage, and Water Supply Alternatives were essentially the same as those observed under the No Action Alternative in most years. The exceedence values under the Reservoir Storage Alternative were slightly higher than those under the No Action Alternative.

Figure 4.3-3
Lake Powell End-of-July Elevations
Comparison of Action Alternatives to No Action Alternative
Percent of Values Greater Than or Equal to Elevation 3,695 feet msl

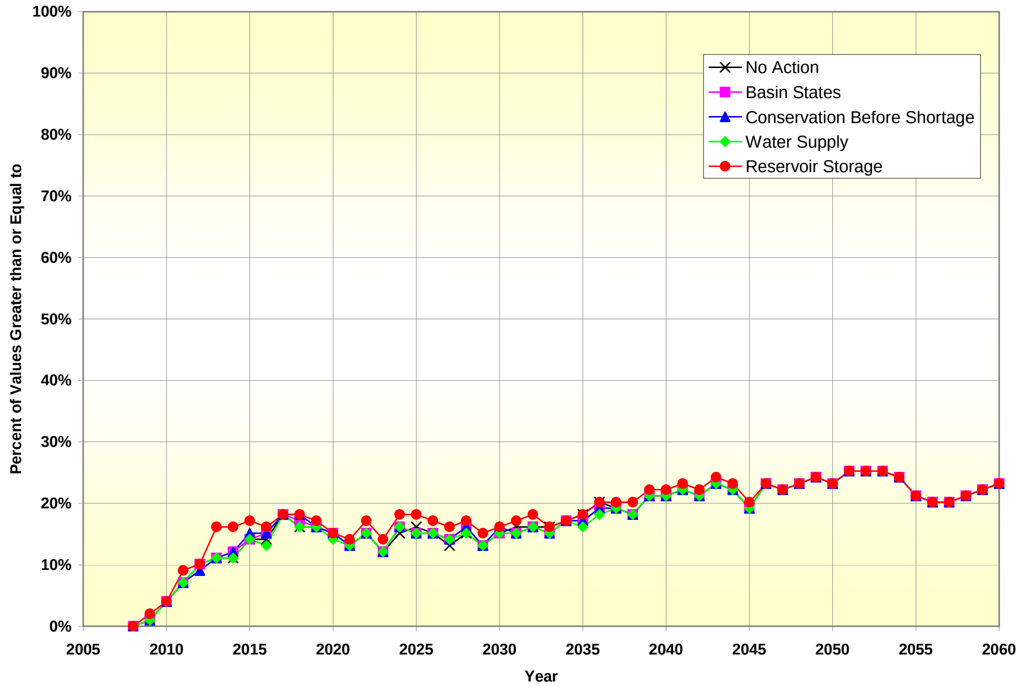


Table 4.3-2
Lake Powell End-of-July Elevations
Comparison of Action Alternatives to No Action Alternative
Percent of Values Greater Than or Equal to Elevation 3,695 feet msl

Alternatives	Year						
	2008	2016	2026	2030	2040	2050	2060
No Action	0%	14%	15%	15%	21%	23%	23%
Basin States	0%	15%	15%	15%	21%	23%	23%
Conservation Before Shortage	0%	15%	15%	16%	21%	23%	23%
Water Supply	0%	13%	15%	15%	21%	23%	23%
Reservoir Storage	0%	16%	17%	16%	22%	23%	23%

The threshold for water access to Rainbow Bridge is an elevation of 3,650 feet msl. Below this threshold elevation, access to Rainbow Bridge would require hiking. As shown in Figure 4.3-4, the Reservoir Storage Alternative had the lowest frequency of occurrences below this threshold, and the Water Supply Alternative had higher frequency of occurrences below elevation 3,650 feet msl relative to the No Action Alternative.

Figure 4.3-4
Lake Powell End-of-September Elevations
Comparison of Action Alternatives to No Action Alternative
Percent of Values Less Than or Equal to Elevation 3,650 feet msl

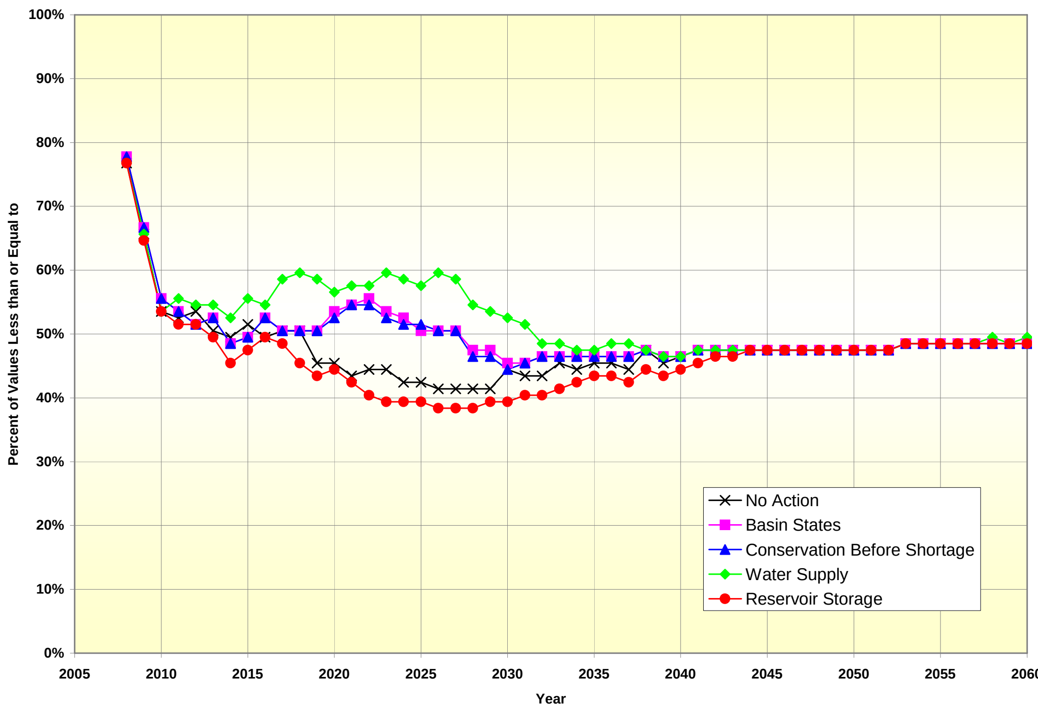


Table 4.3-3 summarizes the results shown in Figure 4.3-4 for elevation 3,650 feet msl for the No Action Alternative and the action alternatives for selected years. All alternatives were similar at the beginning and end of the modeled years, but variation did occur from about 2016 until about 2040. The water levels under the Reservoir Storage Alternative fell below elevation 3,650 feet msl less frequently than those under the No Action Alternative and the water levels under the Basin States, Conservation Before Shortage, and Water Supply alternatives fell below elevation 3,650 feet msl more frequently than those under the No Action Alternative.

Table 4.3-3
Lake Powell End-of-September Elevations
Comparison of Action Alternatives to No Action Alternative
Percent of Values Less Than or Equal to Elevation 3,650 feet msl

Alternatives	Year						
	2008	2016	2026	2030	2040	2050	2060
No Action	77%	49%	41%	44%	46%	47%	48%
Basin States	78%	53%	51%	45%	46%	47%	48%
Conservation Before Shortage	78%	53%	51%	44%	46%	47%	48%
Water Supply	77%	55%	60%	53%	46%	47%	49%
Reservoir Storage	77%	49%	38%	39%	44%	47%	48%

Figure 4.3-5 illustrates the results for elevations equal to or less than 3,626 feet msl. An elevation of 3,626 feet msl is the level at which there is a navigational detour at the Wahweap Marina and at Gregory Butte. As is shown on this figure, the Reservoir Storage Alternative had less impact on this threshold than the No Action Alternative. The elevations under the Water Supply, Basin States, and Conservation Before Shortage alternatives fell below elevation 3,626 feet msl more frequently than those under the No Action Alternative. All alternatives were similar by about 2053.

Figure 4.3-5
Lake Powell End-of-September Elevations
Comparison of Action Alternatives to No Action Alternative
Percent of Values Less Than or Equal to Elevation 3,626 feet msl

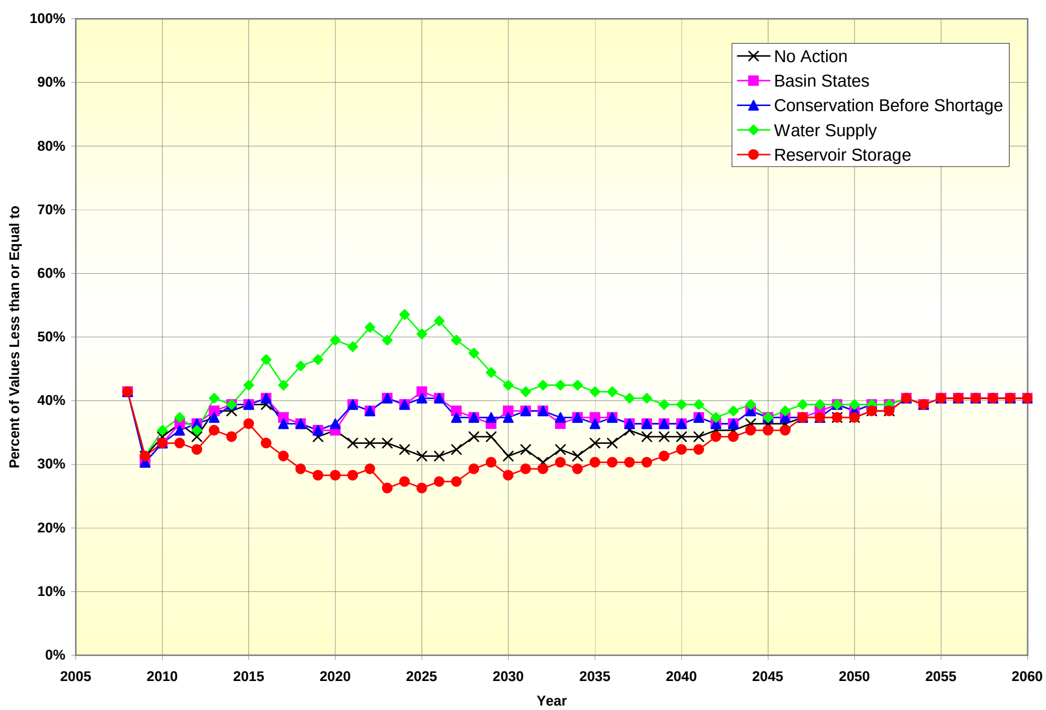


Table 4.3-4 summarizes the data illustrated in Figure 4.3-5 for elevation 3,626 feet msl. The water levels under the Reservoir Storage Alternative fell below elevation 3,626 feet msl less frequently than those under the No Action Alternative. The water levels under the Water Supply, Basin States, Conservation Before Shortage alternatives were observed to fall below elevation 3,626 feet msl more frequently than those under the No Action Alternative.

Table 4.3-4
Lake Powell End-of- September Elevations
Comparison of Action Alternatives to No Action Alternative
Percent of Values Less Than or Equal to Elevation 3,626 feet msl

Alternatives	Year						
	2008	2016	2026	2030	2040	2050	2060
No Action	41%	39%	31%	31%	34%	37%	40%
Basin States	41%	40%	40%	38%	36%	38%	40%
Conservation Before Shortage	41%	40%	40%	37%	36%	38%	40%
Water Supply	41%	46%	53%	42%	39%	39%	40%
Reservoir Storage	41%	33%	27%	28%	32%	37%	40%

Figure 4.3-6 compares the percent of values less than or equal to elevation 3,620 feet msl for the No Action Alternative and the action alternatives. Elevation 3,620 feet msl is the water level at which the Hite Marina, Hite Public Ramp, and Castle Rock Cut are closed. Lake Powell elevations under the Water Supply, Basin States, and Conservation Before Shortage alternative were observed to fall below elevation 3,620 feet msl more frequently than those under the No Action Alternative. The water levels under the Reservoir Storage Alternative fell below elevation 3,620 feet msl less frequently than those under the No Action Alternative for most of the modeled years.

Table 4.3-5 shows that all of the different action alternatives varied from the No Action Alternative from about 2016 until about 2040. All of the alternatives, including the No Action Alternative, fell below elevation 3,620 feet msl about 21 to 40 percent of the time.

Figure 4.3-6
Lake Powell End-of-September Elevations
Comparison of Action Alternatives to No Action Alternative
Percent of Values Less Than or Equal to Elevation 3,620 feet msl

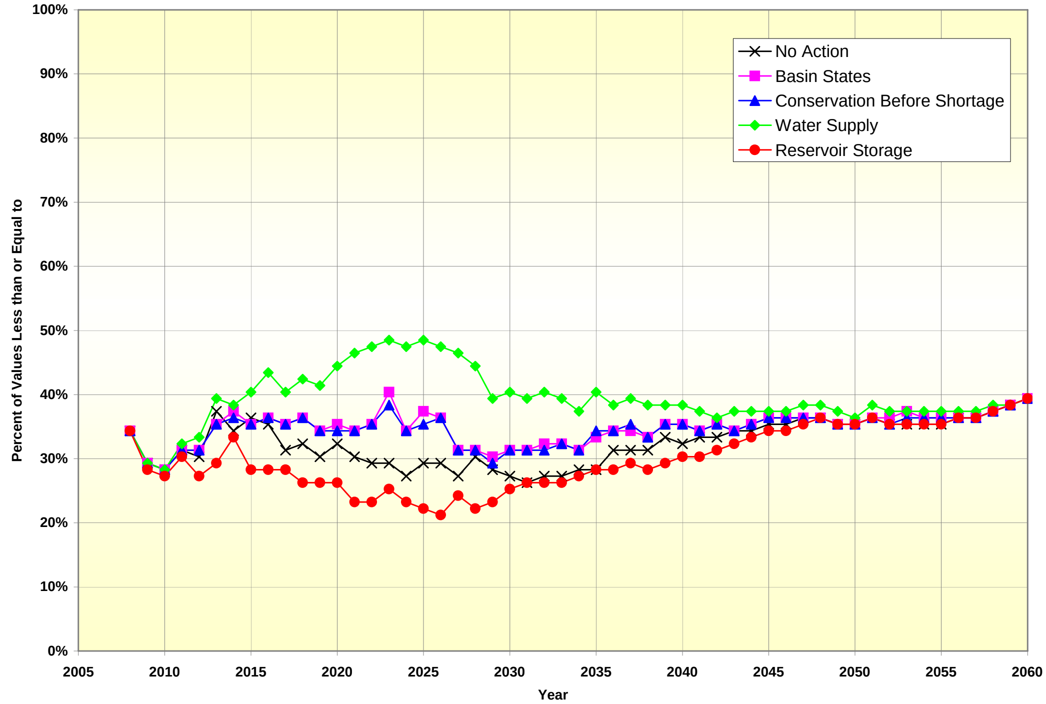


Table 4.3-5
Lake Powell End-of-September Elevations
Comparison of Action Alternatives to No Action Alternative
Percent of Values Less Than or Equal to Elevation 3,620 feet msl

Alternatives	Year						
	2008	2016	2026	2030	2040	2050	2060
No Action	34%	35%	29%	27%	32%	35%	39%
Basin States	34%	36%	36%	31%	35%	35%	39%
Conservation Before Shortage	34%	36%	36%	31%	35%	35%	39%
Water Supply	34%	43%	47%	40%	38%	36%	39%
Reservoir Storage	34%	28%	21%	25%	30%	35%	39%

Figure 4.3-7 compares the percent of values less than or equal to elevation 3,588 feet msl for the No Action Alternative and the action alternatives. When Lake Powell elevations are below 3,588 feet msl, the Antelope Point Public Launch Ramp is closed. The water levels under the Reservoir Storage Alternative were observed to fall below elevation 3,588 feet msl less frequently than those under the No Action Alternative for most of the modeled years. The water levels under the Water Supply, Basin States, and Conservation Before Shortage alternatives were observed to fall below elevation 3,588 feet msl more frequently than those under the No Action Alternative.

Figure 4.3-7
Lake Powell End-of-September Elevations
Comparison of Action Alternatives to No Action Alternative
Percent of Values Less Than or Equal to Elevation 3,588 feet msl

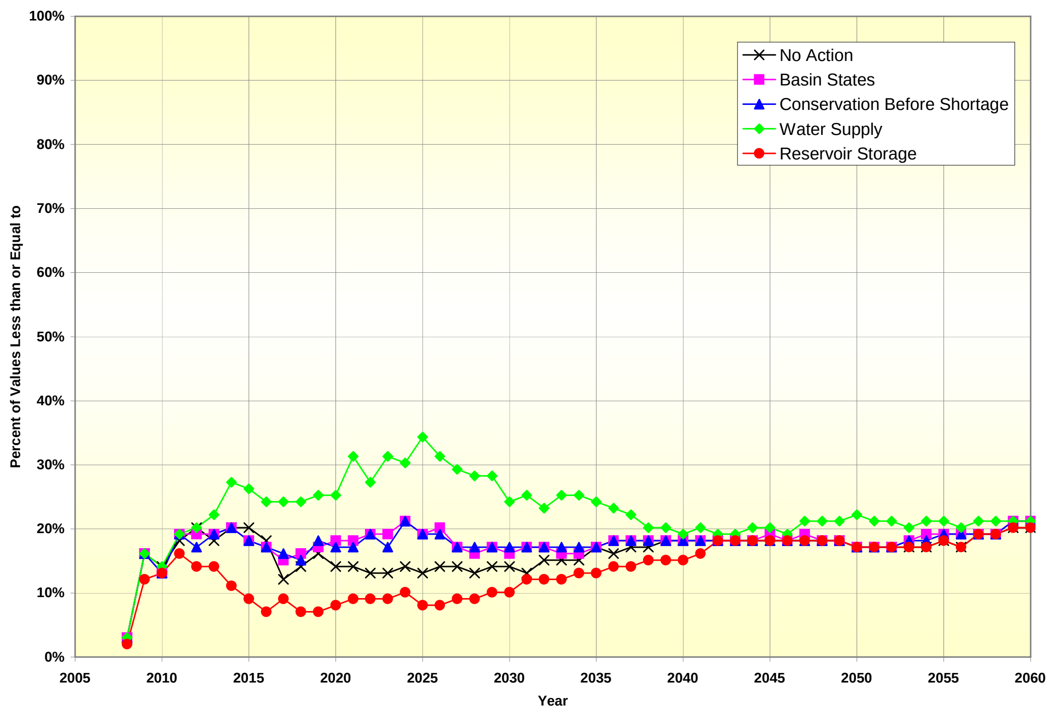


Table 4.3-6 provides a summary of the data illustrated in Figure 4.3-7 for an elevation of 3,588 feet msl. In general, elevations for all alternatives dropped below elevation 3,588 feet msl between 2 to 21 percent of the time. The exceptions are the water levels under the Water Supply Alternative which fell below elevation 3,588 feet msl between 3 to 31 percent of the time.

Table 4.3-6
Lake Powell End-of-September Elevations
Comparison of Action Alternatives to No Action Alternative
Percent of Values Less Than or Equal to Elevation 3,588 feet msl

Alternatives	Year						
	2008	2016	2026	2030	2040	2050	2060
No Action	3%	18%	14%	14%	18%	17%	20%
Basin States	3%	17%	20%	16%	18%	17%	21%
Conservation Before Shortage	3%	17%	19%	17%	18%	17%	21%
Water Supply	3%	24%	31%	24%	19%	22%	21%
Reservoir Storage	2%	7%	8%	10%	15%	17%	20%

Figure 4.3-8 compares the percent of values less than or equal to elevation 3,560 feet msl for the No Action Alternative and the action alternatives. Below an elevation of 3,560 feet msl, the Wahweap and Stateline Public Launch Ramps, the Bullfrog Low Water Alternative Launch Ramp, and the Halls Crossing Public Launch Ramps are closed. Results indicate that for all alternatives, the Lake Powell end-of-September elevations were lower than 3,560 feet msl between 0 to 12 percent of the time, with the exception of the Water Supply Alternative. The water levels under the Water Supply Alternative fell below elevation 3,560 feet msl as much as 20 percent of the time.

Table 4.3-7 provides a summary of the data illustrated in Figure 4.3-8 for elevation 3,560 feet msl. The water levels under the Water Supply Alternative fell below elevation 3,560 feet msl more frequently than those under the No Action Alternative. The water levels under the Reservoir Storage Alternative fell below elevation 3,560 feet msl less frequently than those under the No Action Alternative.

Figure 4.3-9 compares the percent of values equal to or less than elevation 3,555 feet msl for the No Action Alternative and the action alternatives. Below an elevation of 3,555 feet msl, the Wahweap, Antelope Point, Bullfrog, and Halls Crossing marinas are closed. Results indicate that for all alternatives, the Lake Powell end-of-September elevations were lower than 3,555 feet msl between 0 to 10 percent of the time. The exceptions are the water levels under the Water Supply Alternative which had elevations lower than 3,555 feet msl as much as 19 percent of the time.

Figure 4.3-8
Lake Powell End-of-September Elevations
Comparison of Action Alternatives to No Action Alternative
Percent of Values Less Than or Equal to Elevation 3,560 feet msl

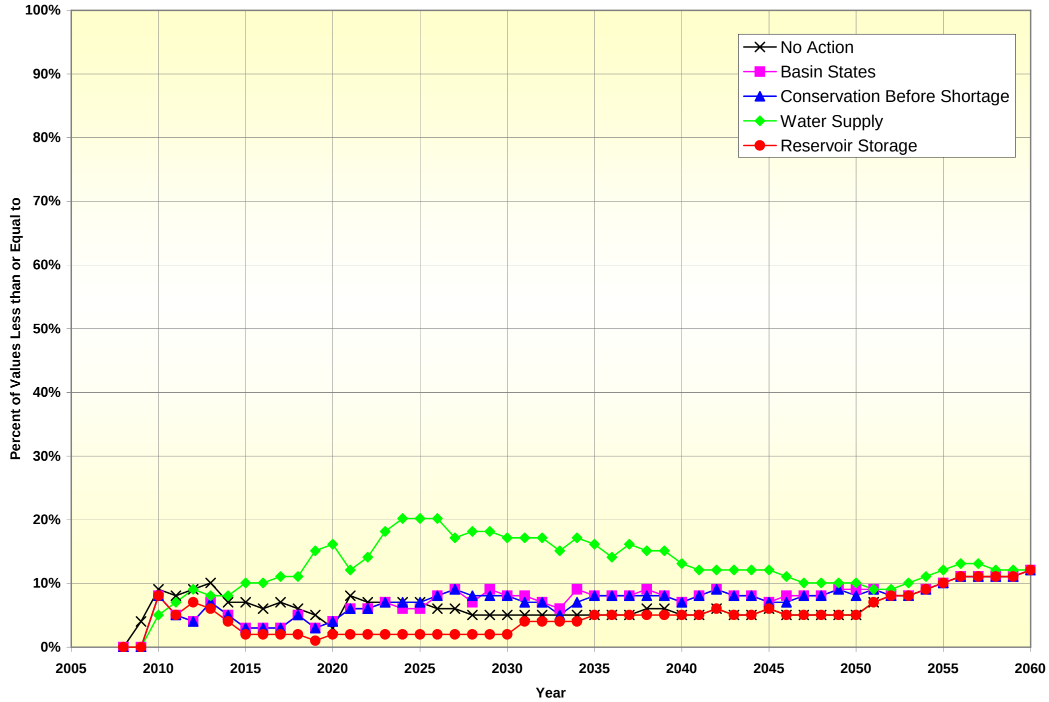


Table 4.3-7
Lake Powell End-of- September Elevations
Comparison of Action Alternatives to No Action Alternative
Percent of Values Less Than or Equal to Elevation 3,560 feet msl

Alternative	Year						
	2008	2016	2026	2030	2040	2050	2060
No Action	0%	6%	6%	5%	5%	5%	12%
Basin States	0%	3%	8%	8%	7%	9%	12%
Conservation Before Shortage	0%	3%	8%	8%	7%	8%	12%
Water Supply	0%	10%	20%	17%	13%	10%	12%
Reservoir Storage	0%	2%	2%	2%	5%	5%	12%

Figure 4.3-9
Lake Powell End-of-September Elevations
Comparison of Action Alternatives to No Action Alternative
Percent of Values Less Than or Equal to Elevation 3,555 feet msl

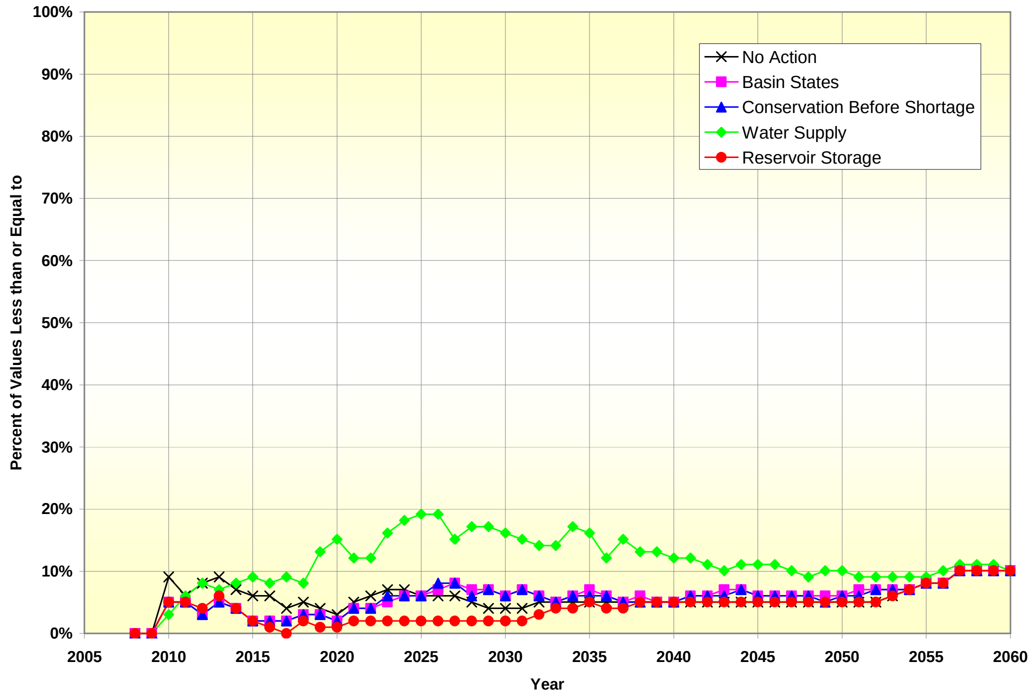


Table 4.3-8 provides a summary of the data illustrated in Figure 4.3-9 for elevation 3,555 feet msl. The water levels under the Water Supply Alternative fell below elevation 3,555 feet msl more frequently than those under the No Action Alternative. The water levels under the Reservoir Storage Alternative fell below elevation 3,555 feet msl less frequently than those under the No Action Alternative through year 2030 and thereafter, the values were similar.

Table 4.3-8
Lake Powell End-of-September Elevations
Comparison of Action Alternatives to No Action Alternative
Percent of Values Less Than or Equal to Elevation 3,555 feet msl

Alternative	Year						
	2008	2016	2026	2030	2040	2050	2060
No Action	0%	6%	6%	4%	5%	5%	10%
Basin States	0%	2%	7%	6%	5%	6%	10%
Conservation Before Shortage	0%	2%	8%	6%	5%	6%	10%
Water Supply	0%	8%	19%	16%	12%	10%	10%
Reservoir Storage	0%	1%	2%	2%	5%	5%	10%

Figure 4.3-10 compares the percent of values equal to or less than 3,550 feet msl for the No Action Alternative and the action alternatives. Below this elevation, the operation of the John Atlantic Burr Ferry may be affected. The Lake Powell end-of-September elevations under all of the alternatives were lower than 3,550 feet msl infrequently, ranging between zero to 10 percent. The exception to this was the Water Supply Alternative, which had water levels that fell below elevation 3,550 feet msl as much as 18 percent of the time. The water levels under the Reservoir Storage, Basin States, and Conservation Before Shortage Alternatives were all very similar to those under the No Action Alternative throughout the period of analysis.

Figure 4.3-10
Lake Powell End-of-September Elevations
Comparison of Action Alternatives to No Action Alternative
Percent of Values Less Than or Equal to Elevation 3,550 feet msl

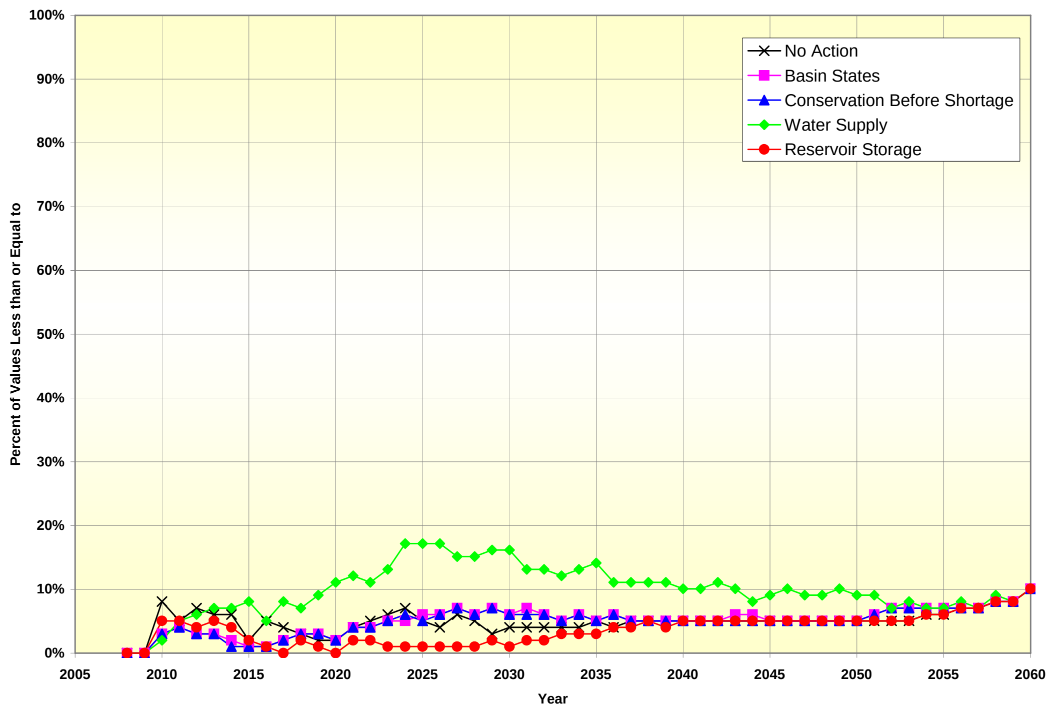


Table 4.3-9 provides a summary of the data illustrated in Figure 4.3-10 and shows that the water levels under the Basin States, Conservation Before Shortage, and Reservoir Storage alternatives were generally within the same range as those under the No Action Alternative. The water levels under the Water Supply Alternative fell below elevation 3,550 feet msl most frequently compared to the other alternatives, as much as 17 percent of the time.

Table 4.3-9
Lake Powell End-of-September Elevations
Comparison of Action Alternatives to No Action Alternative
Percent of Values Less Than or Equal to Elevation 3,550 feet msl

Alternatives	Year						
	2008	2016	2026	2030	2040	2050	2060
No Action	0%	5%	4%	4%	5%	5%	10%
Basin States	0%	1%	6%	6%	5%	5%	10%
Conservation Before Shortage	0%	1%	6%	6%	5%	5%	10%
Water Supply	0%	5%	17%	16%	10%	9%	10%
Reservoir Storage	0%	1%	1%	1%	5%	5%	10%

Figure 4.3-11 compares the percent of values for Lake Powell end-of-March elevations that were less than or equal to an elevation of 3,490 feet msl, the minimum power pool for Lake Powell and the Glen Canyon Powerplant, between the No Action Alternative and the action alternatives. The figure shows that the Lake Powell end-of-March elevation fell below 3,490 feet msl under the No Action, Basin States, Conservation Before Shortage, and Reservoir Storage alternatives very infrequently. The Lake Powell end-of-March elevations under the Water Supply Alternative were observed to fall below 3,490 feet msl more frequently than those under the No Action Alternative, with the differences being as high as seven percent.

Figure 4.3-11
Lake Powell End-of-March Elevations
Comparison of Action Alternatives to No Action Alternative
Percent of Values Less Than or Equal to Elevation 3,490 feet msl

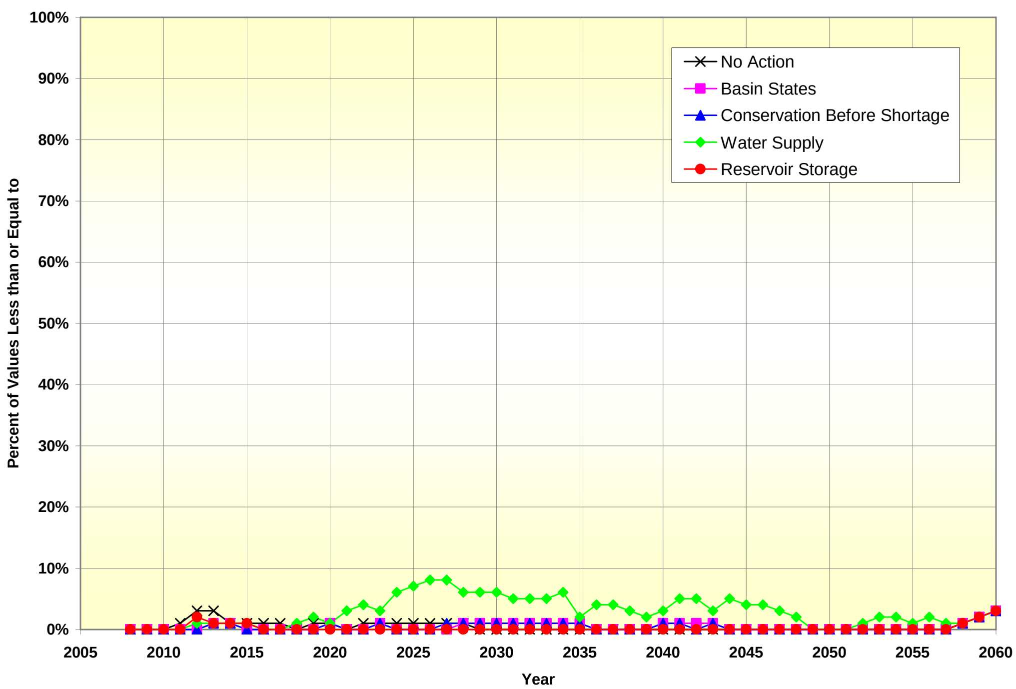


Table 4.3-10 provides a summary of the data illustrated in Figure 4.3-11 for elevation 3,490 feet msl. As show on this table, the water levels under all of the alternatives, with the exception of the Water Supply Alternative, fell below elevation 3,490 feet msl less than three percent of the time.

Table 4.3-10
Lake Powell End-of-March Elevations
Comparison of Action Alternatives to No Action Alternative
Percent of Values Less Than or Equal to Elevation 3,490 feet msl

Alternatives	Year						
	2008	2016	2026	2030	2040	2050	2060
No Action	0%	1%	1%	0%	0%	0%	3%
Basin States	0%	0%	0%	1%	1%	0%	3%
Conservation Before Shortage	0%	0%	0%	1%	1%	0%	3%
Water Supply	0%	0%	8%	6%	3%	0%	3%
Reservoir Storage	0%	0%	0%	0%	0%	0%	3%

4.3.3 Glen Canyon Dam to Lake Mead

The river flows that occur between Glen Canyon Dam and Lake Mead result mostly from controlled releases from Glen Canyon Dam (Lake Powell). The gains from tributaries in this reach on average are less than three percent of the total inflow, are concentrated over very short periods of time, and will not be affected by the proposed federal action. As noted in Section 3.3, future annual and monthly releases may be affected by the proposed federal action. However, each alternative may alter the probability (when compared to the No Action Alternative) of the magnitude and timing of particular releases.

Table 4.3-11 provides a comparison of the relative frequency of occurrence of annual releases from Lake Powell under the No Action Alternative and the action alternatives, during the period between 2009 through 2060. The reported values are water year values. Releases greater than 9.0 maf generally correspond to years where either equalization or spill avoidance releases are made from Lake Powell. As is shown, the most frequently occurring releases for all alternatives are 8.23 maf. Releases less than the annual minimum objective release of 8.23 maf occurred less than one percent of the time under the No Action Alternative, approximately 3.7 percent under the Basin States, Conservation Before Shortage, and Water Supply alternatives, and approximately six percent under the Reservoir Storage Alternative. Releases greater than the annual minimum objective release of 8.23 maf occurred approximately 35.5 percent under the No Action Alternative, approximately 42.4 percent under the Basin States, Conservation Before Shortage, and Water Supply alternatives, and approximately 36.67 percent under the Reservoir Storage Alternative.

Table 4.3-11
Glen Canyon Dam Water Year Releases
Probability of Occurrence of Different Size Annual Releases
Comparison of Action Alternatives to No Action Alternative
Water Years 2009 through 2060

	Alternative				
Glen Canyon Dam Release Volumes	No Action	Basin States	Conservation Before Shortage	Water Supply	Reservoir Storage
Greater than 9.00 mafy	29.80%	35.53%	35.53%	36.67%	30.94%
Between 8.51 to 9.00 mafy	3.44%	4.58%	4.58%	3.44%	3.44%
Between 8.24 to 8.50 mafy	2.29%	2.29%	2.29%	2.29%	2.29%
Minimum Objective Release of 8.23 mafy	64.18%	53.87%	53.87%	53.87%	57.30%
Between 7.51 to 8.22 mafy	0.27%	0.00%	0.00%	1.15%	6.00%
Between 7.0 to 7.50 mafy	0.00%	3.71%	3.71%	2.56%	0.00%
Less than 7.0 mafy	0.00%	0.00%	0.00%	0.00%	0.00%
Total	100.0%	100.0%	100.0%	100.0%	100.0%

Figure 4.3-12 presents a comparison of the 90th, 50th, and 10th percentile values observed under the action alternatives to those under the No Action Alternative. As illustrated in Figure 4.3-12, the 90th percentile values under all of the alternatives fluctuate and range between 12.0 mafy to about 13.4 mafy, primarily due to spill avoidance releases. For the 50th percentile values, the Reservoir Storage Alternative and the No Action Alternatives are nearly identical, with consistent releases of 8.23 maf. The Basin States, Conservation Before Shortage, and Water Supply alternatives show releases greater than the minimum objective release of 8.23 maf, up to 9.5 maf, a result of balancing or equalization releases. The 10th percentile values showed that the Water Supply Alternative varied only in the initial three years, providing slightly lower releases than the No Action Alternative. The Basin States and Conservation Before Shortage alternatives also provided slightly lower annual release volumes than the No Action Alternative through the year 2016. The 10th percentile values for releases under the Reservoir Storage Alternative are not as low as those of the other action alternatives but are slightly lower than those of the No Action Alternative and extend through 2026.

Figure 4.3-12
Glen Canyon Dam Water Year Releases
Comparison of Action Alternatives to No Action Alternative
90th, 50th, and 10th Percentile Values

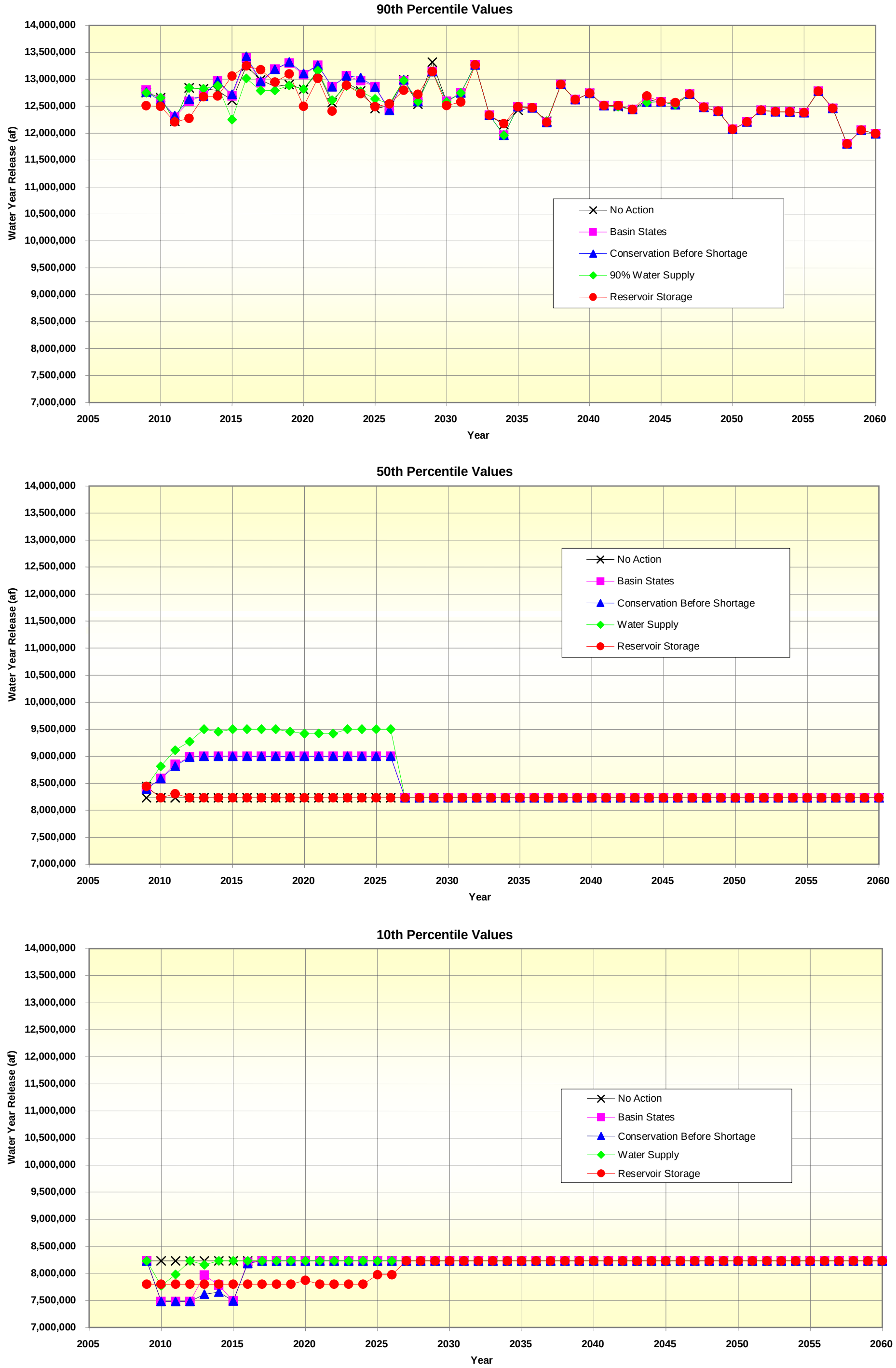
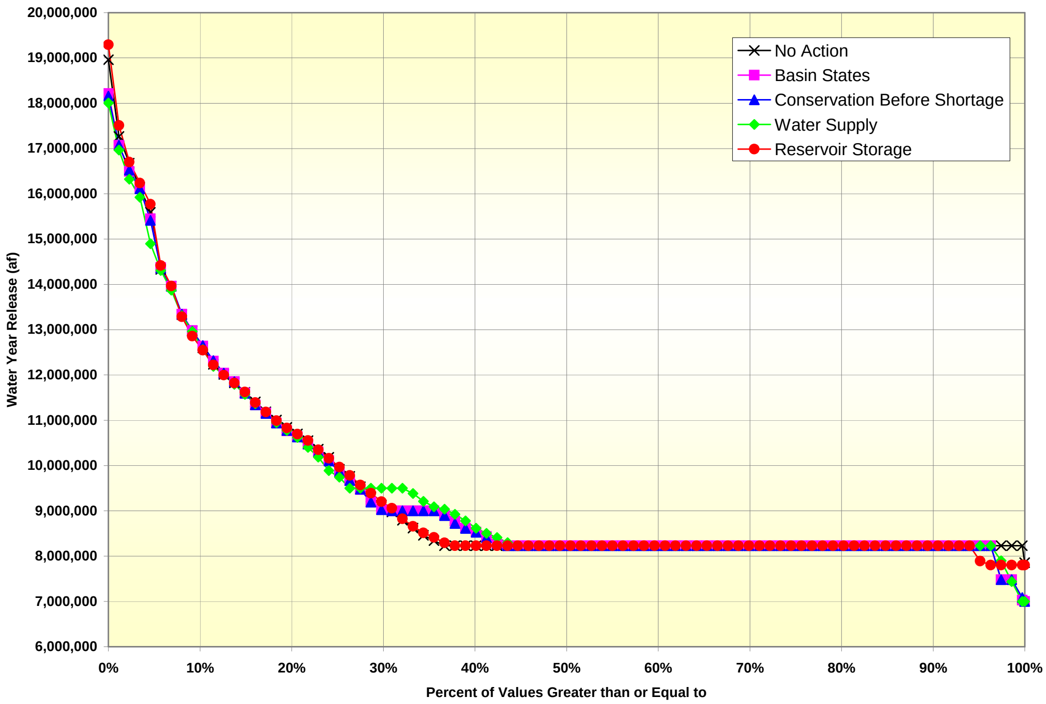


Figure 4.3-13 illustrates the cumulative distribution of the Glen Canyon Dam water year releases under the No Action Alternative and the action alternatives for the modeling period 2009 through 2060. This figure provides a means for comparing the frequency that the minimum objective release of 8.23 maf is made under the different alternatives as well as identifying the frequency and magnitude of Glen Canyon Dam releases above and below the minimum objective release of 8.23 maf. As illustrated in Figure 4.3-13, the minimum objective release of 8.23 maf in all alternatives is met or exceeded 95 percent or more of the time.

Figure 4.3-13
Glen Canyon Dam Water Year Releases
Comparison of Action Alternatives to No Action Alternative
Water Years 2009 through 2060



4.3.3.1 Effect of Glen Canyon Dam Annual Releases on Daily River Flows Below Glen Canyon Dam

As illustrated in Figure 4.3-13, the primary difference among alternatives in Glen Canyon Dam releases occurs in years when balancing of Lake Powell and Lake Mead occurs (between the 30th and 40th percentiles) and when releases are constrained at specific Lake Powell elevations (between the 95th to 100th percentiles). These circumstances occur relatively infrequently and the majority of future releases under any alternative is expected to be 8.23 maf or higher. However, in order to assess potential impacts from departures from the No Action Alternative, Tables 4.3-12 through 4.3-14 are presented to illustrate most probable daily flow characteristics for various annual releases ranging from 7.0 to 9.5 maf. These tables provide a means for comparing the average, minimum, and maximum flows that could be expected under the different Glen Canyon Dam release volumes observed in the modeling of the different alternatives.

Table 4.3-12
Average Daily Glen Canyon Dam Releases (cfs)
Corresponding to Various Annual Release Volumes

	7.0 maf	7.48 maf	7.8 maf	8.23 maf	9.0 maf	9.5 maf
Oct	9,758	7,806	9,758	9,758	9,758	9,758
Nov	10,083	8,403	10,083	10,083	10,083	10,083
Dec	13,011	9,758	9,758	13,011	13,011	13,011
Jan	10,717	13,011	13,011	13,011	13,011	13,824
Feb	9,771	10,804	10,804	10,804	11,704	11,704
Mar	7,354	9,758	9,758	9,758	10,571	10,571
Apr	7,599	8,403	10,083	10,083	10,083	10,924
May	7,354	9,758	9,758	9,758	10,571	13,011
Jun	9,119	10,083	10,083	10,924	13,444	15,125
Jul	11,767	13,011	13,011	13,824	16,263	17,077
Aug	11,767	13,011	13,011	14,637	17,077	17,890
Sep	7,599	10,083	10,083	10,588	13,444	14,285

Table 4.3-13
Minimum Hourly Glen Canyon Dam Release (cfs)
Corresponding to Various Annual Release Volumes

	7.0 maf	7.48 maf	7.8 maf	8.23 maf	9.0 maf	9.5 maf
Oct	6,458	5,006	6,458	6,458	6,458	6,458
Nov	6,783	5,603	6,783	6,783	6,783	6,783
Dec	8,711	6,458	6,458	8,711	8,711	8,711
Jan	7,417	8,711	9,711	8,711	8,711	9,524
Feb	6,971	7,504	7,504	7,504	8,404	8,404
Mar	5,000	6,458	6,458	6,458	7,271	7,271
Apr	5,000	5,603	6,783	6,783	6,783	7,624
May	5,000	6,458	6,458	6,458	7,271	8,711
Jun	6,319	6,783	6,783	7,624	9,144	10,825
Jul	8,467	8,711	8,711	9,524	11,963	12,777
Aug	8,467	8,711	8,711	10,337	12,777	13,590
Sep	5,000	6,783	6,783	7,288	9,144	9,985

Table 4.3-14
Maximum Hourly Glen Canyon Dam Release (cfs)
Corresponding to Various Annual Release Volumes

	7.0 maf	7.48 maf	7.8 maf	8.23 maf	9.0 maf	9.5 maf
Oct	12,458	10,006	12,458	12,458	12,458	12,458
Nov	12,783	10,603	12,783	12,783	12,783	12,783
Dec	16,711	12,458	12,458	16,711	16,711	16,711
Jan	13,417	16,711	15,711	16,711	16,711	17,524
Feb	11,971	13,504	13,504	13,504	14,404	14,404
Mar	10,000	12,458	12,458	12,458	13,271	13,271
Apr	10,000	10,603	12,783	12,783	12,783	13,624
May	10,000	12,458	12,458	12,458	13,271	16,711
Jun	11,319	12,783	12,783	13,624	17,144	18,825
Jul	14,467	16,711	16,711	17,524	19,963	20,777
Aug	14,467	16,711	16,711	18,337	20,777	21,590
Sep	10,000	12,783	12,783	13,288	17,144	17,985

Table 4.3-12 provides a listing of the average flow for the month that would occur under the various annual releases. Tables 4.3-13 and 4.3-14 provide listings of the minimum and maximum hourly flow from Glen Canyon Dam under the various annual releases when the parameters of the 1996 Glen Canyon Dam ROD (Section 3.3) are applied to the monthly volumes.

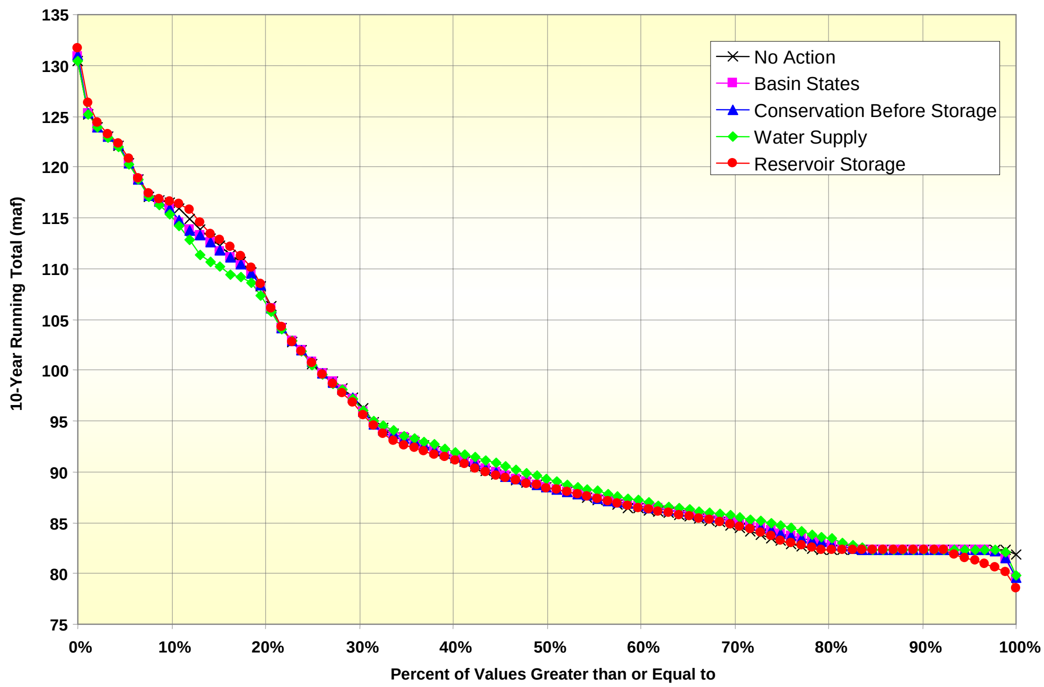
The monthly release values listed in Table 4.3-12 for the months of October, November and December in the 7.0 maf column are identical to monthly releases in 8.23 maf years. This occurs because the operation is governed by balancing releases between Lake Powell and Lake Mead in 7.0 maf years and the first inflow forecast for the upcoming year is not available until January. Beginning in January and continuing through the remainder of the water year, monthly releases from Lake Powell in 7.0 maf years are adjusted to balance volumes between Lake Powell and Lake Mead. It should also be noted that the variability in forecasts and different levels of Lake Powell and Lake Mead in 7.0 maf years result in there not being a consistent monthly pattern for these years, as opposed to the other years in the table where the monthly pattern is more predictable. The 7.0 maf pattern shown in Table 4.3-13 represents Trace 91 for water year 2014 from the Water Supply Alternative.

These hourly releases are needed in order to analyze potential downstream impacts to water quality and other resources.

4.3.3.2 10-year Running Total of Glen Canyon Dam Releases

Figure 4.3-14 compares the 10-year running totals of the Glen Canyon Dam water year releases (10-year running total) under the action alternatives to the No Action Alternative. The values used to compute the 10-year running total for the years between 2008 through 2017 included a combination of historical values (for years prior to 2006), projections from the 24-month study (for years 2006 and 2007), and output from the CRSS model (for years 2008 and later). As noted in Section 4.2, the 24-month study was used to project the starting conditions for the reservoir levels for January 1, 2008.

Figure 4.3-14
Glen Canyon Dam 10-Year Running Total of Annual Releases
Comparison of Action Alternatives to No Action Alternative
Years 2008 through 2060



The upper limit of the 10-year running total was similar under the No Action Alternative and the action alternatives and equaled approximately 131 maf. The 10-year running total under all of the alternatives, including the No Action Alternative, was always above 75 maf.

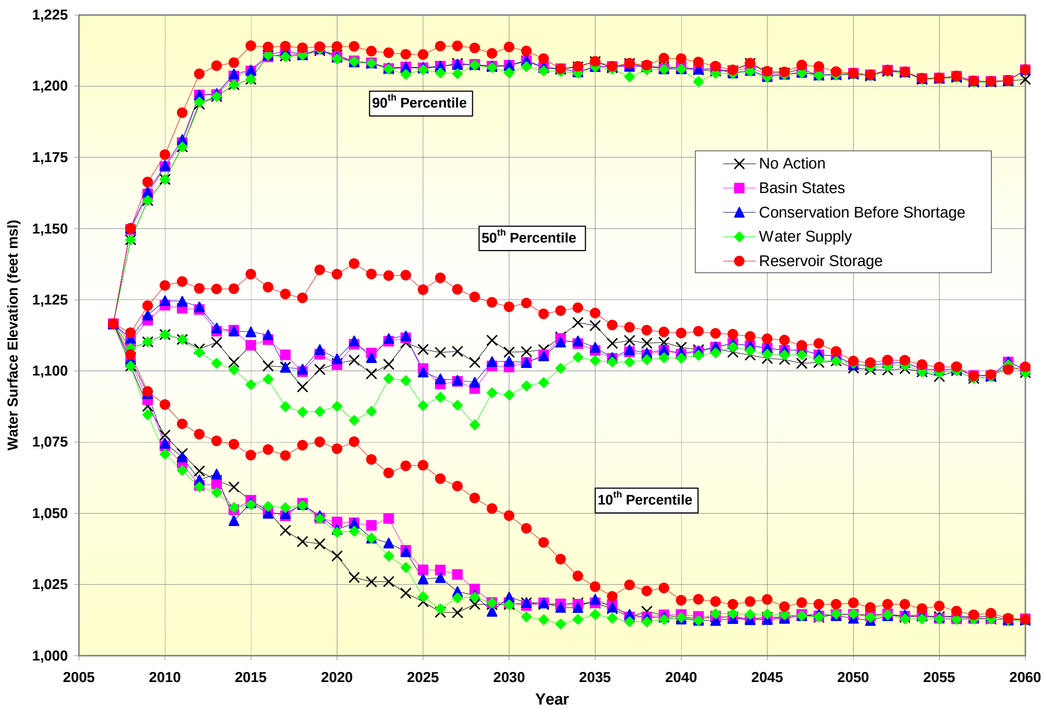
The 10-year running total under the No Action Alternative was less than 8.23 maf less than one percent of the years with a minimum value of 81.9 maf. The 10-year running total under the Basin States and Conservation Before Shortage alternatives was less than 82.3 maf in approximately two percent of the years and the minimum value was 79.6 maf. The 10-year running total under the Water Supply Alternative was less than 82.3 maf in only one percent of the years and the minimum value was 79.8 maf. The 10 year running total under the Reservoir Storage Alternative was less than 82.3 maf in approximately 6.7 percent of the years and the minimum value was 78.5 maf.

4.3.4 Lake Mead and Hoover Dam

As noted in Section 3.3, future elevations of Lake Mead are expected to be within the range of historic water levels. However, each alternative may alter the probability (when compared to the No Action Alternative) that the reservoir may be at a given elevation in the future.

Figure 4.3-15 presents a comparison of the 90th, 50th, and 10th percentile values observed for the action alternatives to those under the No Action Alternative. Under the No Action Alternative, the elevation of Lake Mead was projected to fluctuate between full (1,219.6 feet msl) and lower water during the period of analysis (2008 through 2060). The 90th percentile line increases from starting conditions to nearly full pool, about elevation 1,212 feet msl. The median water level values (50th percentile) under the No Action Alternative fluctuated between approximately 1,100 feet msl to approximately 1,120 feet msl between 2008 and 2035. The 10th percentile values show a declining trend between 2008 and 2025, from about 1,101 feet msl to about 1,018 feet msl.

Figure 4.3-15
Lake Mead End-of-December Elevations
Comparison of Action Alternatives to No Action Alternative
90th, 50th, and 10th Percentile Values



All action alternatives showed similar 90th percentile values compared to the No Action Alternative. It should be noted that the Lake Mead elevations depicted in Figure 4.3-15 represent water levels at the end of December which is when lake levels are typically at a seasonal high. Conversely, the Lake Mead water level generally reaches its annual low in July.

The Basin States and Conservation Before Shortage alternatives had slightly higher 50th percentile values than the No Action Alternative between 2008 through 2024, then dropped below those of the No Action Alternative between 2025 and about 2041, and thereafter were similar. The Water Supply Alternative had lower 50th percentile values than the No Action Alternative between 2012 through 2041, and thereafter were similar. Conversely, the Reservoir Storage Alternative had higher 50th percentile values than the No Action. During the interim period, the 10th percentile values for the Basin States, Conservation Before Shortage, and Water Supply alternatives are higher than the No Action Alternative, and the values for the Reservoir Storage Alternative are significantly higher than the No Action.

Table 4.3-15 provides a summary of the data illustrated in Figure 4.3-15 which reflects the 90th, 50th, and 10th percentile values observed under the No Action Alternative and the action alternatives. The values presented in this table include those for years 2026 and 2060 only. The 90th, 50th, and 10th percentile values under the action alternatives differ from the No Action Alternative to some extent in year 2026 and at very insignificant levels in year 2060.

Table 4.3-15
Lake Mead End-of-December Elevations (feet msl)
Comparison of Action Alternatives to No Action Alternative
90th , 50th , and 10th Percentile Values

Alternative	Year 2026			Year 2060		
	90th Percentile	50th Percentile	10th Percentile	90th Percentile	50th Percentile	10th Percentile
No Action	1,206.87	1,106.50	1,015.31	1,202.39	1,099.41	1,012.44
Basin States	1,207.05	1,095.39	1,030.07	1,205.79	1,100.55	1,012.95
Conservation Before Shortage	1,207.05	1,097.22	1,027.39	1,205.79	1,100.55	1,012.70
Water Supply	1,204.72	1,090.78	1,016.47	1,205.59	1,099.41	1,012.42
Reservoir Storage	1,214.05	1,132.64	1,062.16	1,205.80	1,101.47	1,012.75

The 90th percentile values in year 2026 vary little between the action alternatives and the No Action Alternative. The exception to this is the Reservoir Storage Alternative which is approximately seven feet higher than that of the No Action Alternative.

The 50th percentile values for the Basin States, Conservation Before Shortage, and Water Supply alternatives in year 2026 are approximately 11, 9, and 15 feet lower than that of the No Action Alternative, respectively. In contrast, the 50th percentile value for the Reservoir Storage Alternative in year 2026 is approximately 26 feet higher than that of the No Action Alternative.

The 10th percentile values for the Basin States, Conservation Before Shortage, Water Supply, and Reservoir Storage alternatives were all higher than that of No Action Alternative in year 2026 as shown on Table 4.3-15. The greatest difference observed occurs between the Reservoir Storage Alternative and No Action Alternative which is about 47 feet.

Figure 4.3-16 illustrates the results for exceedence values above an elevation of 1,200 feet msl, nearly the full pool elevation of Lake Mead. All of the action alternatives were very similar to the No Action Alternative throughout the modeled years, with exceedence values ranging between zero to 20 percent.

Figure 4.3-16
Lake Mead End-of-December Elevations
Comparison of Action Alternatives to No Action Alternative
Percent of Values Greater Than or Equal to Elevation 1,200 feet msl

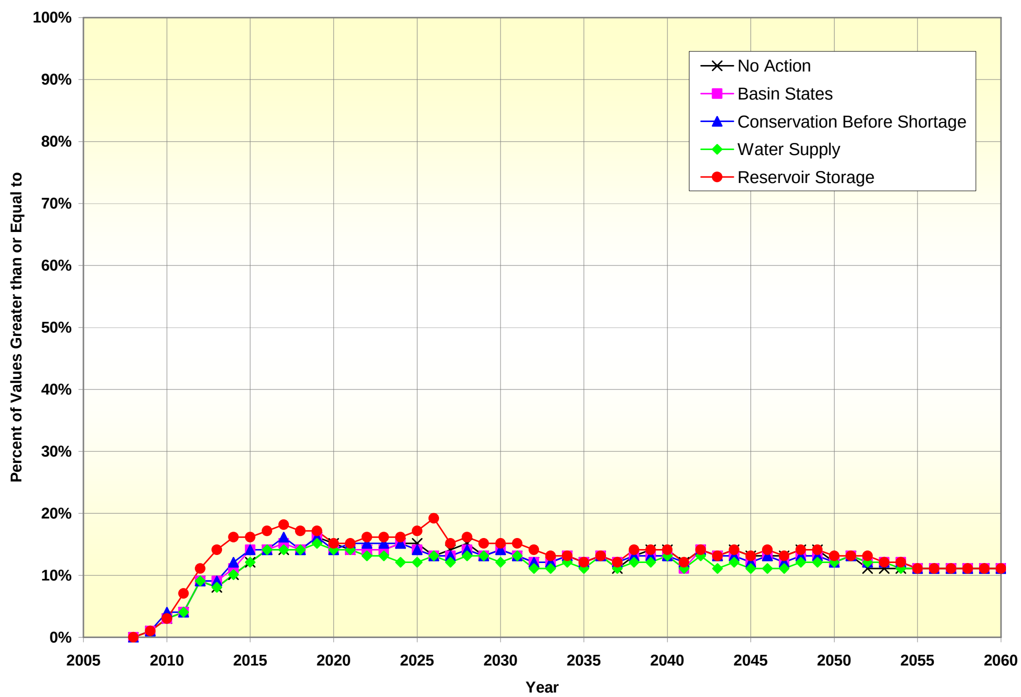


Table 4.3-16 provides a summary of the exceedence values for elevation 1,200 feet msl for selected years. As listed in this table, the exceedence values for the alternatives are similar, although the Reservoir Storage Alternative provides slightly higher exceedence values.

Table 4.3-16
Lake Mead End-of- December Elevations
Comparison of Action Alternatives to No Action Alternative
Percent of Values Greater Than or Equal to Elevation 1,200 feet msl

Alternatives	Year						
	2008	2016	2026	2030	2040	2050	2060
No Action	0%	14%	13%	14%	14%	12%	11%
Basin States	0%	14%	13%	14%	13%	12%	11%
Conservation Before Shortage	0%	14%	13%	14%	13%	12%	11%
Water Supply	0%	14%	13%	12%	13%	12%	11%
Reservoir Storage	0%	17%	19%	15%	14%	13%	11%

Figure 4.3-17 illustrates the frequency that future Lake Mead end-of-December elevations would drop below elevation 1,178 feet msl. Lake Mead elevations of 1,178 feet msl and 1,000 feet msl were used by the Clean Water Coalition as reference elevations for its Lake Mead water quality analysis (Systems Conveyance and Operations Program Final Environmental Impact Statement [SCOP FEIS] October 2006). The SCOP FEIS analyzed water quality changes corresponding to Lake Mead elevation drawdown from 1,178 feet msl to 1,000 feet msl. These potential Lake Mead water quality changes are discussed in Section 4.5. As shown in Figure 4.3-17, the results for the Basin States and Conservation Before Shortage alternatives are similar to those of the No Action Alternative. The water levels under the Reservoir Storage Alternative were observed to fall below elevation 1,178 feet msl less frequently than those under the No Action Alternative. The water levels under the Water Supply Alternative were observed to fall below elevation 1,178 feet msl more frequently than those under the No Action Alternative.

Table 4.3-17 provides a summary of the results illustrated in Figure 4.3-17 for elevation 1,178 feet msl in tabular form for selected years. As shown in Table 4.3-17, the water levels under the Basin States and Conservation Before Shortage alternatives are similar to those under the No Action Alternative. The water levels under the Reservoir Storage Alternative fell below elevation 1,178 feet msl less frequently than those under the No Action Alternative. The water levels under the Water Supply Alternative fell below elevation 1,178 feet msl more frequently than those under the No Action Alternative.

Figure 4.3-17
Lake Mead End-of-December Elevations
Comparison of Action Alternatives to No Action Alternative
Percent of Values Less Than or Equal to Elevation 1,178 feet msl

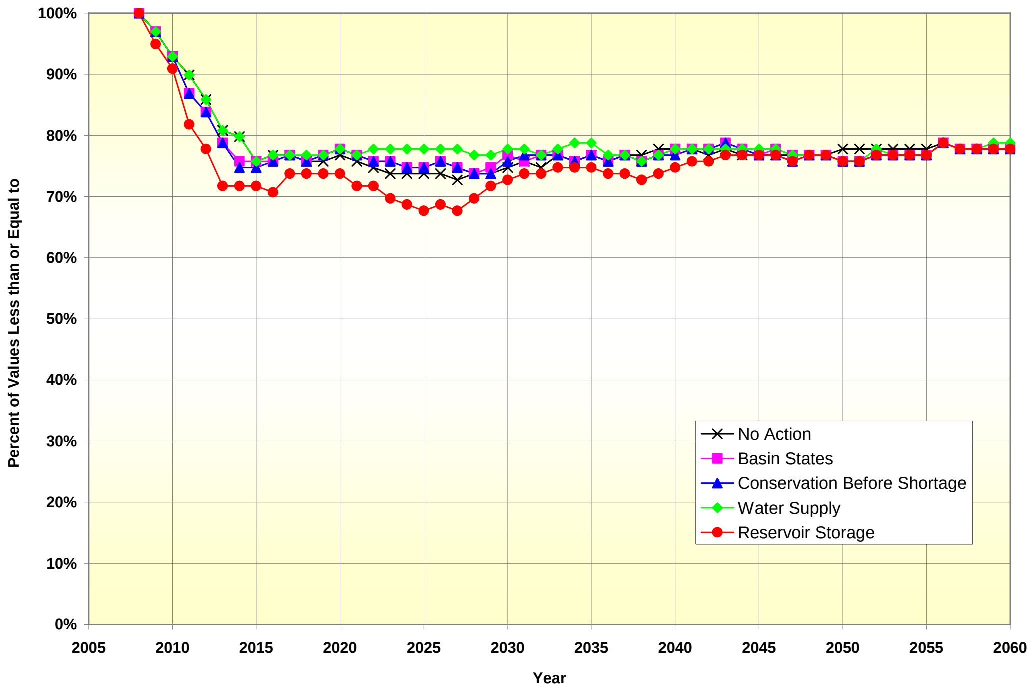


Table 4.3-17
Lake Mead End-of-December Water Elevations
Comparison of Action Alternatives to No Action Alternative
Percent of Values Less than or Equal to Elevation 1,178 feet msl

Alternatives	Year						
	2008	2016	2026	2030	2040	2050	2060
No Action	100%	77%	74%	75%	78%	78%	78%
Basin States	100%	76%	76%	77%	78%	76%	78%
Conservation Before Shortage	100%	76%	76%	76%	77%	76%	78%
Water Supply	100%	77%	78%	78%	78%	76%	79%
Reservoir Storage	100%	71%	69%	73%	75%	76%	78%

Figure 4.3-18 illustrates the frequency that future Lake Mead end-of-July elevations would drop below elevation 1,175 feet msl. Below this elevation, the Pearce Bay Launch Ramp is closed and whitewater boaters must paddle an additional 16 miles to South Cove. As illustrated in Figure 4.3-18, the results for the Basin States, Conservation Before Shortage, and Water Supply alternatives are similar to those of the No Action Alternative. The water levels under the Reservoir Storage Alternative were observed to fall below elevation 1,175 feet msl less frequently than those under the No Action Alternative.

Figure 4.3-18
Lake Mead End-of-July Elevations
Comparison of Action Alternatives to No Action Alternative
Percent of Values Less Than or Equal to Elevation 1,175 feet msl

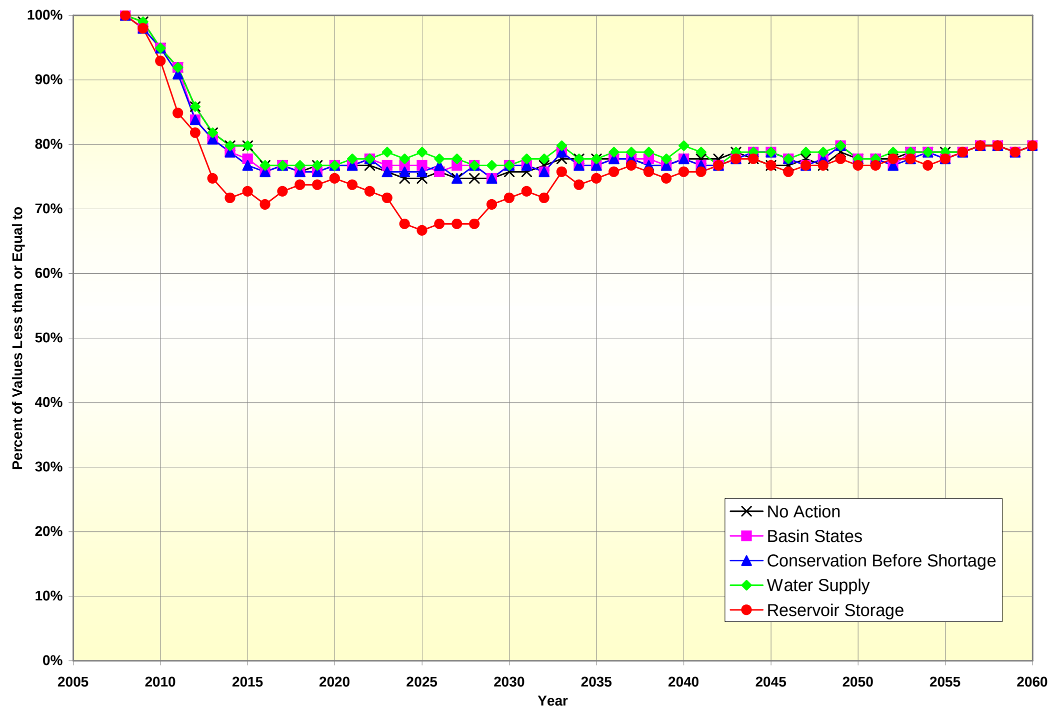


Table 4.3-18 provides a summary of the results illustrated in Figure 4.3-18 for elevation 1,175 feet msl for selected years. As shown in Table 4.3-18, the water levels under the Basin States, Conservation Before Shortage, and Water Supply alternatives are similar to those under the No Action Alternative. The water levels under the Reservoir Storage Alternative fell below elevation 1,175 feet msl less frequently than those under the No Action Alternative through about 2040.

Table 4.3-18
Lake Mead End-of-July Elevations
Comparison of Action Alternatives to No Action Alternative
Percent of Values Less Than or Equal to Elevation 1,175 feet msl

Alternatives	Year						
	2008	2016	2026	2030	2040	2050	2060
No Action	100%	77%	76%	76%	78%	78%	80%
Basin States	100%	76%	76%	77%	78%	78%	80%
Conservation Before Shortage	100%	76%	77%	77%	78%	78%	80%
Water Supply	100%	77%	78%	77%	80%	78%	80%
Reservoir Storage	100%	71%	68%	72%	76%	77%	80%

Figure 4.3-19 illustrates the frequency that Lake Mead end-of-July elevations would fall below elevation 1,170 feet msl. This Lake Mead elevation is the minimum water level needed to maintain navigation between Grand Wash and Pearce Ferry. At water levels below 1,170 feet msl, potential sediment aggradation could potentially impair navigation between these two locations. As illustrated in Figure 4.3-19, the results for the Basin States and Conservation Before Shortage alternatives are similar to those observed under the No Action Alternative. The water levels under the Water Supply alternative were observed to fall below elevation 1,170 feet msl more frequently than those under the No Action Alternative between 2019 and 2033. The water levels under the Reservoir Storage Alternative were observed to fall below elevation 1,170 feet msl less frequently than those under the No Action Alternative.

Table 4.3-19 provides a summary of the results illustrated in Figure 4.3-19 for the Lake Mead end-of-July elevation of 1,170 feet msl for selected years.

Figure 4.3-19
Lake Mead End-of-July Elevations
Comparison of Action Alternatives to No Action Alternative
Percent of Values Less Than or Equal to Elevation 1,170 feet msl

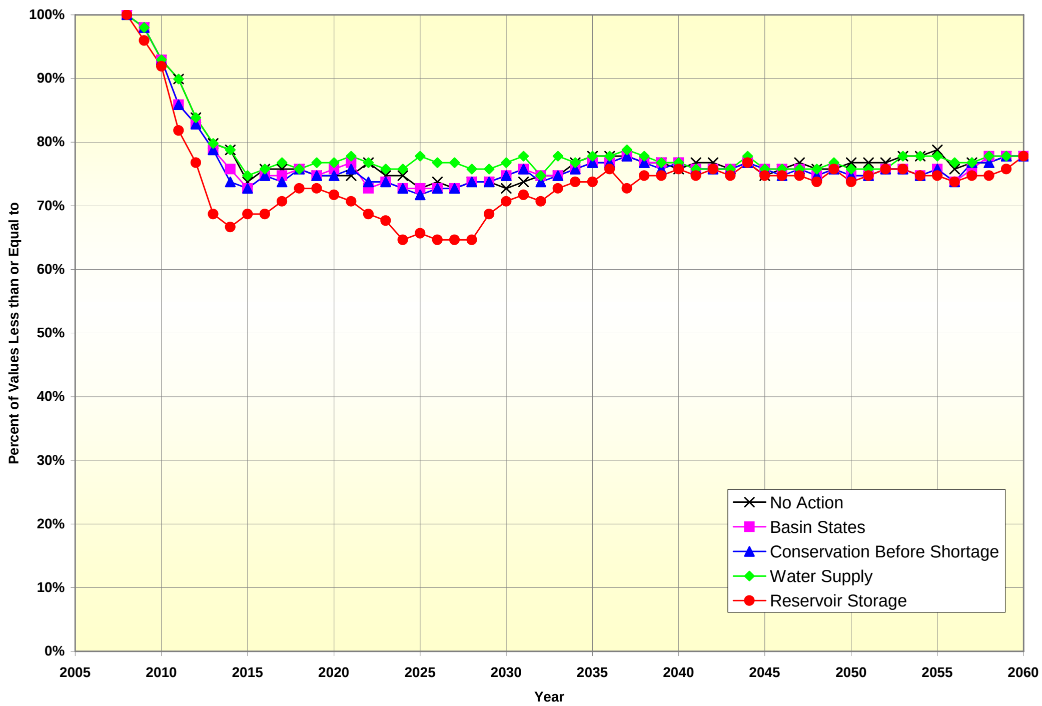


Table 4.3-19
Lake Mead End-of- July Elevations
Comparison of Action Alternatives to No Action Alternative
Percent of Values Less Than or Equal to Elevation 1,170 feet msl

Alternatives	Year						
	2008	2016	2026	2030	2040	2050	2060
No Action	100%	76%	74%	73%	76%	77%	78%
Basin States	100%	75%	73%	75%	77%	75%	78%
Conservation Before Shortage	100%	75%	73%	75%	77%	75%	78%
Water Supply	100%	76%	77%	77%	77%	76%	78%
Reservoir Storage	100%	69%	65%	71%	76%	74%	78%

Figure 4.3-20 illustrates the frequency that Lake Mead end-of-July elevations fall below elevation 1,125 feet msl. At lake elevations lower than 1,125 feet msl, the Overton Beach Marina, Callville Ramp, and South Cove Ramp are closed. As illustrated in Figure 4.3-20, the frequency that elevations fall below elevation 1,125 feet msl for the Basin States and Conservation Before Shortage alternatives are similar to those observed under the No Action Alternative. The water levels under the Water Supply Alternative were observed to fall below elevation 1,125 feet msl more frequently than those under the No Action alternative between 2008 and 2035. The water levels under the Reservoir Storage Alternative were observed to fall below elevation 1,125 feet msl less frequently than those under the No Action Alternative between 2010 and 2037.

Figure 4.3-20
Lake Mead End-of-July Elevations
Comparison of Action Alternatives to No Action Alternative
Percent of Values Less Than or Equal to Elevation 1,125 feet msl

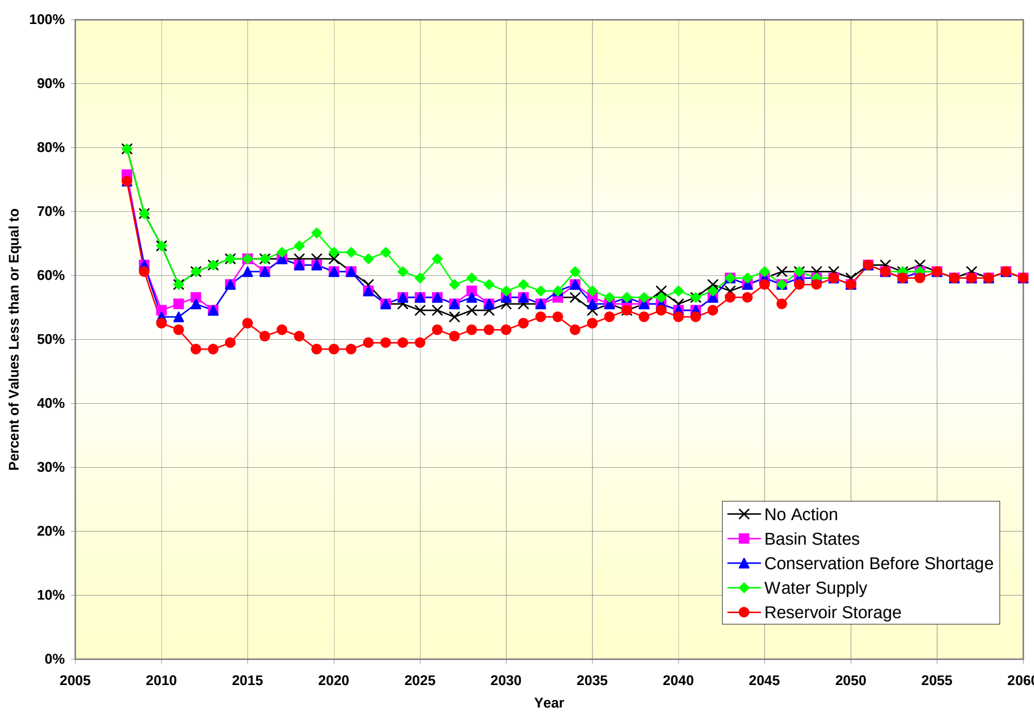


Table 4.3-20 provides a summary of the results for the Lake Mead end-of-July elevation of 1,125 feet msl for selected years.

Table 4.3-20
Lake Mead End-of-July Elevations
Comparison of Action Alternatives to No Action Alternative
Percent of Values Less Than or Equal to Elevation 1,125 feet msl

Alternatives	Year						
	2008	2016	2026	2030	2040	2050	2060
No Action	80%	63%	55%	56%	56%	60%	60%
Basin States	76%	61%	57%	57%	55%	59%	60%
Conservation Before Shortage	75%	61%	57%	57%	55%	59%	60%
Water Supply	80%	63%	63%	58%	58%	59%	60%
Reservoir Storage	75%	51%	52%	52%	54%	59%	60%

Figure 4.3-21 illustrates the frequency that Lake Mead end-of-July elevations would fall below elevation 1,080 feet msl. At lake elevations below 1,080 feet msl, the operations at the Lake Mead Marina Public Launch Ramp, Hemenway Public Launch Ramp, and Temple Bar Public Launch Ramp could potentially be affected. As illustrated in Figure 4.3-21, the Reservoir Storage Alternative was observed to fall below elevation 1,080 feet msl less frequently than under the No Action Alternative between 2010 and 2045. The water levels under the Basin States and Conservation Before Shortage alternatives were observed to fall below elevation 1,080 feet msl slightly less frequently than those under the No Action Alternative between 2013 and 2023 and then slightly more frequently between 2023 and 2038. The water levels under the Water Supply Alternative were observed to fall below elevation 1,080 feet msl more frequently than those under the No Action Alternative between 2012 and 2040.

Table 4.3-21 provides a summary of the results for the Lake Mead-end-of-July elevation of 1,080 feet msl for selected years. As shown in Table 4.3-21, the action alternatives vary from the No Action Alternative mostly between years 2016 and 2030 and are similar in subsequent years.

Figure 4.3-21
Lake Mead End-of-July Elevations
Comparison of Action Alternatives to No Action Alternative
Percent of Values Less Than or Equal to Elevation 1,080 feet msl

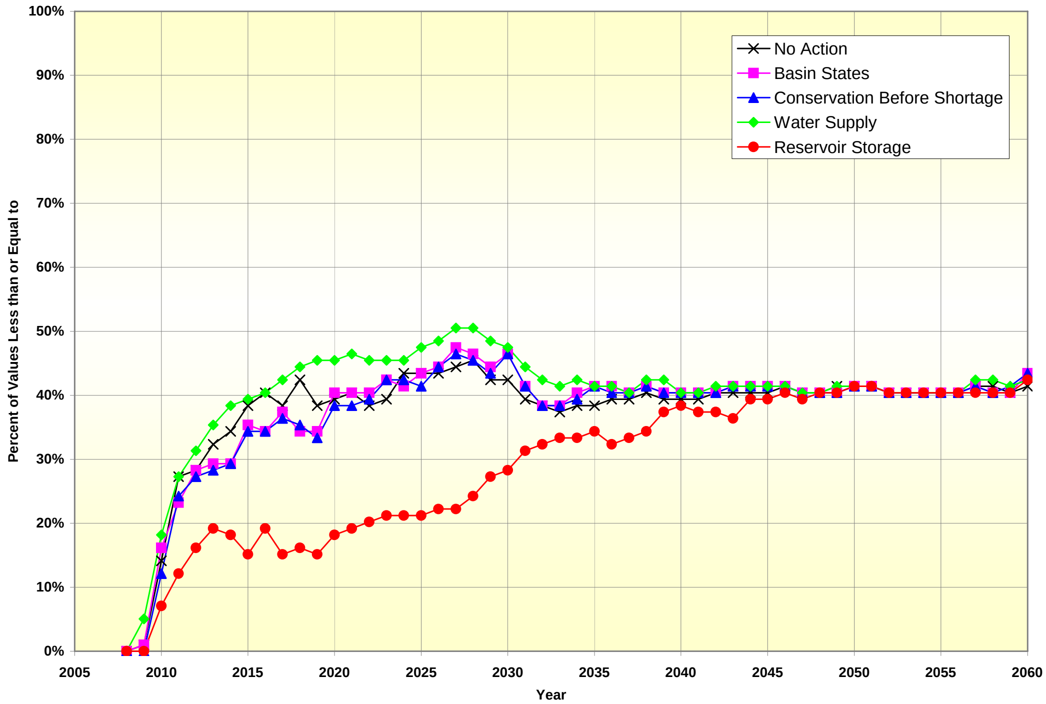


Table 4.3-21
Lake Mead End-of-July Elevations
Comparison of Action Alternatives to No Action Alternative
Percent of Values Less Than or Equal to Elevation 1,080 feet msl

Alternatives	Year						
	2008	2016	2026	2030	2040	2050	2060
No Action	0%	40%	43%	42%	39%	41%	41%
Basin States	0%	34%	44%	46%	40%	41%	43%
Conservation Before Shortage	0%	34%	44%	46%	40%	41%	43%
Water Supply	0%	40%	48%	47%	40%	41%	42%
Reservoir Storage	0%	19%	22%	28%	38%	41%	42%

Figure 4.3-22 illustrates the frequency that Lake Mead end-of-July elevations would fall below elevation 1,050 feet msl. The Lake Mead elevation of 1,050 feet msl is the minimum elevation needed for efficient power generation at the Hoover Powerplant, the minimum elevation for operation of the upper intake of the SNWA and the minimum elevation for the Echo Bay Boat Launch. As illustrated in Figure 4.3-22, the water levels under the Basin States, Conservation Before Shortage, and Water Supply alternatives were observed to fall below elevation 1,050 feet msl less frequently than those under the No Action Alternative from 2016 through 2027. The water levels under the Reservoir Storage Alternative were observed to fall below elevation 1,050 feet msl less frequently than those under the No Action Alternative (lower by as much as 10 to 20 percent), reflecting higher reservoir elevations.

Figure 4.3-22
Lake Mead End-of-July Elevations
Comparison of Action Alternatives to No Action Alternative
Percent of Values Less Than or Equal to Elevation 1,050 feet msl

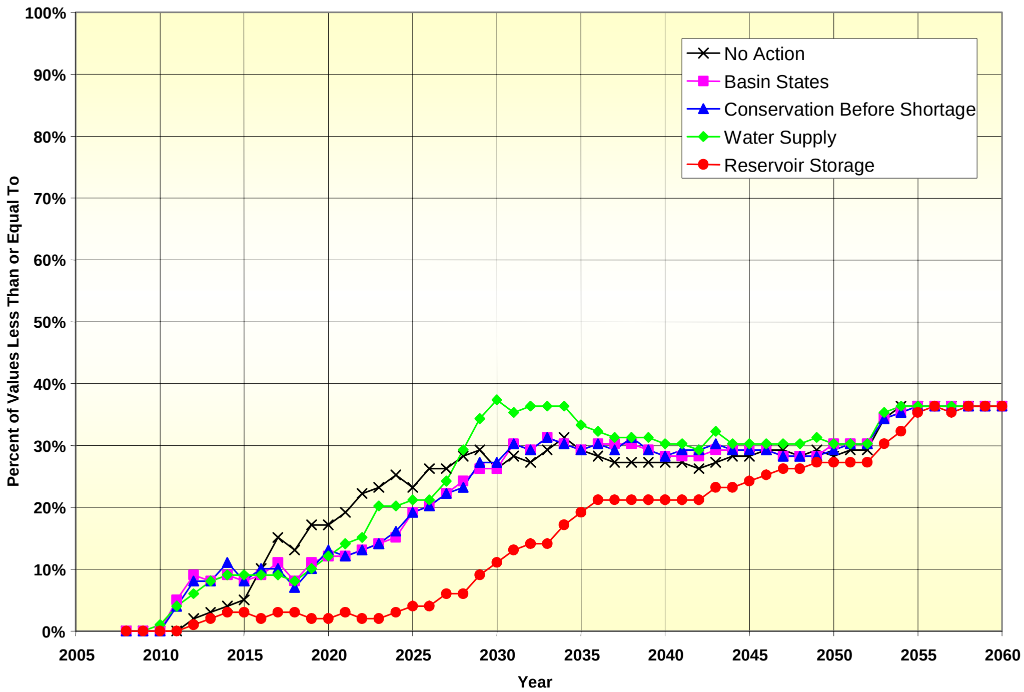


Table 4.3-22 provides a summary of the results illustrated in Figure 4.3-22 for the Lake Mead end-of-July elevation of 1,050 feet msl for selected years.

Table 4.3-22
Lake Mead End-of-July Elevations
Comparison of Action Alternatives to No Action Alternative
Percent of Values Less Than or Equal to Elevation 1,050 feet msl

Alternatives	Year						
	2008	2016	2026	2030	2040	2050	2060
No Action	0%	10%	26%	26%	27%	28%	36%
Basin States	0%	9%	20%	26%	28%	30%	36%
Conservation Before Shortage	0%	10%	20%	27%	28%	29%	36%
Water Supply	0%	9%	21%	37%	30%	30%	36%
Reservoir Storage	0%	2%	4%	11%	21%	27%	36%

Figure 4.3-23 illustrates the frequency that Lake Mead end-of-July elevations would fall below elevation 1,000 feet msl. The Lake Mead elevation of 1,000 feet msl is the minimum elevation needed by the SNWA to pump water from Lake Mead through its lower intake. As illustrated in Figure 4.3-23, the Lake Mead end-of-July water levels under the No Action, Conservation Before Shortage, and Reservoir Storage alternatives do not fall below elevation 1,000 feet msl. The water levels under the Water Supply and Basin States alternatives do show some instances where the water levels fall below 1,000 feet msl, although the frequency and probability are low. The maximum observed probability for elevations falling below 1,000 feet msl under the Water Supply Alternative is six percent and occurs towards the end of the interim period. Under the Basin States Alternative, the maximum observed probability for elevations falling below 1,000 feet msl is two percent and also occurs toward the end of the interim period.

Table 4.3-23 provides a summary of the results illustrated in Figure 4.3-23 for the Lake Mead end-of-July elevation of 1,000 feet msl for selected years. The Water Supply and Basin States alternatives are the only alternatives that show instances where the water levels fall below elevation 1,000 feet msl, and they occur in year 2026.

Figure 4.3-23
Lake Mead End-of-July Elevations
Comparison of Action Alternatives to No Action Alternative
Percent of Values Less Than or Equal to Elevation 1,000 feet msl

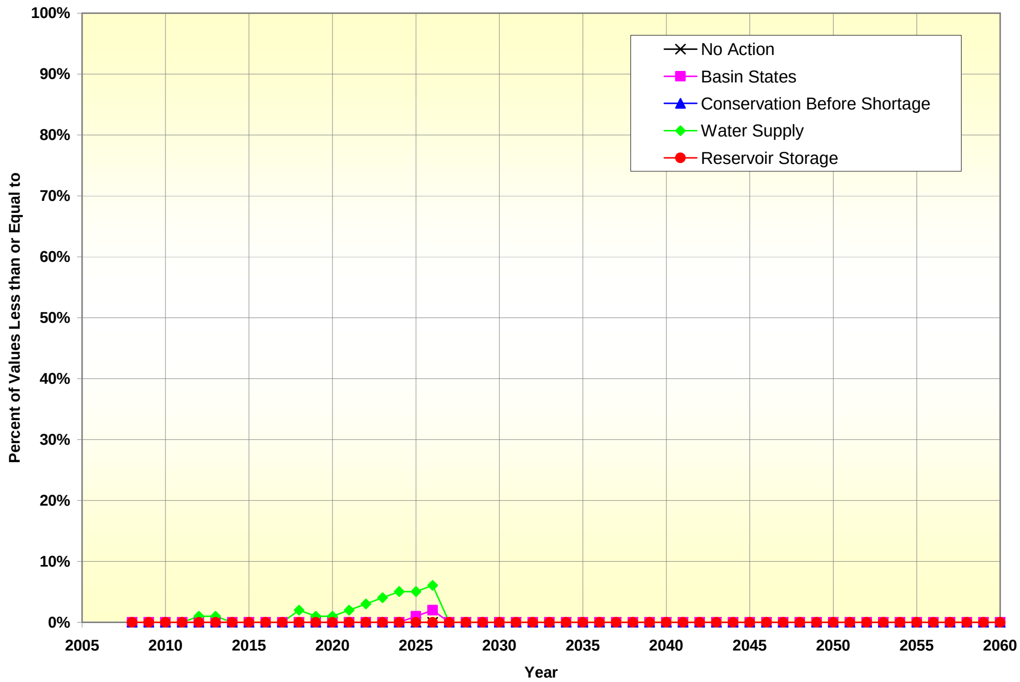


Table 4.3-23
Lake Mead End-of-July Elevations
Comparison of Action Alternatives to No Action Alternative
Percent of Values Less Than or Equal to Elevation 1,000 feet msl

Alternatives	Year						
	2008	2016	2026	2030	2040	2050	2060
No Action	0%	0%	0%	0%	0%	0%	0%
Basin States	0%	0%	2%	0%	0%	0%	0%
Conservation Before Shortage	0%	0%	0%	0%	0%	0%	0%
Water Supply	0%	0%	6%	0%	0%	0%	0%
Reservoir Storage	0%	0%	0%	0%	0%	0%	0%

Figure 4.3-24 illustrates the minimum Lake Mead end-of-July elevations that were observed in the modeling of the action alternatives and No Action Alternative during the period of analysis (2008 through 2060). The minimum lake elevations under the No Action Alternative never fall below Lake Mead elevation 1,000 feet msl throughout the period of analysis. Similarly, the minimum lake elevations under the Basin States, Conservation Before Shortage, and Reservoir Storage alternatives never fall below Lake Mead elevation 1,000 feet

msl throughout the period of analysis. The minimum lake elevations under the Reservoir Storage Alternative are generally higher than those observed under the No Action Alternative. The minimum lake elevations under the Water Supply Alternative are generally lower than those observed under the No Action Alternative and fall below Lake Mead elevation 1,000 feet msl during the interim period. The minimum Lake Mead end-of-July elevation values under the action alternatives and the No Action Alternative all converge between 2027 through 2030 and generally remain at about 1,000 feet msl after 2030.

Figure 4.3-24
Lake Mead End-of-July Elevations
Comparison of Action Alternatives to No Action Alternative
Minimum Water Elevation Values (feet msl)

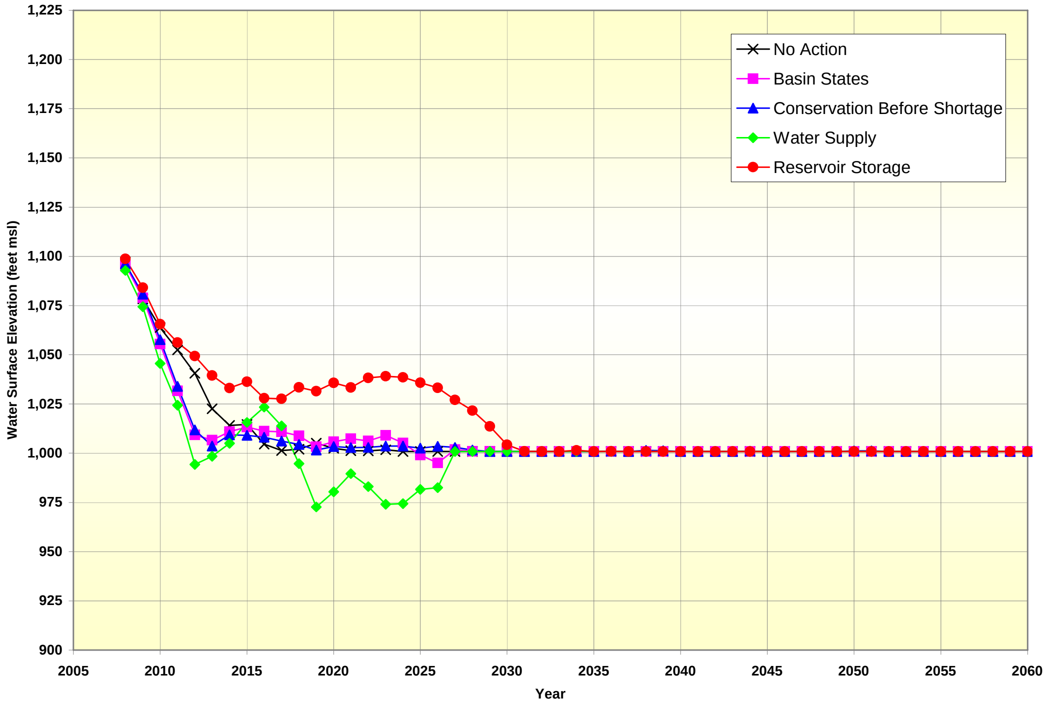


Table 4.3-24 provides a summary of the results illustrated in Figure 4.3-24 for the Lake Mead end-of-July minimum elevations. As shown on this table, the greatest variability between the action alternatives and the No Action Alternative occurs during the interim period. The Lake Mead elevations fall below elevation 1,000 feet msl under the Water Supply Alternative only.

Table 4.3-24
Lake Mead End-of-December Elevations
Comparison of Action Alternatives to No Action Alternative
Minimum Elevation Values (feet msl)

Alternatives	Year						
	2008	2016	2026	2030	2040	2050	2060
No Action	1,097.1	1,004.7	1,000.9	1,000.9	1,000.9	1,000.9	1,000.9
Basin States	1,095.7	1,011.3	995.0	1,000.9	1,000.9	1,000.9	1,000.9
Conservation Before Shortage	1,096.3	1,008.2	1,003.5	1,000.9	1,000.9	1,001.1	1,000.9
Water Supply	1,092.9	1,023.4	982.5	1,000.9	1,000.9	1,000.9	1,000.9
Reservoir Storage	1,098.8	1,028.0	1,033.2	1,004.2	1,000.9	1,000.9	1,000.9

4.3.4.1 Storage of Conserved Water in Lake Mead

One of the elements of the proposed federal action is a mechanism for the storage and delivery of conserved water and non-system waters in Lake Mead. The general concept of this proposed program is that water users would conserve water or secure non-system water which could then be stored in Lake Mead. One of the potential effects of this alternative is an increase in the amount of water that would remain in storage in Lake Mead. The three alternatives that include some form of the storage and delivery mechanism are the Basin States, Conservation Before Shortage, and Reservoir Storage alternatives. The modeling results discussed previously for the Basin States, Conservation Before Shortage, and Reservoir Storage alternatives all include the storage and delivery mechanism. The specific assumptions with respect to the storage and delivery mechanism considered and modeled under each of these alternatives are discussed in Section 4.2 and Appendix M.

A simulation was performed for each of these alternatives to isolate the effects of the storage and delivery mechanism on the behavior of the system. This was accomplished by holding all other assumptions constant and removing the storage and delivery mechanism. Figure 4.3-25 presents a comparison of the 90^{th}, 50^{th}, and 10^{th} percentile values observed for the action alternatives to those under the No Action Alternative. This figure illustrates the Lake Mead elevations for the Basin States, Conservation Before Shortage, and Reservoir Storage alternatives if the storage and delivery mechanism is not in place. The Lake Mead elevations illustrated in Figure 4.3-25 for these alternatives can be contrasted to those shown in Figure 4.3-15 which shows the Lake Mead elevations for these alternatives if the storage and delivery mechanism is in place. As illustrated by this comparison, the inclusion of mechanism in these alternatives would have a tendency to provide higher Lake Mead elevations and also changes the relative difference of these alternatives to the No Action Alternative.

Figure 4.3-25
Lake Mead End-of-December Elevations
Comparison of Action Alternatives With Storage and Delivery Mechanism Removed to No Action Alternative
10th, 50th, and 90th Percentile Values

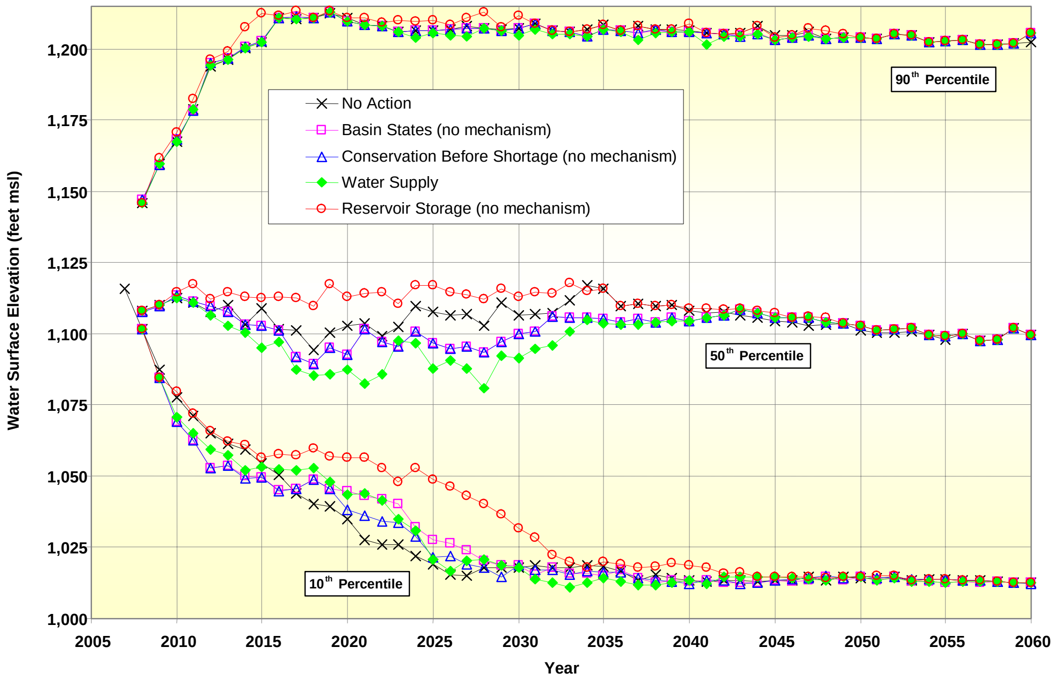


Figure 4.3-26 compares the 90th, 50th, and 10th percentile Lake Mead elevations for the Basin States, Conservation Before Shortage, and Reservoir Storage alternatives with the storage and delivery mechanism to the same alternatives without the mechanism.

Figure 4.3-26
Lake Mead End-of-December Elevations
Comparison of Action Alternatives With and Without a Storage and Delivery Mechanism
10th, 50th, and 90th Percentile Values

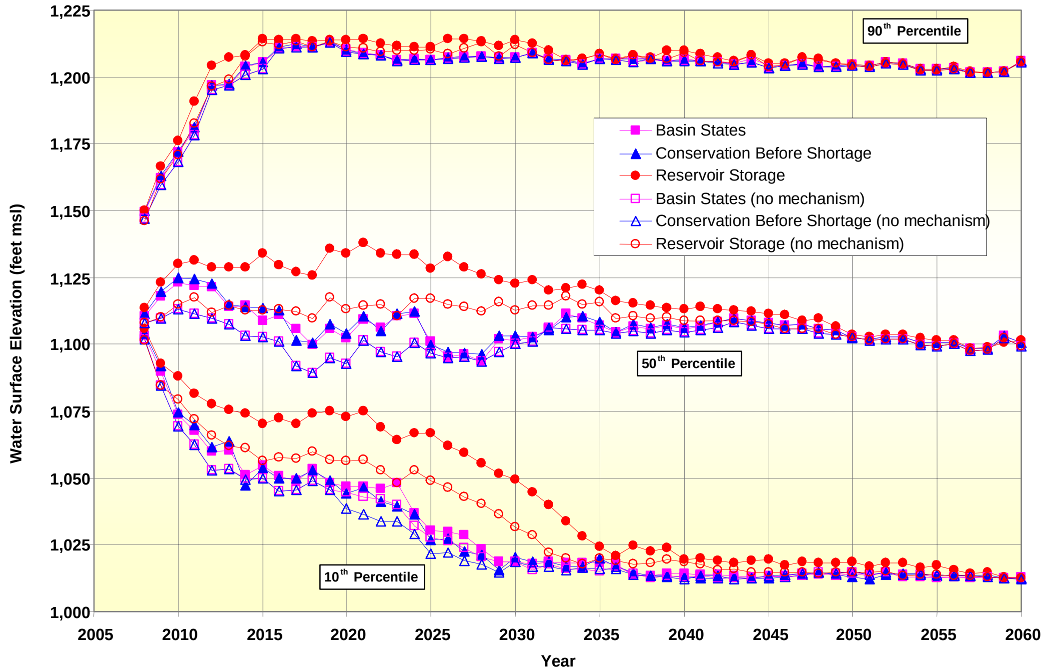


Table 4.3 25 provides a summary of the increases in Lake Mead elevations for selected years that can be attributed to the inclusion of the storage and delivery mechanism in the Basin States, Conservation Before Shortage, and Reservoir Storage alternatives. As shown on this figure and table, for the 50th and 10th percentile values, the storage and delivery mechanism could potentially provide higher Lake Mead elevations, by as much as 17.8 feet under the Reservoir Storage Alternative, 11.6 feet under the Conservation Before Shortage Alternative, and nearly ten feet under the Basin States Alternative.

Table 4.3-25
Increase / Decrease ( ) in Lake Mead Elevations (feet msl) Resulting From a Storage and Delivery Mechanism
Comparison of Action Alternatives With and Without a Storage and Delivery Mechanism
90th, 50th, and 10th Percentile Values

Year	Basin States			Conservation Before Shortage			Reservoir Storage		
	90th Percentile	50th Percentile	10th Percentile	90th Percentile	50th Percentile	10th Percentile	90th Percentile	50th Percentile	10th Percentile
2008	2.4	2.7	1.3	3.0	3.7	2.4	4.0	5.5	4.2
2016	(0.6)	9.9	5.7	0.1	11.6	5.1	1.9	16.5	14.8
2026	0.2	0.5	3.8	0.2	2.3	5.4	5.5	17.8	15.9
2030	0.2	1.3	0.1	0.2	3.3	1.8	1.9	9.8	17.6
2040	0.7	1.3	1.3	0.1	1.6	0.7	0.8	4.5	0.7
2050	0.4	(0.5)	0.1	0.4	(0.5)	(1.8)	0.4	0.8	3.8
2060	0.2	1.1	0.5	0.2	1.1	0.4	0.2	2.1	0.3

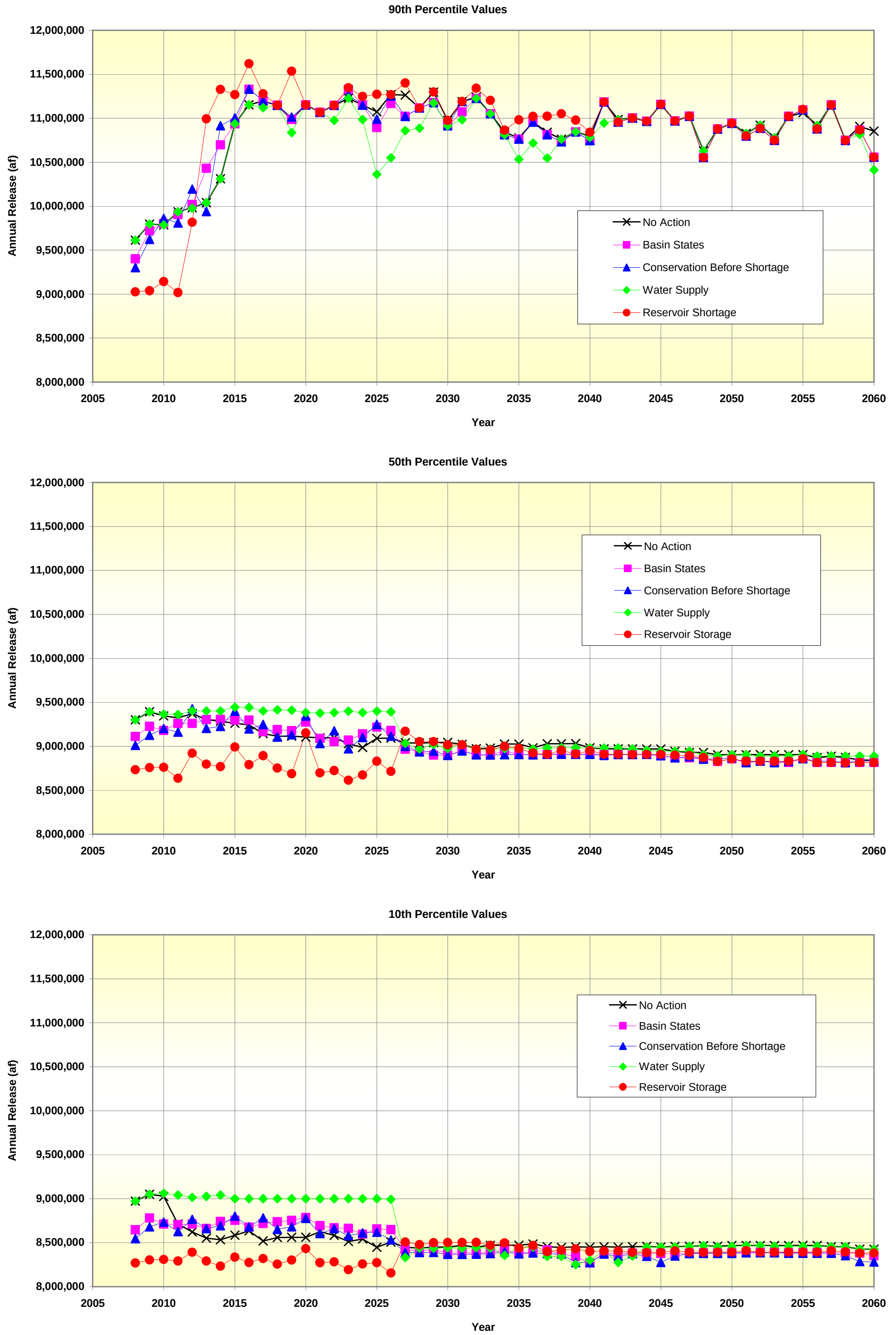
4.3.5 Hoover Dam to Davis Dam

The river flows between Hoover Dam and Lake Mohave are comprised mainly of releases from Hoover Dam (Lake Mead) and tributary inflows. These inflows, mostly from side washes, comprise less than one percent of the total annual flow in this reach. During the 10-year period between 1996 and 2005, the annual Hoover Dam releases have ranged between 8.274 maf and 12.774 maf and averaged 10.415 maf.

As noted in Section 3.3, future annual and monthly releases may be affected by the proposed federal action. Each alternative may alter the probability (when compared to the No Action Alternative) of the magnitude and timing of particular releases. However, as expressed in Section 3.3, due to the presence of Lake Mohave immediately downstream, these potential changes in releases will have an effect only on hydropower generation.

Figure 4.3-27 presents a comparison of the 90^{th}, 50^{th}, and 10^{th} percentile values observed under the No Action and action alternatives for Hoover Dam annual (calendar year) releases. The greatest variability between the action alternatives and No Action Alternative generally occurs during the period between 2008 and 2026. Also, the greatest variability occurs between the Reservoir Storage Alternative and No Action Alternative and is consistent with the underlying strategy of the Reservoir Storage Alternative which is to maintain more water in storage. This is facilitated through more frequent voluntary and involuntary delivery reductions and is reflected in the 50^{th} and 10^{th} percentile values which are lower for this alternative between 2008 and 2026. Since more water is held in storage, as compared to the No Action Alternative, the Reservoir Storage Alternative provides more opportunities for more frequent and higher flood/surplus releases, which is reflected in the 90^{th} percentile values for this alternative. In contrast, the strategy of the Water Supply Alternative is to meet the water users' delivery requirements with less regard to preserving water in storage. As such, the 50^{th} and 10^{th} percentile values under the Water Supply Alternative show that more water is delivered under this alternative between 2008 and 2026, as compared to the No Action Alternative. The range of water releases that occur under the Basin States and Conservation Before Shortage alternatives generally coincides with the range of releases under the No Action Alternative.

Figure 4.3-27
Hoover Dam Annual Releases
Comparison of Action Alternatives to No Action Alternative
90th, 50th and 10th Percentile Values



Another observation relates to the 50th and 10th percentile annual Hoover Dam release volumes that are consistently lower under the Basin States, Conservation Before Shortage, and Reservoir Storage alternatives as compared to the No Action Alternative after 2026. This difference can be attributed to the assumption that SNWA would develop additional permanent non-system water supplies.

Figure 4.3-28 illustrates the cumulative distribution of Hoover Dam annual releases under the No Action and action alternatives for years 2008 through 2060. The observed annual releases under all the alternatives (including the No Action Alternative) fluctuate between 7.45 maf to about 17.3 maf. The lowest minimum annual release is 6.73 maf and occurs under the Water Supply Alternative, although it only occurs about one percent of the time.

Figure 4.3-28
Hoover Dam Annual Releases
Comparison of Action Alternatives to No Action Alternative
Years 2008 through 2060

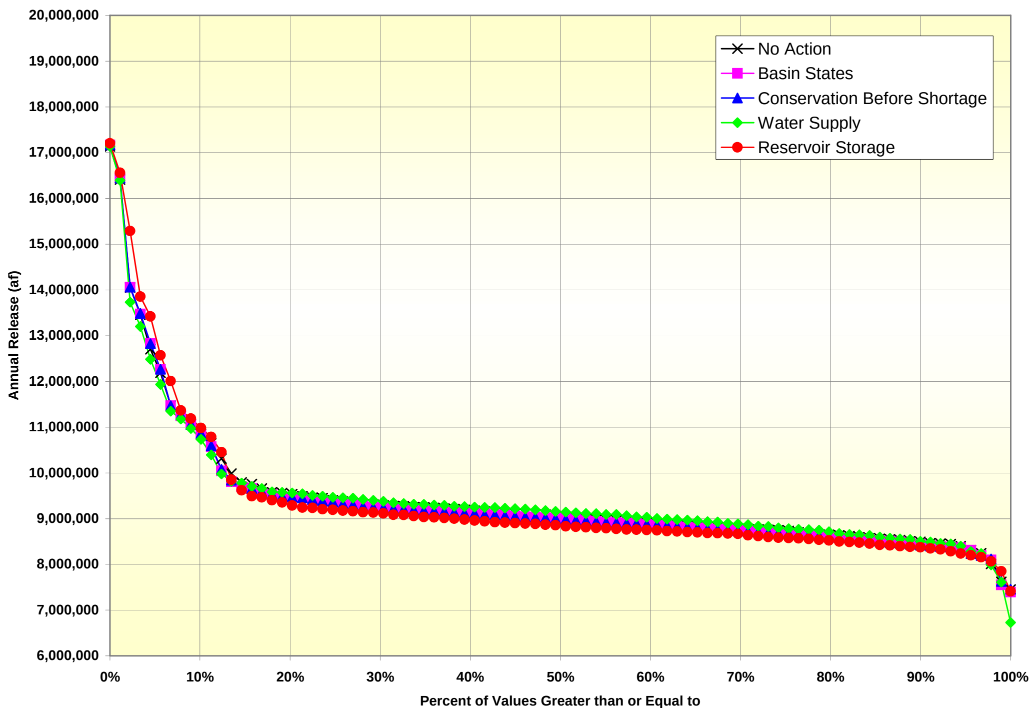


Table 4.3-26 provides a summary of the distribution of the Hoover Dam releases within different flow ranges of interest. As shown on this table, the Hoover Dam releases in the range identified as typical under Normal conditions (i.e. 8.5 mafy to 9.5 mafy) are similar under all the alternatives. The greatest variability between the action alternatives and the No Action Alternative occurs in the frequency of releases that are greater than 9.5 mafy and those between 7.50 and 8.49 mafy.

Table 4.3-26
Hoover Dam Annual Releases
Probability of Occurrence of Different Annual Release Volumes
Comparison of Action Alternatives to No Action Alternative
Calendar Years 2008 through 2060

	Alternative				
Hoover Dam Release Volumes	No Action	Basin States	Conservation Before Shortage	Water Supply	Reservoir Storage
Greater than 9.50 mafy	20.2%	18.0%	18.0%	22.5%	14.6%
Between 8.50 to 9.50 mafy	68.6%	68.6%	66.3%	67.5%	65.2%
Between 7.50 to 8.49 mafy	10.1%	12.4%	14.6%	9.0%	19.1%
Less than 7.5 mafy	1.0%	1.0%	1.0%	1.0%	1.0%
Total	100.0%	100.0%	100.0%	100.0%	100.0%

4.3.5.1 Lake Mohave Water Levels

Lake Mohave is operated under a rule curve that provides specific “target elevations” at the end of each month (Section 3.3). The same rule curve would be used and applied in the future operations under the No Action Alternative and the action alternatives. Therefore, end-of-month elevations in Lake Mohave are not affected by the proposed federal action.

4.3.6 Davis Dam to Parker Dam

4.3.6.1 River Flows

The flows between Davis Dam and Parker Dam are comprised mainly of releases from Davis Dam (Lake Mohave) and tributary inflows from the Bill Williams River. During the 10-year period between 1996 and 2005, the annual Davis Dam releases have ranged between 8.1 maf and 12.6 maf and averaged 10.2 maf. Releases greater than 9.5 maf generally correspond to years when surplus or flood flow releases are made at Hoover Dam and are passed through Lake Mohave. Flows less than 8.5 maf are associated with voluntary or involuntary delivery reductions to water users in the Lower Basin.

Figure 4.3-29 presents a comparison of the 90^{th}, 50^{th}, and 10^{th} percentile values observed for the action alternatives to those under the No Action Alternative. The values and variability of the 90^{th}, 50^{th}, and 10^{th} percentile values under the No Action Alternative and action alternatives are similar to those in Figure 4.3-27 (Hoover Dam releases) because the releases from Hoover Dam are passed through Lake Mohave. The differences are losses that are attributed to evaporation at Lake Mohave, which would be the same in all of the alternatives due to rule curve operations.

Figure 4.3-29
Davis Dam Annual Releases
Comparison of Action Alternatives to No Action Alternative
90th, 50th, and 10th Percentile Values

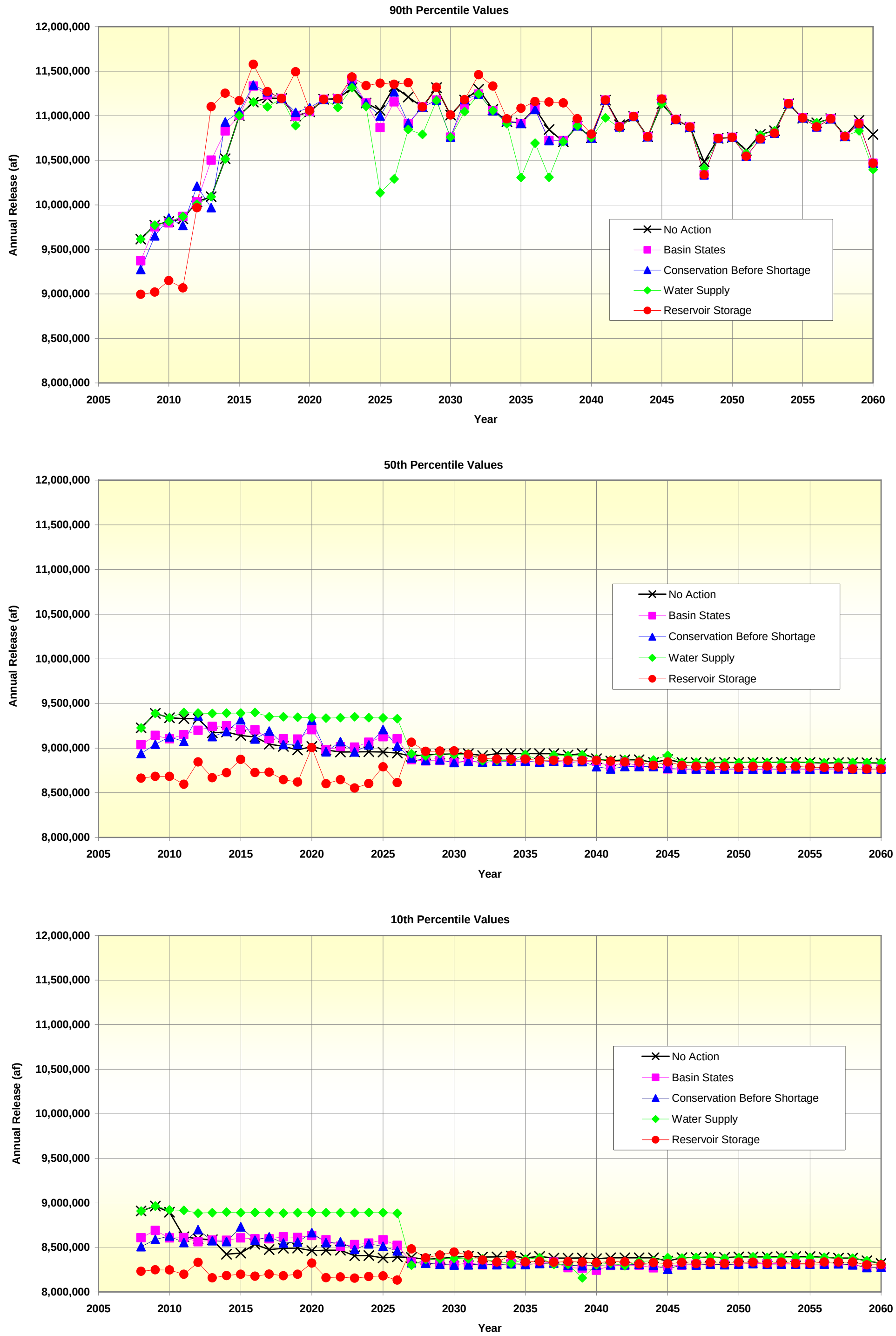
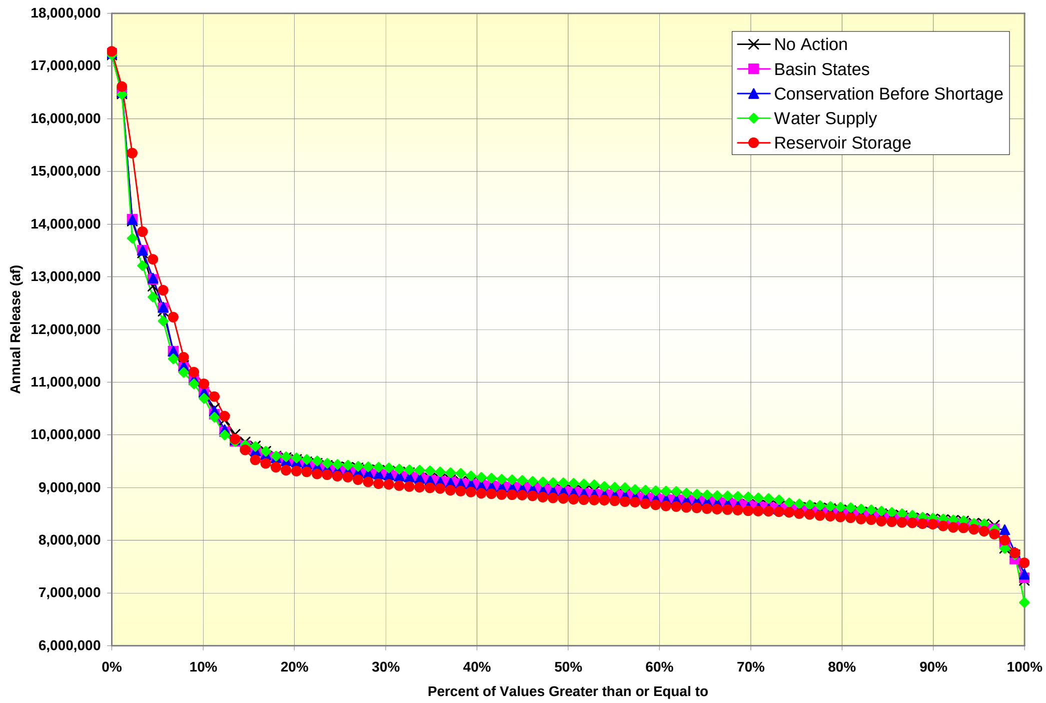


Figure 4.3-30 illustrates the cumulative distribution of the Davis Dam releases for the No Action Alternative and the action alternatives for the period 2008 through 2060. The range and frequency of the releases under the different alternatives are similar to those shown in Figure 4.3-28. Again, the reason for this is that releases from Hoover Dam are passed through Lake Mohave.

Figure 4.3-30
Davis Dam Annual Releases
Comparison of Action Alternatives to No Action Alternative
Years 2008 through 2060

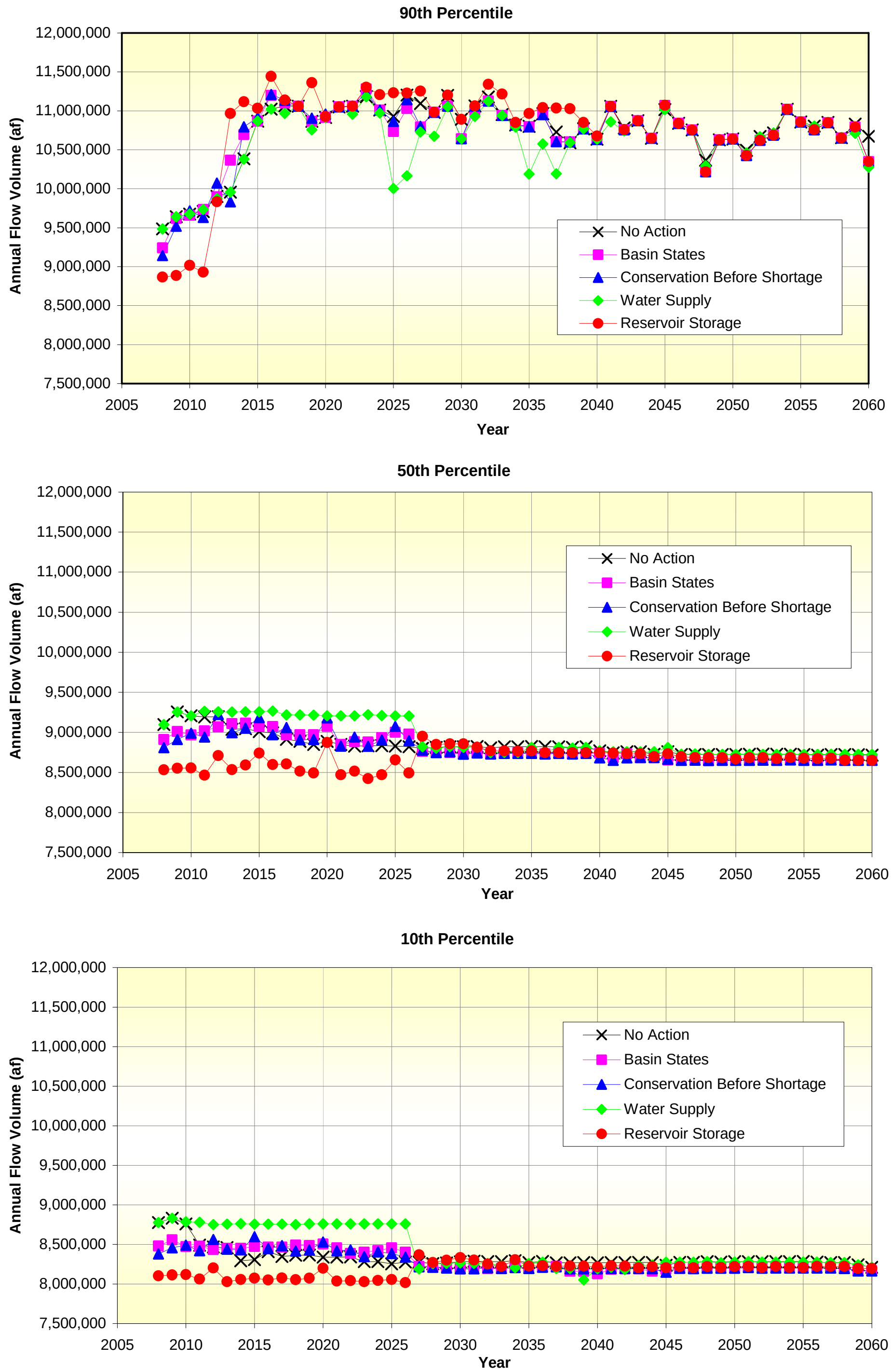


4.3.6.2 Colorado River Annual Flow Near Havasu NWR

A point located immediately downstream of the Havasu NWR was used to further analyze the river flows for this reach.

The 90th, 50th, and 10th percentile annual flow volumes at this point are shown in Figure 4.3-31. The 90th percentile for the Basin States, Conservation Before Shortage, and Water Supply alternatives were similar to those of the No Action Alternative. However, the values for the Water Supply Alternative periodically fell below those of the No Action Alternative during the period between 2025 through 2039. The 90th percentile values for the Reservoir Storage Alternative fluctuated above and below those of the No Action Alternative from about 2008 to 2019.

Figure 4.3-31
Colorado River Annual Flow Near Havasu NWR - RM 242.3 (af)
Comparison of Action Alternatives to No Action Alternative
90th, 50th, and 10th Percentile Values



The 50th percentile values of the Water Supply Alternative were similar to those under the No Action Alternative for the initial 5 years and then were higher by an average of about 250 kafy for the period between 2013 through 2026. This is a direct result of there being essentially no shortages under the Water Supply Alternative during the interim period. The 50th percentile flows of the Basin States and Conservation Before Shortage alternatives were similar to those of the No Action Alternative. The 50th percentile values of the Reservoir Storage Alternative were on average about 450 kaf lower than the No Action Alternative during the interim period (through 2026) and thereafter were similar to those of the No Action Alternative. During the interim period, the Reservoir Storage Alternative maintains more water in storage through more frequent shortages. At the 10th percentile level, although the magnitudes of the annual flows of all the alternatives are generally lower by about 500 kaf, the relative changes in flow volumes of the action alternatives compared to the No Action Alternative are similar to those at the 50th percentile level.

Table 4.3-27 provides a comparison of the 90th, 50th, and 10th percentile annual flow volumes between the action alternatives and the No Action Alternative for selected years.

Table 4.3-27
Colorado River Annual Flow Near Havasu NWR - RM 242.3 (maf)
Comparison of Action Alternatives to No Action Alternative
90th, 50th, and 10th Percentile Values

Alternative	Year 2016			Year 2026			Year 2040			Year 2060		
	90th	50th	10th	90th	50th	10th	90th	50th	10th	90th	50th	10th
No Action	11.021	8.992	8.409	11.202	8.822	8.276	10.636	8.770	8.267	10.673	8.716	8.212
Basin States	11.200	9.070	8.467	11.030	8.979	8.404	10.633	8.739	8.129	10.348	8.652	8.167
Conservation Before Shortage	11.212	8.970	8.448	11.144	8.896	8.341	10.633	8.682	8.192	10.348	8.652	8.167
Water Supply	11.021	9.265	8.758	10.166	9.205	8.759	10.636	8.770	8.194	10.278	8.724	8.212
Reservoir Storage	11.443	8.597	8.053	11.228	8.492	8.018	10.677	8.746	8.217	10.348	8.652	8.198

4.3.6.3 Groundwater

As discussed in Section 3.3, the flows in the Davis Dam to Parker Dam reach are primarily composed of water released from Davis Dam. Therefore, the annual median releases are representative of the annual median flows in the reach. When converted to stage, a comparison of the annual median releases for each alternative may be used as the indicator to analyze potential effects to groundwater adjacent to the river in this reach.

Figure 4.3-32 illustrates the annual median releases from Davis Dam for each alternative for the years 2008 through 2060. These are the same data shown in Figure 4.3-29 converted from acre-feet per year to cubic feet per second. In general, the median releases for the Water Supply and Reservoir Storage alternatives bracket the median releases for the other three alternatives due primarily to the different shortage assumptions for each of the alternatives. Table 4.3-28 compares the annual median values relative to the No Action Alternative for specific years (each action alternative value less the No Action Alternative value). Using appropriate relationships to convert flow-to-stage (LCR MSCP BA, Appendix J, Attachment D), these relative flow differences would result in minor reductions in river stage (on the order of 0.5 feet). Based on the relationships used in the LCR MSCP BA, Appendix K, such river stage reductions would result in corresponding reductions in groundwater elevations adjacent to the river (approximately 0.25 feet to 0.5 feet for gaining and losing reaches respectively).

Figure 4.3-32
Davis Dam Annual Releases
Comparison of Action Alternatives to No Action Alternative
Annual Median (50th Percentile) Values (cfs)

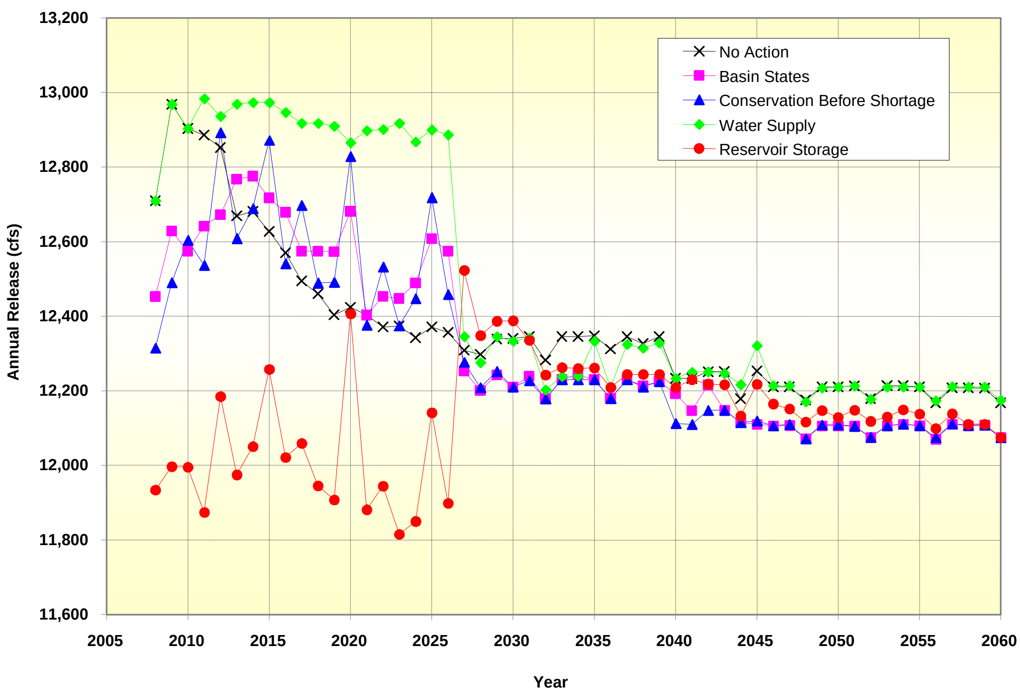


Table 4.3-28
Davis Dam Annual Median Releases
Differences of Action Alternatives Compared to No Action Alternative[1] (cfs)

Year	No Action	Basin States	Conservation Before Shortage	Water Supply	Reservoir Storage
2008	NA	-257	-395	0	-776
2011	NA	-245	-350	98	-1012
2016	NA	109	-29	377	-548
2017	NA	80	203	423	-435
2026	NA	217	102	530	-459
2027	NA	-56	-32	37	214
2040	NA	-41	-121	0	-24
2060	NA	-92	-92	7	-92

1 *Value of Action Alternative minus the value from the No Action Alternative provides the difference shown. A negative value indicates that the value under the Action Alternative is lower than that of the No Action Alternative, i.e. a flow reduction.*

4.3.6.4 Lake Havasu Water Levels

Similar to Lake Mohave, Lake Havasu is also operated under a rule curve. This method of operation provides specific "target elevations" at the end of each month (Section 3.3). The same rule curve would be used and applied in the future operations under the No Action Alternative and the action alternatives. Therefore, end-of-month elevations of Lake Havasu are not affected by the proposed federal action.

4.3.7 Parker Dam to Cibola Gage and Cibola Gage to Imperial Dam

As discussed in Section 3.3, Parker Dam provides the last opportunity to re-regulate Hoover Dam releases because Lake Havasu is the last facility in the lower Colorado River with significant storage. Releases from Parker Dam are made primarily to meet downstream water demands. Once released from Parker Dam, the flow is essentially unregulated until it reaches Imperial Dam.

4.3.7.1 River Flows

The river flows in this reach are essentially the releases from Parker Dam. Releases greater than 7.0 maf generally correspond to years when flood flow releases are being made from Hoover Dam and these flows are passed through Davis Dam and Parker Dam. Releases less than 6.0 maf are generally associated with delivery reductions, which occur more frequently under the Conservation Before Shortage and Reservoir Storage alternatives than under the No Action Alternative.

Figure 4.3-33 presents a comparison of the 90th, 50th, and 10th percentile lines for Parker Dam annual releases under the alternatives. The 90th percentile values represent releases due to flood control operations. The Reservoir Storage Alternative tends to release greater volumes during flood control when compared to the other alternatives since it keeps Lake Mead water levels higher. Beyond year 2045 all flow volumes converged to a release of about 7.40 maf. At the 50th percentile, the Basin States, Conservation Before Shortage and Reservoir Storage alternatives had less release volume than the No Action Alternative until the year 2026. The Water Supply Alternative generally released more volume over that same period. At year 2027, all alternatives converged to about 6.50 maf, with differences due to the assumption that SNWA would develop additional non-system water supplies that are permanent. The comparison of the 10th percentile showed similar results that mirror the 50th percentile values, except the release volumes were about 6.25 maf.

Figure 4.3-34 illustrates the cumulative distribution for the Parker Dam annual releases for the period of 2008 through 2060. The releases under the No Action Alternative range between 14.0 maf to 5.96 maf. The releases under the Basin States and Water Supply alternatives were similar to those observed under the No Action Alternative. The releases under the Conservation Before Shortage and Reservoir Storage alternatives had the lowest releases, 5.60 and 5.35 maf, respectively.

Figure 4.3-33
Parker Dam Annual Releases
Comparison of Action Alternatives to No Action Alternative
90th, 50th, and 10th Percentile Values

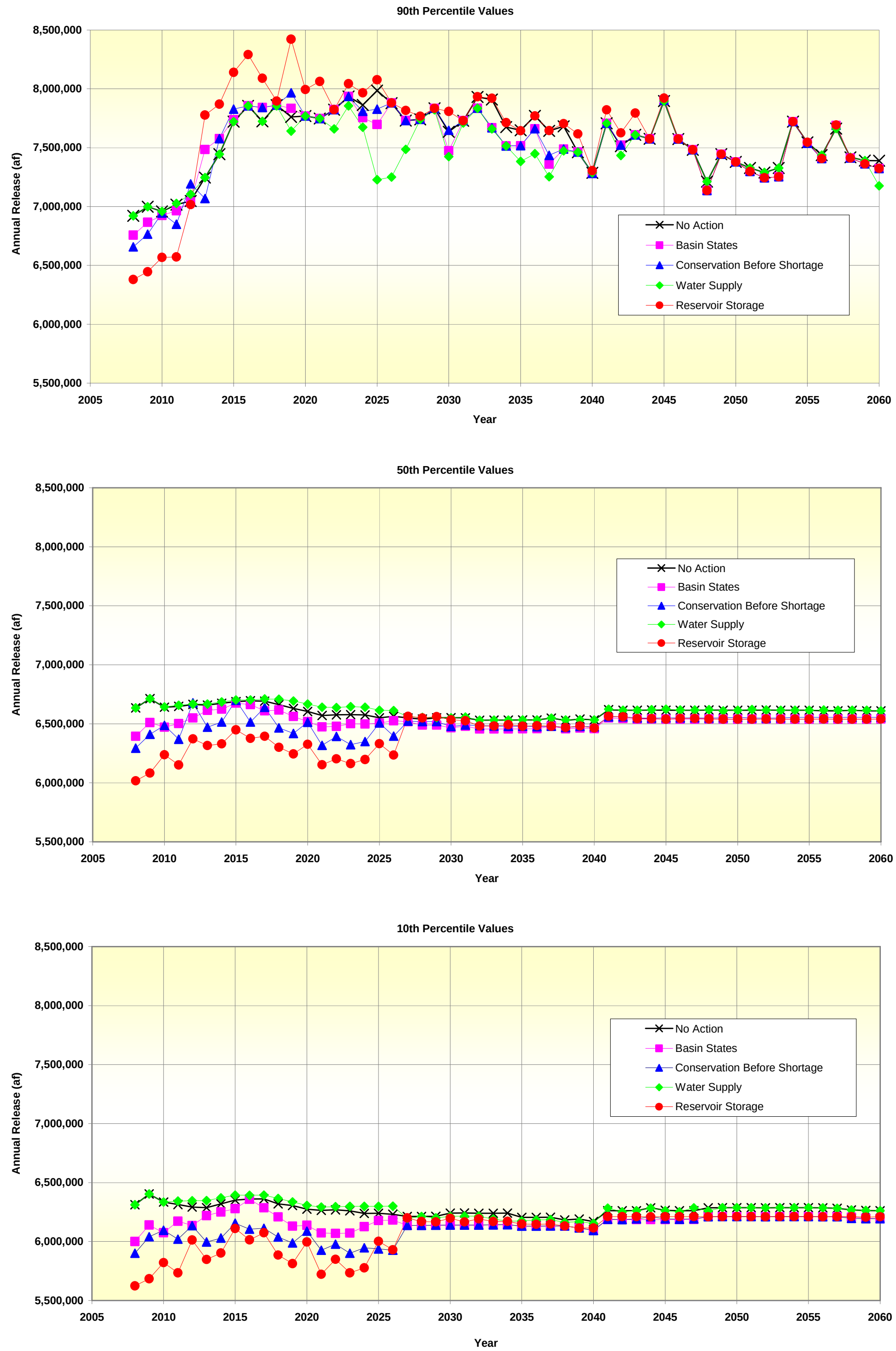
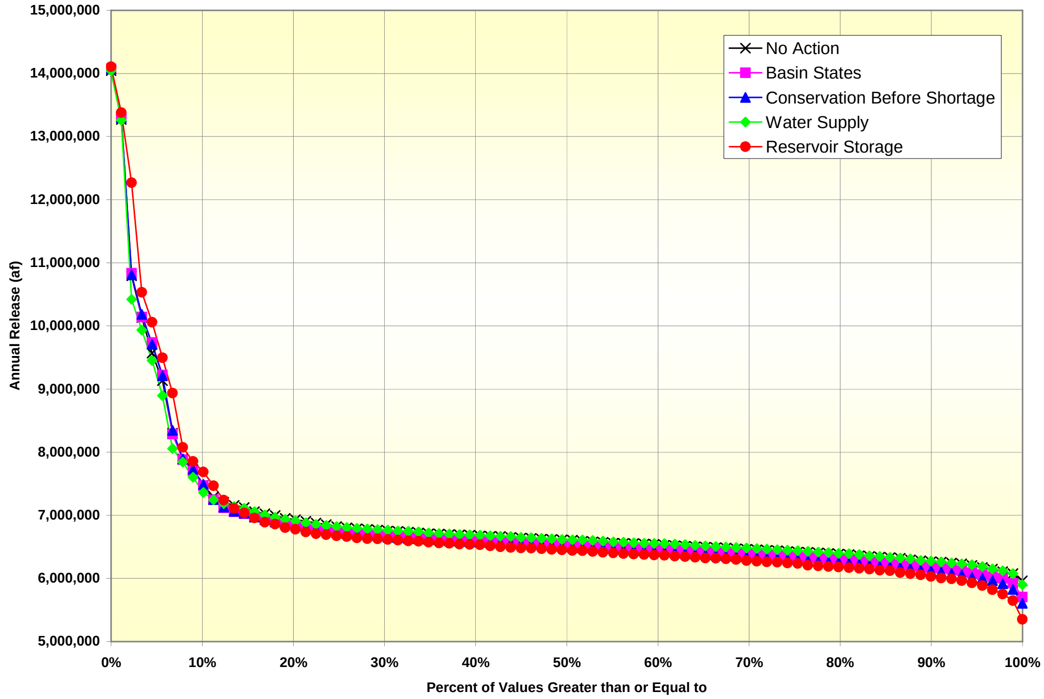


Figure 4.3-34
Parker Dam Annual Releases
Comparison of Action Alternatives to No Action Alternative
Years 2008 through 2060



River Flows Near the Colorado River Indian Reservation. Two other points on the Colorado River were used to analyze flows in the reach between Parker Dam and Imperial Dam. These include a point located immediately upstream of the Colorado River Indian Reservation (CRIR) and a point located immediately downstream of the Palo Verde Diversion Dam.

The CRIR diversion is located at Headgate Rock Dam, approximately 14 miles below Parker Dam. Flows in this reach of the river result primarily from releases at Parker Dam and would be affected by delivery reductions to water users located downstream from this location.

Figure 4.3-35 illustrates that the 90th, 50th, and 10th percentile annual flow values at this location generally reflect the releases from Parker Dam, as shown on Figure 4.3-33. Since there is no significant storage capacity above Headgate Rock Dam, the differences between the flows at this location and the Parker Dam releases are due only to the attenuation of the flows that occurs in the 14 miles of river within this reach.

Figure 4.3-35
Colorado River Annual Flow Upstream of CRIR Diversion - RM 180.8 (af)
Comparison of Action Alternatives to No Action Alternative
90th, 50th, and 10th Percentile Values

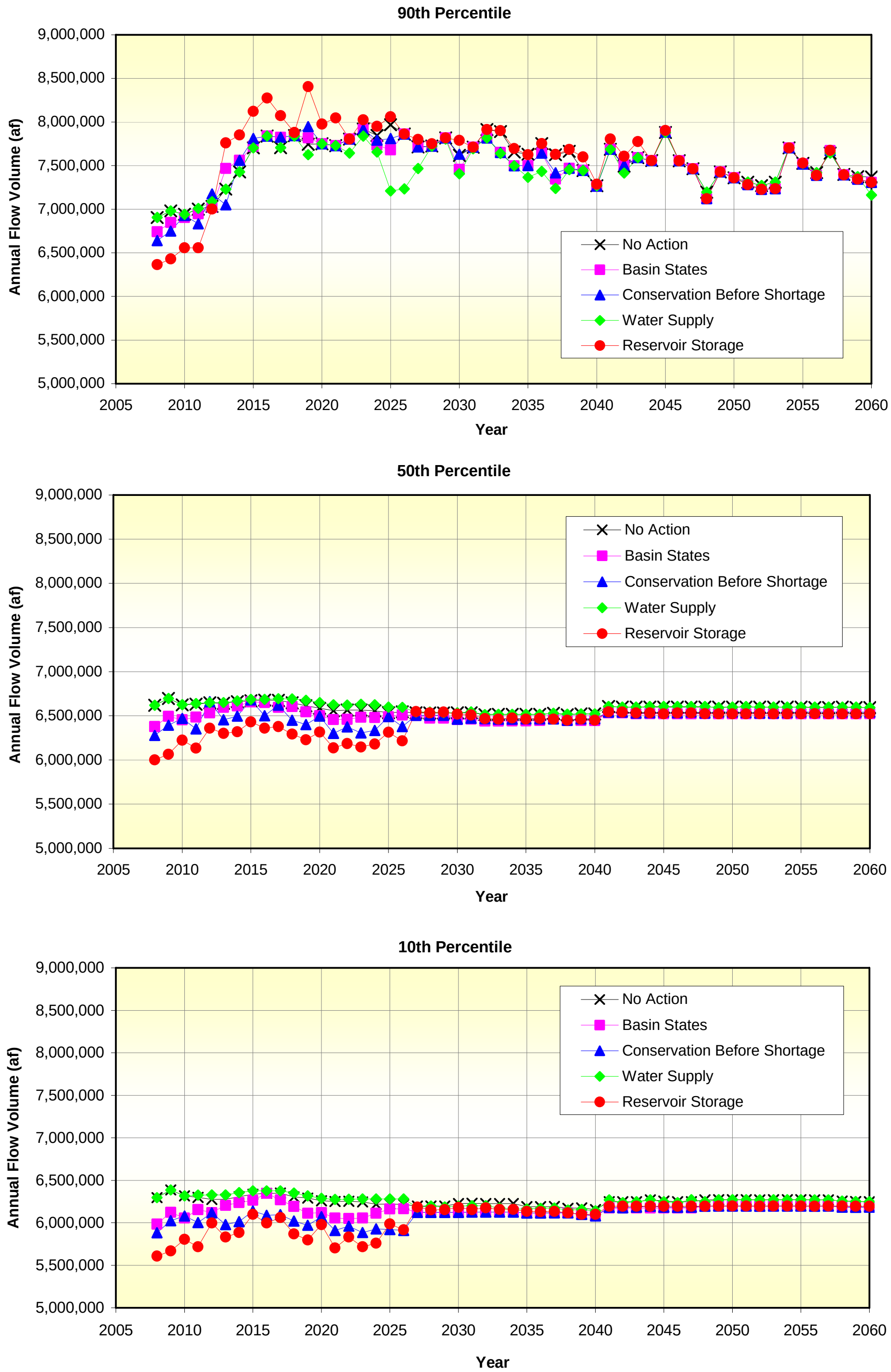


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Table 4.3-29 provides a comparison of the 90th, 50th, and 10th percentile annual flow volumes upstream of the CRIR Diversion among the alternatives for selected years.

Table 4.3-29
Colorado River Annual Flow Upstream of CRIR Diversion - RM 180.8 (mafy)
Comparison of Action Alternatives to No Action Alternative
90th, 50th, and 10th Percentile Values

Alternative	Year 2016			Year 2026			Year 2040			Year 2060		
	90th	50th	10th	90th	50th	10th	90th	50th	10th	90th	50th	10th
No Action	7.838	6.678	6.347	7.861	6.546	6.216	7.269	6.520	6.156	7.371	6.592	6.248
Basin States	7.838	6.650	6.346	7.863	6.509	6.166	7.263	6.445	6.081	7.307	6.524	6.185
Conservation Before Shortage	7.838	6.500	6.088	7.863	6.378	5.909	7.263	6.467	6.081	7.307	6.541	6.183
Water Supply	7.838	6.685	6.375	7.232	6.596	6.281	7.269	6.520	6.141	7.163	6.592	6.248
Reservoir Storage	8.274	6.359	5.997	7.863	6.217	5.916	7.287	6.449	6.100	7.308	6.524	6.195

River Flows Downstream of the Palo Verde Diversion Dam. The flow of the Colorado River between Palo Verde Diversion Dam and Imperial Dam is normally the amount needed to meet both the United States diversion requirements downstream of the Palo Verde Diversion and deliveries to Mexico. The river location that was used to analyze the flows in the reach of the river between Palo Verde Diversion and Imperial Dam is located immediately downstream of the Palo Verde Diversion.

The 90th, 50th, and 10th percentile annual flow volumes for the Colorado River at this point are shown on Figure 4.3-36. The greatest variability between alternatives occurs during the interim period (2008 through 2026). After 2026, the action alternatives converge to the No Action Alternative.

The 90th percentile flow volumes for the action alternatives were generally similar to those of the No Action Alternative, although there was some variability observed under the Water Supply and Reservoir Storage alternatives. The greatest variability occurs during the interim period and reflects the difference in the assumptions with regard to shortage and water conservation.

The 50th percentile annual flow volumes for all alternatives are generally similar with the Reservoir Storage Alternative having the lowest values.

At the 10th percentile level, the Water Supply Alternative shows slightly higher flow volumes compared to the No Action Alternative. The Basin States, Conservation Before Shortage, and Reservoir Storage alternatives show progressively lower flow volumes than the No Action Alternative.

Figure 4.3-36
Colorado River Annual Flow Downstream of Palo Verde Diversion Dam - RM 133.8 (af)
Comparison of Action Alternatives to No Action Alternative
90th, 50th, and 10th Percentile Values

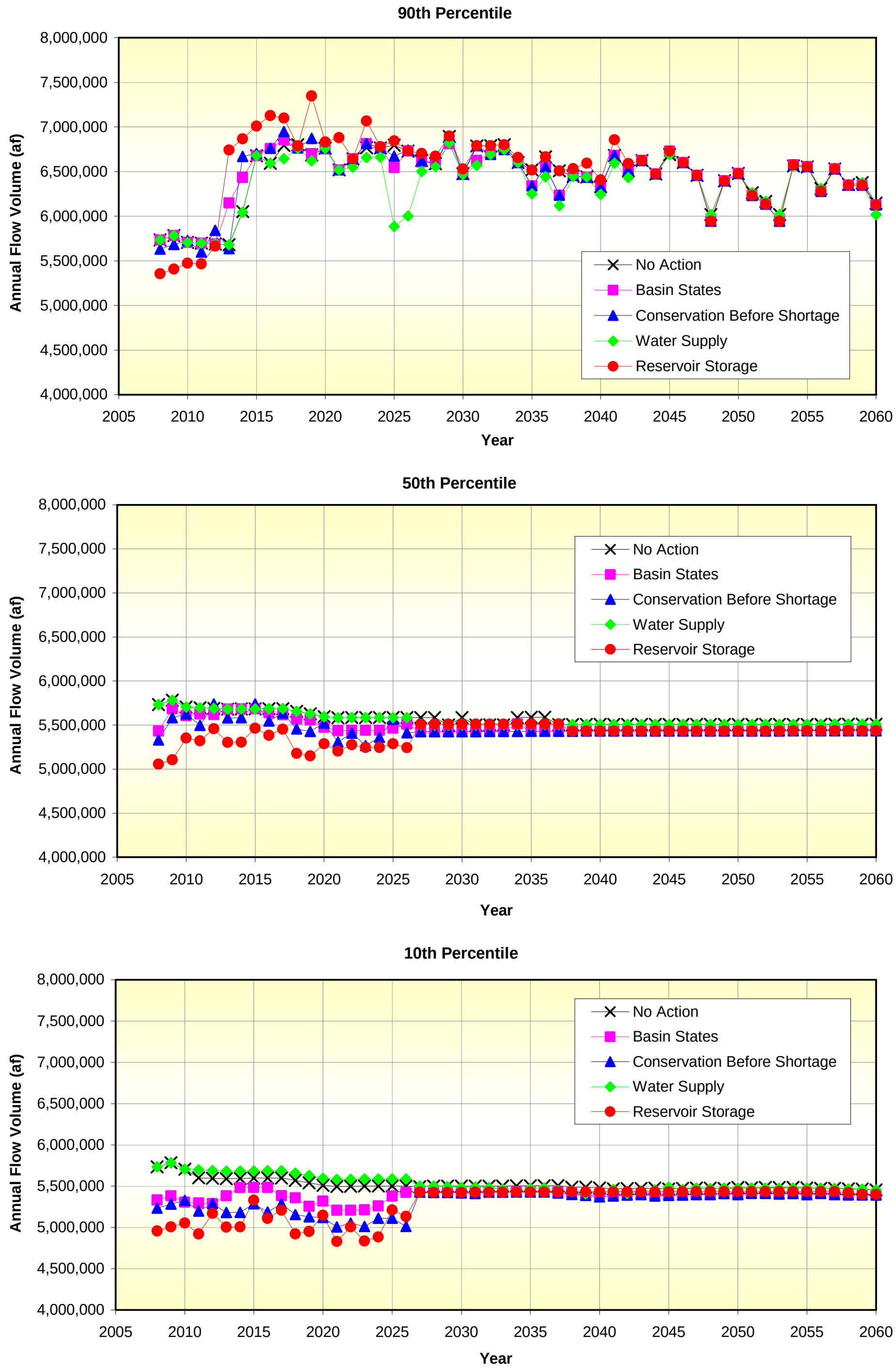


Table 4.3-30 provides a comparison of the 90th, 50th, and 10th percentile annual flow volumes downstream of the Palo Verde Diversion Dam.

Table 4.3-30
Colorado River Annual Flow Downstream of Palo Verde Diversion Dam - RM 133.8 (maf)
Comparison of Action Alternatives to No Action Alternative
90th, 50th, and 10th Percentile Values

	Year 2016			Year 2026			Year 2040			Year 2060		
Alternative	90th	50th	10th	90th	50th	10th	90th	50th	10th	90th	50th	10th
No Action	6.592	5.685	5.598	6.730	5.586	5.500	6.334	5.508	5.478	6.147	5.509	5.453
Basin States	6.758	5.641	5.485	6.731	5.511	5.423	6.326	5.433	5.402	6.126	5.434	5.389
Conservation Before Shortage	6.762	5.547	5.185	6.741	5.411	5.011	6.326	5.433	5.370	6.126	5.434	5.392
Water Supply	6.592	5.685	5.685	6.003	5.586	5.586	6.245	5.508	5.440	6.019	5.509	5.453
Reservoir Storage	7.128	5.384	5.109	6.731	5.244	5.134	6.407	5.433	5.433	6.127	5.434	5.402

4.3.7.2 Groundwater

As discussed in Section 3.3, the flows in the Parker Dam to Imperial Dam reach are primarily composed of water released from Parker Dam and therefore, the annual median releases are representative of the annual median flows in each reach. When converted to stage, a comparison of the annual median releases for each alternative may be used as the indicator to analyze potential effects to groundwater adjacent to the river in this reach.

Figure 4.3-37 illustrates the annual median releases from Parker Dam for each alternative for the years 2008 through 2060. As was the case for Davis Dam, the median releases for the Water Supply and Reservoir Storage alternatives bracket the median releases for the other three alternatives due primarily to the different shortage assumptions for each of the alternatives. Table 4.3-31 compares the annual median values relative to the No Action Alternative for specific years (each action alternative value less the No Action Alternative value). Using appropriate relationships to convert flow-to-stage (LCR MSCP BA, Appendix J, Attachment D), these relative flow differences would result in minor reductions in river stage (on the order of 0.25 feet). Based on the relationships used in the LCR MSCP BA ,Appendix K, such river stage reductions would result in corresponding reductions in groundwater elevations adjacent to the river (approximately 0.15 feet to 0.30 feet reduction for gaining and losing reaches respectively).

Figure 4.3-37
Parker Dam Annual Releases
Comparison of Action Alternatives to No Action Alternative
Annual Median (50th Percentile) Values

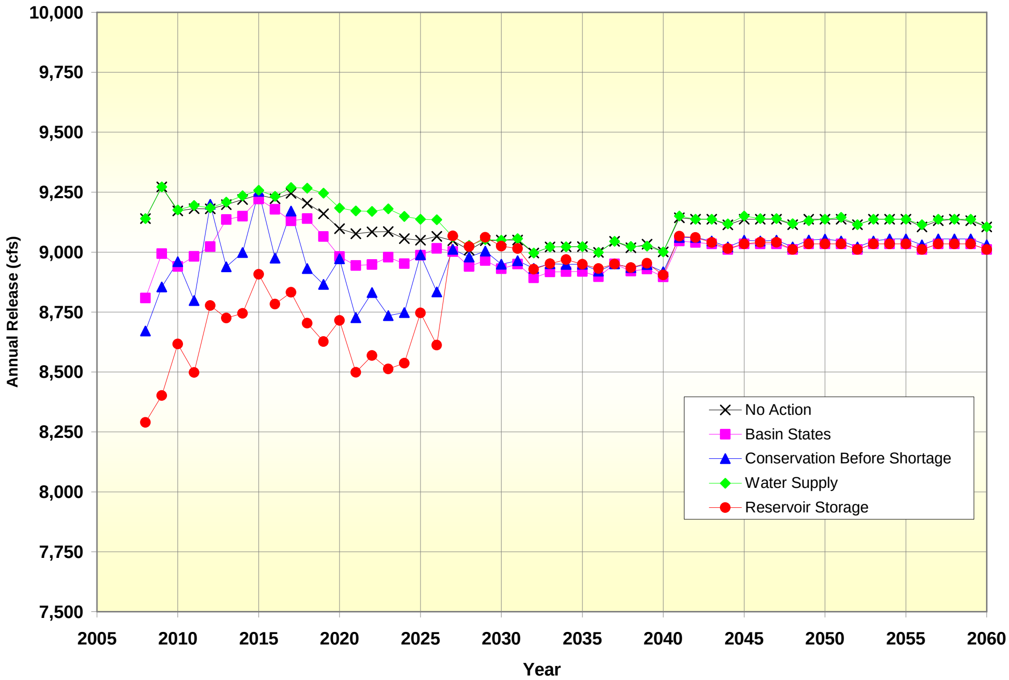


Table 4.3-31
Parker Dam Annual Median Releases
Differences of Action Alternatives Compared to No Action Alternative[1], (cfs)

Year	No Action	Basin States	Conservation Before Shortage	Water Supply	Reservoir Storage
2008	NA	-331	-469	0	-850
2011	NA	-200	-383	13	-684
2016	NA	-44	-248	10	-439
2017	NA	-115	-74	24	-413
2026	NA	-51	-232	69	-454
2027	NA	-45	-37	16	20
2040	NA	-103	-82	0	-96
2060	NA	-95	-75	0	-95

1 *Value of Action Alternative minus the value from the No Action Alternative provides the difference shown. A negative value indicates that the value under the Action Alternative is lower than that of the No Action Alternative, i.e. a flow reduction.*

4.3.8 Imperial Dam to NIB

As noted in Section 3.3, most of the water delivered to Mexico is diverted at Imperial Dam, conveyed via the AAC, and then returned to the Colorado River through the Pilot Knob and Siphon Drop Powerplants and their respective wasteway channels, 2.1 miles and 7.6 miles upstream of the NIB, respectively. The proposed federal action will not alter the operation of these diversions and wasteways and therefore, will not have an effect on this river reach.

4.3.9 NIB to SIB

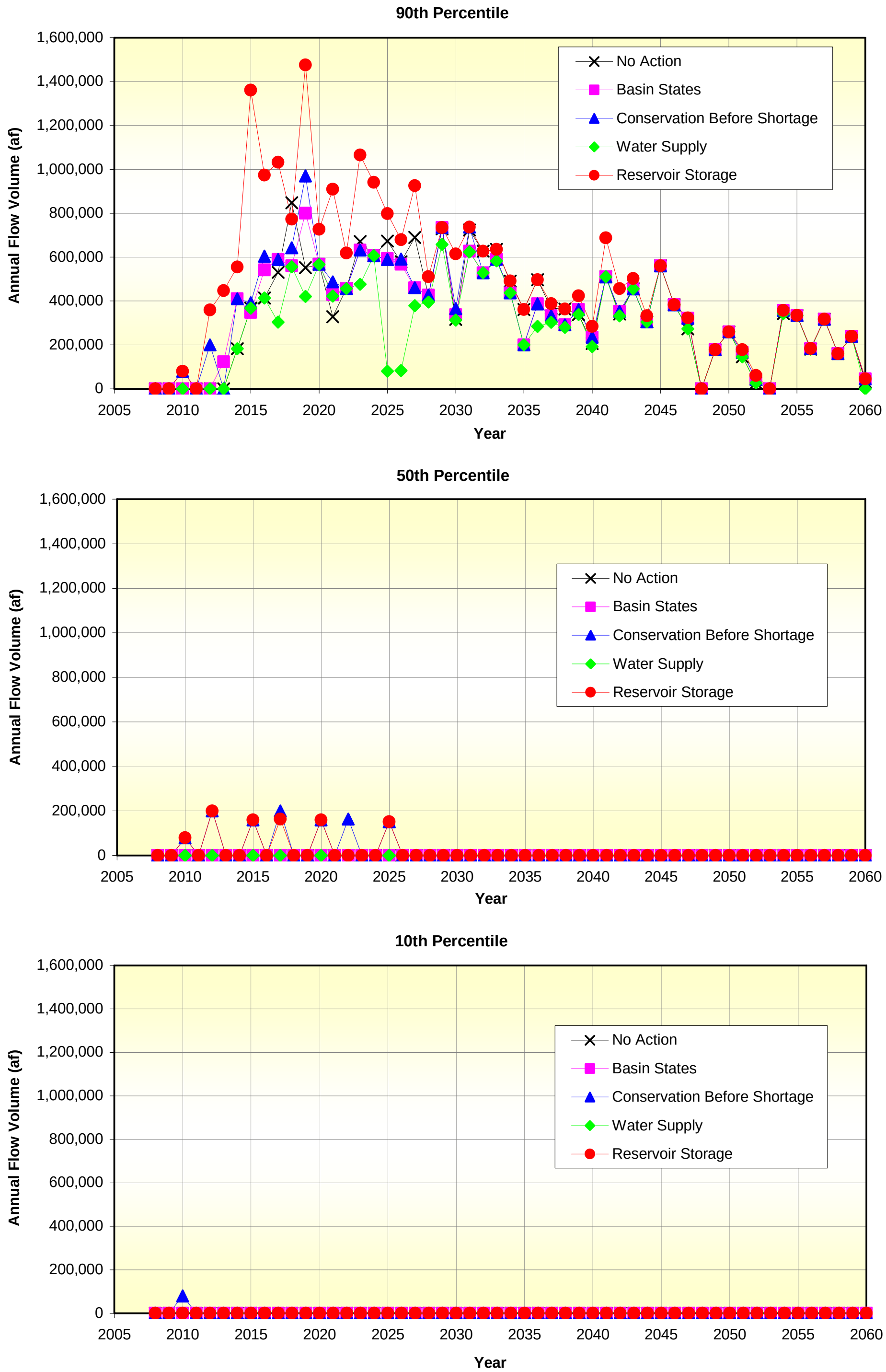
As noted in Section 3.3, Mexico diverts most of its Colorado River water supply at the Morelos Diversion Dam, and except during flood control operations, only limited flows actually pass Morelos Diversion Dam. During flood control operations, releases are made from Hoover Dam as dictated by the flood control criteria established with the USACE (Section 3.3). These releases are dependent upon the amount of available storage in the system (including Lake Powell and Lake Mead) and the hydrologic inflow forecast. The proposed federal action could potentially change the amount of water in storage in Lake Powell and Lake Mead, thereby affecting the frequency and/or volume of flood control releases.

In addition, the modeling assumptions used to model the storage and delivery mechanism for the Conservation Before Shortage and Reservoir Storage alternatives could potentially alter the flows in this reach.[1] It was assumed that water conservation activities in Mexico would result in conserved water that would be stored in Lake Mead and delivered on a periodic basis to Mexico through the NIB to the SIB reach. These modeling assumptions were used in this Draft EIS in order to analyze the potential impacts to resources of the storage and delivery mechanism, particularly with regard to reservoir elevations and river flow impacts. The use of these modeling assumptions does not represent any determination by Reclamation as to whether, or how, any storage/delivery arrangements would actually be implemented in the future. These modeling assumptions are not intended to constitute an interpretation or application of the 1944 Treaty or to represent current or future United States policy regarding deliveries to Mexico. Details of these assumptions are discussed in Section 4.2 and Appendix M.

The 90th, 50th, and 10th percentile annual flow volumes for this reach are shown in Figure 4.3-38.

[1] These flows were modeled as part of the storage and delivery mechanism under the Conservation Before Shortage and Reservoir Storage alternatives. These modeling assumptions were utilized in this Draft EIS in order to analyze the potential impacts to environmental resources of the storage and delivery mechanism, particularly with regard to reservoir elevations and river flow impacts. The use of these modeling assumptions does not represent any determination by Reclamation as to whether, or how, these releases could be made under current administration of the Colorado River.

Figure 4.3-38
Colorado River Annual Flow Below Mexico Diversion at Morelos Diversion Dam - RM 21.1 (af)
Comparison of Action Alternatives to No Action Alternative
90th, 50th, and 10th Percentile Values



Flows at the 90th percentile are produced by flood control operations. The values for the Reservoir Storage Alternative were generally greater than for the other alternatives due to higher reservoir levels. After 2045, the 90th percentile annual flow volumes are all similar. The 90th percentile annual flow volumes for the Water Supply Alternative were generally lower than the other alternatives through about 2030.

Flows at the 50th percentile are comprised solely of non-flood control flows. The No Action, Basin States, and Water Supply alternatives assume no activity with regard to delivery of conserved water to Mexico. The 50th percentile flows for the Conservation Before Shortage and Reservoir Storage alternatives show intermittent annual flow volumes of from about 40 kaf to 200 kaf during the interim period.

At the 10th percentile, the Conservation Before Shortage is the only alternative that shows an annual flow value that is greater than zero, in the year 2010 at a volume of 80 kaf.

Table 4.3-17 provides a summary of the results illustrated in Figure 4.3-17 for elevation 1,178 feet msl in tabular form for selected years. As shown in Table 4.3-17, the water levels under the Basin States and Conservation Before Shortage alternatives are similar to those under the No Action Alternative. The water levels under the Reservoir Storage Alternative fell below elevation 1,178 feet msl less frequently than those under the No Action Alternative. The water levels under the Water Supply Alternative fell below elevation 1,178 feet msl more frequently than those under the No Action Alternative.

Figure 4.3-39 shows the cumulative distribution for annual volumes of excess flows below the Mexico diversion at Morelos Diversion Dam for the period between 2008 through 2060. At flows less than about 250 kaf, the differences are due to the assumed delivery of conserved water to Mexico under the Conservation Before Shortage and Reservoir Storage alternatives. Flows greater than about 250 kaf are the result of flood control operations.

Table 4.3-32 provides a comparison of the 90th, 50th, and 10th percentile annual flow volumes below the Mexico diversion at Morelos Diversion Dam between the action alternatives and No Action Alternative for selected years.

Figure 4.3-39
Excess Flows Below Mexico Diversion at Morelos Diversion Dam
Comparison of Action Alternatives to No Action Alternative
Cumulative Distribution - Years 2008 through 2060

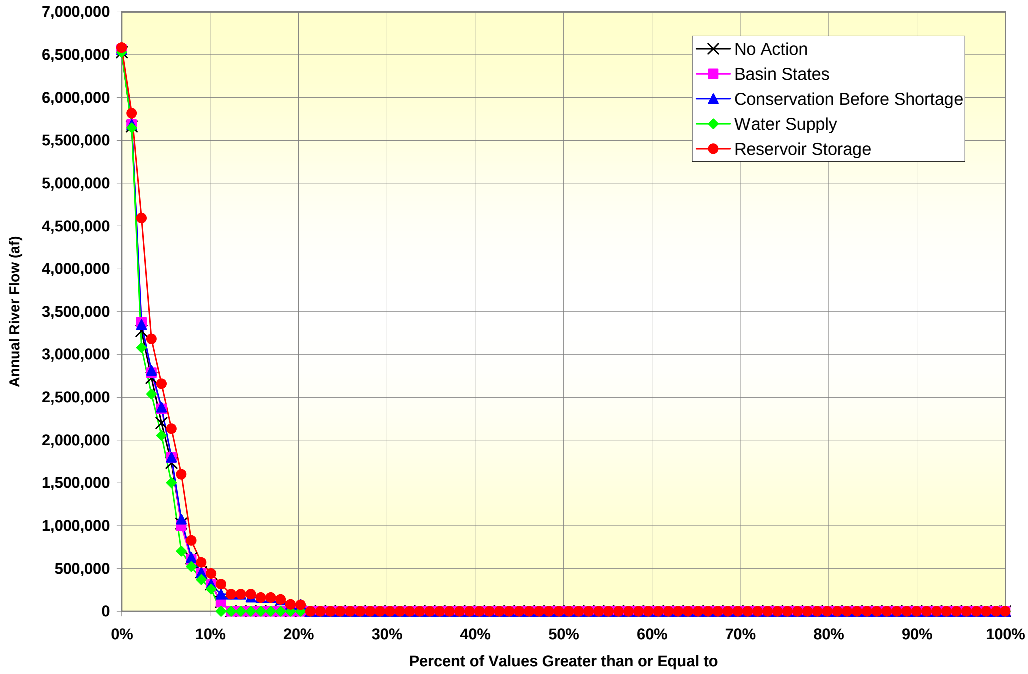


Table 4.3-32
Colorado River Annual Flow Below Mexico Diversion at Morelos Diversion Dam - RM 21.1 (maf)
Comparison of Action Alternatives to No Action Alternative
90th, 50th, and 10th Percentile Values

Alternative	Year 2016			Year 2026			Year 2040			Year 2060		
	90th	50th	10th	90th	50th	10th	90th	50th	10th	90th	50th	10th
No Action	0.414	0.000	0.000	0.579	0.000	0.000	0.206	0.000	0.000	0.032	0.000	0.000
Basin States	0.542	0.000	0.000	0.567	0.000	0.000	0.235	0.000	0.000	0.045	0.000	0.000
Conservation Before Shortage	0.605	0.000	0.000	0.591	0.000	0.000	0.235	0.000	0.000	0.045	0.000	0.000
Water Supply	0.414	0.000	0.000	0.083	0.000	0.000	0.192	0.000	0.000	0.000	0.000	0.000
Reservoir Storage	0.974	0.000	0.000	0.680	0.000	0.000	0.284	0.000	0.000	0.045	0.000	0.000

4.3.10 Summary

The following conclusions were drawn from the analyses of hydrologic resources.

4.3.10.1 Reservoir Storage

The Water Supply Alternative generally provides lower Lake Powell water levels than the No Action Alternative. Conversely, the Reservoir Storage Alternative provides higher Lake Powell levels than the No Action Alternative. The observed Lake Powell water levels under the Basin States and Conservation Before Shortage alternatives are similar to each other. The 50^{th} and 10^{th} percentile values of these two alternatives vary less than those of the Water Supply and Reservoir Storage alternatives. The greatest difference in Lake Powell elevation between the Basin States and Conservation Before Shortage alternatives and the No Action Alternative in any one year is about 10 feet.

The Lake Mead 50^{th} percentile elevations under the Water Supply Alternative are generally lower than those under the No Action Alternative. However, the Lake Mead 10^{th} percentile elevations under the Water Supply Alternative vary and are sometimes higher and sometimes lower than those under the No Action Alternative. The Reservoir Storage Alternative generally provides higher Lake Powell levels than the No Action Alternative. The observed Lake Mead water levels under the Basin States and Conservation Before Shortage alternatives are similar to each other. The 50^{th} and 10^{th} percentile values of these two alternatives vary less than those of the Water Supply and Reservoir Storage alternatives. Both the 50^{th} and 10^{th} percentile values of the Basin States and Conservation Before Shortage alternatives vary from being higher and sometimes lower than those of the No Action Alternative.

Lake Mohave and Lake Havasu are operated on a rule curve and have target end-of-month elevations. This manner of operation will continue in the future and would apply to operations under any of the action alternatives. Therefore, future Lake Mohave and Lake Havasu water levels would be expected to be similar between the action alternatives and the No Action Alternative.

4.3.10.2 Reservoir Releases

Glen Canyon Dam releases less than the annual minimum objective release of 8.23 maf occurred less than one percent of the time under the No Action Alternative, approximately 3.7 percent under the Basin States, Conservation Before Shortage, and Water Supply alternatives, and approximately six percent under the Reservoir Storage Alternative. Releases greater than the annual minimum objective release of 8.23 maf occurred approximately 35.5 percent under the No Action Alternative, approximately 42.4 percent under the Basin States, Conservation Before Shortage, and Water Supply alternatives, and approximately 36.67 percent under the Reservoir Storage Alternative. Releases greater than 9.0 maf generally correspond to years where either equalization or spill avoidance releases are made from Lake Powell. Glen Canyon Dam releases greater than 9.0 maf occurred 29.80 percent of the time under the No Action Alternative, 35.53 percent under the Basin States and Conservation Before Shortage alternatives, 36.67 percent under the Water Supply Alternative, and 30.94 percent under the Reservoir Storage Alternative.

More water is held in storage in Lake Mead under the Reservoir Storage Alternative and therefore the releases from Hoover Dam are lower under this alternative during the interim period (2008 through 2026), as compared to the No Action Alternative. Conversely, the Hoover Dam releases under the Water Supply Alternative are greater than those under No Action Alternative because less water is held in storage under the Water Supply Alternative. The Hoover Dam releases under the Basin States and Conservation Before Shortage alternatives are slightly less than those under the No Action Alternative and the differences can be attributed to the assumption that SNWA would develop additional non-system water supplies that are permanent, such as desalination. The assumption is that these supplies would be exchanged with other downstream Colorado River water users and the point of delivery of the exchanged water would move from below Hoover Dam to Lake Mead, resulting in reduced releases from Hoover Dam. Other reductions in releases under the action alternatives can be attributed to both voluntary and involuntary delivery reductions, i.e. water conservation and shortages. The alternative with the greatest effect on Hoover Dam releases due to shortage related delivery reductions is the Reservoir Storage Alternative.

The releases from Davis Dam and Parker Dam generally reflect the same pattern of releases under the different action alternatives as those from Hoover Dam. The differences in the release volumes are mostly attributed to the depletions that occur upstream of each respective dam.

4.3.10.3 River Flows

The river flows in the Glen Canyon Dam to Lake Mead river reach could potentially be reduced below 8.23 maf under the different action alternatives, albeit the frequency of occurrence of these reductions is expected to low. River flow reductions below 8.23 mafy are expected to occur about 3.7 percent of the time under the Basin States, Conservation Before Shortage, and Water Supply alternatives about 3.7 percent of the time and about 6 percent of the time under the Reservoir Storage Alternative. The corresponding seasonal, daily and hourly flows will also be affected although these will continue to be managed consistent with the AMP.

The river flow reductions that were observed for the river reaches downstream of Hoover Dam under the action alternatives were similar to those previously analyzed in the LCR MSCP Final EIS and LCR MSCP BA/BO.

4.3.10.4 Groundwater

The river flow reductions were determined to have no effect on the groundwater resources within the river reach that extends from Glen Canyon Dam to Lake Mead. The river flow reductions that occur below Hoover Dam could potentially affect groundwater resources within the different river reaches where they occur. However, the potential river stage reductions and corresponding potential effects on groundwater resources within these river reaches were determined to be similar to those considered in the LCR MSCP Final EIS and LCR MSCP BA/BO.

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4.4 Water Deliveries

This section compares water deliveries from the Colorado River mainstream to the Lower Division states and Mexico under the No Action and action alternatives. In addition, potential impacts of shortages to water user categories (agricultural, M&I, and Tribal) within Arizona are compared. Details with regard to potential impacts to specific water users, particularly within the state of Arizona, are presented in Appendix G.

4.4.1 Methodology

The methodology used to analyze total water deliveries to each Lower Division state and Mexico for each alternative is based on the hydrologic model (CRSS) described in Section 4.2 and in Appendix A. The modeling assumptions with respect to the distribution of shortages to the Lower Division states and Mexico are summarized in Section 4.2.

4.4.1.1 Shortage Allocation Model

To analyze the potential impacts of shortages to water users within each Lower Division state, a more detailed model referred to as the Shortage Allocation Model was developed. The Shortage Allocation Model was used to estimate delivery of water to Colorado River water entitlement holders within the Lower Division states and Mexico under varying levels of shortages. The entitlements, along with consumptive use schedules and established priorities within each respective Lower Division state, were included as parameters in the Shortage Allocation Model. In addition, the shortage distribution within the CAP is consistent with the Arizona Water Settlement Act (AWSA).

The Shortage Allocation Model allocates shortages to the Lower Division states consistent with the shortage sharing assumptions used in the CRSS model. The Shortage Allocation Model then distributes Colorado River water to entitlement holders within each state based on the priority of water rights within each respective state using the assumption that shortages will be shared on a pro rata basis by users of the same priority. A detailed description of the Shortage Allocation Model and the methodologies used to distribute the shortages is provided in Appendix G. A list of each state’s Colorado River water entitlement holders, listed by priority, is included in Appendix E.

Total Lower Basin shortages of 100 kaf to 2.5 maf (in increments of 100 kaf) were analyzed in the Shortage Allocation Model, fully covering the range of total Lower Basin shortages projected to occur under the No Action and action alternatives. The output for each model run shows how shortages were distributed to each entitlement holder within each state. The Shortage Allocation Model also summarized shortages into three water user categories in Arizona (agricultural, M&I, and Tribal), which are presented in Section 4.4.5. Detailed output from the Shortage Allocation Model is provided in Appendix G.

4.4.2 Apportionments to the Upper Division States

The proposed federal action will not affect the apportionments to the Upper Division states nor their ability to use their Compact apportionments and therefore no resource impact analysis was necessary.

4.4.3 Apportionments to the Lower Division States and Water Entitlements within Each State

The proposed federal action will not affect the apportionments to the Lower Division states or the water entitlements to water users within those states and therefore no resource impact analysis was necessary. However, water deliveries to each state and to users within each state may potentially be affected and are analyzed in the following sections.

4.4.4 Lower Division States Water Supply Determination

The proposed federal action would provide guidance to the Secretary's annual determination of the water supply condition (Surplus, Normal, or Shortage) for the Lower Division states. This section compares the probabilities of the determinations that would be made under each alternative.

4.4.4.1 Shortage Conditions

A Shortage condition exists in a particular year when the Secretary determines that there is insufficient mainstream water available to satisfy 7.5 maf of consumptive use in the Lower Division states. The elements of the proposed federal action include shortage guidelines and each alternative assumes a specific formulation for determining Shortage conditions (Chapter 2).

Probability of Involuntary and Voluntary Shortage. The Conservation Before Shortage proposal suggested an approach to the management of shortages in the Lower Basin whereby voluntary water reductions would occur at specific Lake Mead elevations in order to delay the onset of larger, involuntary water reductions. The voluntary water reductions would occur through a compensation program whereby willing Lower Basin Colorado River water users, including Mexico, would be paid to voluntarily and temporarily reduce their water use (Section 2.4). In Section 4.4 (this section), these water delivery reductions are termed voluntary shortages. Conversely, involuntary shortages would be water delivery reductions imposed by the determination of a Shortage condition by the Secretary.

The probability of a determination of Shortage conditions (and associated involuntary delivery reductions) for all alternatives is illustrated in Figure 4.4-1. Under the No Action Alternative, the probability of shortage increases throughout the interim period from about 20 percent in 2011 to about 50 percent in 2026. All action alternatives have lower probabilities of involuntary shortage when compared to the No Action Alternative from 2013 through 2026. Table 4.4-1 shows a comparison of the alternatives with respect to the first year of involuntary shortage. Table 4.4-2 shows the probability of any amount of involuntary Lower Basin shortage for specific years.

Figure 4.4-1
Involuntary Lower Basin Shortages
Comparison of Action Alternatives to No Action Alternative
Probability of Occurrence of Any Amount

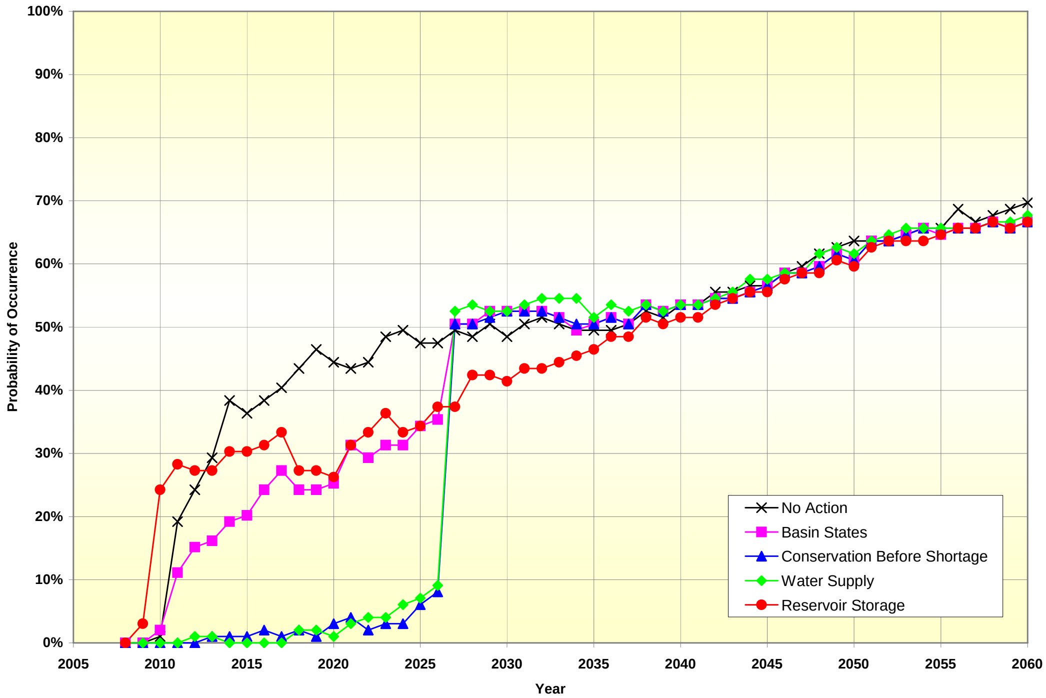


Table 4.4-1
First Year of Occurrence of Involuntary Shortage
Comparison of Action Alternatives and No Action Alternative

Alternative	No Action	Basin States	Conservation Before Shortage	Water Supply	Reservoir Storage
Year	2010	2010	2013	2012	2009

Table 4.4-2
Probability of Occurrence of Any Amount of Involuntary Shortage
Comparison of Action Alternatives to No Action Alternative

Year	No Action	Basin States	Conservation Before Shortage	Water Supply	Reservoir Storage
2008	0%	0%	0%	0%	0%
2017	40%	27%	1%	0%	33%
2026	47%	35%	8%	9%	37%
2027	49%	51%	51%	53%	37%
2040	54%	54%	54%	54%	52%
2060	70%	67%	67%	68%	67%

The Conservation Before Shortage and Water Supply alternatives result in infrequent, involuntary shortages during the interim period due to quite different reasons. The Conservation Before Shortage Alternative assumes that voluntary shortages would occur prior to the determination of an involuntary Shortage condition, whereas the Water Supply Alternative imposes involuntary shortages only if Lake Mead storage approaches the dead pool. Under the Water Supply Alternative, a shortage will also occur to SNWA when Lake Mead's elevation falls below 1,000 feet msl (Section 4.2). Figure 4.4-1 shows that this occurs approximately one to nine percent for years in the interim period in the Water Supply Alternative. Figure 4.4-1 also shows that the probability of involuntary shortages under the Conservation Before Shortage Alternative is similar (approximately one to eight percent over the interim period) since involuntary shortages are imposed under that alternative to protect Lake Mead from falling below elevation 1,000 feet msl.

Figure 4.4-2, Table 4.4-3, and Table 4.4-4 show the comparisons for all alternatives when both involuntary and voluntary shortages are considered. When both involuntary and voluntary shortages are considered, the occurrence of the first shortage (in year 2010) is identical for the Basin States and Conservation Before Shortage alternatives. The probability of shortages is also very similar because the Conservation Before Shortage Alternative assumes an identical strategy to determine the occurrence and magnitude of voluntary shortages as is used by the Basin States Alternative to determine the occurrence and magnitude of involuntary shortages. The Conservation Before Shortage Alternative shows somewhat lower probabilities of both voluntary and involuntary shortage over the interim period when compared to the Basin States Alternative primarily because more water is retained in Lake Mead to greater participation in the storage and delivery mechanism assumed under the Conservation Before Shortage Alternative. Also, the increased amount of involuntary shortage required in certain years to keep Lake Mead above 1,000 feet msl under the Conservation Before Shortage Alternative tends to retain additional water in Lake Mead, as compared to the Basin States Alternative, which decreases the probability of future shortages.

Figure 4.4-2
Involuntary and Voluntary Lower Basin Shortages
Comparison of Action Alternatives to No Action Alternative
Probability of Occurrence of Any Amount

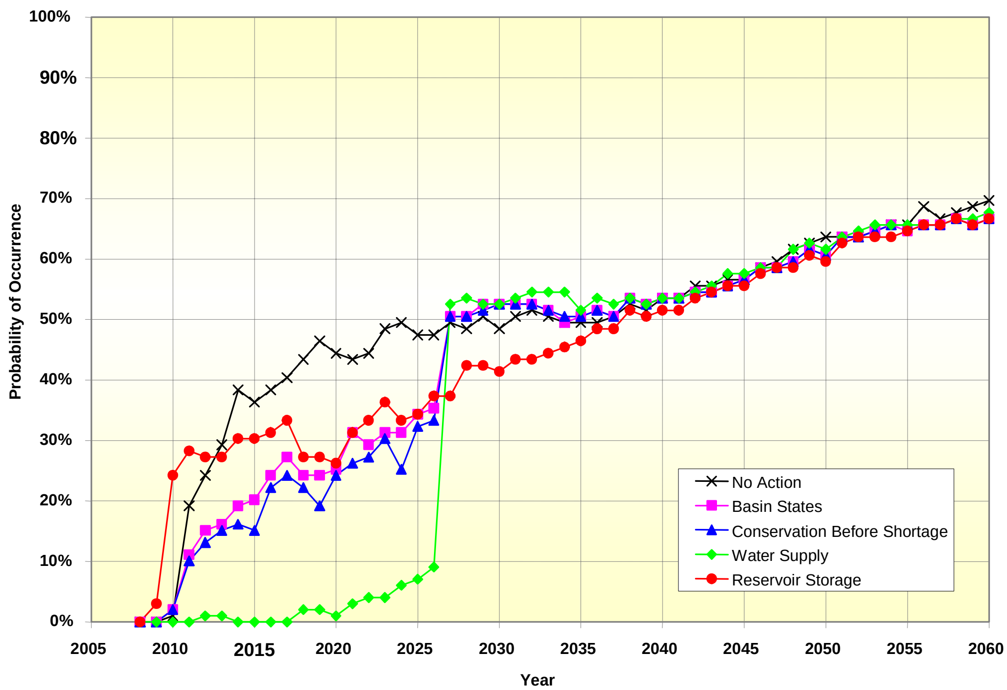


Table 4.4-3
First Year of Occurrence of Involuntary or Voluntary Shortage
Comparison of Action Alternatives to No Action Alternative

Alternative	No Action	Basin States	Conservation Before Shortage	Water Supply	Reservoir Storage
Year	2010	2010	2010	2012	2009

Table 4.4-4
Probability of Occurrence of Involuntary and Voluntary Shortages of Any Amount
Comparison of Action Alternatives to No Action Alternative

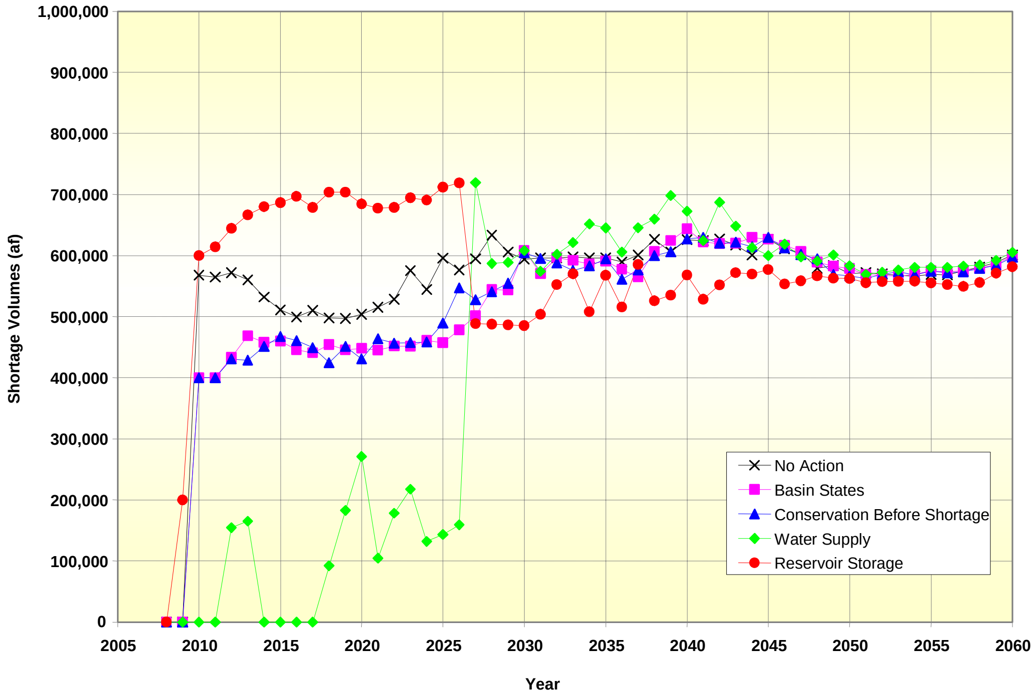
Year	No Action	Basin States	Conservation Before Shortage	Water Supply	Reservoir Storage
2008	0%	0%	0%	0%	0%
2017	40%	27%	24%	0%	33%
2026	47%	35%	33%	9%	37%
2027	49%	51%	51%	53%	37%
2040	54%	54%	54%	54%	52%
2060	70%	67%	67%	68%	67%

Magnitude of Involuntary and Voluntary Shortages. Although the probability of a shortage occurring is an important factor, the magnitude of the shortage is also important. Each alternative has specific assumptions with regard to when and by how much deliveries would be reduced.

The average shortage volumes for each year provide a weighted measure that considers both the frequency and magnitude of the potential shortages. The average shortage volumes are calculated by multiplying the observed volumes of shortages by their respective frequency of occurrence and summing calculated values for each year. A comparison of the average shortage volumes (of both involuntary and voluntary shortages) under the action alternatives to those of the No Action Alternative is provided in Figure 4.4-3.

The average values of the No Action Alternative range between about 500 and 600 kafy over the interim period and are reflective of the occurrence of the more frequent shortages which are on the order of 400 to 500 kafy based on Lake Mead trigger elevations (Section 2.2) as well as infrequent but larger shortages (on the order of 800 kafy to 2,000 kafy) necessary to keep Lake Mead above elevation 1,000 feet msl. The average value of shortages under the Water Supply Alternative are between zero and 270 kafy over the interim period and are indicative of the strategy which essentially determines no shortage except when Lake Mead is below elevation 1,000 feet msl and there is no delivery to SNWA. The Reservoir Storage Alternative shows average values of shortage between 600 and 720 kafy over the interim period since shortages are applied both more often and at higher magnitudes. The Basin States and Conservation Before Shortage alternatives show average values between 400 and about 500 kafy over the interim period. These average values are lower than the average values under the No Action Alternative since the shortages under these alternatives, although similar in magnitude, are applied less often than those under the No Action Alternative.

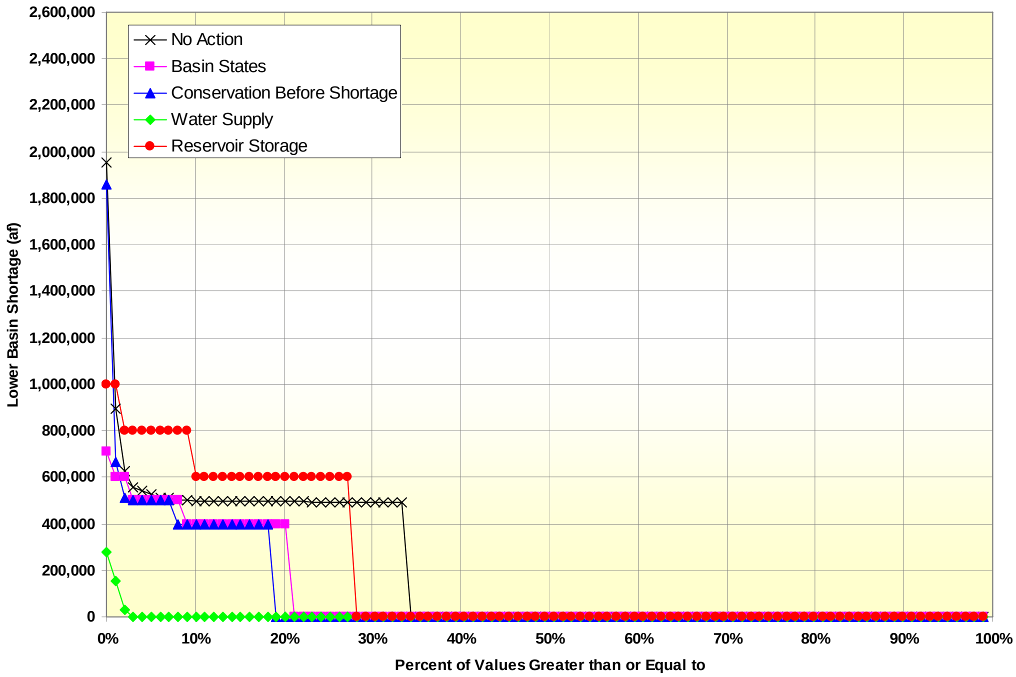
Figure 4.4-3
Involuntary and Voluntary Lower Basin Shortage
Comparison of Action Alternatives to No Action Alternative
Average Shortage Volumes



The Conservation Before Shortage Alternative also shows higher average shortage volumes in the latter years of the interim period when compared to the Basin States Alternative. This is due to involuntary shortages of higher magnitudes occurring at higher frequencies in the latter years under the Conservation Before Shortage Alternative to keep Lake Mead above elevation 1,000 feet msl. Conversely, the Basin States Alternative assumes that when Lake Mead is at or below elevation 1,025 feet msl, additional consultations will occur in order to determine what further actions might be necessary. For modeling purposes, it was assumed that shortages with a magnitude of 600 kaf would continue for Lake Mead elevations below 1,025 feet msl for the Basin States Alternative.

An alternative way to compare the probability and magnitude of shortages between alternatives is to compare the cumulative distribution of shortages over a period of time. Figure 4.4-4 presents the cumulative distributions of both voluntary and involuntary shortages for the interim period, 2008 through 2026.

Figure 4.4-4
Involuntary and Voluntary Lower Basin Shortages
Comparison of Action Alternatives to No Action Alternative
Years 2006 through 2026



Under the No Action Alternative, shortages between 400 and 500 kafy would be applied in about 30 percent of the time, with shortages of greater magnitudes occurring about five percent of the time over the interim period. Under the Basin States and Conservation Before Shortage alternatives, shortages occur less often than under the No Action Alternative (about 21 to 18 percent of the time respectively), with the slight lower probability of the Conservation Before Shortage Alternative due to the assumption of larger amounts of conserved water being stored in Lake Mead under that alternative. The Reservoir Storage Alternative shows that shortages of magnitudes greater than 600 kafy would occur about 10 percent of the time.

Figure 4.4-5 provides the cumulative distribution of shortages for the period between 2027 through 2060. Although all alternatives were assumed to revert back to the No Action assumptions in 2027, the differences in cumulative distributions are attributed to differences in Lake Powell and Lake Mead elevations between the alternatives at the end of the interim period (2026). For example, the occurrence of large shortages (on the order of 2,500 kaf) at low probabilities under the Water Supply Alternative is due to large shortages that must be applied in order to return Lake Mead above elevation 1,000 feet msl for some traces in 2027 and 2028.

Tables 4.4-5 through 4.4-9 present the probability of occurrence of shortages of various magnitudes for years 2017, 2026, 2027, 2040, and 2060 under all alternatives. Also shown are the probabilities for the Conservation Before Shortage Alternative for just involuntary shortages and both involuntary and voluntary shortages.

Figure 4.4-5
Involuntary and Voluntary Lower Basin Shortages
Comparison of Action Alternatives to No Action Alternative
Years 2027 through 2060

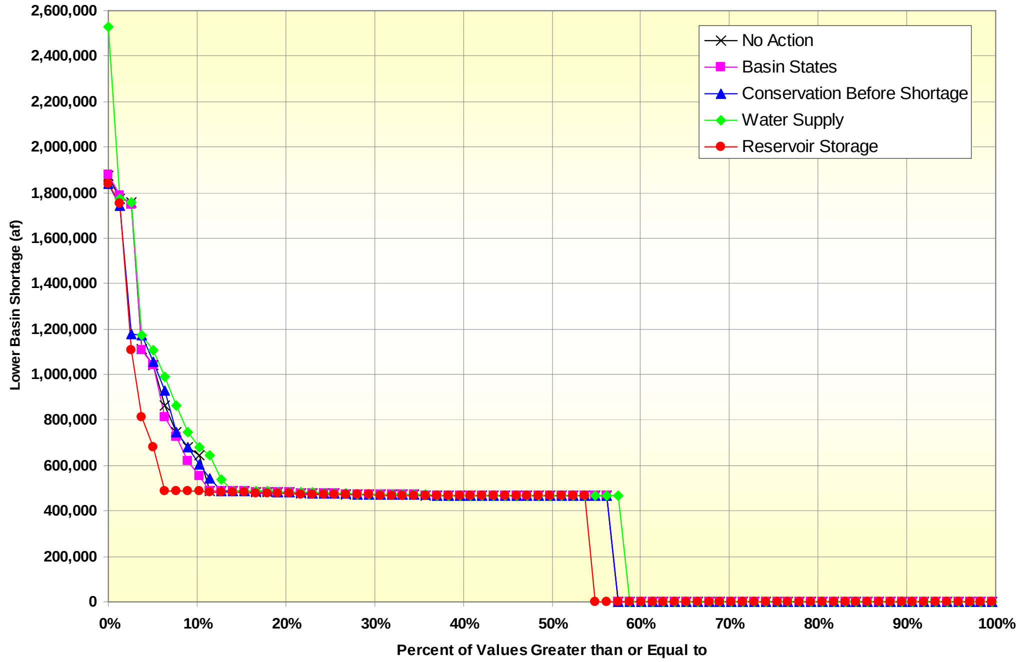


Table 4.4-5
Distribution of Shortages, Year 2017

Shortage (kaf)	No Action	Basin States	Conservation Before Shortage: Involuntary	Conservation Before Shortage: Involuntary & Voluntary	Water Supply	Reservoir Storage
< 400	0%	0%	0%	0%	0%	0%
400 - 499	39%	18%	0%	16%	0%	0%
500 - 599	0%	7%	0%	7%	0%	0%
600 - 799	0%	2%	0%	0%	0%	22%
800 - 999	1%	0%	1%	1%	0%	9%
1,000 – 1,199	0%	0%	0%	0%	0%	2%
1,200 – 1,399	0%	0%	0%	0%	0%	0%
1,400 – 1,599	0%	0%	0%	0%	0%	0%
1,600 – 1,799	0%	0%	0%	0%	0%	0%
1,800 – 1,999	0%	0%	0%	0%	0%	0%
2,000 – 2,499	0%	0%	0%	0%	0%	0%
> 2,500	0%	0%	0%	0%	0%	0%

Table 4.4-6
Distribution of Shortages, Year 2026

Shortage (kaf)	No Action	Basin States	Conservation Before Shortage: Involuntary	Conservation Before Shortage: Involuntary & Voluntary	Water Supply	Reservoir Storage
< 400	0%	0%	2%	2%	9%	0%
400 - 499	39%	16%	0%	16%	0%	0%
500 - 599	1%	12%	0%	11%	0%	0%
600 - 799	3%	7%	4%	4%	0%	19%
800 - 999	2%	0%	1%	1%	0%	14%
1,000 – 1,199	0%	0%	0%	0%	0%	4%
1,200 – 1,399	0%	0%	0%	0%	0%	0%
1,400 – 1,599	0%	0%	0%	0%	0%	0%
1,600 – 1,799	1%	0%	0%	0%	0%	0%
1,800 – 1,999	1%	0%	1%	1%	0%	0%
2,000 – 2,499	0%	0%	0%	0%	0%	0%
> 2,500	0%	0%	0%	0%	0%	0%

Table 4.4-7
Distribution of Shortages, Year 2027

Shortage (kaf)	No Action	Basin States	Conservation Before Shortage		Water Supply	Reservoir Storage
			Involuntary	Involuntary & Voluntary		
< 400	0%	0%	0%	0%	0%	0%
400 - 499	39%	48%	45%	45%	43%	37%
500 - 599	1%	1%	1%	1%	0%	0%
600 - 799	3%	0%	0%	0%	1%	0%
800 - 999	3%	0%	3%	3%	0%	0%
1,000 – 1,199	1%	1%	1%	1%	1%	0%
1,200 – 1,399	0%	0%	0%	0%	1%	0%
1,400 – 1,599	0%	0%	0%	0%	0%	0%
1,600 – 1,799	1%	0%	0%	0%	0%	0%
1,800 – 1,999	1%	0%	0%	0%	2%	0%
2,000 – 2,499	0%	0%	0%	0%	3%	0%
> 2,500	0%	0%	0%	0%	1%	0%

Table 4.4-8
Distribution of Shortages, Year 2040

Shortage (kaf)	No Action	Basin States	Conservation Before Shortage		Water Supply	Reservoir Storage
			Involuntary	Involuntary & Voluntary		
< 400	0%	0%	0%	0%	0%	0%
400 - 499	42%	41%	40%	40%	37%	46%
500 - 599	1%	1%	1%	1%	1%	0%
600 - 799	2%	2%	2%	2%	4%	0%
800 - 999	1%	1%	1%	1%	2%	2%
1,000 – 1,199	3%	3%	7%	7%	4%	0%
1,200 – 1,399	0%	0%	0%	0%	0%	0%
1,400 – 1,599	0%	0%	0%	0%	0%	0%
1,600 – 1,799	3%	4%	1%	1%	4%	2%
1,800 – 1,999	1%	1%	1%	1%	1%	1%
2,000 – 2,499	0%	0%	0%	0%	0%	0%
> 2,500	0%	0%	0%	0%	0%	0%

Table 4.4-9
Distribution of Shortages, Year 2060

Shortage (kaf)	No Action	Basin States	Conservation Before Shortage: Involuntary	Conservation Before Shortage: Involuntary & Voluntary	Water Supply	Reservoir Storage
< 400	0%	0%	0%	0%	0%	0%
400 - 499	55%	53%	49%	49%	53%	54%
500 - 599	1%	0%	3%	3%	1%	0%
600 - 799	4%	5%	5%	5%	4%	5%
800 - 999	3%	2%	2%	2%	3%	1%
1,000 – 1,199	3%	3%	4%	4%	3%	4%
1,200 – 1,399	0%	0%	0%	0%	0%	0%
1,400 – 1,599	0%	0%	0%	0%	0%	0%
1,600 – 1,799	3%	3%	3%	3%	3%	3%
1,800 – 1,999	1%	1%	0%	0%	1%	0%
2,000 – 2,499	0%	0%	0%	0%	0%	0%
> 2,500	0%	0%	0%	0%	0%	0%

The maximum amounts of shortages for each alternative for each year is presented in Figure 4.4-6. Table 4.4-10 lists the maximum values for particular years. The large shortages in 2027 and 2028 are clearly shown for the Water Supply Alternative. By contrast, the Reservoir Storage Alternative has the lowest maximum shortage of any of the alternatives in 2027 because the reservoir would be maintained at relatively higher levels. By 2040, all alternatives have converged essentially to the No Action Alternative values.

Figure 4.4-6
Involuntary and Voluntary Lower Basin Shortages
Comparison of Action Alternatives to No Action Alternative
Maximum Amounts

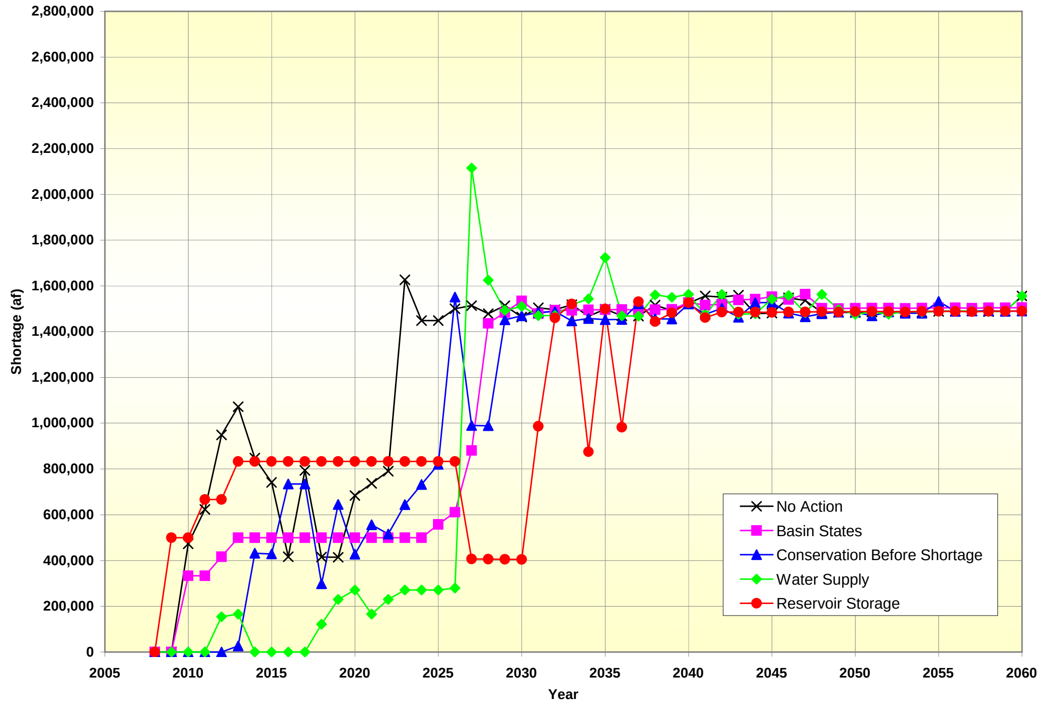
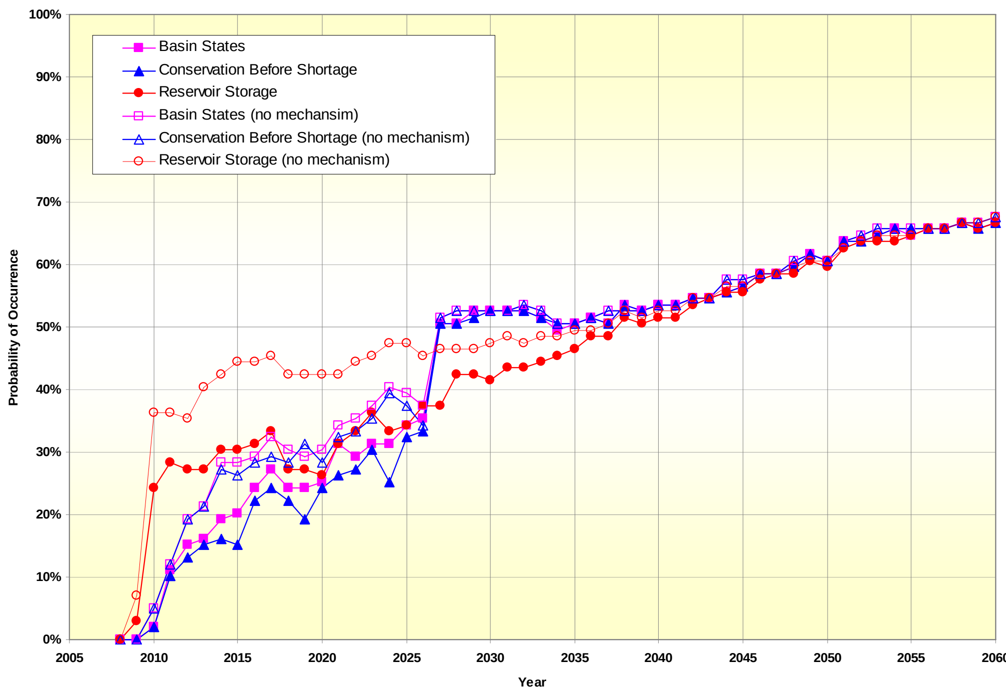


Table 4.4-10
Maximum Occurrence of Involuntary and Voluntary Shortage to the Lower Basin (af)
Comparison of Action Alternatives to No Action Alternative

Year	No Action	Basin States	Conservation Before Shortage	Water Supply	Reservoir Storage
2008	0	0	0	0	0
2017	952,520	600,000	881,221	0	1,000,000
2026	1,800,152	711,370	1,860,797	279,000	1,000,000
2027	1,816,966	1,057,098	1,187,524	2,528,644	488,644
2040	1,828,982	1,832,920	1,824,950	1,875,843	1,832,559
2060	1,867,379	1,805,615	1,788,542	1,867,379	1,787,370

Sensitivity of Shortage Conditions to Storage and Delivery Mechanism. The mechanism to deliver and store conserved system and non-system water assumed as part of the Basin States, Conservation Before Shortage and Reservoir Storage alternatives impacts the probability of shortage occurrences. Because a potential effect of the storage and delivery mechanism is an increase in the amount of water in Lake Mead, a Shortage condition is likely to occur less often with the storage and delivery mechanism in place. Figure 4.4-7 presents the sensitivity of the occurrence of a Shortage condition to the storage and delivery mechanism by comparing these three alternatives with and without the mechanism in place. For each alternative, the inclusion of the mechanism has the effect of decreasing the probability of shortages. Under the Basin States and Conservation Before Shortage alternatives the probability of shortage is reduced an average of about five percent from 2010 through 2026. Under the Reservoir Storage Alternative the reduction is greater, an average of 12 percent from 2010 through 2026, due to the greater amount of storage credits that are assumed to be generated under this alternative.

Figure 4.4-7
Involuntary and Voluntary Lower Basin Shortages
Comparison of Action Alternatives With and Without a Storage and Delivery Mechanism
Probability of Occurrence of Any Amount

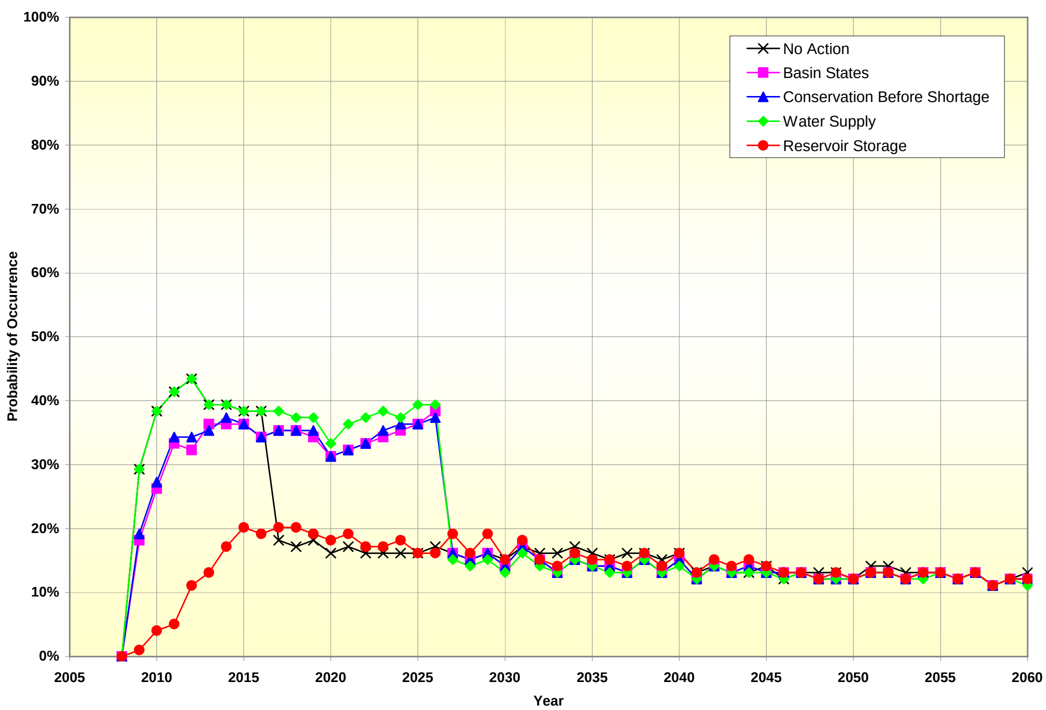


4.4.4.2 Surplus Conditions

A Surplus condition exists in a particular year when the Secretary determines that there is sufficient mainstream water available to satisfy in excess of 7.5 maf of consumptive use in the Lower Division states. The elements of the proposed federal action include a modification and/or extension of the ISG and each alternative expresses a particular assumption for determining Surplus conditions (Chapter 2).

Probability of Surplus of Any Amount. Figure 4.4-8 compares the probabilities of Surplus conditions between the alternatives. For the No Action Alternative, the probability of surplus drops from about 40 percent to 20 percent in 2017 due to the expiration of the ISG. For the Basin States, Conservation Before Shortage and Water Supply alternatives, the probabilities of surplus are between 30 percent and 40 percent through 2026 since they assume an extension of some provisions of the ISG. Probabilities for the Basin States and Conservation Before Shortage alternatives are lower compared to the Water Supply Alternative, however, since both assume that the ISG would be modified and the more permissive provisions (e.g., Partial Domestic Surplus) would be eliminated. For the Reservoir Storage Alternative, surplus determinations are limited to Quantified Surplus (70R Strategy) and Flood Control Surplus conditions, beginning in 2008, and that assumption is reflected in the lower probabilities compared to the other action alternatives throughout the interim period. The probabilities for all alternatives converge to between 10 percent and 20 percent after the interim period since they all revert to the No Action Alternative assumptions after 2026.

Figure 4.4-8
Surplus Conditions
Comparison of Action Alternatives to No Action Alternative
Probability of Occurrence



Probability of Various Types of Surplus. Figure 4.4-9 presents a comparison of the probability of occurrence of the Partial Domestic Surplus condition for each alternative. The probability is zero for the Basin States, Conservation Before Shortage and Reservoir Storage alternatives since no provisions for Partial Domestic Surplus are contained in those alternatives. The probability of Partial Domestic Surplus for the No Action and the Water Supply alternatives are identical through 2016. After 2016, the probability of Partial Domestic Surplus under the No Action Alternative drops to zero since the ISG expire, while the Water Supply Alternative assumes an extension of the existing ISG through 2026.

Figure 4.4-9
Partial Domestic Surplus Deliveries to Lower Basin States
Comparison of Action Alternatives to No Action Alternative
Probability of Occurrence

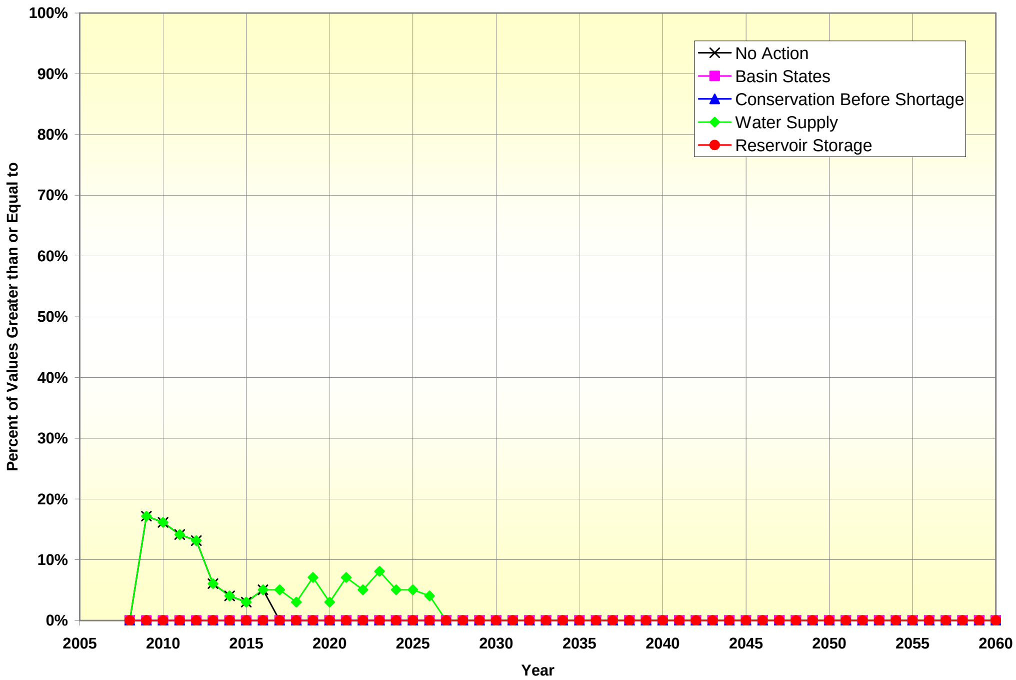


Figure 4.4-10 presents a comparison of the probability of occurrence of the Full Domestic Surplus condition for each alternative. The probability is zero for the Reservoir Storage Alternative since it does not include a provision for this condition. The probability of Full Domestic Surplus for the No Action and Water Supply alternatives are nearly identical through 2016 since they have the same assumptions during that period, with the Water Supply Alternative continuing the Full Domestic Surplus provision through 2026. The Basin States and Conservation Before Shortage alternatives also have nearly identical probabilities through 2026 since they have the same assumptions during

that period. The probabilities for the Basin States and Conservation Before Shortage alternatives are slightly higher than the No Action and Water Supply alternatives since they do not have a provision for Partial Domestic Surplus. This keeps the reservoir slightly higher increasing the chance of a Full Domestic Surplus determination.

Figure 4.4-10
Full Domestic Surplus Deliveries to Lower Basin States
Comparison of Action Alternatives to No Action Alternative
Probability of Occurrence

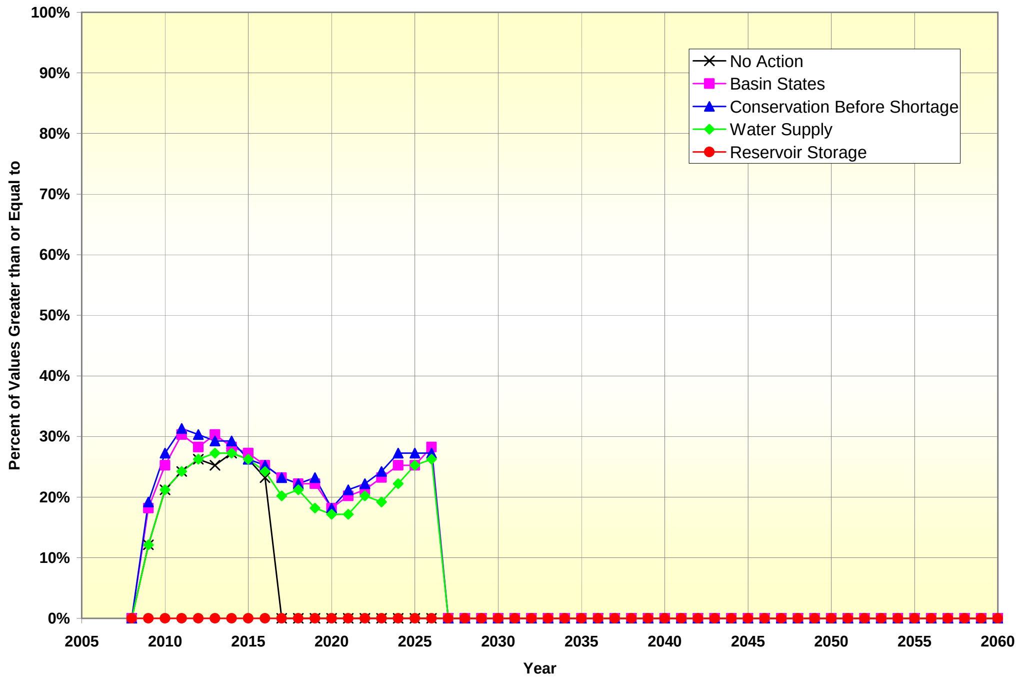
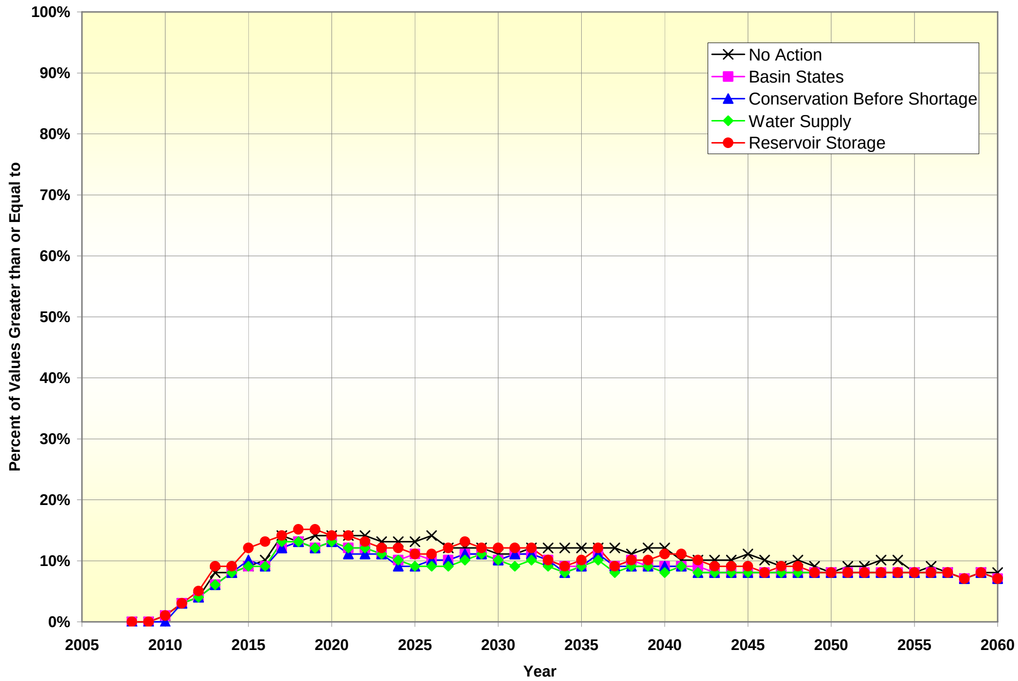


Figure 4.4-11 presents a comparison of the probability of the Quantified (70R) Surplus condition for each alternative. The probabilities for the No Action, Basin States, Conservation Before Shortage, and Water Supply alternatives are nearly identical, with the Reservoir Storage Alternative being slightly higher since it tends to keep the reservoir at higher elevations.

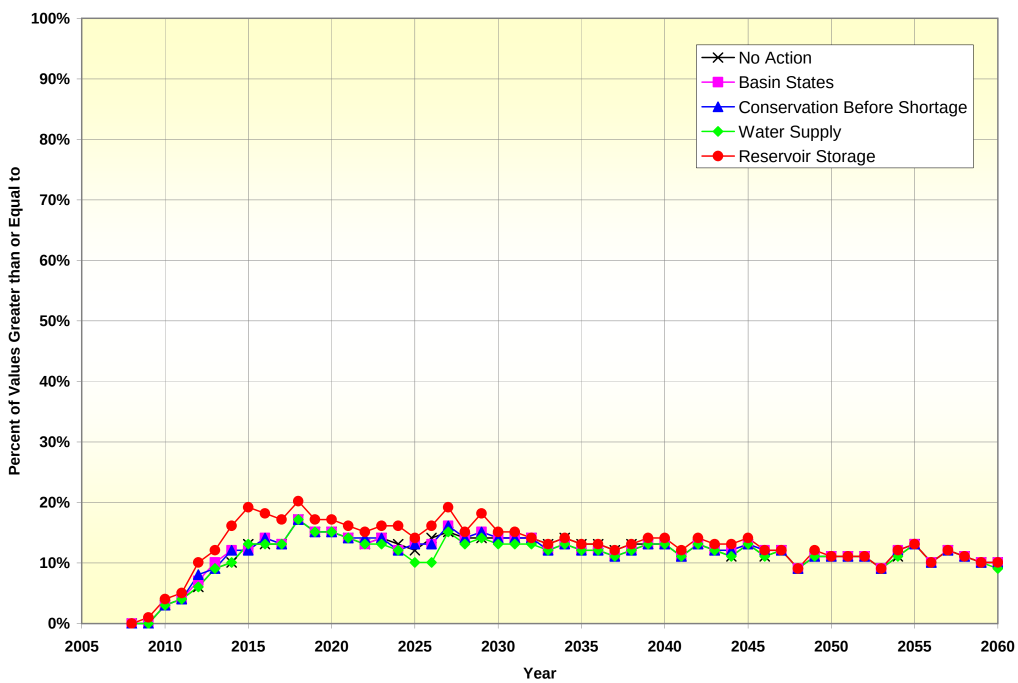
Figure 4.4-12 presents a comparison of the probability of the Flood Control Surplus condition for each alternative. The probabilities for the No Action, Basin States, Conservation Before Shortage, and Water Supply alternatives are nearly identical, with the Reservoir Storage Alternative being slightly higher since it tends to keep the reservoir at higher elevations.

Figure 4.4-11
Quantified Surplus (70R Strategy) Deliveries to Lower Basin States
Comparison of Action Alternatives to No Action Alternative
Probability of Occurrence



1

Figure 4.4-12
Flood Control Surplus Deliveries to Lower Basin States
Comparison of Action Alternatives to No Action Alternative
Probability of Occurrence

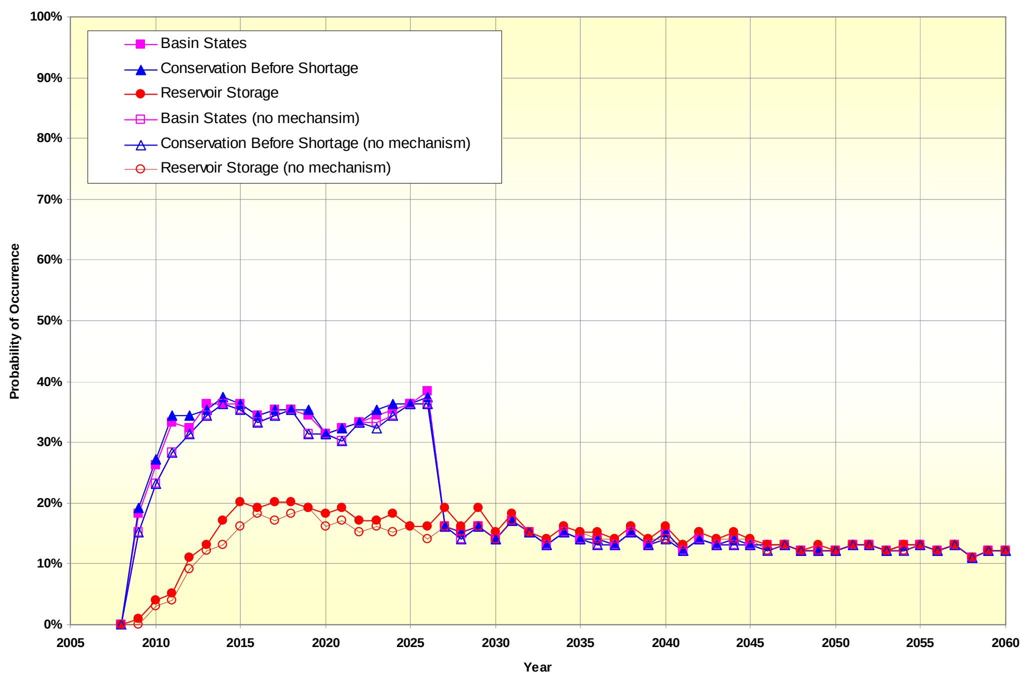


2

Sensitivity of Surplus Conditions to Storage and Delivery Mechanism. The mechanism to deliver and store conserved and non-system water assumed as part of the Basin States, Conservation Before Shortage and Reservoir Storage alternatives impacts the probability of Surplus occurrences. Because a potential effect of the storage and delivery mechanism is an increase in the amount of water in Lake Mead, a Surplus condition is likely to occur more often with the storage and delivery mechanism in place.

Figure 4.4-13 presents the sensitivity of the occurrence of a Surplus condition to the storage and delivery mechanism by comparing these three alternatives with and without the mechanism in place. For each alternative, the inclusion of the mechanism has the effect of slightly increasing the probability of a surplus. The maximum increase is about five percent under the Basin States and Conservation Before Shortage alternatives and occurs in 2011. The maximum increase is about four percent under the Reservoir Storage Alternative, occurring in 2014 and 2015.

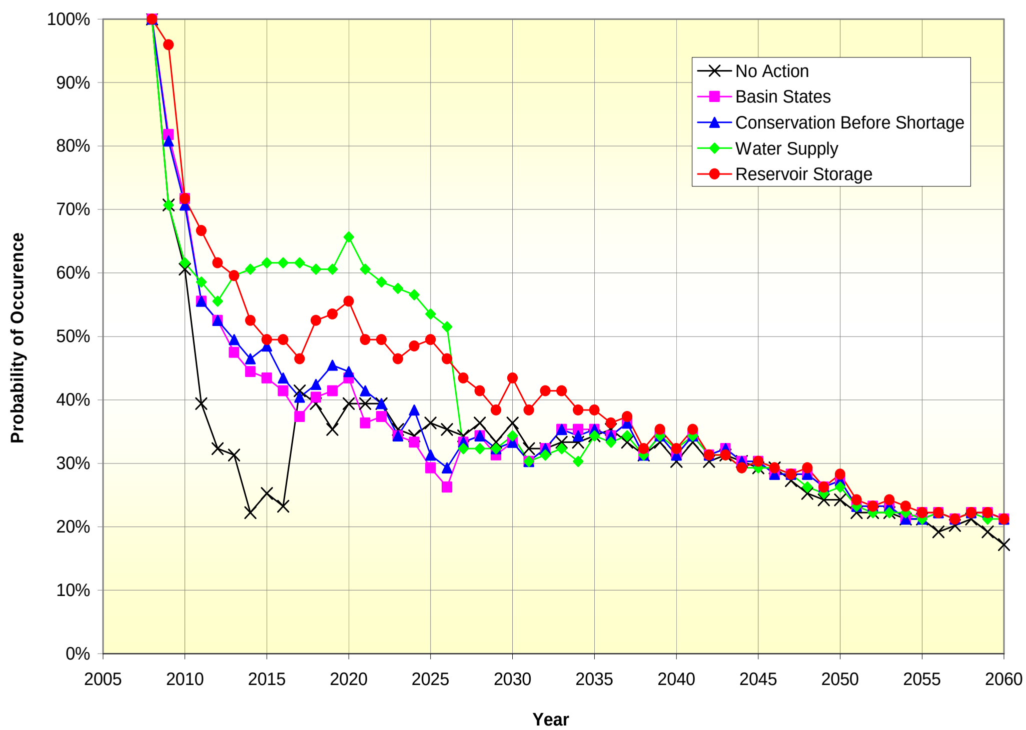
Figure 4.4-13
Surplus Deliveries to Lower Basin States
Comparison of Action Alternatives With and Without a Storage and Delivery Mechanism
Probability of Occurrence



4.4.4.3 Normal Conditions

The probability of a Normal condition is shown in Figure 4.4-14. Under the assumption of an initial Lake Mead elevation of 1,116.53 feet msl on January 1, 2008, the Normal condition would occur for all alternatives with a 100 percent probability in 2008.

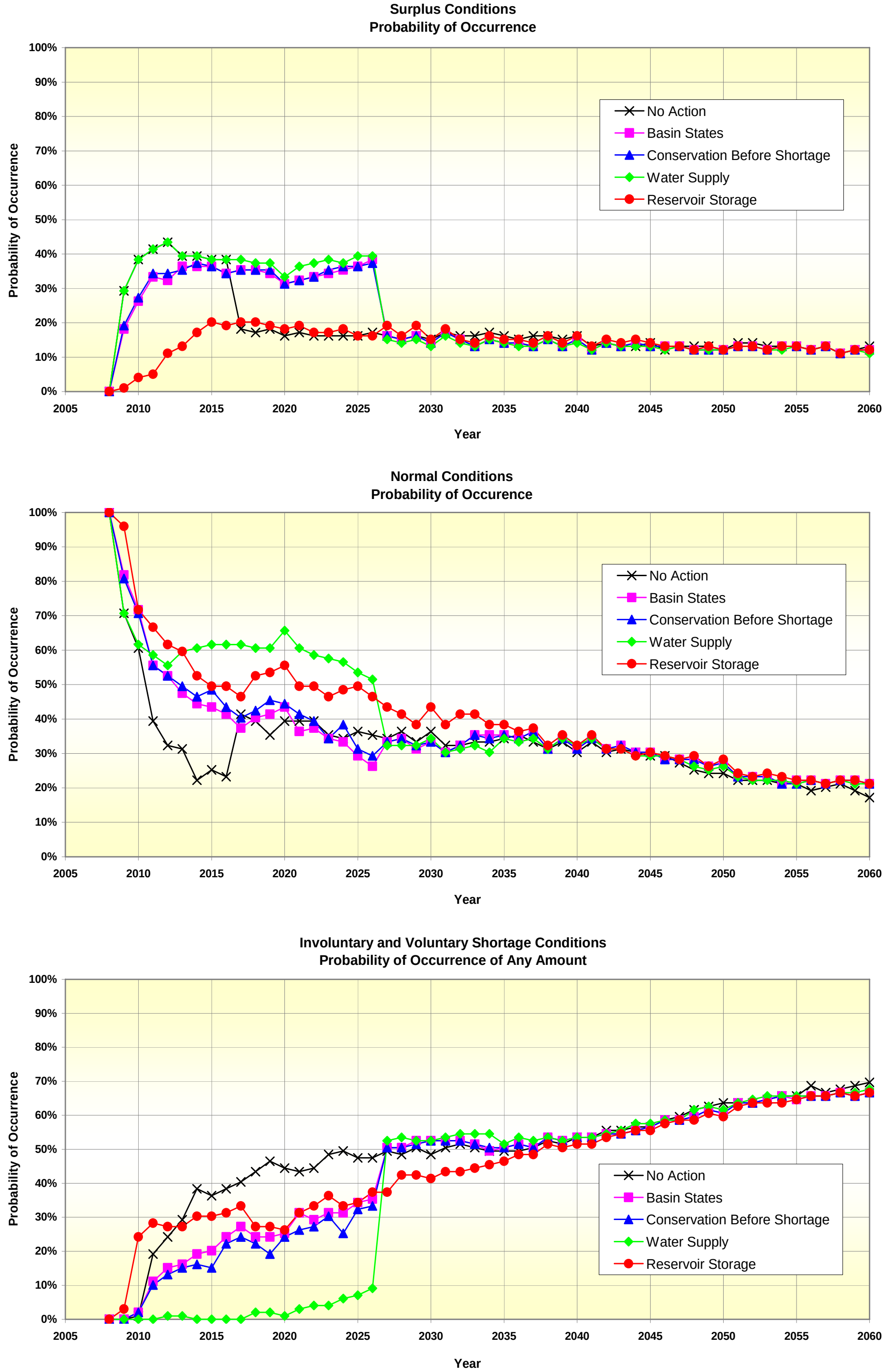
Figure 4.4-14
Probability of Normal Conditions
Comparison of Action Alternatives to No Action Alternative
Years 2008 through 2060



4.4.4.4 Summary of Water Supply Conditions

Figure 4.4-15 illustrates the probabilities of occurrence for the three water supply conditions (Surplus, Normal, and Shortage) under all alternatives.

Figure 4.4-15
Surplus, Normal, and Shortage (Involuntary and Voluntary) Conditions
Comparison of Action Alternatives to No Action Alternatives
Probability of Occurrence



4.4.5 Total Water Deliveries to the Lower Division States

This section presents the simulated water deliveries to the three Lower Division states. Deliveries to each state may deviate from a state's apportionment due to Surplus or Shortage conditions as well as the storage and delivery of conserved water to and from Lake Mead. For the alternatives that do not include some form of a storage and delivery mechanism (the No Action Alternative and the Water Supply Alternative), water deliveries above or below a state's apportionment occur only during Surplus conditions or Shortage conditions respectively. Water deliveries under the Basin States, Conservation Before Shortage and Reservoir Storage alternatives in excess of a state's apportionment can occur due to a Surplus conditions as well as when conserved water previously stored in Lake Mead is delivered. Also under these alternatives, water deliveries less than a state's apportionment can occur due to a Shortage condition as well as when water is being conserved within that state and stored in Lake Mead. In the following sections, the modeled water deliveries are presented with and without the storage and delivery mechanism to facilitate understanding of the differences.

4.4.5.1 Total Water Deliveries to Arizona

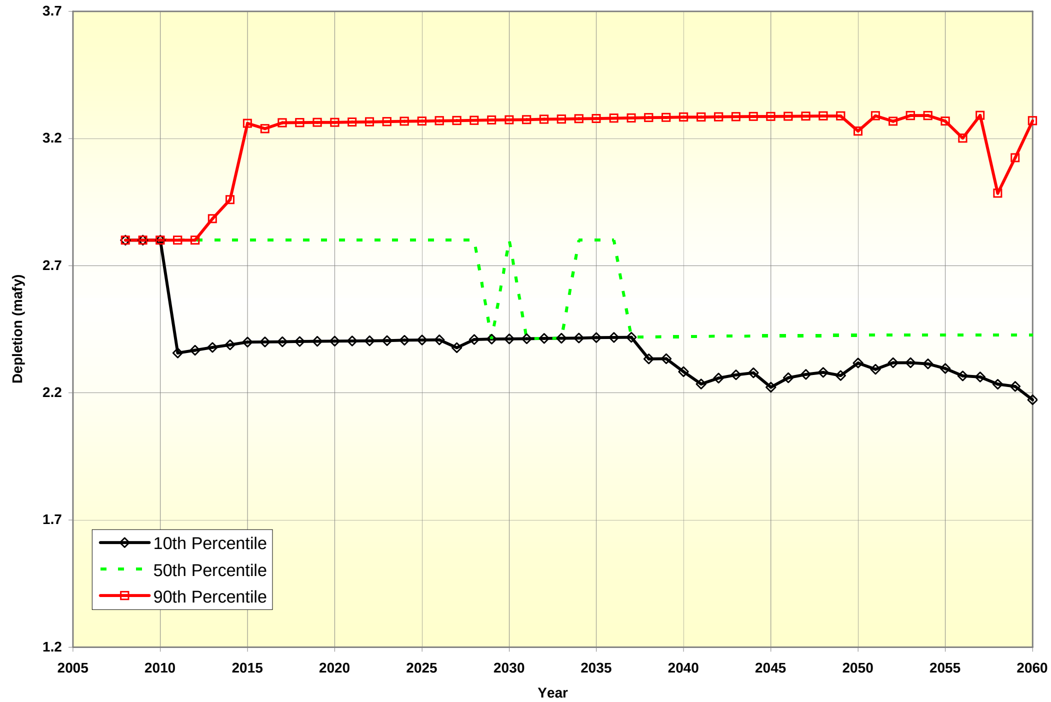
This section presents the simulated water deliveries to Arizona under the No Action Alternative and the action alternatives.

No Action Alternative. Water deliveries to Arizona are projected to fluctuate throughout the 53-year period of analysis reflecting variations in hydrologic conditions. The 90th, 50^{th,} and 10th percentile ranking of modeled water deliveries to Arizona under the No Action Alternative are presented in Figure 4.4-16. Since the No Action Alternative does not include a storage and delivery mechanism, deviations from annual deliveries of 2.8 mafy are due to Shortage and Surplus conditions.

The 90th percentile line generally coincides with Arizona's depletion schedule during full surplus water supply conditions. The exceptions to this are the periods from 2008 through 2014 and 2055 through 2060. As indicated by this 90th percentile line, the probability that the No Action Alternative would provide Arizona's full surplus depletion schedule is at least 10 percent for the period 2015 through 2055.

The 50th percentile line represents the median annual depletion values. This 50th percentile line generally coincides with Arizona's projected depletion schedule under Normal conditions through year 2028. After 2028, the median annual Arizona modeled depletion values fluctuate between 2.41 maf and 2.80 maf.

Figure 4.4-16
Arizona Modeled Annual Depletions
No Action Alternative
90th, 50th, and 10th Percentile Values



The 10th percentile line represents the depletion values above which 90 percent of the annual depletion values were observed. The 10th percentile annual depletion values were 2.80 maf from 2008 through 2010, approximately 2.4 maf from 2011 through 2037. After 2037, the 10th percentile annual depletion values fluctuated between 2.17 maf and 2.33 maf.

Comparison of Action Alternatives Without the Storage and Delivery Mechanism to No Action Alternative. Figure 4.4-17 provides a comparison of the cumulative distribution of Arizona's depletions under the action alternatives without the storage and delivery mechanism to those of the No Action Alternative during the interim period (years 2008 through 2026). The results presented in Figure 4.4-17 can be used to compare how often Arizona might expect deliveries above and below its 2.8 mafy apportionment due to Surplus and Shortage conditions under the different alternatives.

Figure 4.4-17
Arizona Modeled Annual Depletions
Comparison of Action Alternatives (Without Storage and Delivery Mechanism) to No Action Alternative
Years 2008 through 2026

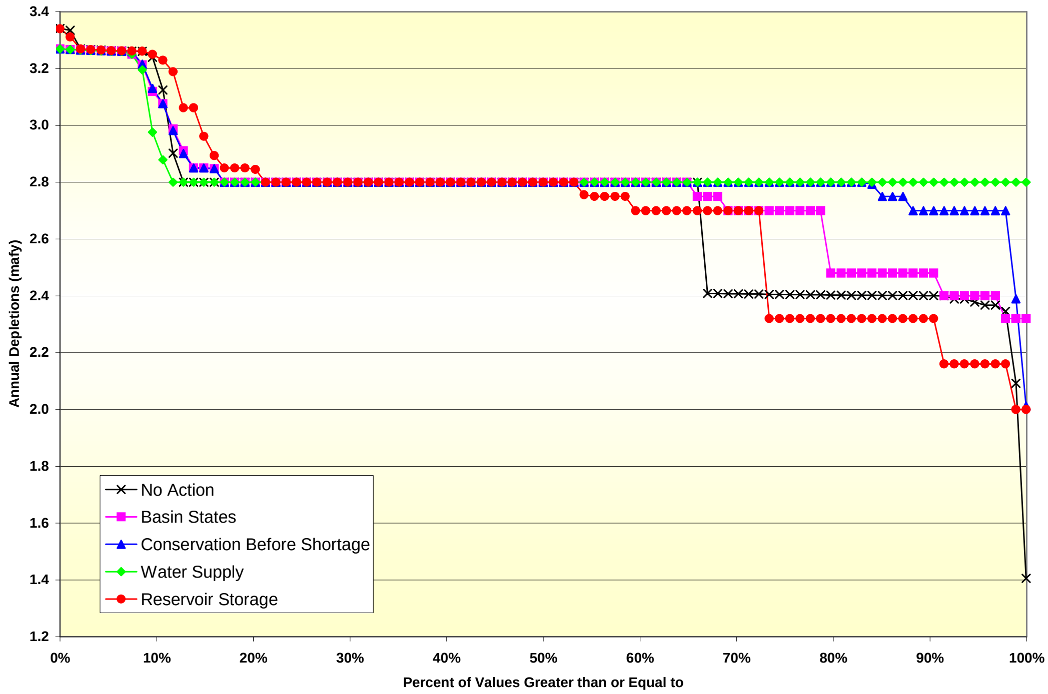


Figure 4.4-18 provides a similar comparison of the cumulative distribution of water deliveries to Arizona under the action alternatives without the storage and delivery mechanism to those of the No Action Alternative for the 34-year period (years 2027 through 2060) that would follow the interim period.

Sensitivity of Total Water Deliveries to Arizona to Storage and Delivery Mechanism. Arizona water deliveries under the Basin States, Conservation Before Shortage, and Reservoir Storage alternatives are impacted by the modeling assumptions made to postulate potential future participation in a storage and delivery mechanism (Appendix M). This section isolates the impacts of those assumptions on Arizona's modeled depletions.

Figure 4.4-18
Arizona Modeled Annual Depletions
Comparison of Action Alternatives (Without Storage and Delivery Mechanism) to No Action Alternative
Years 2027 through 2060

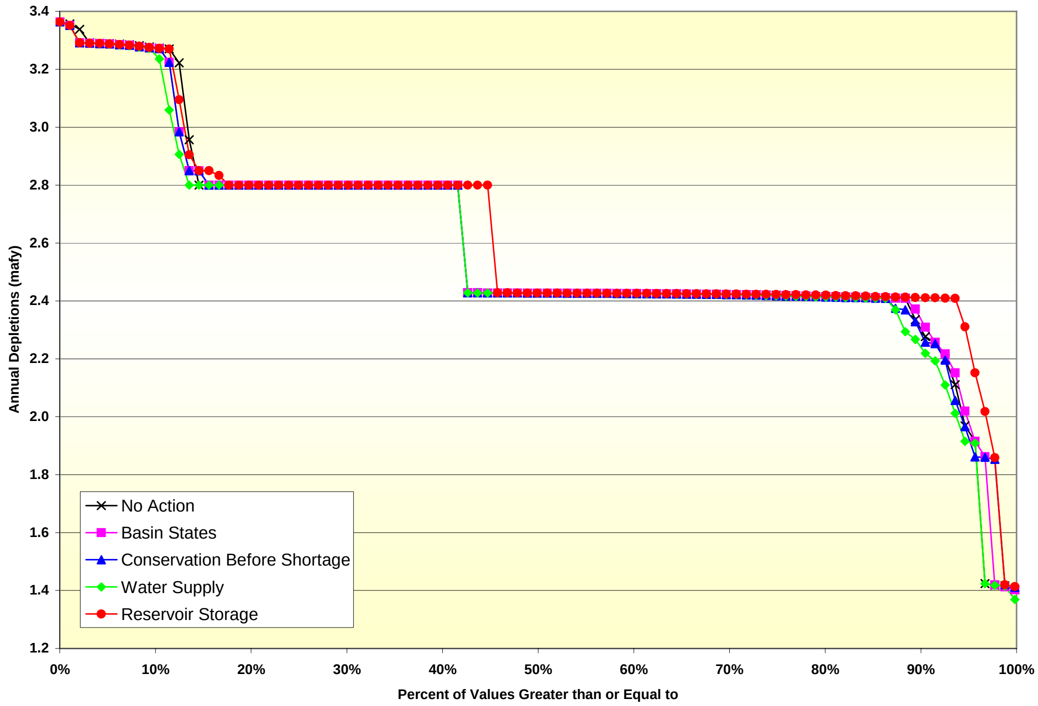
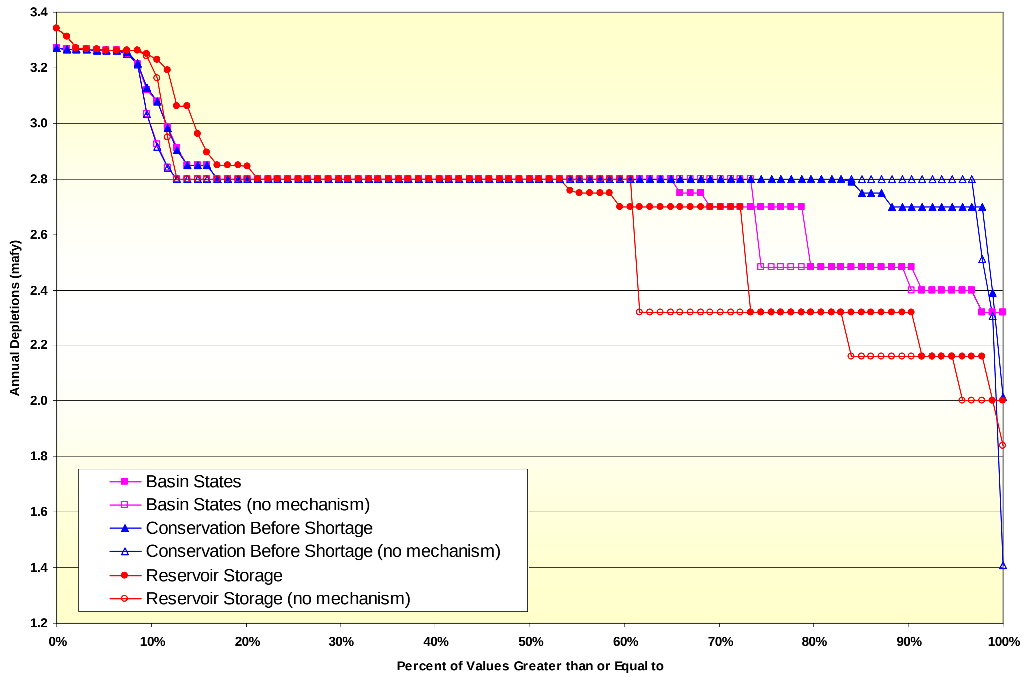


Figure 4-4.19 provides a comparison of the cumulative distribution of Arizona's depletions under the Basin States, Conservation Before Shortage, and Reservoir Storage alternatives, with and without the mechanism in place during the interim period. With the mechanism in place, deliveries of approximately 2.7 mafy are due to the storage of conserved water. With the mechanism removed, occurrences of deliveries less than 2.8 mafy or greater than 2.8 mafy reflect only Shortage or Surplus conditions respectively. These observations mirror the effects of the mechanism on the probability of voluntary and involuntary total Lower Basin Shortage and Surplus Conditions presented in the previous subsection.

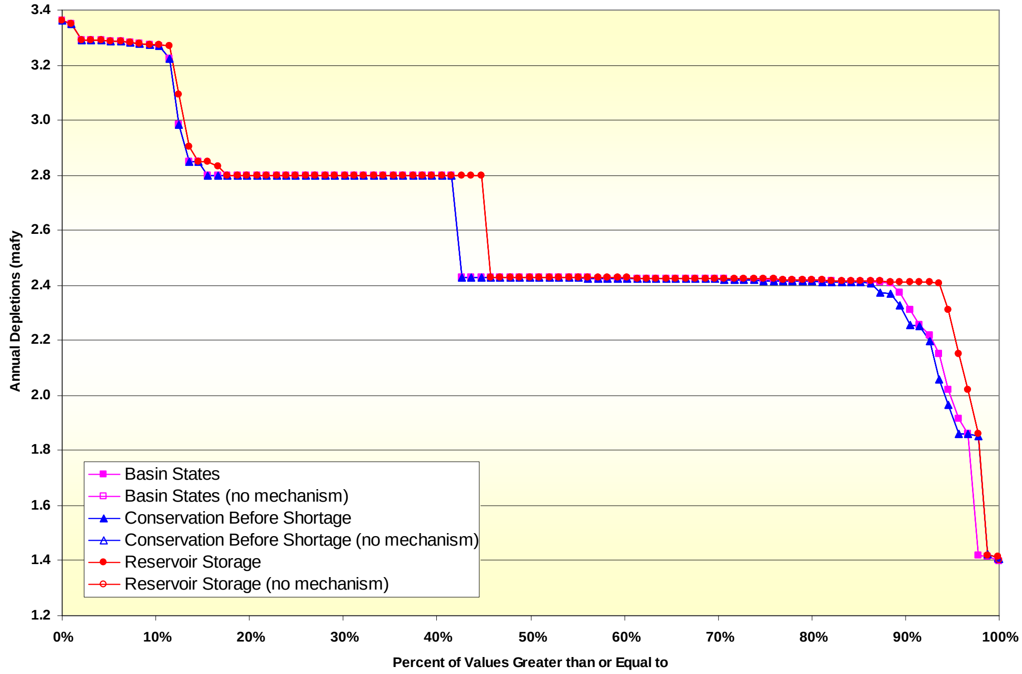
Figure 4.4-19
Arizona Modeled Depletions
Comparison of Action Alternatives With and Without Storage and Delivery Mechanism
Years 2008 through 2026



1

2 Figure 4-4.20 provides a comparison of the cumulative distribution of Arizona's
3 depletions under the action alternatives that include a storage and delivery mechanism,
4 with and without the mechanism in place for the 34-year period that would follow the
5 interim period. There is almost no effect of the mechanism during these years as it is
6 assumed only conserved water previously stored in Lake Mead may be delivered during
7 this period.

Figure 4.4-20
Arizona Modeled Depletions
Comparison of Action Alternatives With and Without Storage and Delivery Mechanism
Years 2027 through 2060

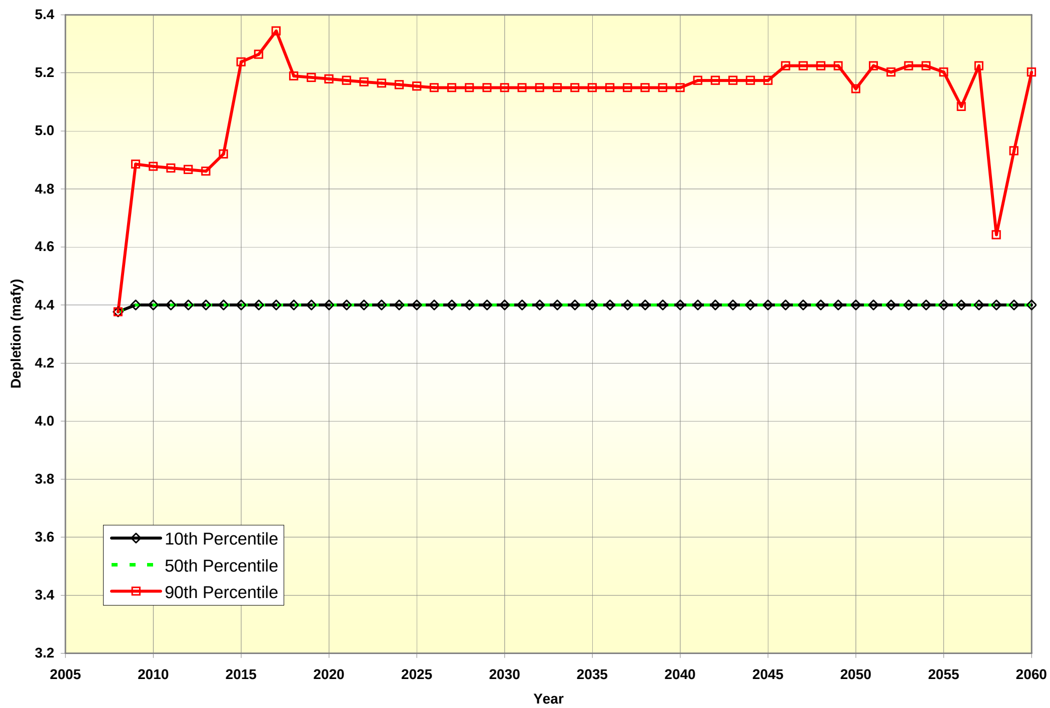


4.4.5.2 Total Water Deliveries to California

This section presents the simulated water deliveries to California under the No Action Alternative and the action alternatives.

No Action Alternative. Water deliveries to California are projected to fluctuate throughout the 53-year period of analysis reflecting variations in hydrologic conditions. The 90th, 50th, and 10th percentile ranking of modeled water deliveries to California under the No Action Alternative are presented in Figure 4.4-21. Since the No Action Alternative does not include a storage and delivery mechanism, deviations from annual deliveries of 4.4 mafy are due to Shortage and Surplus conditions.

Figure 4.4-21
California Modeled Annual Depletions
No Action Alternative
90th, 50th, and 10th Percentile Values



The 90th percentile line generally coincides with California's depletion schedule during full surplus water supply conditions. The exceptions to this are the periods from 2008 through 2014 and from 2055 through 2060. As indicated by this 90th percentile line, the probability that the No Action Alternative would provide California's full surplus depletion schedule is at least 10 percent for the period from 2015 through 2055.

The 50th percentile line represents the median annual depletion values. This 50th percentile line generally coincides with California's projected depletion schedule under Normal conditions throughout the 53-year period of analysis.

The 10th percentile line represents the depletion values above which 90 percent of the annual depletion values were observed. The 10th percentile annual depletion values also generally coincide with California's projected depletion schedule under Normal conditions throughout the 53-year period of analysis. This means that there is at least a 90 percent probability that California will receive its Normal conditions scheduled deliveries from 2008 through 2060.

Comparison of Action Alternatives Without the Storage and Delivery Mechanism to No Action Alternative. Figure 4.4-22 provides a comparison of the cumulative distribution of California's depletions under the action alternatives without the storage and delivery mechanism to those of the No Action Alternative during the interim period (years 2008 through 2026). The results presented in Figure 4.4-22 can be used to compare how often California might expect deliveries above and below its 4.4 mafy apportionment due to Surplus and Shortage conditions under the different alternatives.

Figure 4.4-22
California Modeled Annual Depletions
Comparison of Action Alternatives (Without Storage and Delivery Mechanism) to No Action Alternative
Years 2008 through 2026

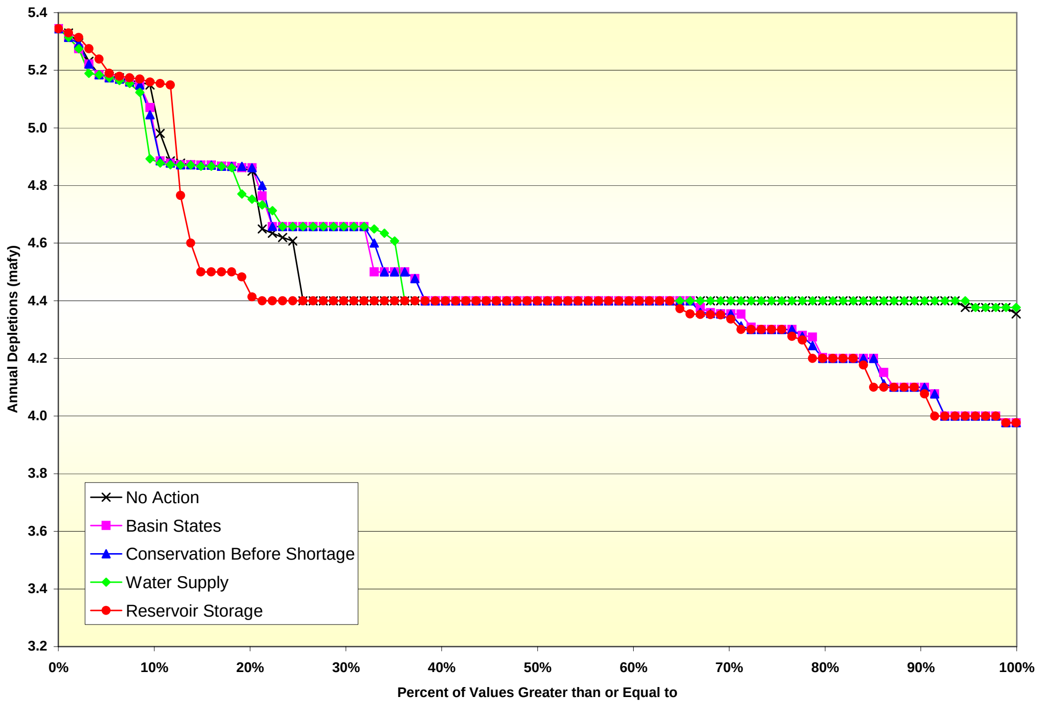
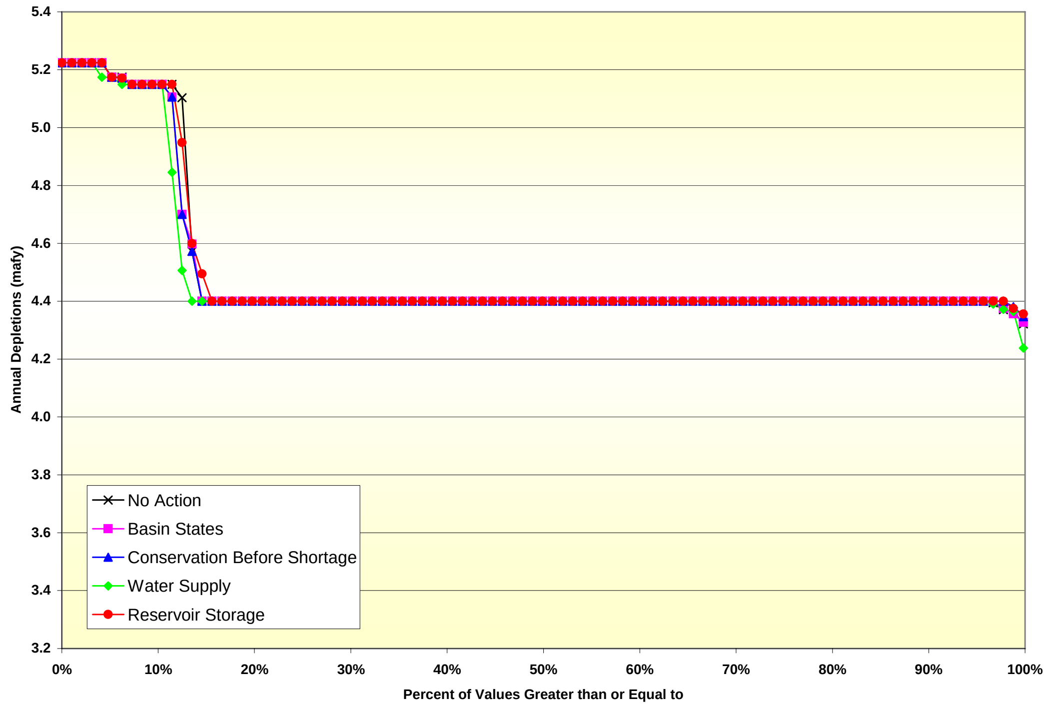


Figure 4.4-23 provides a similar comparison of the cumulative distribution of water deliveries to California under the action alternatives without the storage and delivery mechanism to those of the No Action Alternative for the 34-year period (years 2027 through 2060) that would follow the interim period.

Figure 4.4-23
California Modeled Annual Depletions
Comparison of Action Alternatives (Without Storage and Delivery Mechanism) to No Action Alternative
Years 2027 through 2060



Sensitivity of Total Water Deliveries to California to Storage and Delivery Mechanism. California water deliveries under the Basin States, Conservation Before Shortage and Reservoir Storage alternatives are impacted by modeling assumptions made to postulate potential future participation in a storage and delivery mechanism (Appendix M). This section isolates the impacts of those assumptions on California's depletions.

Figure 4-4.24 provides a comparison of the cumulative distribution of California's depletions under the action alternatives that include a storage and delivery mechanism, with and without the mechanism in place during the interim period. For alternatives with the mechanism removed, occurrences of deliveries less than 4.4 mafy reflect only Shortage conditions. Removing the mechanism shows that there is almost no occurrence of deliveries less than 4.4 mafy due to Shortage conditions. The five percent occurrence of deliveries less than 4.4 mafy when the mechanism is not in place reflects California's scheduled delivery of less than 4.4 maf in 2008 which coincides with scheduled repayment of inadvertent overruns by IID and CVWD.

Figure 4.4-24
California Modeled Annual Depletions
Comparison of Action Alternatives With and Without Storage and Delivery Mechanism
Years 2008 through 2026

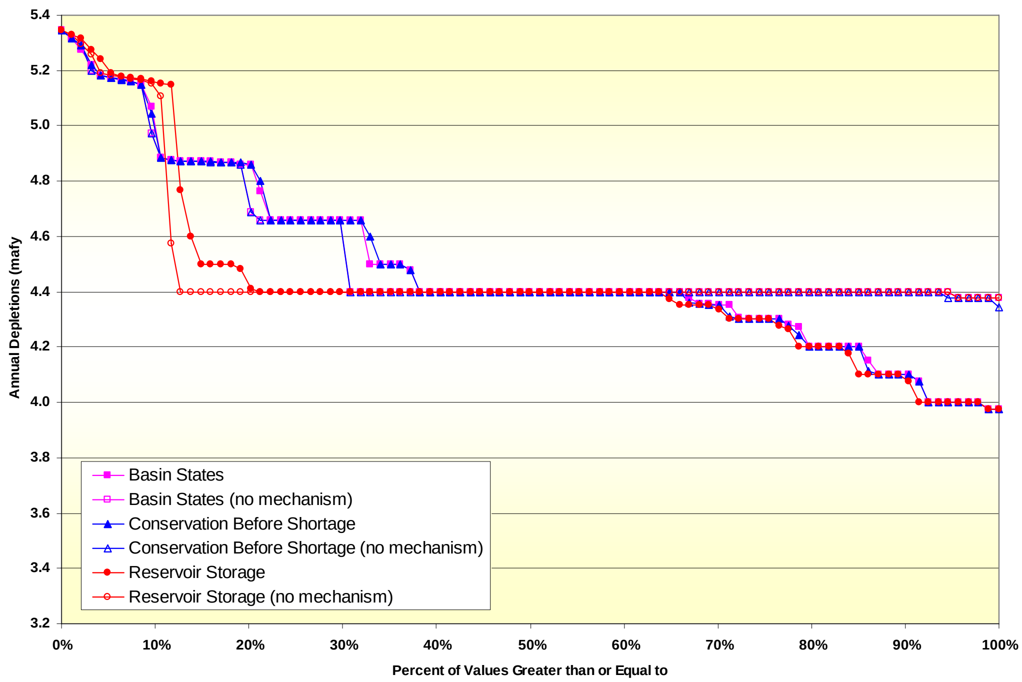
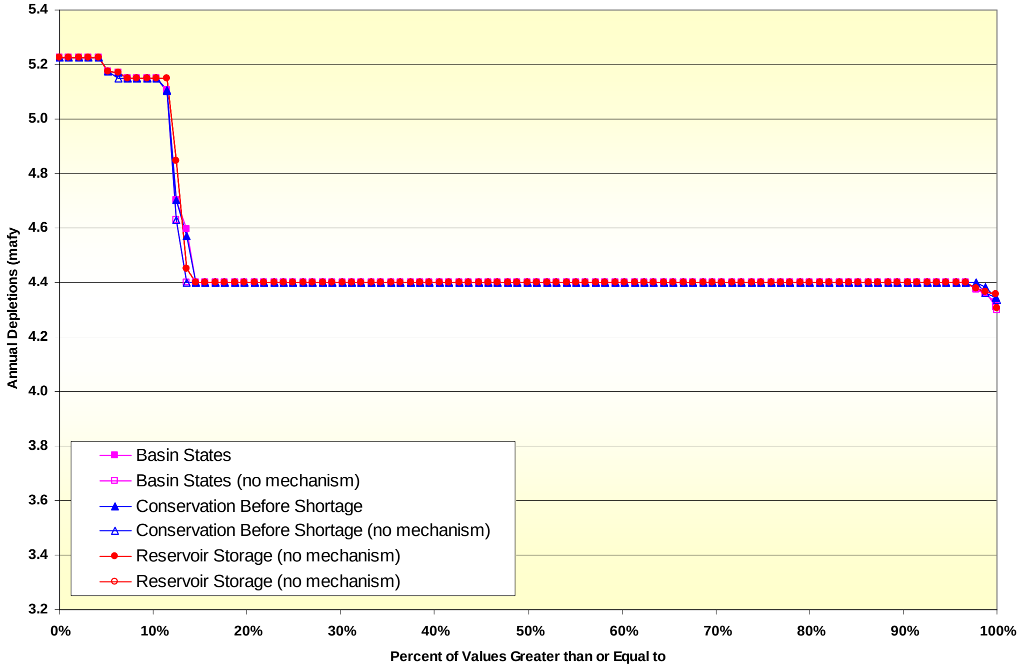


Figure 4-4.25 provides a comparison of the cumulative distribution of California's depletions under the action alternatives that include a storage and delivery mechanism, with and without the mechanism in place for the 34-year period that would follow the interim period. There is almost no effect of the mechanism during these years as it is assumed only conserved water previously stored in Lake Mead may be delivered during this period.

Figure 4.4-25
California Modeled Annual Depletions
Comparison of Action Alternatives With and Without Storage and Delivery Mechanism
Years 2027 through 2060



4.4.5.3 Total Water Deliveries to Nevada

This section presents the simulated water deliveries to Nevada under the No Action Alternative and the action alternatives.

No Action Alternative. Water deliveries to Nevada are projected to fluctuate throughout the 53-year period of analysis reflecting variations in hydrologic conditions. The 90th, 50th, and 10th percentile ranking of modeled water deliveries to Nevada under the No Action Alternative are presented in Figure 4.4-26. Since the No Action Alternative does not include a storage and delivery mechanism, deviations from annual deliveries of 300 kafy are due to Shortage and Surplus conditions.

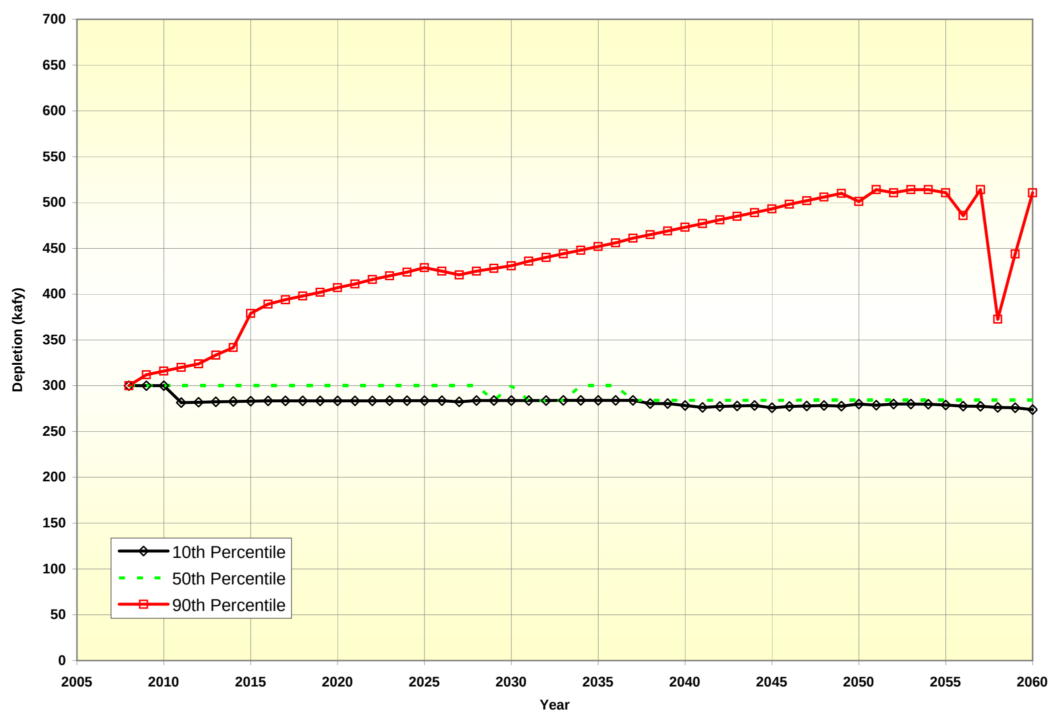
The 90th percentile line generally coincides with Nevada's depletion schedule during full surplus water supply conditions. The exception to this is the period of 2055 through 2060. As indicated by this 90th percentile line, the probability that the No Action Alternative would provide Nevada's full surplus depletion schedule is at least 10 percent for the period of 2008 through 2055.

The 50th percentile line represents the median annual depletion values. This 50th percentile line generally coincides with Nevada's projected depletion schedule under Normal conditions throughout the 53-year period of analysis.

The 50th percentile line represents the median annual depletion values. This 50th percentile line generally coincides with Nevada's projected depletion schedule under Normal conditions through year 2028. After 2028, the median annual Nevada modeled depletion values fluctuate between 283.8 kaf and 300 kaf.

The 10th percentile line represents the depletion values above which 90 percent of the annul depletion values were observed. The 10th percentile annual depletion values fluctuated between 273.9 kaf and 300 kaf.

Figure 4.4-26
Nevada Modeled Annual Depletions
No Action Alternative
90th, 50th, and 10th Percentile Values



Comparison of Action Alternatives Without the Storage and Delivery Mechanism to No Action Alternative. Figure 4.4-27 provides a comparison of the cumulative distribution of Nevada's depletions under the action alternatives without the storage and delivery mechanism to those of the No Action Alternative during the interim period (years 2008 through 2026). The results presented in Figure 4.4-27 can be used to compare how often Nevada might expect deliveries above and below its 300 kafy apportionment due to Surplus and Shortage conditions under the different alternatives.

Figure 4.4-27
Nevada Modeled Annual Depletions
Comparison of Action Alternatives (Without Storage and Delivery Mechanism) to No Action Alternative
Years 2008 through 2026

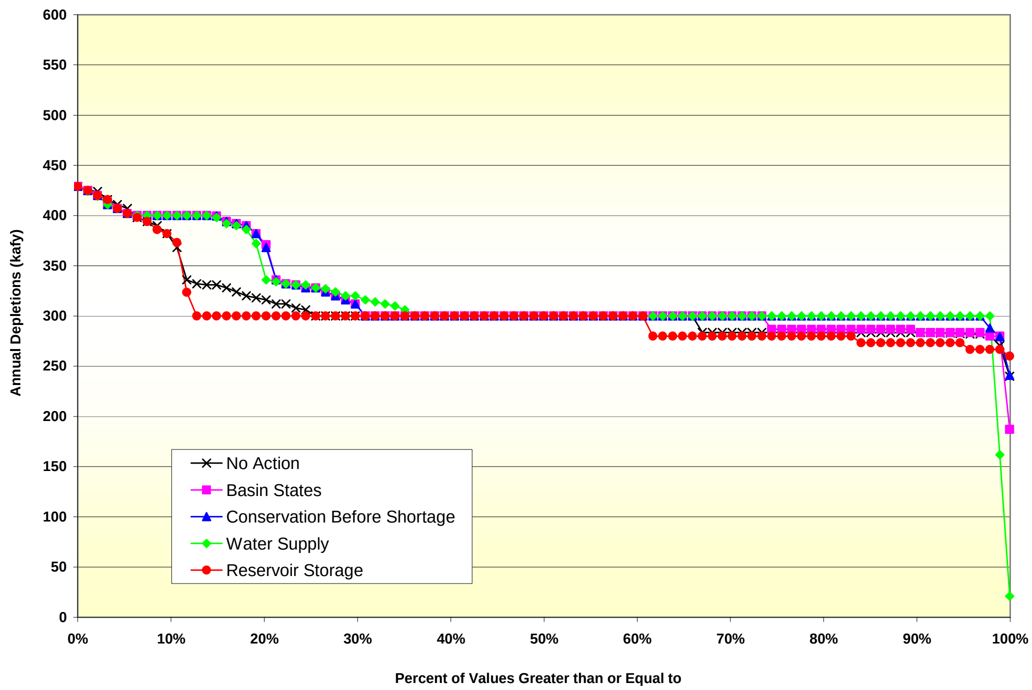
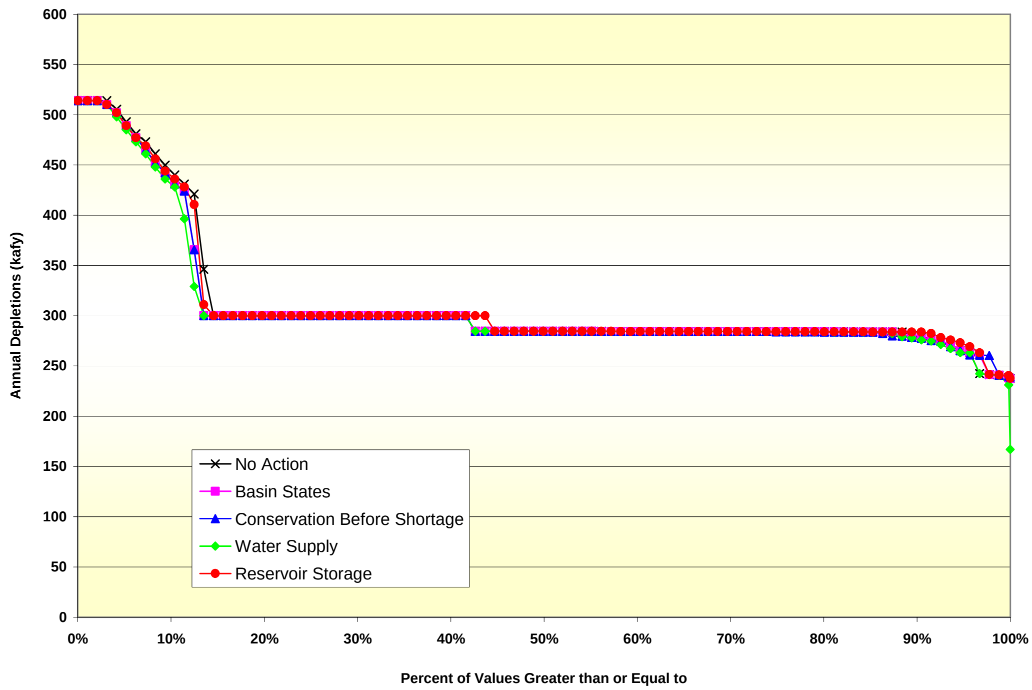


Figure 4.4-28 provides a similar comparison of the cumulative distribution of water deliveries to Nevada under the action alternatives without the storage and delivery mechanism to those of the No Action Alternative for the 34-year period (years 2027 through 2060) that would follow the interim period.

Figure 4.4-28
Nevada Modeled Annual Depletions
Comparison of Action Alternatives (Without Storage and Delivery Mechanism) to No Action Alternative
Years 2027 through 2060

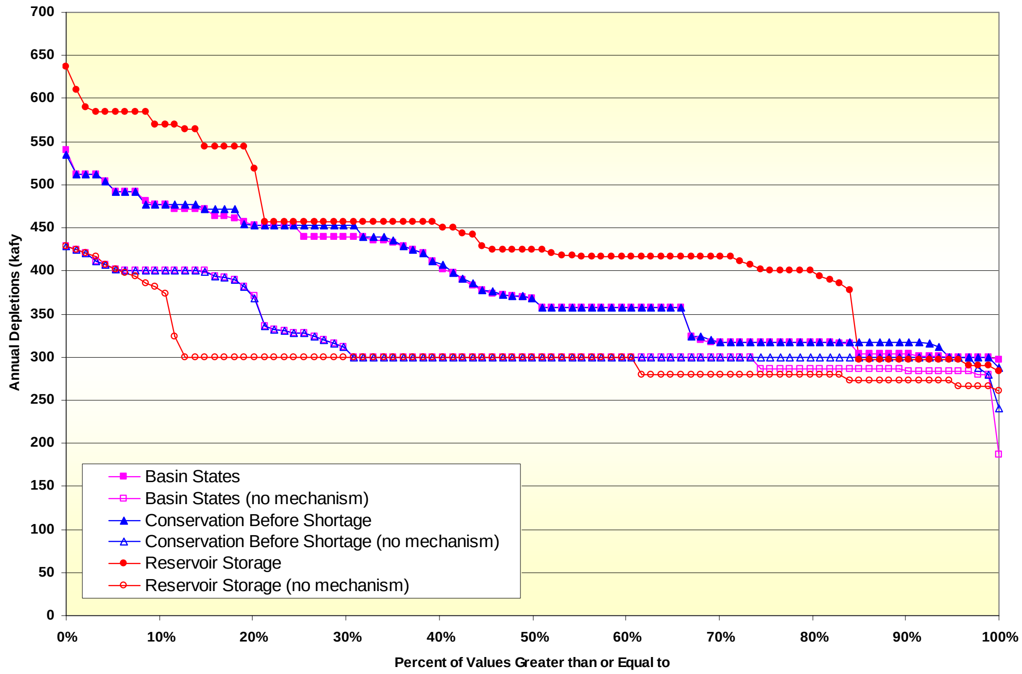


Sensitivity of Total Water Deliveries to Nevada to Storage and Delivery Mechanism. Nevada water deliveries under the Basin States, Conservation Before Shortage and Reservoir Storage alternatives are impacted by the modeling assumptions made to postulate potential future participation in a storage and delivery mechanism (Appendix M). This section isolates the impacts of those assumptions on Nevada's modeled depletions.

Figure 4-4.29 provides a comparison of the cumulative distribution of Nevada's depletions under the action alternatives that include a storage and delivery mechanism, with and without the mechanism in place during the interim period. With the mechanism removed the occurrence of deliveries greater than 300 kafy is about 55 percent less under the Basin States and Conservation Before Shortage alternatives. Under the Reservoir Storage Alternative the occurrence of deliveries above 300 kafy is about 70 percent less with the mechanism removed. This indicates that the majority of the occurrences of deliveries above 300 kafy in the Basin States, Conservation Before Shortage and Reservoir Storage alternatives can be attributed to the delivery of conserved and non-system water to Nevada. Also, the magnitude of the deliveries above 300 kafy is less with the storage and delivery mechanism not in place. Under the Basin States and

Conservation Before Shortage alternatives the deliveries range from about 55 kaf to 140 kaf less. Under the Reservoir Storage Alternative, the deliveries range from about 100 kaf to 265 kaf less.

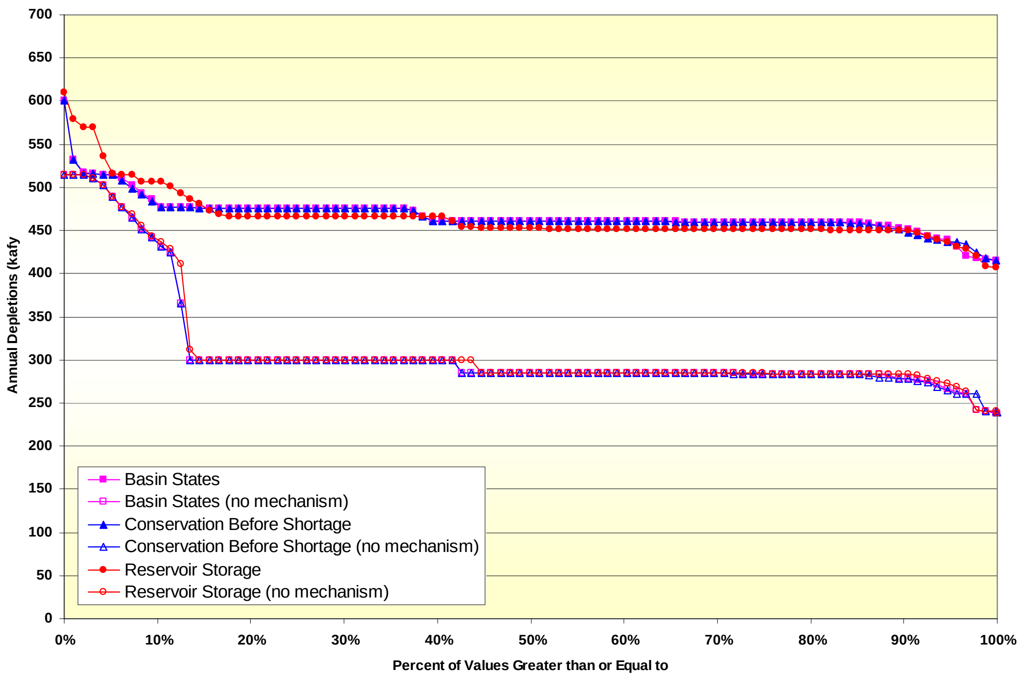
Figure 4.4-29
Nevada Modeled Annual Depletions
Comparison of Action Alternatives With and Without Storage and Delivery Mechanism
Years 2008 through 2026



With the mechanism removed the occurrence of deliveries less than 300 kafy is about 25 percent greater under the Basin States Alternative, two percent greater under the Conservation Before Shortage Alternative and about three percent greater under the Reservoir Storage Alternative. This indicates that as a result of the delivery of conserved and non-system water Nevada does not often receive deliveries less than 300 kafy.

Figure 4-4.30 provides a comparison of the cumulative distribution of Nevada's depletions under the action alternatives that include a storage and delivery mechanism, with and without the mechanism in place for the 34-year period that would follow the interim period. The results of the mechanism removed emphasize the modeling assumption that there about 150 kafy of conserved and non-system water available to Nevada after the interim period under these alternatives (Appendix M).

Figure 4.4-30
Nevada Modeled Annual Depletions
Comparison of Action Alternatives With and Without Storage and Delivery Mechanism
Years 2027 through 2060



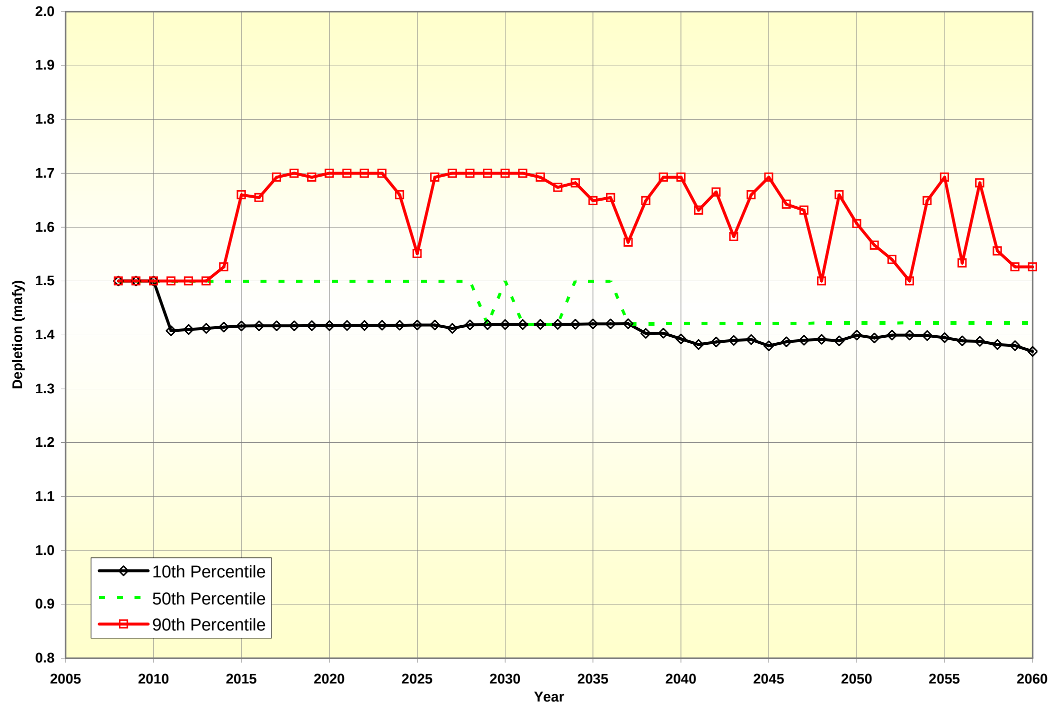
4.4.6 Water Deliveries to Mexico

This section presents the simulated water deliveries to Mexico under the No Action Alternative and action alternatives. The model assumes a delivery to Mexico of 1.5 mafy with additional deliveries of up to 200 kaf when Lake Mead is in flood control operations. Reductions in deliveries to Mexico are simulated consistent with the modeling assumptions noted in Section 2.2, Section 4.2, and Appendix A.

No Action Alternative. The water deliveries to Mexico are projected to fluctuate throughout the 53-year period of analysis reflecting variations in hydrologic conditions. The 90th, 50th, and 10th percentile ranking of modeled water deliveries to Mexico under the No Action Alternative are presented in Figure 4.4-31. Since the No Action Alternative does not include a storage and delivery mechanism, deviations from annual deliveries of 1.5 mafy are due to Shortage conditions and when Lake Mead is in Flood Control operations.

The upper range of 90th percentile annual depletion values shown on Figure 4.4-31 generally coincides with Mexico's depletion schedule during Lake Mead flood control operations. The 90th percentile values fluctuate between 1.5 mafy to 1.7 mafy between 2014 through 2060.

Figure 4.4-31
Mexico Modeled Annual Depletions
No Action Alternative
90th, 50th, and 10th Percentile Values



The 50th percentile line represents the median annual depletion values in years 2008 and 2028. After 2028, the 50th percentile annual depletion values fluctuate between 1.419 maf and 1.5 maf. The drop in the modeled water deliveries to Mexico below Mexico's 1.5 maf allotment reflects the modeling assumptions with respect to shortages.

The 10th percentile line represents the median annual depletion values in years 2008 and 2010 and fall to 1.408 in 2011. After 2011, the annual depletion values fluctuate between 1.369 mafy and 1.421 mafy. The drop in the modeled water deliveries to Mexico below Mexico's 1.5 maf allotment reflects the modeling assumptions with respect to shortages.

Comparison of Action Alternatives Without the Storage and Delivery Mechanism to No Action Alternative. Figure 4.4-32 provides a comparison of the cumulative distribution of Mexico's depletions under the action alternatives without the storage and delivery mechanism to those of the No Action Alternative during the interim period (years 2008 through 2026). The results presented in Figure 4.4-32 can be used to compare how often Mexico might expect deliveries above and below its 1944 Treaty allocation of 1.5 maf due to Surplus and Shortage conditions under the different alternatives. The occurrences of deliveries greater than 1.5 afy reflect both times when additional water up to 200 kafy is made available during Flood Control conditions. The occurrences of deliveries less than 1.5 mafy reflect deliveries to Mexico during Shortage conditions and reflect the modeling assumptions with regard to the sharing of shortages between the Lower Division states and Mexico.

Figure 4.4-32
Mexico Modeled Annual Depletions
Comparison of Action Alternatives (Without Storage and Delivery Mechanism) to No Action Alternative
Years 2008 through 2026

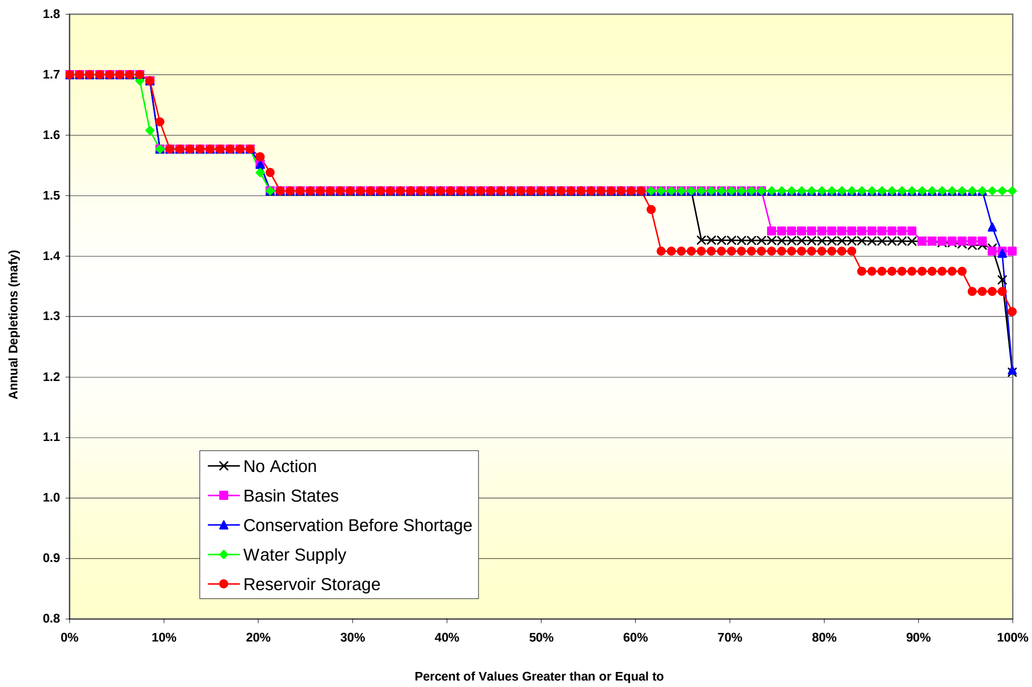
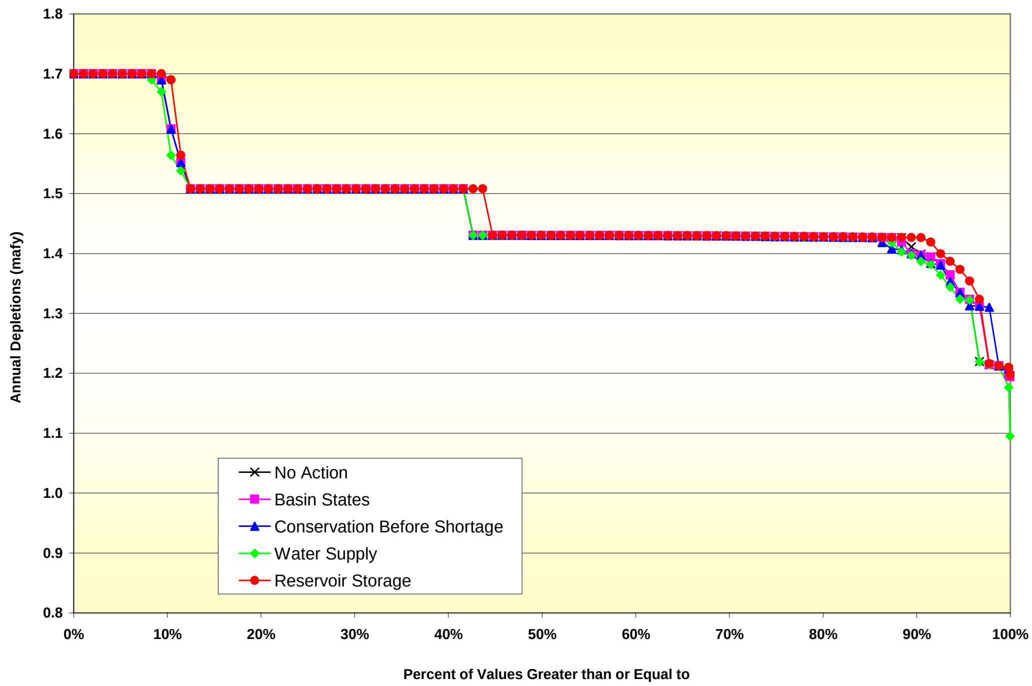


Figure 4.4-33 provides a similar comparison of the cumulative distribution of the water deliveries to Mexico under the action alternatives without the storage and delivery mechanism to those of the No Action Alternative for the 34-year period (years 2027 through 2060) that would follow the interim period.

Figure 4.4-33
Mexico Modeled Annual Depletions
Comparison of Action Alternatives (Without Storage and Delivery Mechanism) to No Action Alternative
Years 2027 through 2060



Sensitivity of Total Water Deliveries to Mexico to Storage and Delivery Mechanism. As noted before, modeling was performed to support the analysis of the storage and delivery mechanism (Appendix M). At this time, it is unknown which entities might participate in this proposed mechanism that allows the storage and delivery of conserved system and non-system water. Furthermore, the timing and magnitude of the storage and delivery of conserved water is unknown. However, modeling assumptions with respect to the entities that might participate and their respective level of participation were needed to enable the analysis of the mechanism and its potential effects on environmental resources, particularly to reservoir storage and river flows below Lake Mead.

The results of the analysis that compares the cumulative distribution of Mexico's depletions under the action alternatives with and without the storage and delivery mechanism to those of the No Action Alternative are provided in Appendix P. The modeling assumptions are not intended to constitute an interpretation or application of the 1944 Treaty or to represent current or future United States policy regarding deliveries to Mexico.

4.4.7 Distribution of Shortages to and within the Lower Division States

Although the Consolidated Decree and the CRBPA provide some direction to the Secretary with regard to the distribution of shortages to the Lower Division states, no specific guidelines exist with regard to exactly how those shortages would be distributed. Furthermore, although priority systems exist within each state, exactly how shortages would be distributed to water users of equal priority within a state is unknown. Therefore, specific modeling assumptions were made in order to facilitate the comparison of each alternative. These assumptions are discussed in Section 4.2, Appendix A, and Appendix G and are consistent between all alternatives.

4.4.7.1 Distribution of Shortages within Arizona

Table 4.4-11 shows different Lower Basin shortage volumes and the portion of the shortage that was assumed to be distributed to Arizona. This table shows the shortage distribution in different years because the distribution changes at the higher magnitudes of shortage due to the changes in the scheduled use of the Arizona 4th Priority water users (Section 4.2).

Table 4.4-11
Shortage Allocation to Arizona (af)

Year	Total Lower Basin Shortage							
	200,000	400,000	500,000	600,000	800,000	1,200,000	1,800,000	2,500,000
2008	160,000	320,000	400,000	480,000	640,000	960,000	1,440,000	1,587,484
2017	160,000	320,000	400,000	480,000	640,000	960,000	1,397,578	1,533,925
2026	160,000	320,000	400,000	480,000	640,000	960,000	1,394,205	1,530,879
2027	160,000	320,000	400,000	480,000	640,000	960,000	1,393,837	1,530,547
2040	160,000	320,000	400,000	480,000	640,000	960,000	1,388,281	1,525,531
2060	160,00	320,000	400,000	480,000	640,000	960,000	1,388,281	1,525,531

As noted in Table 4.4-11, total Lower Basin shortages up to 2.5 maf were analyzed to fully analyze the range of total Lower Basin shortages that could occur.

Table 4.4-12 and Table 4.4-13 provide the probability of occurrence of the total Lower Basin Shortage volumes that are shown in Table 4.4-11 for two periods, 2008 through 2026 and 2027 through 2060, respectively. The probability of shortages with a magnitude of zero includes periods when Surplus or Normal conditions are in effect.

Table 4.4-12
Probability of Occurrence of Shortages Less Than or Equal to, Years 2008 through 2026 (percent)

Alternative	Total Voluntary or Involuntary Lower Basin Shortage								
	0	200,000	400,000	500,000	600,000	800,000	1,200,000	1,800,000	2,500,000
No Action	66.1	66.1	66.1	90.3	97.8	98.4	99.5	99.8	100
Basin States	78.8	78.8	91.3	97.7	99.8	100	100	100	100
Conservation Before Shortage	81.1	81.2	92.6	97.7	98.8	99.5	99.9	99.9	100
Water Supply	97.8	99.3	100	100	100	100	100	100	100
Reservoir Storage	72.5	72.5	72.5	72.5	90.8	98.1	100	100	100

Table 4.4-13
Probability of Occurrence of Shortages Less Than or Equal to, Years 2027 through 2060 (percent)

Alternative	Total Voluntary or Involuntary Lower Basin Shortage								
	0	200,000	400,000	500,000	600,000	800,000	1,200,000	1,800,000	2,500,000
No Action	42.5	42.5	42.5	88.7	89.5	93.1	96.7	99.6	100
Basin States	42.6	42.6	42.6	89.2	89.9	93.4	96.9	99.2	100
Conservation Before Shortage	42.6	42.6	42.6	87.3	89.8	92.7	98.1	99.8	100
Water Supply	41.6	41.6	41.6	86.6	88	91.8	96.3	99.4	99.9
Reservoir Storage	45.5	45.5	45.5	94	94.5	95.5	97.8	99.9	100

Under most circumstances, the probabilities of involuntary and voluntary shortages being allocated to Arizona are the same as the probability of shortage allocations to the Lower Basin under the No Action Alternative and for each of the action alternatives. The overall probabilities are shown in Table 4.4-13. Table 4.4-14 shows the maximum shortage that would be assigned to Arizona under the No Action Alternative and the action alternatives.

Table 4.4-14
Maximum Shortage Allocation to Arizona (af)

Year	No Action	Basin States	Conservation Before Shortage	Water Supply	Reservoir Storage
2008	0	0	0	0	0
2017	762,016	480,000	704,977	0	800,000
2026	1,395,118	621,896	1,406,802	233,200	800,000
2027	1,397,580	845,678	950,019	1,385,026	390,915
2040	1,394,587	1,395,404	1,393,740	1,403,706	1,395,330
2060	1,402,157	1,389,542	1,385,332	1,402,157	1,385,026

While shortage allocations to California and Nevada would affect single entities within each state (MWD in California and SWNA in Nevada) allocations within Arizona are distributed among a number of water users based upon Arizona's system of water rights priorities (Section 3.4 and Appendix G). This shortage distribution is based solely on current priorities and does not reflect management decisions that may be taken by Arizona entities to obtain additional water supplies to offset shortages. Table 4.4-15 summarizes how shortages of different volumes in Arizona would be distributed among Arizona's priorities and how this distribution changes over time. The table also does not show 5th priority users and the CAP Bank who now rely on unused and surplus water because by 2017 no unused water will be available to the 5th priority users and surplus water will not be available in shortage years.

Table 4.4-15
Distribution of Shortages Among Arizona Entities[1] (af)

Lower Basin Shortage Allocations	200,000	400,000	500,000	600,000	800,000	1,200,000	1,800,000	2,500,000
Year 2017								
CAP Non-Indian Agricultural Priority	142,684	272,691	272,691	272,691	272,691	272,691	272,691	272,691
CAP Tribes	0	2,553	16,920	62,958	114,969	218,772	357,350	367,977
CAP M&I	0	10,124	67,099	92,402	183,074	364,639	605,637	610,313
4th Priority Users on Mainstream	9,807	19,614	24,517	29,421	39,227	58,841	84,825	84,825
2nd and 3rd Priority (Includes Some CAP Users)	0	0	0	0	0	0	13,653	149,999
Year 2026								
CAP Non-Indian Agricultural Priority	65,979	65,979	65,979	65,979	65,979	65,979	65,979	65,979
CAP Tribes	38,941	111,547	151,901	175,815	227,576	331,099	467,921	478,430
CAP M&I	37,378	107,070	137,866	185,101	275,637	456,711	694,543	699,167
4th Priority Users on Mainstream	10,212	20,425	25,531	30,637	40,850	61,275	88,046	88,046
2nd and 3rd Priority (Includes Some CAP Users)	0	0	0	0	0	0	14,785	151,460
Year 2027								
CAP Non-Indian Agricultural Priority	31,869	31,867	31,867	31,867	31,867	31,867	31,867	31,867
CAP Tribes	61,303	140,306	178,018	202,008	253,748	357,229	493,846	504,338
CAP M&I	49,070	112,307	145,717	192,848	283,349	464,351	701,812	706,429
4th Priority Users on Mainstream	10,272	20,544	25,680	30,817	41,089	61,633	88,529	88,529
2nd and 3rd Priority (Includes Some CAP Users)	0	0	0	0	0	0	14,909	151,620

Table 4.4-15 (continued)
Distribution of Shortages Among Arizona Entities (af)

Lower Basin Shortage Allocations	200,000	400,000	500,000	600,000	800,000	1,200,000	1,800,000	2,500,000
Year 2040								
CAP Non-Indian Agricultural Priority	0	0	0	0	0	0	0	0
CAP Tribes	74,171	138,517	156,515	181,583	233,056	336,001	469,648	480,025
CAP M&I	55,727	132,886	185,640	231,324	321,356	501,419	733,523	738,089
4th Priority Users on Mainstream	11,048	22,096	27,620	33,144	44,192	66,288	94,702	94,702
2nd and 3rd Priority (Includes Some CAP Users)	0	0	0	0	0	0	16,791	154,042
Year 2060								
CAP Non-Indian Agricultural Priority	0	0	0	0	0	0	0	0
CAP Tribes	132,218	172,941	186,015	211,449	262,604	339,336	497,743	508,120
CAP M&I	90,217	190,126	247,367	292,248	381,725	560,677	791,351	795,917
4th Priority Users on Mainstream	11,968	23,935	29,919	35,903	47,870	71,806	102,584	102,584
2nd and 3rd Priority (Includes Some CAP Users)	0	0	0	0	0	0	16,791	154,042

1 CAP users incur five percent conveyance loss through the CAP system due to seepage and therefore the sum of the Arizona shortages in any one column do not add up to the total shortage volume allocated to Arizona at each Lower Basin Shortage increment noted at the top of the table.

A major change in the allocation of Arizona shortages occurs during 2017 and 2040 within the CAP and can be seen in Table 4.4-15. The allocation of shortages to individual users within the CAP is affected by the water priority scheme within the CAP, the AWSA, and the water use buildup schedules for the CAP users. Over time, the impact of a given shortage to the CAP increasingly impacts the higher priority Indian and M&I users as their use builds up and the shortage cannot be absorbed by the lower priorities.

Prior to the enactment of the AWSA, there were differing views as to how mild shortages would be distributed between the CAP Indian and M&I priority users. As part of the AWSA, a compromise was reached. Also, under the AWSA, the CAP irrigation districts agreed to relinquish their long-term water service subcontracts for Non-Indian Agricultural priority water. Approximately 300 kaf was relinquished, with approximately 200 kaf being made available for Indian water rights settlements and approximately 100 kaf was made available for future M&I use. In return, the irrigation districts obtained CAP distribution system debt relief, relief from the acreage limitation provisions of Federal Reclamation law, and a commitment from the CAP to receive an interim water supply at an affordable rate.

4.4.7.2 Distribution of Shortages within California

The preceding section discussed the modeled allocation of water to California under Normal, Surplus and Shortage water supply conditions. The following section provides a discussion of how shortages that are allocated to California are distributed to the Colorado River water entitlement holders, based on the shortage sharing assumptions programmed into the Shortage Allocation Model.

The distribution or allocation of California shortages among California's Colorado River water entitlement holders is based on California's system of water entitlement priorities. Of particular note is the frequency and magnitude of the shortages that are allocated to California. Because California's deliveries are not affected by Stage 1 shortages (Section 4.2), the total Lower Basin shortage has to exceed 1.7 maf (the upper limit of the Stage 1 Lower Basin shortages) before deliveries to California are affected. As a result of this, California receives less frequent shortages than Arizona and Nevada, and the magnitude of shortages to California are relatively smaller.

Table 4.4-16 provides an overview of the portion of the total Lower Basin shortage that is allocated to California. As shown on this table, only Stage 2 shortages (Section 4.2) affect California water deliveries. A Stage 2 shortage would occur if the total Lower Basin shortage exceeds 1.827 maf in year 2008. This threshold decreases to 1.714 maf in 2060.

Table 4.4-16
Shortage Allocation to California (af)

Lower Basin Shortage Allocations	200,000	400,000	500,000	600,000	800,000	1,200,000	1,800,000	2,500,000
Shortage allocation to California – 2008	0	0	0	0	0	0	0	412,516
Shortage allocation to California – 2017	0	0	0	0	0	0	42,421	466,075
Shortage allocation to California – 2026	0	0	0	0	0	0	45,795	469,120
Shortage allocation to California – 2027	0	0	0	0	0	0	46,163	469,452
Shortage allocation to California – 2040	0	0	0	0	0	0	52,719	474,468
Shortage allocation to California – 2060	0	0	0	0	0	0	51,719	474,468

The probability of the shortage volumes shown in Table 4.4-16 are shown in Tables 4.4-2 and 4.4-13.

Table 4.4-17 shows the maximum shortage volumes that would be assigned to California under the No Action Alternative and the four action alternatives. Because of the large magnitude Lower Basin shortages assumed to be required to trigger shortages in California, many shortages declared in the Lower Basin would not trigger shortages in California.

Table 4.4-17
Maximum Shortage Allocation to California (af)

Year	No Action	Basin States	Conservation Before Shortage	Water Supply	Reservoir Storage
2008	0	0	0	0	0
2017	0	0	0	0	0
2026	45,798	0	81,835	0	0
2027	55,625	0	0	511,784	0
2040	68,599	70,931	66,220	96,968	70,717
2060	91,745	52,187	51,389	91,745	51,356

Maximum shortage values presented in Table 4.4-17 for California vary with both the maximum level of declared shortage in the Lower Basin and with the timing of the shortage. Under almost all conditions, the California shortage is allocated to the MWD. However, under the maximum shortage amount that occurs under the Water Supply Alternative, which occurs less than one percent of the time, the shortage allocated to California would include a very small portion of shortage (4,203 af) that would be allocated to other California users.

4.4.7.3 Distribution of Shortages to Nevada

Table 4.4-18 shows different Lower Basin shortage volumes and the portion of the shortage that is allocated to Nevada. The shortage allocation to Nevada represents approximately 3.33 percent of the total Lower Basin shortage amount. This percentage does not vary with time and is distributed among users served by the SNWA.

Table 4.4-18
Shortage Allocation to Nevada (af)

Lower Basin Shortage Allocations	200,000	400,000	500,000	600,000	800,000	1,200,000	1,800,000	2,500,000
Shortage allocation to Nevada	6,667	13,333	16,667	20,000	26,667	40,000	60,000	83,333

The probability of occurrence of the shortage volumes shown in Table 4.4-18 are shown in Tables 4.4-12 and 4.4-13.

Table 4.4-19 shows the maximum shortage volumes that would be assigned to Nevada under the No Action Alternative and action alternatives for selected years.

Table 4.4-19
Maximum Shortage Allocation to Nevada (af)

Year	No Action	Basin States	Conservation Before Shortage	Water Supply	Reservoir Storage
2008	0	0	0	0	0
2017	31,750	20,000	29,375	0	33,333
2026	60,000	23,710	62,025	9,300	33,333
2027	60,565	35,235	39,585	84,290	16,290
2040	60,965	61,100	60,630	65,530	61,085
2060	62,245	60,185	59,620	62,245	59,580

4.4.7.4 Distribution of Shortages to Mexico

As discussed in Section 4.2, for modeling purposes an assumption was made that Mexico's delivery would be reduced below 1.5 mafy when Lower Basin shortages occur. The amount of the reduction is 16.67 percent of the total Lower Basin shortage volume. The shortage distribution to Mexico is summarized in Table 4.4-20.

Table 4.4-20
Shortage Distribution to Mexico (af)[1]

Lower Basin Shortage Allocations	200,000	400,000	500,000	600,000	800,000	1,200,000	1,800,000	2,500,000
Shortage allocation to Mexico	33,333	66,667	83,333	100,000	133,333	200,000	300,000	416,667

1. These modeling assumptions do not reflect policy decisions and are not intended to constitute an interpretation or application of the 1944 Treaty.

The probability of involuntary shortages being allocated to Mexico are the same as the probability of Lower Basin shortage. The probability of the shortage volumes shown in Table 4.4-20 under the No Action Alternative and for each of the action alternatives are shown in Tables 4.4-12 and 4.4-13.

This table indicates that, while the proportion of the Lower Basin shortage distributed to Mexico is constant, the probability of the occurrence of shortage increases over time. Table 4.4-21 below, shows the maximum shortage that would be distributed to Mexico under the No Action Alternative and the action alternatives.

Table 4.4-21
Maximum Shortage Allocation to Mexico[1] (af)

Year	No Action Alternative	Basin States	Conservation Before Shortage	Water Supply	Reservoir Storage
2008	0	0	0	0	0
2017	158,750	100,000	146,870	0	166,667
2026	300,025	118,560	310,135	46,500	166,667
2027	302,830	176,185	197,920	421,440	81,440
2040	304,830	305,485	304,160	312,640	305,425
2060	311,230	300,935	298,090	311,230	297,895

1. These modeling assumptions do not reflect policy decisions and are not intended to constitute an interpretation or application of the 1944 Treaty.

4.4.8 Summary

The following conclusions were drawn from the analyses of water deliveries.

4.4.8.1 Normal Conditions

All of the action alternatives improve water supply conditions during the interim period relative to the No Action Alternative, improve the probability that normal deliveries will be met, and reduce the probability that Shortage condition deliveries will occur. The differences between the action alternatives and the No Action Alternative, in terms of the probability of occurrence for Normal conditions water supply deliveries, diminish after 2027 and converge by about 2038.

4.4.8.2 Surplus Conditions

The Water Supply Alternative exhibits the same probability of Surplus condition deliveries as the No Action Alternative (between about 30 to 40 percent) between 2008 and 2016 due to the provisions for the Partial Domestic Surplus as provided in the ISG. The ISG provisions terminate under the No Action Alternative in 2016. These conditions are retained in the Water Supply Alternative through 2026 and therefore this alternative consistently provides the highest probability of Surplus condition deliveries during the interim period. The Reservoir Storage Alternative exhibits the lowest probabilities (between about 10 to 20 percent) during the interim period because surplus determinations are limited to Quantified and Flood Control Surplus conditions beginning in 2008. The surplus provisions under the Basin States and Conservation Before Shortage alternatives are similar and the probability of Surplus conditions between 2010 and the probability of occurrence through 2016 is slightly less than under the No Action Alternative due to the absence of the Partial Domestic Surplus provision in these two alternative. After the end of the interim period in 2026 the probability for all alternatives converges to between 10 and 20 percent.

The mechanism to deliver and store conserved and system and non-system water assumed as part of the Basin States, Conservation Before Shortage and Reservoir Storage alternatives has the effect of increasing the occurrence of a Surplus Condition. The maximum increase observed is about four to five percent occurring in one to two years.

4.4.8.3 Shortage Conditions

During most of the interim period, the probability of involuntary and voluntary shortage is less under all of the action alternatives compared to the No Action Alternative. The probability of occurrence of shortages under the Water Supply Alternative is generally less than under the No Action Alternative and the action alternatives during the interim period because shortages under the Water Supply Alternative only occur if the Lake Mead water level is drawn down close to the top of the dead pool elevation or if Lake Mead's elevation falls below 1,000 feet msl. However, after 2026, the Water Supply Alternative has the highest probability of occurrence due to the depleted storage conditions and because the shortage determination method reverts back to the No Action Alternative provisions. In terms of magnitude, the average shortages that occur under the Water Supply Alternative (zero and 270 kafy) are significantly less than those observed under the No Action Alternative (500 and 600 kafy) during the interim period. After 2026, higher average and maximum shortage volumes are observed under the Water Supply Alternative relative to the No Action Alternative and the remaining action alternatives.

The probability of occurrence of shortages under the Reservoir Storage Alternative is slightly higher than under the No Action Alternative between 2008 and 2013. However, after 2013 and through about 2037, shortages under the Reservoir Storage Alternative occur less frequently as compared to the No Action Alternative. In terms of magnitude, the average shortage volumes that are observed during the interim period are highest under the Reservoir Storage Alternative (between 600 and 720 kafy). This occurs because the Reservoir Storage Alternative contains the most aggressive shortage strategy that applies shortages both more often and at higher magnitudes.

Shortages also occur less frequent under the Basin States and Conservation Before Shortage alternatives during the interim period as compared to the No Action Alternative and are similar after 2026. The probability values of the Basin States Alternative and Conservation Before Shortage Alternative differ a maximum of about five percent with those of the Conservation Before Shortage Alternative being generally slightly lower than those under the Basin States Alternative. In terms of magnitude, the average Involuntary and Voluntary Shortages that are observed under the Basin States and Conservation Before Shortage alternatives are similar to each other (between 400 and 500 kafy) and both are less than those observed under the No Action Alternative during the interim period. After 2026, the average shortage volumes are similar. The maximum observed Involuntary and Voluntary water delivery reduction in any one year to Arizona, California, and Nevada are 1.4 maf, 456 kaf, and 65 kaf, respectively.

The mechanism to deliver and store conserved system and non-system water assumed as part of the Basin States, Conservation Before Shortage and Reservoir Storage alternatives has the effect of decreasing the occurrence of shortages. The greatest reduction during the interim period occurs in the Reservoir Storage Alternative (about 12 percent) as it is assumed that a larger amount of storage credits are generated under this alternative. The Conservation Before Shortage Alternative is assumed to have a larger storage and delivery mechanism than the Basin States Alternative, resulting in a shortage probability of about two to three percent less during the interim period.

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4.5 Water Quality

4.5.1 Introduction

This section describes the methods used to determine the potential effects to water quality associated with each alternative considered in the proposed federal action, and discusses the results of these analyses.

4.5.2 Methodology

The salinity module of the CRSS RiverwareTM model was used to analyze changes in salinity concentration for all the alternatives from Lake Powell to Imperial Dam.

Using the hydrologic output from CRSS, the CE-QUAL-W2 model was used to simulate temperatures of Lake Powell releases and the Generalized Environmental Modeling System for Surface Waters (GEMSS) was used to simulate river temperatures between Glen Canyon Dam and Lake Mead for each of the alternatives. Detailed descriptions of these models are provided in Appendix F. Qualitative assessments of other water quality parameters in Lake Powell were based on historical data.

For all parameters other than salinity, the analysis of potential impacts to Lake Mead water quality were based on a combination of detailed water quality modeling and analysis conducted for the Systems Conveyance and Operations Program Final EIS (SCOP FEIS, Clean Water Coalition October 2006), historical data, and other information. The modeling for the SCOP FEIS analyzed the potential effects on water quality of rerouting effluent from the Las Vegas Wash to Lake Mead's Boulder Basin via a pipeline. The detailed modeling considered lake levels down to 1,000 feet msl and two levels of total annual average effluent flows (462 cfs expected by 2030 and 616 cfs expected by 2050). Under the SCOP FEIS preferred alternative (referred to as the Boulder Islands North Alternative), impacts to water quality are considered to be insignificant and negligible with no violation of drinking water standards for Lake Mead water levels drawn down to elevation 1,000 feet msl with projected 2050 effluent inflow levels. This information was combined with the probabilities of Lake Mead water levels reaching elevation 1,000 feet msl under No Action Alternative and action alternatives considered in this Draft EIS to assess potential impacts.

Furthermore, an adaptive management plan for Boulder Basin would be implemented as part of the SCOP preferred alternative. The Boulder Basin Adaptive Management Plan (BBAMP) would establish objectives regarding drinking water quality, downstream water quality, nutrient management, and recreational use including sport fisheries. As part of the BBAMP, water quality parameters would be monitored to establish baseline conditions and analyze the need for potential mitigation measures in the future. (Clean Water Coalition 2006). The qualitative assessments also used this information.

4.5.2.1 Salinity

Reclamation developed a computational model for salinity to aid in the development of salinity reduction targets for the Colorado River Basin Salinity Control Program (SCP) (Prairie and Callejo 2005). The salinity model simulates the effects of water development projects on future salinity concentration levels in the Colorado River. The model includes future salinity control units that have been authorized for construction but may not have yet been completed. The salinity control criteria are purposely designed to be long-term and non-degradational goals, rather than exceedence standards such as are used for industry or drinking water. Efforts of the SCP are designed to meet the standards by implementing, as needed, the most cost effective salinity control projects. This ensures that the salinity control criteria will continue to be met in the future, even with the salinity impacts produced by increasing Upper Basin depletions.

The salinity data used in the CRSS salinity model are based on a monthly regression of natural flow and salinity data from 1971 through 1995 in the Upper Basin (Prairie et al 2005). The Lower Basin monthly regressions are based on the 1971 through 2004 natural flow and salinity data. The monthly regression models allow extension of the CRSS salinity model data over the period 1906 through 2004, the period for which natural flow data is available. The CRSS salinity model data includes salinity control levels and salt loading due to agriculture return flows as used in the 2005 Triennial Review (Colorado River Salinity Control Forum 2005). The model simulates annual average salinity concentrations for locations below Hoover Dam, below Parker Dam, and at Imperial Dam.

The CRSS salinity model is intended for long-term (15 to 20 years) simulation and it is highly sensitive to initial conditions during the first 10 to 12 years. The model assumes salinity is a conservative water quality parameter, and reservoirs are modeled as fully mixed systems.

4.5.2.2 Temperature

Lake Powell undergoes seasonal transformations that can dramatically affect the temperatures of both the reservoirs and the dam releases. During the spring, solar radiation and warmer air temperatures begin to warm the upper surface layers of the reservoirs. This warming is also affected by spring inflow volumes and temperatures. Larger inflows bring greater volumes of warmer water that can cause higher release temperatures. Reservoir draw downs can bring the warmer surface water closer to the power plant intake penstocks, also producing warmer releases. As summer progresses, surface warming of reservoirs increases, as does the warming of releases as the water moves downstream. During the winter months, reservoir temperature stratification is usually eliminated by reservoir mixing, and both reservoir and downstream water cooling occurs. The CE-QUAL-W2 model simulates this annual process and can analyze reservoir and dam release temperatures for various reservoir starting elevations and inflows. The CRSS output of dam release and reservoir elevations was used in the CE-QUAL-W2 model to establish a relationship between reservoir elevations and dam release temperatures and project the impact of reservoir draw down on dam release temperatures. Calibration of the CE-QUAL-W2 model for Lake Powell used historic temperature profiles from 1990 to 2005 at 13 reservoir stations.

This 15-year data set provided a limited range of historic reservoir elevations, inflows and releases. By using a combination of historic and modeled data for various reservoir elevations, and by analyzing the impact of a repetition of the recent drought years, dam release temperatures for a larger range of reservoir elevations could be analyzed.

The GEMSS was used to route Glen Canyon Dam release temperatures through the Grand Canyon downstream to Lake Mead. The GEMSS model was calibrated for water temperature at three locations in this river reach: Lees Ferry, 15.9 miles downstream of Glen Canyon Dam; a point one mile downstream of the Little Colorado River confluence; and the Diamond Creek gaging station 240 miles downstream of Glen Canyon Dam. Below Diamond Creek, water temperatures approached equilibrium with the ambient air temperature, and the rate of temperature change decreased. Since Lees Ferry temperatures are nearly identical to dam release temperatures, only the results for the Little Colorado River confluence and Diamond Creek sites are included in this document.

For any specific reservoir starting elevation, there is a range of potential dam release temperatures because the reservoir is affected by the magnitude of spring inflow and summer meteorological conditions. Downstream water temperatures produced by a routing of these releases are also affected by meteorological conditions and the magnitude of dam releases. Thus, for a single reservoir elevation the CE-QUAL-W2 and GEMSS modeling resulted in a range of water temperatures.

The assessment of potential effects of the alternatives on temperature in Lake Mead was based on the Lake Mead water quality information provided in the SCOP FEIS.

4.5.2.3 Other Water Quality Parameters

Historic water quality data from Lake Powell and Lake Mead and water quality information from the SCOP FEIS for Lake Mead were used to develop qualitative assessments of potential effects of the alternatives on sediment, nutrients and algae, dissolved oxygen, metals, and perchlorate.

4.5.3 Salinity

Table 4.5-1, Table 4.5-2, and Table 4.5-3 present the SCP salinity control criteria and the CRSS salinity model simulations of salinity concentrations for the years 2008, 2026 and 2060, respectively. The projected salinity concentrations presented are the flow-weighted annual averages for the selected year under the No Action Alternative and the action alternatives. The results assume continuation of existing salinity control programs and projects. Therefore, the flow-weighted annual average salinity concentrations should not increase over time under the No Action Alternative for the current plan of implementation, which extends through 2025 (Colorado River Salinity Control Forum 2005).

The flow-weighted average annual salinity criteria for locations on the lower Colorado River listed in Table 4.5-1, Table 4.5-2, and Table 4.5-3 are not exceeded at any time under any of the alternatives. This is due in part to the presumed continuation of existing levels of salinity controls under the SCP in the CRSS salinity model. The Water Supply Alternative generally provides salinity concentrations equal to or lower than the No Action Alternative. During some years the Reservoir Storage Alternative produces higher salinity concentrations than the No Action Alternative. At all times the differences in salinity concentrations among the different alternatives is less than three percent.

Table 4.5-1
Projected Colorado River Salinity in 2008

Alternative	Below Hoover Dam SCP Criteria 723 mg/L	Below Parker Dam SCP Criteria 747 mg/L	At Imperial Dam SCP Criteria 879 mg/L
	Projected Value (mg/L)	Projected Value (mg/L)	Projected Value (mg/L)
No Action	635	654	767
Basin States	635	655	772
Conservation Before Shortage	635	655	774
Reservoir Storage	637	657	782
Water Supply	635	654	767

Table 4.5-2
Projected Colorado River Salinity in 2026

Alternative	Below Hoover Dam SCP Criteria 723 mg/L	Below Parker Dam SCP Criteria 747 mg/L	At Imperial Dam SCP Criteria 879 mg/L
	Projected Value (mg/L)	Projected Value (mg/L)	Projected Value (mg/L)
No Action	603	624	744
Basin States	607	628	751
Conservation Before Shortage	607	629	756
Reservoir Storage	615	637	764
Water Supply	598	619	740

Table 4.5-3
Projected Colorado River Salinity in 2060

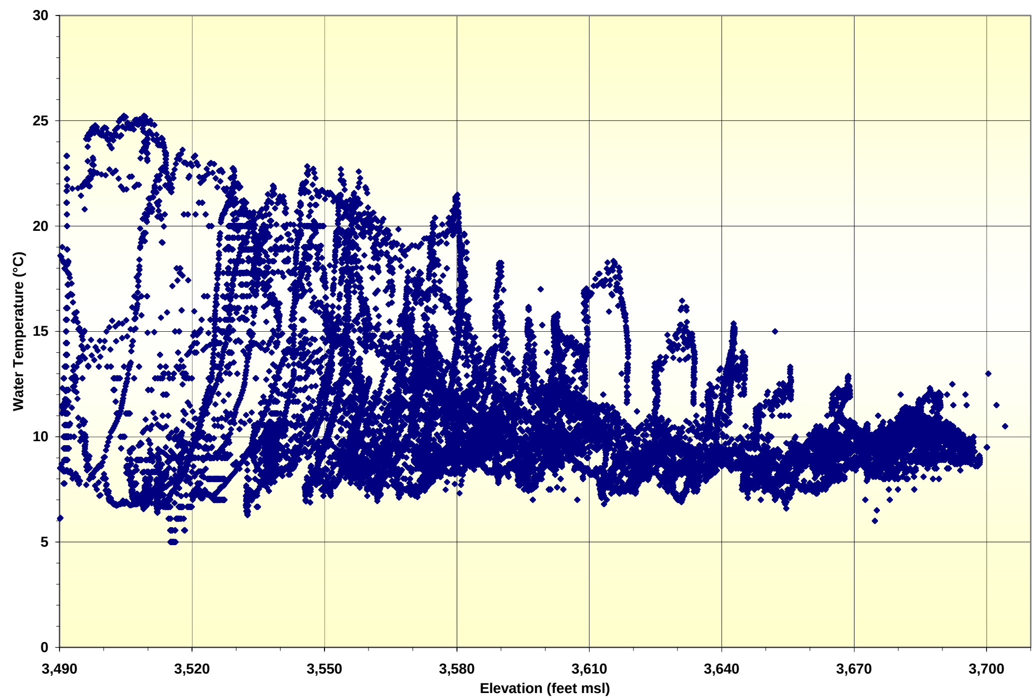
Alternative	Below Hoover Dam SCP Criteria 723 mg/L	Below Parker Dam SCP Criteria 747 mg/L	At Imperial Dam SCP Criteria 879 mg/L
	Projected Value (mg/L)	Projected Value (mg/L)	Projected Value (mg/L)
No Action	626	648	779
Basin States	630	653	786
Conservation Before Shortage	630	653	786
Reservoir Storage	630	653	786
Water Supply	626	648	780

4.5.4 Temperature

4.5.4.1 Lake Powell and Glen Canyon Dam

The release temperature ranges presented in Figure 4.5-1 are comprised of historic and modeled data and represent a yearly range including seasonal fluctuations. This graph shows that as Lake Powell's elevation decreases, the range of annual release temperature fluctuations increases. The minimum release temperature occurs in the winter and it is fairly consistent at about 7 °C to 10 °C (44.6ºF to 50 ºF). The peak summer release temperature varies significantly with elevation, peaking at about 25 °C (77 º F) as the reservoir elevation drops to near the minimum power pool elevation of 3,490 feet msl. The nearer the reservoir elevation is to the power plant penstock intakes, the higher the summer and fall release temperatures. Reservoir elevations near the full pool elevation of 3,700 feet msl show much less variation among seasons, with releases consistently cold from 8 °C to 12 °C (46.4 ºF to 53.6 ºF). During extreme drought events, the elevation of Lake Powell may drop below the minimum power pool elevation of 3,490 feet msl. If this occurs, releases would be discontinued from the powerplant penstocks and releases would be made through the river outlet tubes, which are located at elevation 3,374 feet msl. Under these conditions, the temperature of the water released from Glen Canyon Dam could potentially change from about 25 °C to less than 10 °C (77 ºF to less than 50 ºF). If the reservoir elevation were to drop further, closer to the elevation of the river outlet tubes, the releases would again gradually warm.

Figure 4.5 -1
Historic Data and CE-QUAL-W2 Model Results for Lake Powell Release Temperatures by Elevation



In addition to the seasonal ranges described above, Table 4.5-4 and Table 4.5-5 present projected release temperature ranges associated with the CRSS projected 90th, 50th, and 10th percentile elevations of Lake Powell in 2016, 2026, and 2060 for the months of July and October, respectively. This represents the period of time when maximum warming occurs in Lake Powell and the downstream releases. The release temperature ranges in Table 4.5-4 and Table 4.5-5 reflect the variability of hydrologic, meteorological, and hydraulic conditions. The sensitivity of release temperatures to these conditions increases with decreasing reservoir elevations. This sensitivity causes a wide range of possible release temperatures at similar reservoir elevations. In general, for a given month and reservoir elevation a higher release temperature is associated with an above average inflow volume and a lower release temperature is associated with a below average inflow volume. Therefore, the ranges shown in these tables reflect different release temperatures for these specific months and reservoir elevations, ranges which are due primarily to large differences in reservoir inflows.

For reservoir elevations at or above the 90th percentile elevation for all years there are no differences among the alternatives. Overall, the temperature ranges for July and October for the No Action Alternative, Basin States Alternative, and Conservation Before Shortage Alternative are similar for 2016, 2026, and 2060 for the 50th and 10th percentile reservoir elevations, respectively. The temperature range for the Water Supply Alternative is warmer due to the corresponding lower Lake Powell reservoir elevations for the 10th and 50th percentiles. The Reservoir Storage Alternative results in cooler water temperatures for the 10th and 50th percentile reservoir elevations for some years, due to higher reservoir elevations.

Table 4.5-4
Lake Powell July Elevations and Release Temperatures
90th, 50th, and 10th Percentile Values

	90th Percentile		50th Percentile		10th Percentile	
Year	Elevation (feet msl)	Temperature (°C)	Elevation (feet msl)	Temperature (°C)	Elevation (feet msl)	Temperature (°C)
2016						
No Action	3,698.7	9 to 11	2,650.3	8.5 to 11.5	3,583.5	9 to 17
Basin States	3,698.5	9 to 11	3,646.4	8.5 to 11.5	3,587.2	9 to 17
Conservation Before Shortage	3,698.1	9 to 11	3,646.4	8.5 to 11.5	3,587.7	9 to 17
Water Supply	3,698.5	9 to 11	3,642.0	8.5 to 11.5	3,572.0	10 to 19
Reservoir Storage	3,698.8	9 to 11	3,650.3	8.5 to 11.5	3,599.5	8.5 to 15
2026						
No Action	3,697.9	9 to 11	3,658.8	8.5 to 11	3,579.4	9.5 to 18
Basin States	3,697.7	9 to 11	3,648.6	8.5 to 11.5	3,572.6	10 to 19
Conservation Before Shortage	3,697.7	9 to 11	3,649.2	8.5 to 11.5	3,573.5	10 to 19
Water Supply	3,697.6	9 to 11	3,631.0	8.5 to 12	3,527.5	17 to 22
Reservoir Storage	3,698.8	9 to 11	3,664.2	8.5 to 11	3,600.3	8.5 to 15
2060						
No Action	3,699.3	9 to 11	3,657.0	8.5 to 11	3,558.6	10 to 20
Basin States	3,699.3	9 to 11	3,657.0	8.5 to 11	3,558.6	10 to 20
Conservation Before Shortage	3,699.3	9 to 11	3,657.0	8.5 to 11	3,558.6	10 to 20
Water Supply	3,699.3	9 to 11	3,657.0	8.5 to 11	3,55i8.6	10 to 20
Reservoir Shortage	3,699.3	9 to 11	3,657.0	8.5 to 11	3,558.6	10 to 20

Table 4.5-5
Lake Powell October Elevations and Release Temperatures
90th, 50th, and 10th Percentile Values

Year	90th Percentile		50th Percentile		10th Percentile	
	Elevation (feet msl)	Temperature (°C)	Elevation (feet msl)	Temperature (°C)	Elevation (feet msl)	Temperature (°C)
2016						
No Action	3,689.6	9 to 11.5	3,644.1	9 to 15	3,574.6	11 to 21
Basin States	3,689.6	9 to 11.5	3,640.5	9 to 15	3,574.2	11 to 21
Conservation Before Shortage	3,689.6	9 to 11.5	3,640.5	9 to 15	3,574.5	11 to 21
Water Supply	3,689.4	9 to 11.5	3,634.7	9 to 16	3,560.7	12 to 22
Reservoir Storage	3,690.0	9 to 11.5	3,647.0	9 to 15	3,588.0	10 to 20
2026						
No Action	3,689.2	9 to 11.5	3,656.6	8.5 to 14	3,569.8	11 to 21
Basin States	3,689.2	9 to 11.5	3,637.1	9 to 15.5	3,569.4	11 to 21
Conservation Before Shortage	3,689.2	9 to 11.5	3,640.6	9 to 15	3,570.1	11 to 21
Water Supply	3,689.2	9 to 11.5	3,622.4	9 to 18	3,512.9	16 to 24
Reservoir Storage	3,689.7	9 to 11.5	3,659.1	8.5 to 14	3,591.5	10 to 20
2060						
No Action	3,689.9	9 to 11.5	3,647.1	9 to 15	3,552.2	13 to 22
Basin States	3,689.9	9 to 11.5	3,647.1	9 to 15	3,552.2	13 to 22
Conservation Before Shortage	3,689.9	9 to 11.5	3,647.1	9 to 15	3,552.2	13 to 22
Water Supply	3,689.9	9 to 11.5	3,647.1	9 to 15	3,552.2	13 to 22
Reservoir Shortage	3,689.9	9 to 11.5	3,647.1	9 to 15	3,552.2	13 to 22

4.5.4.2 Glen Canyon Dam to Lake Mead

Using historic data and output from the CE-QUAL-W2 model as input, the GEMSS model analyzed monthly temperatures for July and October for the CRSS 90th, 50th, and 10th percentile projected reservoir releases. These monthly temperatures are presented for each alternative in Table 4.5-6 and Table 4.5-7 for the confluence with the Little Colorado River, and in Table 4.5-8 and Table 4.5-9 for the gage below Diamond Creek, and are consistently higher than the dam release temperatures shown in Table 4.5-4 and Table 4.5-5. The data listed in these tables are ranges, and refer to the variability of temperatures due to three factors: variable release volume; release temperature ranges; and downstream meteorology.

The ranges presented in Table 4.5-4 and Table 4.5-5 cascade in the downstream temperature modeling. The rate at which water that is released from a reservoir approaches ambient air temperature as it travels downstream depends on these factors. In general, warmer downstream water temperatures result from smaller release volumes, higher release temperatures, and warmer ambient air temperatures. However, the relationship between release temperature and downstream temperature was nonlinear (e.g., a 1 °C (33.8 ° F) increase in release temperature does not necessarily result in a 1 °C

(33.8 ºF) increase downstream). In general, the temperature ranges for July and October for the No Action Alternative, Basin States Alternative, Conservation Before Shortage Alternative, and Water Supply Alternative are similar. The range of temperatures varies by less than about 2 ºC (35.6 º F) for each of these alternatives. The range of temperatures for the Reservoir Storage Alternative tended to be cooler for both the 50th and 10th percentile river flows. This is due to higher Lake Powell elevations in this alternative.

Table 4.5-6
Colorado River at Little Colorado River Confluence July Water Temperatures
90th, 50th, and 10th Percentile Values

Year	90th Percentile Temperature (°C)	50th Percentile Temperature (°C)	10th Percentile Temperature (°C)
2016			
No Action	10 to 14	10 to 14	12 to 22
Basin States	10 to 14	10 to 15	13 to 22
Conservation Before Shortage	10 to 14	10 to 15	13 to 22
Water Supply	10 to 14	10 to 15	13 to 23
Reservoir Storage	10 to 14	10 to 13	12 to 21
2026			
No Action	10 to 14	10 to 14	12 to 22
Basin States	10 to 14	10 to 15	13 to 22
Conservation Before Shortage	10 to 14	10 to 15	13 to 22
Water Supply	10 to 14	10 to 15	13 to 23
Reservoir Storage	10 to 14	10 to 13	12 to 21
2060			
No Action	10 to 14	10 to 14	12 to 22
Basin States	10 to 14	10 to 15	13 to 22
Conservation Before Shortage	10 to 14	10 to 15	13 to 22
Water Supply	10 to 14	10 to 15	13 to 23
Reservoir Storage	10 to 14	10 to 13	12 to 21

Table 4.5-7
Colorado River at Little Colorado River Confluence October Water Temperatures
90th, 50th, and 10th Percentile Values

Year	90th Percentile	50th Percentile	10th Percentile
	Temperature (°C)	Temperature (°C)	Temperature (°C)
2016			
No Action	10 to 11	12 to 16	11 to 21
Basin States	10 to 11	9 to 17	11 to 22
Conservation Before Shortage	10 to 11	9 to 17	11 to 22
Water Supply	10 to 11	9 to 16	14 to 22
Reservoir Storage	10 to 11	8 to 14	12 to 21
2026			
No Action	10 to 11	12 to 16	11 to 21
Basin States	10 to 11	9 to 17	11 to 22
Conservation Before Shortage	10 to 11	9 to 17	11 to 22
Water Supply	10 to 11	9 to 16	14 to 22
Reservoir Storage	10 to 11	8 to 14	12 to 21
2060			
No Action	10 to 11	12 to 16	11 to 21
Basin States	10 to 11	9 to 17	11 to 22
Conservation Before Shortage	10 to 11	9 to 17	11 to 22
Water Supply	10 to 11	9 to 16	14 to 22
Reservoir Storage	10 to 11	8 to 14	12 to 21

Table 4.5-8
Colorado River Below Diamond Creek July Water Temperatures
90th, 50th, and 10th Percentile Values

Year	90th Percentile Temperature (°C)	50th Percentile Temperature (°C)	10th Percentile Temperature (°C)
2016			
No Action	15 to 25	13 to 18	15 to 25
Basin States	15 to 25	14 to 19	16 to 25
Conservation Before Shortage	15 to 25	14 to 19	16 to 25
Water Supply	15 to 25	14 to 19	17 to 26
Reservoir Storage	15 to 25	14 to 18	15 to 24
2026			
No Action	15 to 25	13 to 18	15 to 25
Basin States	15 to 25	14 to 19	16 to 25
Conservation Before Shortage	15 to 25	14 to 19	16 to 25
Water Supply	15 to 25	14 to 19	17 to 26
Reservoir Storage	15 to 25	14 to 18	15 to 24
2060			
No Action	15 to 25	13 to 18	15 to 25
Basin States	15 to 25	14 to 19	16 to 25
Conservation Before Shortage	15 to 25	14 to 19	16 to 25
Water Supply	15 to 25	14 to 19	17 to 26
Reservoir Storage	15 to 25	14 to 18	15 to 24

Table 4.5-9
Colorado River Below Diamond Creek October Water Temperatures
90th, 50th, and 10th Percentile Values

Year	90th Percentile Temperature (°C)	50th Percentile Temperature (°C)	10th Percentile Temperature (°C)
2016			
No Action	11 to 16	13 to 18	13 to 22
Basin States	11 to 16	10 to 19	12 to 23
Conservation Before Shortage	11 to 16	10 to 19	12 to 23
Water Supply	11 to 16	10 to 18	14 to 23
Reservoir Storage	11 to 16	9 to 17	12 to 22
2026			
No Action	11 to 16	13 to 18	13 to 22
Basin States	11 to 16	10 to 19	12 to 23
Conservation Before Shortage	11 to 16	10 to 19	12 to 23
Water Supply	11 to 16	10 to 18	14 to 23
Reservoir Storage	11 to 16	9 to 17	12 to 22
2060			
No Action	11 to 16	13 to 18	13 to 22
Basin States	11 to 16	10 to 19	12 to 23
Conservation Before Shortage	11 to 16	10 to 19	12 to 23
Water Supply	11 to 16	10 to 18	14 to 23
Reservoir Storage	11 to 16	9 to 17	12 to 22

4.5.4.3 Lake Mead and Hoover Dam

Water quality modeling provided in the SCOP FEIS showed that lake temperatures would change by no more than 1 ºC (33.8 º F) when the Lake Mead elevations are drawn down from 1,178 feet to 1,000 feet msl (Clean Water Coalition 2006). For the No Action, Conservation Before Shortage, and Reservoir Storage alternatives, the hydrologic modeling shows the probability of Lake Mead being below elevation 1,000 feet msl is zero (Section 4.3). For the Basin States Alternative, the hydrologic modeling showed zero probability through 2024 with a small probability (of one and two percent in 2025 and 2026). For the Water Supply Alternative, the hydrologic modeling shows the probabilty is small through 2020, increasing to a six percent chance by 2026. Based on these results, potential effects of the alternatives on temperature in Lake Mead are considered negligible.

4.5.5 Sediment and Dissolved Oxygen

The maximum headcutting of reservoir deltas occurs when a deeply drawn down reservoir is followed by very high inflows, similar to that observed in Lake Powell in 2005. This condition is very dependent on the reservoir elevation and spring inflow volume. Compared to the No Action Alternative, the projected additional reservoir draw down for the Water Supply Alternative could result in additional headcutting in the sediment deltas and accompanying water quality impacts. The Reservoir Storage Alternative could result in a decrease in headcutting if the projected reservoir elevations remain higher than for the No Action Alternative. Since the projected reservoir draw down for the Conservation Before Shortage Alternative and the Basin States Alternative are similar, headcutting to the sediment deltas would likely be similar.

Quantified water quality impacts from reservoir sediment delta headcutting are not currently available, nor is it possible to quantitatively distinguish the impact of sediment headcutting among the alternatives. However, recent history shows that high inflows causing headcutting likely increases phosphorus release and biological oxygen demand. Large spring inflows then can bring this plume of low dissolved oxygen water near the powerplant intakes and result in low dissolved oxygen releases. There may be short term impacts to food base and trout resources between Glen Canyon Dam and Lees Ferry from these occurrences. Recurrences of low dissolved oxygen such as occurred in 2005 below Glen Canyon Dam may result from reservoir draw down cycles under any of the alternatives, but as described in Section 3.5.5 the river reaerates after passing through rapids downstream of Lees Ferry. Additionally, average or lower inflows do not seem to have the power to create adverse conditions such as in 2005.

With respect to riverine sediment transport in the Glen Canyon Dam to Lake Mead reach, annual releases lower than 8.23 maf associated with the action alternatives would transport less sediment through the Grand Canyon into Lake Mead than the No Action Alternative, but would be offset by equalization or balancing releases in these alternatives (Figure 4.3-13).

To estimate the sediment transport impacts of potentially modifying the annual release volumes from Glen Canyon Dam, the USGS prepared an analysis relating normalized sediment transport from the Grand Canyon to annual release volumes. Table 4.5-10 shows this relationship, with 8.23 maf release volumes as the basis for normalization.

Table 4.5-10
Relationship of Glen Canyon Dam Annual Release Volumes to Sediment Transport

Release (maf)	Normalized Sand Export
6.00	0.26
7.00	0.51
8.00	0.89
8.23	1.00
9.00	1.43
10.00	2.15
11.00	3.03
12.00	4.11
13.00	5.43
14.00	7.01
15.00	8.88
16.00	11.02
17.00	13.53

Table 4.5-10
Relationship of Glen Canyon Dam Annual Release Volumes to Sediment Transport

Release (maf)	Normalized Sand Export
18.00	16.67
19.00	19.72
20.00	23.40

Annual release volumes from all the traces of the RiverWare™ analysis for all the alternatives were applied to this sand export relationship for the years 2008, 2016, and 2026. Relative differences among the alternatives were calculated by comparing the action alternatives to the No Action Alternative at the 10th, 50th, and 90th percentiles of sand export. These normalized comparisons are shown in Tables 4.5-11 through 4.5-13 for the years 2008, 2016, and 2026, respectively.

Table 4.5-11
Comparison of Sediment Export among Alternatives (Normalized to 8.23 maf annual releases)
2008

Alternative	90th Percentile	50th Percentile	10th Percentile
No Action	4.4	1	1
Basin States	4.8	1	1
Conservation Before Shortage	4.8	1	1
Reservoir Storage	4.4	1	1
Water Supply	4.4	1	1

Table 4.5-12
Comparison of Sediment Export among Alternatives (Normalized to 8.23 maf annual releases)
2016

Alternative	90th Percentile	50th Percentile	10th Percentile
No Action	5.68	1	1
Basin States	5.7	1.4	1
Conservation Before Shortage	5.71	1.4	0.99
Reservoir Storage	5.68	1	0.81
Water Supply	5.33	1.8	1

Table 4.5-13
Comparison of Sediment Export among Alternatives (Normalized to 8.23 maf annual releases)
2026

Alternative	90th Percentile	50th Percentile	10th Percentile
No Action	4.76	1	1
Basin States	4.57	1.4	1
Conservation Before Shortage	4.54	1.4	1
Reservoir Storage	4.81	1	0.96
Water Supply	4.81	1.8	1

The data provided in the table above show that in the near term, the alternatives transport nearly the same amount of sediment, but that in 2016 and 2026, the Basin States and Conservation Before Shortage alternatives generally transport more sediment as water is moved from Lake Powell to Lake Mead to meet water supply demands, while the Water Supply Alternative transports even more sediment as greater volumes of water are moved to Lake Mead. The Reservoir Storage Alternative reduces the amount of transport as releases and water deliveries are reduced to keep Lake Mead, and subsequently Lake Powell, fuller.

Modeling completed for the SCOP FEIS determined that there would be no adverse effect on dissolved oxygen as a result from the SCOP project or from the drawdown of Lake Mead from elevation 1,178 feet to 1,000 feet msl. For the No Action, Conservation Before Shortage, and Reservoir Storage alternative, the hydrologic modeling shows the probability of Lake Mead being below elevation 1,000 feet msl is zero (Section 4.3). For the Basin States Alternative, the hydrologic modeling showed zero probability through 2024 with a small probability (of one and two percent in 2025 and 2026). For the Water Supply Alternative, the hydrologic modeling shows the probabilty is small through 2020, increasing to a six percent chance by 2026. Based on these results, potential effects of the alternatives on dissolved oxygen in Lake Mead are considered negligible. Futhermore, monitoring of dissolved oxygen levels in Lake Mead will be conducted as part of the SCOP BBAMP (Clean Water Coalition 2006).

4.5.6 Nutrients and Algae

Most of the 1.0 mg/L of total phosphorus concentration entering Lake Powell from the major tributaries is bound to the sediment and primarily settles out with the sediment (Section 3.5). Bioavailable phosphorus from the major inflows is generally only 0.007 to 0.009 mg/L and phosphorus concentrations released from Glen Canyon Dam and Hoover Dam generally range from only 0.004 to 0.008 mg/L with occasional spikes to near 0.012 mg/L. Sediment delta headcutting, as discussed above, releases phosphorus. This release can significantly boost primary productivity in reservoir inflow areas. A decrease in reservoir elevation could result in additional headcutting in the sediment deltas; however, data is not available to project the amount of headcutting and phosphorous release for different reservoir elevations.

When Lake Powell is full, Glen Canyon Dam release temperatures and inflow temperatures into Lake Mead are cool, and the plume of water entering Lake Mead drops to depths below which algae can grow. Therefore, much of the inflowing phosphorus that is not settled out with the sediment in Lake Mead travels to Hoover Dam. However, when Lake Powell elevations are low enough to produce warm Glen Canyon Dam releases and inflow temperatures into Lake Mead, the inflow plume into Lake Mead will remain nearer the surface where light would increase productivity. The algae thus produced would settle out, trap more phosphorus in the sediment in Lake Mead, and reduce the phosphorus transport down reservoir into Boulder Basin. Due to the complexity of the system, the direct impact due to the different alternatives can not be projected.

Modeling results provided in the SCOP FEIS showed that there would be no adverse effects on phosphorous concentrations, other nutrients or algae as a result of the SCOP or from Lake Mead being drawn down from elevation 1,178 feet to 1,000 feet msl (Clean Water Coalition 2006). For the No Action, Conservation Before Shortage, and Reservoir Storage alternatives, the hydrologic modeling shows the probability of Lake Mead being below elevation 1,000 feet msl is zero (Section 4.3). For the Basin States Alternative, the hydrologic modeling showed zero probability through 2024 with a small probability (of one and two percent in 2025 and 2026). For the Water Supply Alternative, the hydrologic modeling shows the probabilty is small through 2020, increasing to a six percent chance by 2026. Based on these results, the concentrations of phosphorus in Boulder Basin and Las Vegas Bay should remain within the Nevada TMDL under all alternatives. Furthermore, the SCOP BBAMP will monitor nutrients and chlorophyll levels in Lake Mead and manage nutrient loadings if water quality objectives are not met (Clean Water Coalition 2006).

4.5.7 Metals

The modeling results provided in the SCOP FEIS for Lake Mead show that the lake's ability to dilute contaminant and nutrient loadings from Las Vegas Valley wastewater treatment plants is not significantly diminished when Lake Mead elevation is 1,000 feet msl in comparison to 1,178 feet msl (Clean Water Coalition 2006). For the No Action, Conservation Before Shortage, and Reservoir Storage alternatives, the hydrologic modeling shows the probability of Lake Mead being below elevation 1,000 feet msl is zero (Section 4.3). For the Basin States Alternative, the hydrologic modeling showed zero probability through 2024 with a small probability (of one and two percent in 2025 and 2026). For the Water Supply Alternative, the hydrologic modeling shows the probabilty is small through 2020, increasing to a six percent chance by 2026. Therefore, it is anticipated that drawdown of Lake Mead under any of the alternatives will not increase metals concentrations as a result of reduced dilution.

4.5.8 Perchlorate

Since 1999, perchlorate containment and reduction strategies have resulted in the decline of detectable concentrations in Lake Mead, Willow Beach, and Lake Havasu and other sampling locations in the lower Colorado River, as well as in areas using Colorado River water in Arizona. Perchlorate concentrations are ranging from non-detectable levels to six ppb, indicating a slow and steady decline (Personal Communication, Blasius). The modeling provided for the SCOP FEIS included a perchlorate analysis and showed that the dilution capacity of Lake Mead did not significantly change when the Lake Mead water levels are drawn down from 1,178 feet msl to 1,000 feet msl. For the No Action, Conservation Before

Shortage, and Reservoir Storage alternatives, the hydrologic modeling shows the probability of Lake Mead being below elevation 1,000 feet msl is zero (Section 4.3). For the Basin States Alternative, the hydrologic modeling showed zero probability through 2024 with a small probability (of one tand two percent in 2025 and 2026). For the Water Supply Alternative, the hydrologic modeling shows the probabilty is small through 2020, increasing to a six percent chance by 2026. Therefore, Lake Mead draw down under any of the action alternatives is not expected to affect perchlorate concentrations.

4.5.9 Summary

The following conclusions were drawn from the analyses of potential effects on water quality constituents of concern.

4.5.9.1 Salinity

The future average annual salinity levels under the action alternatives are not expected to exceed the salinity numeric criteria established by the Colorado River Salinity Control Forum for different locations on lower Colorado River.

4.5.9.2 Temperature

The temperature range for Glen Canyon Dam releases under the Water Supply Alternative is warmer due to the corresponding lower Lake Powell reservoir elevations for the 10^{th} and 50^{th} percentiles. The Reservoir Storage Alternative results in cooler temperatures for Glen Canyon Dam release under the 10^{th} and 50^{th} percentile reservoir elevations for some years. The temperature of Glen Canyon Dam releases under the Basin States Alternative and Conservation Before Shortage Alternative are similar to those under the No Action Alternative.

For Lake Mead, modeling performed for the SCOP EIS showed that lake temperatures would change by no more than 1 ºC (33.8 º F) when the Lake Mead elevations are drawn down from 1,178 feet msl to 1,000 feet msl (Clean Water Coalition 2006). The probability of Lake Mead being drawn down below elevation 1,000 feet msl is small for all alternatives. Therefore, potential effects of the alternatives on temperature in Lake Mead are considered negligible.

4.5.9.3 Other Water Quality Parameters

The following findings relate to other water quality parameters analyzed for Lake Powell:

- ♦ Quantified water quality impacts from reservoir sediment delta headcutting are not currently available;
- ♦ The projected elevations and corresponding changes in dilution capacity are not expected to result in metals concentrations of concern; and
- ♦ It is not anticipated that any of the action alternatives would result in a significantly increased concentration of perchlorate.

For Lake Mead, hydrologic and water quality modeling provided in the SCOP FEIS determined that drawing the Lake Mead water level down to an elevation of 1,000 feet msl would not have a significant effect on water quality in Lake Mead, Hoover Dam releases, and the SNWA water pumped from Lake Mead. The probability of Lake Mead being drawn down below elevation 1,000 feet msl is small for all alternatives. Therefore, potential effects of the alternatives on water quality parameters in Lake Mead are considered negligible.

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4.6 Air Quality

This section describes the methods of analysis and potential effects on air quality at Lake Powell and Lake Mead, focusing on particulate matter. Potential effects on the Glen Canyon to Lake Mead reach from particulate emissions at the Lake Mead delta are also considered.

4.6.1 Methodology

Fugitive emissions can result from exposed sediment on the shorelines of Lake Powell and Lake Mead as a result of fluctuations in their elevations. The mass of particulates generated per acre of exposed shoreline will vary depending upon sediment characteristics and other factors such as saturation, sediment disturbance, wind speeds, and topography. The method for assessing potential fugitive emissions from exposed shoreline sediment at Lake Powell and Lake Mead includes the following assumptions.

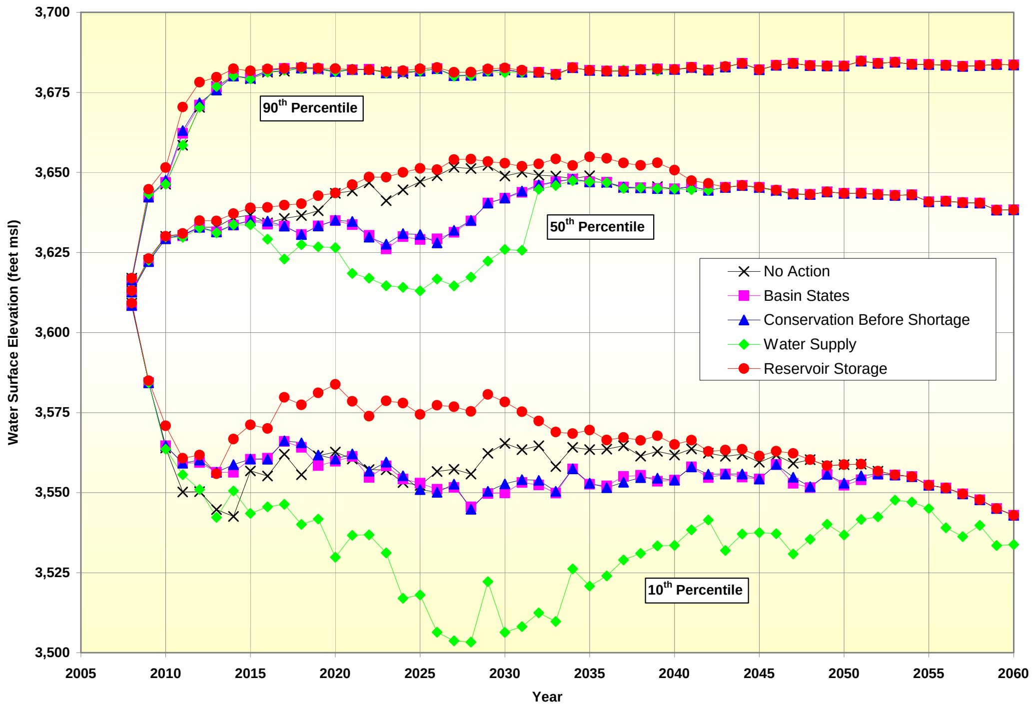
- The area of exposed shoreline for Lake Powell was developed using an average shoreline slope of 45 degrees. The area of exposed shoreline for Lake Mead was developed from bathymetry data.
- Incremental changes to Lake Powell and Lake Mead elevations were developed corresponding to the years 2008 through 2060 from the CRSS modeling output. The 10th percentile elevations at the end of March for Lake Powell and the end of December at Lake Mead were selected as worst case assumptions that still have a reasonable probability of occurring. These are then correlated to the reservoir surface areas (acres) and compared to the maximum elevations for Lake Powell (3,700 feet msl) and Lake Mead (1,229 feet msl) to determine acres of exposed shoreline.

4.6.2 Lake Powell and Glen Canyon Dam

4.6.2.1 No Action Alternative

The lowest Lake Powell elevation occurs in March (Figure 4.6-1). For a comparative evaluation, the years 2008, 2016, 2025, 2040, 2050, and 2060 were examined under the No Action Alternative. The low Lake Powell elevation at the 10th percentile was projected for the year 2025 with a maximum 16,656 acres of exposed shoreline.

Figure 4.6-1
Lake Powell End-of-March Elevations
Comparison of Action Alternatives to No Action Alternative
90th, 50th, and 10th Percentile Values



The potential for fugitive emissions is limited by the extent of the area containing fine sediment and that has the potential to generate dust. Areas of fine sediment at Lake Powell comprise about three percent of the 1,960 miles of shoreline (National Park Service 2002). The remainder of the Lake Powell shoreline consists of Navajo Sandstone and other Glen Canyon Group rock formations. These rock formations are not conducive to creating significant amounts of dust.

4.6.2.2 Basin States Alternative

At the 10th percentile, Lake Powell elevation is projected to be 3,553 feet msl in the year 2025, resulting in 16,582 acres of exposed shoreline. This would result in a decrease of less than one percent in exposed shoreline compared to the No Action Alternative (Table 4.6-1). With this decrease in acreage, the potential to exceed the federal PSD Class II threshold or state and national AAQS when compared to the No Action Alternative is slightly decreased.

Table 4.6-1
Lake Powell End-of-March 10th Percentile Elevation and Exposed Shoreline (Rounded to Nearest Whole Number)

Year	No Action Alternative	Basin States Alternative	Conservation Before Shortage Alternative	Water Supply Alternative	Reservoir Storage Alternative
2008 Surface Elevation (feet msl)	3,609	3,608	3,608	3,609	3,609
Exposed Shoreline Area (acres x 1,000)	10	10	10	10	10
Percent Difference Compared to No Action Alternative	0	1	1	0	0
2016 Surface Elevation (feet msl)	3,555	3,561	3,560	3,546	3,570
Exposed Shoreline Area (acres x 1,000)	16	16	16	17	15
Percent Difference Compared to No Action Alternative[1]	0	(4)	(4)	7	(10)
2025 Surface Elevation (feet msl)	3,552	3,553	3,551	3,518	3,574
Exposed Shoreline Area (acres x 1,000)	17	17	17	21	14
Percent Difference Compared to No Action Alternative	0	0	1	23	(15)
2040 Surface Elevation (feet msl)	3,562	3,554	3,554	3,534	3,565
Exposed Shoreline Area (acres x 1,000)	16	16	16	19	15
Percent Difference Compared to No Action Alternative	0	6	6	20	(2)
2050 Surface Elevation (feet msl)	3,559	3,552	3,553	3,537	3,559
Exposed Shoreline Area (acres x 1,000)	16	17	16	18	16
Percent Difference Compared to No Action Alternative	0	5	4	16	0
2060 Surface Elevation (feet msl)	3,543	3,543	3,543	3,534	3,543
Exposed Shoreline Area (acres x 1,000)	18	18	18	19	18
Percent Difference Compared to No Action Alternative	0	0	0	6	0

1 Parenthesis indicates a reduction in exposed shoreline compared to the No Action Alternative

4.6.2.3 Conservation Before Shortage Alternative

At the 10th percentile, Lake Powell elevation is projected to be 3,551 feet msl in the year 2025. Draw downs to this level could result in 16,806 acres of exposed shoreline. This would result in an increase of about one percent in exposed shoreline compared to the No Action Alternative (Table 4.6-1).

This slight increase in acreage would not increase the potential to exceed the PSD Class II threshold or the state or national AAQS when compared to the No Action Alternative. Because of the sandstone formations of Lake Powell, dust would not be of concern.

4.6.2.4 Water Supply Alternative

At the 10th percentile, Lake Powell elevation is projected to be 3,518 feet msl in the year 2025, resulting in 20,516 acres of exposed shoreline. This would cause an increase of 23 percent in exposed shoreline compared to the No Action Alternative (Table 4.6-1).

This increase would potentially have a negative impact on air quality compared to the No Action Alternative. As sediment comprises about three percent of the 1,960 miles of shoreline, this increase in acreage would not result in exceedance of the PSD Class II threshold or the state or national AAQS. Neither the small source area susceptible to wind erosion nor the geologic formations would be conducive to creating dust.

4.6.2.5 Reservoir Storage Alternative

At the 10th percentile, Lake Powell elevation is projected to be 3,574 feet msl in the year 2025. Draw down of the Lake Powell water level to this elevation would result in a decrease of 14,162 acres of exposed shoreline. The Reservoir Storage Alternative would result in a decrease of about 15 percent in exposed shoreline compared to the No Action Alternative (Table 4.6-1).

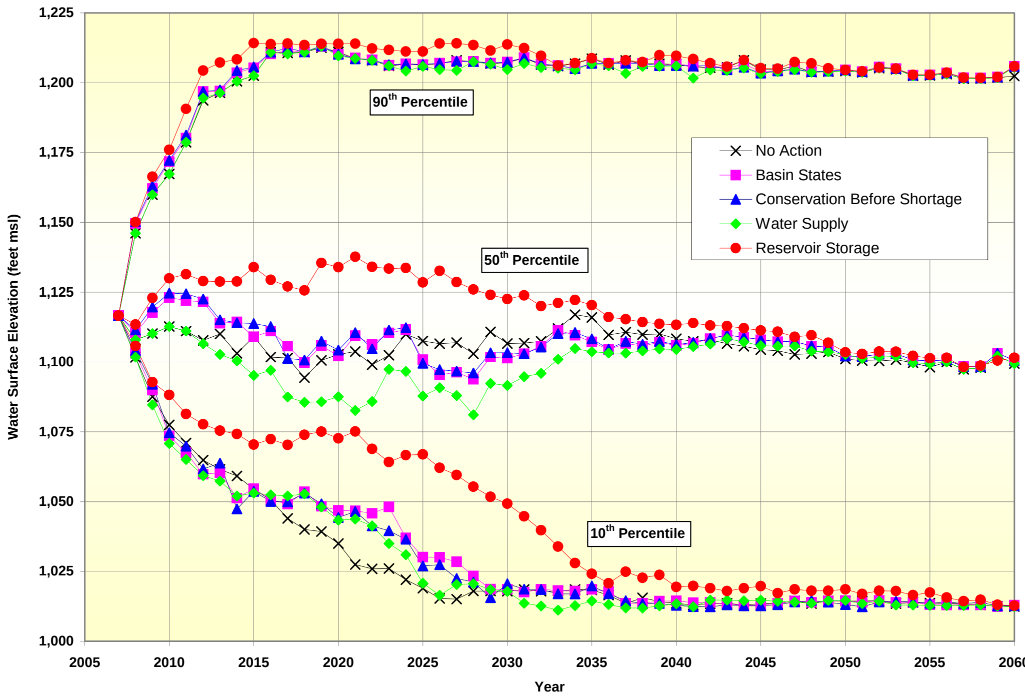
Compared to the No Action Alternative, the Reservoir Storage Alternative would result in the highest reduction in dust emissions and increased beneficial impact to air quality. Due to a decrease in exposed shoreline acreage, the potential to exceed the PSD Class II threshold or the state or national AAQS is also decreased.

4.6.3 Glen Canyon Dam to Lake Mead, Lake Mead and Hoover Dam

4.6.3.1 No Action Alternative

The lowest Lake Mead elevation occurs in December (Figure 4.6-2). Under the No Action Alternative, Lake Mead elevation would be drawndown to elevation 1,019 feet msl for the year 2025, resulting in 86,770 acres of exposed shoreline (Table 4.6-2).

Figure 4.6-2
Lake Mead End-of-December Elevations
Comparison of Action Alternatives to No Action Alternative
90th, 50th, and 10th Percentile Values



4.6.3.2 Basin States Alternative

At the 10th percentile, Lake Mead elevation is projected to be 1,030 feet msl in the year 2025, resulting in 83,920 acres of exposed shoreline. The Basin States Alternative would result in a decrease of about three percent in exposed shoreline when compared to the No Action Alternative (Table 4.6-2). This decrease in acreage would be directly proportional to the area susceptible to wind erosion and fugitive dust emission. With a decrease in exposed shoreline acreage, the potential to exceed the PSD Class I or II thresholds or the state or national AAQS would also decrease. The three percent decrease would result in a beneficial effect compared to the No Action Alternative.

Table 4.6-2
Lake Mead End-of-December 10th Percentile Elevation and Exposed Shoreline (Rounded to Nearest Whole Number)

Year	No Action Alternative	Basin States Alternative	Conservation Before Shortage Alternative	Water Supply Alternative	Reservoir Storage Alternative
2008 Surface Elevation (feet msl)	1,102	1,103	1,104	1,102	1,106
Exposed Shoreline Area (acres x 1,000)	90	90	87	90	88
Percent Difference Compared to No Action Alternative[1]	0	(1)	(3)	0	(2)
2016 Surface Elevation (feet msl)	1,051	1,051	1,050	1,052	1,072
Exposed Shoreline Area (acres x 1,000)	76	76	76	76	73
Percent Difference Compared to No Action Alternative	0	0	0	(1)	(4)
2025 Surface Elevation (feet msl)	1,019	1,030	1,027	1,021	1,069
Exposed Shoreline Area (acres x 1,000)	87	84	85	86	72
Percent Difference Compared to No Action Alternative	0	(3)	(2)	(1)	(17)
2040 Surface Elevation (feet msl)	1,014	1,014	1,013	1,013	1,019
Exposed Shoreline Area (acres x 1,000)	89	89	90	89	87
Percent Difference Compared to No Action Alternative	0	0	0	0	(3)
2050 Surface Elevation (feet msl)	1,014	1,015	1,013	1,015	1,019
Exposed Shoreline Area (acres x 1,000)	89	89	89.67	89	87
Percent Difference Compared to No Action Alternative	0	0	0.81	0	(2)
2060 Surface Elevation (feet msl)	1,012	1,013	1,013	1,012	1,013
Exposed Shoreline Area (acres x 1,000)	90	90	90	90	90
Percent Difference Compared to No Action Alternative	0	0	0	0	0

1 Parenthesis indicates a reduction in exposed shoreline compared to the No Action Alternative

4.6.3.3 Conservation Before Shortage Alternative

At the 10th percentile, Lake Mead elevation is projected to be 1,027 feet msl in the year 2025, resulting in more than 84,670 acres of exposed shoreline. The Conservation Before Shortage Alternative would result in a decrease of more than two percent in exposed shoreline when compared to the No Action Alternative (Table 4.6-2).

The decrease in acreage would be directly proportional to the area susceptible to wind erosion and fugitive dust emissions. With a decrease in exposed shoreline acreage, the potential to exceed the PSD Class I or II thresholds or the state or national AAQS would also decrease. The decrease would result in a beneficial impact to the environment compared to the No Action Alternative.

4.6.3.4 Water Supply Alternative

At the 10th percentile, Lake Mead elevation is projected to be 1,021 feet msl in the year 2025, resulting in more than 86,100 acres of exposed shoreline. The Water Supply Alternative would result in a decrease of about one percent in exposed shoreline when compared to the No Action Alternative (Table 4.6-2). The Water Supply Alternative would have no impact or a slight benefit compared to the No Action Alternative.

The decrease in acreage would be directly proportional to the area susceptible to wind erosion and fugitive dust emissions. With a small decrease in exposed shoreline acreage, the potential to exceed the PSD Class I or II thresholds or the state or national AAQS would also decrease. The decrease would have no impact or a slight benefit compared to the No Action Alternative.

4.6.3.5 Reservoir Storage Alternative

At the 10th percentile, Lake Mead elevation is projected to be 1,069 feet msl in the year 2025, resulting in more than 71,730 acres of exposed shoreline. The Reservoir Storage Alternative would result in a decrease of about 17 percent in exposed shoreline when compared to the No Action Alternative (Table 4.6-2). Compared to the No Action Alternative, the Reservoir Storage Alternative would have the most potential to reduce fugitive emissions and result in beneficial impact to air quality.

The decrease in acreage would be directly proportional to the area susceptible to wind erosion and fugitive dust emissions. With a decrease in exposed shoreline acreage, the potential to exceed the PSD Class I or II thresholds or the state or national AAQS would also be decreased. The decrease would result in a beneficial impact to the environment compared to the No Action Alternative.

4.6.4 Summary

As reservoir elevations decrease and more shoreline is exposed, the potential for increased fugitive dust emission increases. The exposed shoreline acreage under the Basin States Alternative and under the Conservation Before Shortage Alternative are similar to that under the No Action Alternative at both Lake Powell and Lake Mead and in the Glen Canyon Dam to Lake Mead reach. The Water Supply Alternative would have the greatest increase in exposed shoreline acreage compared to the No Action Alternative at Lake Powell, but would be similar to the No Action Alternative at Lake Mead and the Glen Canyon Dam to Lake

Mead reach. The Reservoir Storage Alternative would have the greatest reduction in exposed shoreline acreage compared to the No Action Alternative for both Lake Powell (15 percent in 2025) and Lake Mead (17 percent in 2025) and the Glen Canyon Dam to Lake Mead reach.

An increase in fugitive emissions as a result of increased exposed shoreline would be limited in Lake Powell because the increased exposure of acreage would be comprised largely of sandstone, which is not conducive to generating fugitive emissions of PM-10s. All of the action alternatives have the potential to decrease acreage of exposed shoreline at Lake Mead compared to the No Action Alternative and thus decrease particulate emissions at Lake Mead and in the Glen Canyon Dam to Lake Mead reach.

4.7 Visual Resources

This section describes the methods and potential effects on visual resources at Lake Powell and Lake Mead, focusing on selected attraction features, calcium carbonate rings, and sediment deltas.

4.7.1 Methodology

To determine how changes in reservoir elevation might affect visual resources, data provided in Table 4.3-3 were used to compare effects of the alternatives for Lake Powell attraction features. Table 4.3-3 provides percentage of values less than or equal to a given elevation for multiple years. The narrative describes effects for year 2026 because the greatest differences among alternatives are projected then.

For calcium carbonate rings, the lowest water surface elevation reached under the 10th percentile projections was used to provide a worst case or maximum extent of the calcium carbonate ring. The height of the calcium carbonate ring was calculated as the distance in feet from full pool elevations for Lake Powell and Lake Mead, to the lowest projected elevation during the modeling time period (3,700 feet msl for Lake Powell and 1,221 feet msl for Lake Mead).

4.7.2 Lake Powell and Glen Canyon Dam

4.7.2.1 Attraction Features

Views of attraction features may be altered due to changes in reservoir elevations, with the key elevations ranging from 3,650 feet to 3,550 feet msl.

No Action Alternative. In 2026, there is a 59 percent probability of water being visible under or near Rainbow Bridge. There is a four percent probability of exposing Cathedral in the Desert. The upstream face of Glen Canyon Dam will be slightly more exposed, but this is not considered a measurable visual impact.

Basin States Alternative and Conservation Before Shortage Alternative. In 2026, there is a 49 percent chance of water being visible under or near Rainbow Bridge. Under these two action alternatives, there is a six percent chance of exposing Cathedral in the Desert.

Water Supply Alternative. In 2026, there is a 40 percent probability of viewing water under or near Rainbow Bridge and a 17 percent chance of exposing Cathedral in the Desert.

Reservoir Storage Alternative. In 2026, there is a 62 percent chance of viewing water under or near Rainbow Bridge and a one percent chance of exposing Cathedral in the Desert.

4.7.2.2 Calcium Carbonate Ring

No Action Alternative. The 10th percentile projections result in a maximum decrease to elevation 3,540 feet msl, thus creating a potential calcium carbonate ring of 160 feet in height.

Basin States Alternative and Conservation Before Shortage Alternative. Under these two action alternatives, the 10th percentile projections result in a maximum decrease to elevation 3,550 feet msl, thus creating a potential calcium carbonate ring of 150 feet in height.

Water Supply Alternative. Under the Water Supply Alternative, the 10th percentile projections result in a maximum decrease to elevation 3,505 feet msl, thus creating a potential calcium carbonate ring of 195 feet in height.

Reservoir Storage Alternative. Under this alternative, the 10th percentile projections result in a maximum decrease to elevation 3,540 feet msl, thus creating a potential calcium carbonate ring of 160 feet in height.

4.7.2.3 Sediment Deltas

No Action Alternative. Sediment deltas will continue to build up over time and be visible under the No Action Alternative. Ferrari's (2006) longitudinal profile indicates that the sediment delta is visible for at least 15 miles upstream of Hite. At 10th percentile projections, the delta may be visible from as far away as 25 miles, essentially from Hite to Gypsum Canyon. The primary effect is to Cataract Canyon boaters.

Basin States Alternative and Conservation Before Shortage Alternative. Under these two action alternatives, the visual effects of the sediment delta would be similar to the No Action Alternative. For most of the modeled timeframe, the sediment delta would be slightly more visible to boaters than under the No Action Alternative due to the slightly reduced Lake Powell elevation. The difference with the No Action Alternative is so slight and incremental over time, that there would be no visual impact.

Water Supply Alternative. The Water Supply Alternative results in the lowest Lake Powell elevations for most of the modeled timeframe; consequently, the sediment delta would be most visible under this alternative. As with the calcium carbonate ring, while there is a difference between the Water Supply Alternative and the No Action Alternative, for most visitors, there would probably not be a measurable visual impact. Thus, there would be low visual impact when compared to the No Action Alternative.

Reservoir Storage Alternative. Under this action alternative, Lake Powell elevations for most of the modeled timeframe are higher than the No Action Alternative; consequently, the sediment delta and visual impact on Cataract Canyon boaters will be reduced. Thus, there is no visual impact when compared to the No Action Alternative.

4.7.3 Glen Canyon Dam to Lake Mead

The proposed federal action would have no effects on the visual resources in this reach.

4.7.4 Lake Mead and Hoover Dam

4.7.4.1 Attraction Features

Hoover Dam is a major destination and a national landmark. The proposed federal action would not have any visual effects on this resource.

4.7.4.2 Calcium Carbonate Ring

No Action Alternative. The 10th percentile projections for Lake Mead result in a maximum decrease to elevation 1,012 feet msl, thus creating a potential calcium carbonate ring of 209 feet in height.

Basin States Alternative and Conservation Before Shortage Alternative. The 10th percentile projections for Lake Mead result in a maximum decrease to elevation 1,012 feet msl, thus creating a potential calcium carbonate ring of 209 feet in height.

Water Supply Alternative. The 10th percentile projections for Lake Mead result in a maximum decrease to elevation 1,011 feet msl, thus creating a potential calcium carbonate ring of 210 feet in height.

Reservoir Storage Alternative. The 10th percentile projections for Lake Mead result in a maximum decrease to elevation 1,013 feet msl, thus creating a potential calcium carbonate ring of 208 feet in height.

4.7.4.3 Sediment Deltas

No Action Alternative. Studies at Lake Mead (Ferrari 2006) show that sediment deltas 47 miles long will continue to be present through the Lower Granite Gorge to about Iceberg Canyon. This sediment delta will continue to build up over time and be visible under the No Action Alternative. The primary visual effect is to visitors using upper Lake Mead, Pearce's Ferry, the Overton Arm, and Overton Beach.

Basin States Alternative and Conservation Before Shortage Alternative. Under these two action alternatives, the visual effects of the deltas will be virtually indistinguishable from those of the No Action Alternative.

Water Supply Alternative. The Water Supply Alternative only deviates from the No Action Alternative around the year 2025, when it results in slightly lower Lake Mead elevations. Consequently, the visual effect of the deltas is slightly worse than under the No Action Alternative. Thus, the visual effect would be minimal when compared to the No Action Alternative.

Reservoir Storage Alternative. Under the Reservoir Storage Alternative, Lake Mead elevations for the modeled timeframe through 2030 are higher than under the No Action Alternative; consequently, the visual impact of the deltas will be less than that under the No Action Alternative or not visible at all.

4.7.5 Summary

For attraction features, the percent probability of water being visible under or near Rainbow Bridge ranged from a low of 40 percent in Water Supply Alternative to 62 percent under the Reservoir Storage Alternative. There was a range from 17 percent probability of exposing Cathedral in the Desert to one percent under the Water Supply Alternative and under the Reservoir Storage Alternative, respectively. Some visitors consider water under or near Rainbow Bridge a negative impact, because it is a change from pre-dam conditions. However, for other visitors, the view is improved with water under the bridge. Most would agree that Cathedral in the Desert was one of the most spectacular geological features in Glen Canyon before inundation; seeing this feature would be considered a positive visual impact. There would be no visual effect on attraction features at Lake Mead.

For calcium carbonate rings at Lake Powell, the maximum height ranged from 195 feet under the Water Supply Alternative to 150 feet under the Basin States and Conservation Before Shortage alternatives. At Lake Mead, the maximum height was essentially unchanged under any of the alternatives with the range from 208 to 210 feet. For both reservoirs, the presence of the calcium carbonate ring is more of an effect that the height at any given reservoir elevation. Therefore, while there are numeric differences in the projected height of the rings, the overall difference in visual impact among the alternatives is not significant.

At both Lake Powell and Lake Mead sediment deltas will continue to build up over time and be visible under all alternatives. The differences among all alternatives are negligible for both Lakes Powell and Mead.

4.8 Biological Resources

This section describes the environmental consequences related to biological resources and describes the methods used to determine the effects associated with implementation of the proposed federal action. This section also provides a description of two ongoing environmental protection programs within the study area.

4.8.1 Related Environmental Programs

Reclamation is committed to compliance with environmental statutes such as the Endangered Species Act and the Grand Canyon Protection Act. The following are ongoing collaborative programs intended to meet environmental compliance requirements.

4.8.1.1 Glen Canyon Dam Adaptive Management Program

Impacts to biological resources below Glen Canyon Dam are considered in the AMP, which was established to monitor the effects of Glen Canyon Dam operations and other management actions on the downstream environment. This program makes recommendations to the Secretary regarding ways to fulfill the resource protection requirements of the Grand Canyon Protection Act while complying with all applicable federal law. This program will continue to analyze the effects of varied conditions on biological resources below Lake Powell under the No Action Alternative and the action alternatives.

4.8.1.2 Lower Colorado Multi-Species Conservation Program

For a portion of the study area, Reclamation is the implementing agency for the LCR MSCP. This program mitigates potential flow-related and non-flow related impacts to biological resources along the lower Colorado River. These impacts result from various federal and non-federal actions over the next 50 years along the lower Colorado River from Lake Mead to the SIB. This habitat-based program is being implemented to mitigate impacts to special status species, although benefits of the LCR MSCP will accrue to all species that utilize those habitats. This program covers potential impacts to the same types of habitats that may be impacted by flow-related impacts of the action alternatives. For NEPA purposes, the No Action Alternative is used as baseline. If needed, LCR MSCP mitigation would be the primary source of mitigation to offset the impacts of the final selected action alternative within the LCR MSCP study area. For example, the LCR MSCP identified and it is mitigating impacts on LCR MSCP covered species and their habitats. These impacts included the potential loss of up to:

- 2,008 acres of cottonwood-willow habitats;
- 133 acres of marsh habitat; and
- 399 acres of backwater habitat.

To address these impacts, the LCR MSCP would:

- restore 5,940 acres of cottonwood-willow habitat;

- restore 512 acres of marsh habitat;
- restore 360 acres of backwater habitat;
- stock 660,000 razorback sucker over the term of the LCR MSCP; and
- stock 620,000 bonytail over the term of the LCR MSCP.

In addition, these habitats would be actively managed to provide habitat values greater than those of the impacted habitats. The quality and in most cases the quantity of restored habitat will be greater than the impacted habitats. Restoration and management of these habitats for LCR MSCP covered species would provide benefit to all flora and fauna that utilize cottonwood-willow, marsh and backwater habitats along the Lower Colorado River.

LCR MSCP flow-related covered activities include flow reductions due to implementation of future shortages in the Lower Basin. Reclamation is committed to enacting the conservation measures of the LCR MSCP and these measures will effectively offset any potential minor impacts identified in this Draft EIS to cottonwood willow, marsh, and backwaters from Lake Mead to the SIB.

4.8.2 Methodology

Two types of modeling results were used to perform the biological analysis, as follows:

- hydrologic modeling (CRSS) – reservoir elevations, dam releases, river flows; and
- water quality modeling (CE-QUAL-W2 and GEMMS) – temperatures.

This analysis evaluates the relative difference between the action alternatives and the No Action Alternative. The level of available information varies with the study reaches; therefore, the methodology is adjusted according to the availability of information for a particular reach or group of reaches.

4.8.2.1 Assumptions

Desert scrub plant communities would not be affected by lowered reservoir elevations, river stage, or groundwater. Cottonwood/willow/marsh vegetation types could be adversely affected by lowered reservoir elevations, river stage, or groundwater and may be lost. Tamarisk and mesquite communities would not be adversely affected by lowered groundwater. For example, it has been reported that groundwater declines of approximately 3.6 feet caused 92 to 100 percent of cottonwoods and willows to die, while only zero to 13 percent of tamarisk died at their sample sites along the Bill Williams River (Shafroth et. al. 2000).

Davis Dam and Parker Dam will continue to be operated to meet target reservoir elevations and these operations will not vary between alternatives, thus the proposed federal action will not impact riparian and marsh vegetation or wildlife habitats supported by these reservoirs.

The biological analyses are dependent upon the data inputs, modeling assumptions and validity of the CE-QUAL-W2 and GEMMS models for water quality. The historic data and water temperature models represent limited combinations of weather patterns, hydrology, discharge patterns, and reservoir elevations. The upper and lower temperature bounds from this analysis are the best estimates of probable discharge temperature ranges at the indicated elevations. Additional discussion and data on temperature is provided in Chapter 4.5 and in Appendix P.

Inflow temperatures to Lake Mead often do not warm to equilibrium temperatures during much of the year. This is due to upstream cold releases from Lake Powell. The cool inflows restrict the depth of surface water warming and contribute to cooler discharge temperatures from Hoover Dam. If Lake Powell releases were significantly warmer, then inflow temperatures to Lake Mead could reach equilibrium and discharge temperatures would be warmer.

4.8.2.2 Vegetation Assessment Methodology

Lake Powell and Lake Mead. Reservoir elevations for the action alternatives were compared to the No Action Alternative to determine whether shoreline vegetation is more or less likely to establish and/or be inundated.

Glen Canyon Dam to NIB. Vegetation impacts were assumed to be limited to those plant communities that consist of obligate phreatophytes (reliant on alluvial groundwater). The LCR MSCP vegetation analysis anticipated that flow-related effects would have limited impact on saltcedar and mesquite land cover types because these species are facultative phreatophytes (not solely reliant on alluvial groundwater) and are more tolerant to reductions in surface and groundwater water levels than cottonwood/willow or marsh land cover types. The same assumption was used for this analysis.

Projections of monthly releases from Glen Canyon Dam, Hoover Dam, Davis Dam, and Parker Dam for each action alternative were compared to the No Action Alternative. The differences between the alternatives primarily at the 10^{th} percentile were used as an indicator of potential low-flow conditions, which has the most potential to adversely affect vegetation. To estimate the significance of potential impacts, the potential flow differences were analyzed to determine if they would fall inside or outside the annual range of flows that have historically occurred in the Colorado River. Both Scott et. al. (1999) and Shafroth et. al. (2000) indicated that phreatophytes may develop root systems according to the hydrologic regime under which they developed. Flow variations of several thousand cfs within one month and between months are considered within the range of normal conditions.

Since the groundwater elevation along the Colorado River responds slowly to the releases from the dams and the corresponding changes in river stage, it was assumed that annual median changes in releases indicate potential changes in the alluvial water table elevation near the river. These potential water table changes could impact riparian phreatophytes and other riparian vegetation. A comparison of the median annual releases under each alternative to the median annual releases under the No Action Alternative showed minor reductions in river stage and corresponding water table elevations (Section 4.3.6.3 and 4.3.7.2).

NIB to SIB. Potential flow changes below the NIB as a result of implementation of the proposed federal action would primarily be the result of potential changes in excess flows (flood flows) arriving at the NIB. The differences in probability of these excess flows under each of the alternatives could potentially affect vegetation between the NIB and the SIB. Probabilities of these excess flows passing below the Morelos Diversion Dam under the action alternatives were compared against the No Action Alternative to analyze potential vegetation impacts.

4.8.2.3 Wildlife Assessment Methodology

Terrestrial wildlife was assumed to be affected only where the vegetation shows substantial changes from the No Action Alternative.

An analysis of river sport fishery and aquatic food base impacts was based on release temperature modeling, surface temperature data for Lake Powell and review of the temperature conclusions in the SCOP FEIS (Clean Water Coalition 2006) for Lake Mead. Since the sport fishery is primarily of interest to anglers, effects on this resource are discussed in the Recreation Section 4.12.

4.8.2.4 Special Status Species Assessment Methodology

Lake Powell and Lake Mead. Impacts to terrestrial special status species at these reservoirs were based primarily on the vegetation impact assessment. Potential impacts to special status fish were assessed by comparing reservoir elevations under each action alternative to the No Action Alternative. The potential range of release temperatures from Lake Powell was also used to analyze potential impacts to special status fish between Glen Canyon Dam and Lake Mead. Previous impact analysis for Lake Mead used elevation 1,160 feet msl as a threshold for potential impact to razorback sucker spawning areas in the lake. However, recent monitoring has shown the two subpopulations of razorback sucker in Lake Mead would change their spawning locations in response to lower reservoir elevations (Albrecht and Holden 2006). Lake Mead is currently below elevation 1,160 feet msl. The elevation range of 1,120 feet msl to 1,150 feet msl was used for comparison purposes in this analysis.

Glen Canyon Dam to NIB. Impacts to terrestrial special status species along the river were based primarily on the vegetation impact assessment. Impacts to special status fish were based on comparing the range of potential dam release temperatures (available for Glen Canyon Dam) to the life history temperature tolerances. Fishery impacts were also based on comparing the monthly Lake Mead elevations and monthly releases from Davis Dam and Parker Dam, where temperature data were not available. Changes in dam releases that would fall outside the range of flows that typically occur were deemed to cause impacts. Changes in release temperatures from Glen Canyon Dam under the No Action Alternative were used to determine whether impacts to the aquatic food base could in turn impact the special status fishery in the Grand Canyon. This analysis used larval chironomids, larval simuliids, *Gammarus lacustris*, and *Cladophora glomerata* as indicator organisms. If a particular alternative would substantially affect non-native sport fish (Section 4.12), this was included in the special status fishery assessment.

NIB to SIB. Special status fish species do not exist in this reach so the analysis was limited to terrestrial special status species. Flows in this reach of the river are sporadic, with the river channel in the lower portion of the reach being frequently dry.

4.8.3 Effects on Vegetation and Wildlife

This section discusses the potential impacts to vegetation and wildlife that may result from implementation of the proposed federal action.

4.8.3.1 Lake Powell and Lake Mead

No Action Alternative. Under the No Action Alternative, fluctuation of these reservoirs will continue to inhibit plant growth around the reservoirs over the long term. Lake Powell elevations trend upward under the 50th and 90th percentiles and somewhat downward under the 10th percentile. Figures P-7, P-8 and P-9 provide Lake Powell end-of-March, July, and September elevations. Lake Mead exhibits a slight downward trend under the 50th percentile and a more pronounced downward trend under the 10th percentile. Figures P-10, P-11, and P-12 provide Lake Mead end-of-month elevations for March, July, and September. To the extent that lake elevations may be reduced, these lower lake elevations may have effects on biological resources, as described in the following paragraphs.

The sediment deltas in both reservoirs are expected to continue to be colonized by weeds and tamarisk. The Lake Mead delta and the lower portion of the Grand Canyon especially have had riparian vegetation become established and persist over long periods of time, until inundated by rising reservoir elevations. The type of vegetation that becomes established in these delta areas is dependent on two factors. The first factor is timing. If the sediment becomes exposed during seed fall for cottonwood or willow, then those species are likely to become established. If the sediment becomes exposed during the fall months, then saltcedar is likely to be established and become the dominant vegetation.

A second factor that may influence the type of plant community that would become established in the delta areas is the depth to groundwater or river elevation from these exposed sediments. As the reservoir elevation declines and the sediment becomes exposed, the river elevation as it downcuts through the newly exposed delta would help determine whether cottonwoods or willows can survive, even if they become established. If the river elevation drops too far below the root zone of cottonwoods and willows, plant mortality would begin to occur, thus, opening gaps for saltcedar and other species to become established.

Wildlife that utilizes these reservoirs and their shorelines are affected by the fluctuating nature of these habitats to some extent. Reservoir fluctuation would continue into the future, which would continue to alter habitat along the shoreline and below full-pool elevation as has occurred in the past.

Action Alternatives. While the action alternatives differ from the No Action Alternative to some degree, all the action alternatives exhibit similar fluctuations compared to the No Action Alternative. Temporary establishment and loss of vegetation and wildlife habitat below the full-pool elevation would occur similarly under all alternatives. In general, the Reservoir Storage Alternative tends to result in higher reservoir elevations and the Water Supply Alternative tends to result in lower reservoir elevations than the No Action Alternative. The Conservation Before Shortage and Basin States alternatives tend to have similar reservoir elevations as the No Action Alternative, though somewhat lower in some years. Lower elevations would provide increased exposed shoreline where desirable and undesirable plants could temporarily colonize. Higher elevations would provide decreased exposed shoreline for plant colonization and would thus provide less opportunity for temporary desirable and undesirable plant communities to develop. The higher elevations under the Reservoir Storage Alternative may occur during the interim period and modeling period. Tenth percentile Reservoir Storage Alternative lake elevations return to the No Action Alternative conditions in approximately 2034 for Lake Powell and in 2036 for Lake Mead. Lower elevations would increase the distance between permanent shoreline vegetation and aquatic habitats, which would increase the distance wildlife would need to travel between cover habitat and the lake edge. Higher elevations would decrease the distance between permanent shoreline vegetation and the lake edge.

The lower reservoir elevations that may occur with the Water Supply Alternative would fall outside the potential range of the No Action Alternative. At these low reservoir elevations, there would be a greater potential for sediment headcutting at the inflow areas causing movement of sediment further into the reservoirs. The Water Supply Alternative would have the greatest potential effect on these deltas due to increased reservoir drawdown, which would impact vegetation and wildlife habitats. These impacts may occur in the interim period and the modeling period. The lower lake elevations under the Water Supply Alternative may remain lower than under the No Action Alternative until approximately 2036 for Lake Powell and until 2040 for Lake Mead at the 50^{th} percentile, and until 2055 for Lake Powell at the 10^{th} percentile.

4.8.3.2 Glen Canyon Dam to Lake Mead

No Action Alternative. The No Action Alternative at the 10^{th} and 50^{th} percentile average monthly releases range from approximately 9,000 cfs to 14,000 cfs (Table 4.3-12). Additional data on Glen Canyon Dam releases is provided in Figures P-13 through P-24 in Appendix P. This range is similar to the range observed from 2000 to the present, though lower than the high water years between 1995 and 2000. Therefore, the release conditions which the vegetation and wildlife below Glen Canyon Dam have experienced since 2000 would continue into the future at these percentile levels. The vegetation and wildlife are likely adjusting or have adjusted to these lower flows. Stabilized flows have been observed to favor riparian vegetation development at numerous locations in the Western United States (Reclamation 1995 and USGS 2004). This trend benefits species that utilize shrubby riparian vegetation. The overall release trend indicates that the magnitude of monthly releases would generally be lower in the future in many months.

Action Alternatives. The action alternatives at the 10^{th} percentile release all tend to be lower than the No Action Alternative, with the Reservoir Storage Alternative being the closest to the No Action Alternative. Tenth percentile release reductions are typically between 700 and 2,000 cfs, though the Water Supply Alternative may be lower than the No Action Alternative by up to 3,800 cfs in July and September. Low flows have the greatest likelihood of negatively impacting riparian and marsh vegetation and wildlife that utilize such habitats. The impacts would be minor because for the most part, these reduced releases remain within the range of annual fluctuation and would be temporary. The impacts may cause stress to phreatophytes, but would not be expected to cause significant plant die-off. These impacts would affect obligate phreatophytes such as willow more than facultative phreatophytes such as tamarisk. Thus these minor impacts may favor continued tamarisk expansion, though tamarisk is expanding along the Colorado River under existing conditions. Because Glen Canyon Dam releases under all the alternatives generally return to the No Action Alternative conditions near the end of the interim period, conditions causing these impacts would end after the interim period. However, the effects on phreatophytes and continued tamarisk expansion may be observable even after conditions return to the No Action Alternative conditions.

The magnitude of flows exceeding the No Action Alternative that may occur under the action alternatives (90^{th} percentile releases) is relatively small, with the exception of the Reservoir Storage Alternative. Releases under the Reservoir Storage Alternative in June may be up to 6,800 cfs above the No Action Alternative and approach 30,000 cfs. These high flows may cause scouring of vegetation that may have developed lower on the banks under previously lower flow conditions. These flows are below the levels of the experimental high flows that have occurred in the past, which have exceeded 40,000 cfs. Despite scouring losses from these higher flows, they would provide an overall benefit to vegetation and wildlife in the long term.

Minor negative impacts to riparian vegetation from lower 10^{th} percentile releases with all alternatives would impact the habitats for herptofauna, small mammals, waterfowl, and songbirds that utilize those habitats. Snakes found below Glen Canyon Dam are typically found in drier portions of the reach and should not be impacted by these alternatives. Fiftieth percentile elevation releases from Lake Powell will have similar temperatures as the No Action Alternative for all the action alternatives and would thus cause no temperature related impacts to amphibians along the river. Only the Water Supply Alternative may result in higher temperatures in some years and may provide some thermal benefit to amphibian reproduction along the river. It would be difficult to measure these potential impacts as the impacts to vegetation should be minor and thus indirect impacts to species using those habitats would be small. These potential small habitat impacts are unlikely to impact large mammals in the canyon. Due to the potential minor impacts to riparian vegetation, all the alternatives would have a similar minor impact to wildlife between Glen Canyon Dam and Lake Mead.

4.8.3.3 Hoover Dam to Davis Dam

No Action Alternative. The Hoover Dam to Davis Dam reach consists primarily of the reservoir pool of Lake Mohave, the elevation of which is controlled by operation of Davis Dam. Lake Mohave and Lake Havasu are operated on a monthly rule curve and end-of-month target elevations and therefore significant fluctuations do not occur. No change in vegetation or wildlife is expected over the interim period or the modeling period. Figures P-25 through P-36 of Appendix P provide information on monthly Hoover Dam releases.

Action Alternatives. Elevations in these reservoirs under the action alternatives would not deviate from the No Action Alternative elevations. Accordingly, there would be no impacts to vegetation or wildlife at the reservoirs. Because vegetation is limited between Hoover Dam and Lake Mohave, potential flow differences among alternatives in this reach of the Colorado River would not substantially impact vegetation or wildlife.

4.8.3.4 Davis Dam to Parker Dam

No Action Alternative. Fluctuations below Davis Dam of several thousand cfs have occurred in the recent past and would continue into the future. Vegetation and wildlife habitat along the Colorado River are constantly making minor adjustments as these flows fluctuate, which would continue into the future.

Action Alternatives. Release rates for Davis Dam fall within a relatively narrow band for all months at the 50^{th} and 90^{th} percentiles. Figures P-37 through P-48 in Appendix P provide monthly Davis Dam releases. The Reservoir Storage Alternative results in lower releases during the interim period, while the Water Supply Alternative results in higher releases. The higher releases would benefit vegetation and wildlife, but these benefits would be minor. Lower releases under the Reservoir Storage Alternative would negatively impact vegetation and wildlife compared to the releases under the No Action Alternative. The Conservation Before Shortage and Basin States alternatives essentially follow the No Action Alternative, and where there are differences they are isolated small differences. Therefore, the Conservation Before Shortage and Basin States alternatives should have no measurable impacts on vegetation between Davis Dam and Parker Dam. The Reservoir Storage Alternative may cause some higher releases due to increased flood control releases not seen in the other alternatives. These typically occur in winter months, outside the growing season. These flows may be up to 6,000 cfs over the No Action Alternative at the 90^{th} percentile although would still not be large enough to cause significant scouring or over bank flooding. Thus no substantial riparian benefits are expected. The No Action Alternative and the action alternatives converge relatively quickly after the end of the interim period. Conditions under the action alternatives generally return to the conditions under the No Action Alternative relatively soon after the interim period, though effects on the vegetation of interim period conditions may be observed beyond the interim period.

Impacts of the lower releases under the Reservoir Storage Alternative would have similar impacts to wildlife as discussed for lower releases between Glen Canyon Dam and Lake Mead.

4.8.3.5 Parker Dam to Imperial Dam

No Action Alternative. Figures P-49 through P-60 in Appendix P provide data on monthly Parker Dam releases. At the 90th percentile level, monthly releases from Parker Dam exhibit a downward trend through a reduction in high winter flows. Flows above Imperial Dam exhibit a small downward trend at the 10th and 50th percentiles, but generally level-off after the interim period. At the 90th percentile, high flows above Imperial Dam in winter become less common into the future as well. Vegetation and wildlife below Parker and above Imperial Dam would experience a fluctuating release pattern over time. Vegetation and wildlife would need to adjust to these reduced high flows but the gradual nature of the declines should not substantially affect vegetation or wildlife. Fluctuations below Parker Dam and above Imperial Dam of several thousand cfs have occurred in the recent past and are expected to continue into the future. The plant communities along the Colorado River are constantly making minor adjustments as these flows fluctuate.

Action Alternatives. Parker Dam releases under the Water Supply and Basin States alternatives follow the No Action Alternative closely and would therefore not impact vegetation or wildlife. Releases under the Conservation Before Shortage and Reservoir Storage alternatives trend somewhat lower than the No Action Alternative, though still within the range of flow variation that occurs. These lower releases would have minor negative impacts to cottonwood/willow, marsh, and the wildlife that depend on these habitats. The Reservoir Storage Alternative shows some higher releases during the winter, but given the capacity of the channel in this reach, it is not likely that these flows would substantially benefit riparian vegetation or wildlife habitat from over bank flooding. These differences from the No Action Alternative releases tend to return to the No Action Alternative conditions relatively soon after the interim period.

Flows above Imperial Dam under the Water Supply Alternative are similar to the No Action Alternative and would therefore not impact vegetation or wildlife. Flows above Imperial Dam during the growing season tend to be less than under the No Action Alternative for the Reservoir Storage, Basin States, and Conservation Before Shortage alternatives. Of these three alternatives, the Basin States Alternative exhibits the least reduction from the No Action Alternative, while the Reservoir Storage Alternative exhibits the most reduction. At the 10th percentile, these three alternatives would have minor negative impacts on cottonwood-willow and marsh habitats and the wildlife that rely on these habitats. These impacts would only occur during the interim period. The impacts are expected to be minor because the flow reductions are typically 1,000 cfs and less for the Reservoir Storage Alternative and 500 cfs and less for the Basin States Alternative, which are within the range of variation that regularly occurs.

4.8.3.6 Imperial Dam to NIB

As noted in Section 3.3, most of the water delivered to Mexico is diverted at Imperial Dam, conveyed via the AAC, and then returned to the Colorado River through the Pilot Knob and Siphon Drop Powerplants and their respective wasteway channels, 2.1 and 7.6 miles upstream of the NIB, respectively (Section 3.3). The proposed federal action will not alter the operation of these diversions and wasteways and therefore will not have an effect on the river reach between Imperial Dam and the NIB.

4.8.3.7 NIB to SIB

No Action Alternative. The frequency and magnitude of flows are important factors in maintaining riparian habitat and wildlife between Morelos Diversion Dam and the SIB; however, the potential biological effects downstream of the NIB cannot be specifically determined because of the uncertainty of water use once it flows to the NIB and becomes available to Mexico.

The volume of water passing by Morelos Diversion Dam (Section 3.3) as a result of cancelled water orders by contract users is rare enough to not have much effect on vegetation or wildlife below the NIB. The hydrologic models assume that any water in excess of Mexico's scheduled normal or surplus deliveries would not be diverted by Mexico and would continue down the Colorado River channel between Morelos Diversion Dam to the SIB. This assumption results in the probability of flows passing Morelos Diversion Dam that might be somewhat higher than may actually occur, and the potential impacts discussed in the following section are based on this assumption.

Under the No Action Alternative conditions, flows below the Morelos Diversion Dam will continue to be primarily the result of dam leakage and agricultural return flows. Flows past the Morelos Diversion Dam will continue to be relatively rare events. It is expected that the riparian and marsh vegetation and wildlife will continue to experience some year-round flow in the upper part of the reach and sporadic flow in the lower part of this reach under the No Action Alternative. Thus, historical conditions will generally continue under the No Action Alternative.

Action Alternatives. During the interim period and beyond, the Basin States and Water Supply alternatives are just as likely to cause excess flows below Morelos Diversion Dam as the No Action Alternative, and would therefore cause no impact over the No Action Alternative. Further, the probabilities of occurrence are low and are mostly between 10 percent and 15 percent. In representative years (2016, 2026, and 2060), the magnitude of excess flows past Morelos Diversion Dam is zero for 80 percent to 90 percent of the model traces for those years. The Reservoir Storage Alternative may increase the magnitude of these flood control excess flows by as much as one mafy over the No Action Alternative. The Conservation Before Shortage Alternative may increase the magnitude of these flood control excess flows by as much as 0.4 mafy over the No Action Alternative. Figure P-61 in Appendix P provides data on excess flows below the Morelos Diversion Dam.

Due to modeling assumptions under the Conservation Before Shortage and Reservoir Storage alternatives, water is also delivered to Mexico through this reach via periodic flows of about 40 kafy to 200 kafy (Appendix M). These pulse flows[1] would occur approximately every other year during the interim period only. The probability of flows past Morelos Diversion Dam under these two alternatives returns to No Action Alternative conditions after the interim period. These flows would benefit vegetation and wildlife below Morelos Diversion Dam because they would increase river flow, scour and redistribute sediment and provide opportunities for establishment of cottonwood-willow and marsh vegetation. These fluvial processes are valuable to aquatic and riparian systems in the long-term, though temporary losses of riparian or marsh vegetation may occur from scouring, which could temporarily disrupt wildlife.

Table 4.8-1 summarizes impacts to vegetation and wildlife for the alternatives.

4.8.4 Special Status Species

4.8.4.1 Lake Powell

No Action Alternative. Fluctuations of the Lake Powell elevations would continue into the future, precluding the development of stable vegetated terrestrial habitats below elevation 3,700 feet msl because vegetation that develops is periodically dewatered and inundated.

Fish. The Colorado pikeminnow, bonytail chub, razorback sucker and flannelmouth sucker are all occurring in Lake Powell, primarily at the inflow areas of the Colorado River and the San Juan River. Flannelmouth sucker population has been decreasing since the reservoir was formed (Reclamation 2000). Lower elevations would increase the amount of riverine habitat for these species in the river inflow areas, which may be a temporary benefit to these fish.

Birds. Special status birds that currently may be affected by elevation fluctuations at Lake Powell include California condor, Bald eagle, osprey, belted kingfisher, Clark's grebe, and American peregrine falcon. California condors are scavengers, primarily on large mammals and sometimes on fish. The lower reservoir elevations projected for the future may expose additional shoreline for scavenging.

[1] These flows were modeled as part of the storage and delivery mechanism under the Conservation Before Shortage and Reservoir Storage alternatives. The modeling assumptions were utilized in this Draft EIS in order to analyze the potential impacts to environmental resources of the storage and delivery mechanism, particularly with regard to reservoir elevations and river flow impacts. The use of these modeling assumptions does not represent any determination by Reclamation as to whether, or how, these releases could be made under current administration of the Colorado River.

Table 4.8-1
Vegetation and Wildlife Impact Summary
Comparison of Action Alternatives to No Action Alternative

Location	Alternative	Impact	Rationale
Lake Powell and Lake Mead	Conservation Before Shortage and Basin States	No impact	Elevations and fluctuation similar to the No Action Alternative.
	Water Supply	Minor – negative	Reservoir elevations tend to be lower than under the No Action Alternative, with increased opportunities for undesirable plants to colonize shoreline and delta headcutting. Level fluctuations inundate all vegetation below full pool elevation. Lower elevations would increase distance between shoreline vegetation and the Lakes.
	Reservoir Storage	Minor- positive	Elevations tend to be higher than under the No Action Alternative, with decreased opportunities for undesirable plant to colonize shoreline and delta headcutting. Level fluctuations inundate all vegetation below full pool elevation. Higher elevations would decrease distance between shoreline vegetation and Lakes.
Glen Canyon Dam to Lake Mead	All Action Alternatives	Minor – negative	Decreased releases at 10th percentile (for all alternatives there are similar reductions overall). Release differences are within the range of recent history and annual fluctuation.
Hoover Dam to Davis Dam and Lake Havasu to Parker Dam	All Action Alternatives	No impact	Relatively small Hoover Dam release differences and very limited vegetation above Lake Mohave. Monthly rule curves at Lakes Mohave and Havasu prevent water level deviations from the No Action Alternative.
Davis Dam to Lake Havasu	Conservation Before Shortage, Basin States	No impact	Monthly releases closely follow the No Action Alternative.
	Water Supply	Minor- positive	Monthly releases higher than under the No Action Alternative at 10th and 50th percentiles.
	Reservoir Storage	Minor – Negative	Monthly releases lower than under the No Action Alternative at 10th and 50th percentiles.
Parker Dam to Imperial Dam	Water Supply	No impact	Monthly releases closely follow the No Action Alternative.
	Basin States, Conservation Before Shortage and Reservoir Storage	Minor – Negative	Monthly releases lower than under the No Action Alternative at 10th and 50th percentiles (the Reservoir Storage Alternative has the greatest reduction; the Basin States Alternative has the least reduction). The Reservoir Storage Alternative higher flows in the winter are unlikely to have substantial benefits due to channel capacity.
Imperial Dam to NIB	All Action Alternatives	No impact	Flow changes are routed through AAC and Pilot Knob/Siphon Drop power plants rather than river below Imperial Dam.
NIB to SIB	Basin States and Water Supply	No impact	Probability of excess flows past Morelos Diversion Dam is very close to the No Action Alternative.
	Reservoir Storage and Conservation Before Shortage	Moderate – positive	Relatively likely high flows expected past Morelos Diversion Dam, which would benefit the riparian corridor.

Bald eagles in this area are primarily winter residents that feed on fish, waterfowl and carrion. Though there may be effects on fisheries as reservoir elevations decline, no effects on the population of fish are anticipated. Therefore, this food source is expected to remain available for bald eagles under the No Action Alternative.

Ospreys are a rare transient in summer along the Colorado River. However, they could potentially utilize Lake Powell during migration. Fluctuating reservoir elevations would have no direct impacts to ospreys, and no substantial indirect effects on food sources (fish) are expected.

Peregrine falcons may utilize Lake Powell for hunting songbirds, bats and small mammals. Reservoir elevation fluctuations would not directly impact peregrine falcons. Nearby populations in Grand Canyon are considered stable and the species was delisted from federal listing in 1999 (Gloss et. al. 2005).

Belted kingfishers inhabit riparian areas in Arizona and mainly consume fish. Kingfishers could be affected as fish availability fluctuates over time. Given the gradual downward trend for Lake Powell elevations in the future, it is anticipated that fish populations would be able to adjust to the changing conditions. Increased inflow areas as the elevations recede may provide improved shallow water hunting area.

Clark's grebe inhabit marshes and may be found in marsh habitat at the Lake Powell inflow areas. They are common breeders in Utah and utilize lakes and shoreline vegetation for breeding habitat. Future conditions under the No Action Alternative project a decline in reservoir elevations. These declines may dewater marshes at the inflow areas, causing temporary loss of marsh habitat until the marsh re-establishes at a lower elevation, or the lake levels recover.

Mammals. Special status mammals that may utilize Lake Powell include spotted bat, Townsend's big-eared bat, pale Townsend's big eared bat, fringed myotis, and occult little brown bat. All of these species may utilize riparian habitats around the shoreline of Lake Powell. As elevations fluctuate, these habitats may be dewatered or inundated and localized effects on food source populations may occur. Given the wide-ranging nature of these species, the No Action Alternative or any of the action alternatives would not be expected to substantially impact these species. Accordingly, these species would not be discussed further for this reach.

Amphibians. Northern leopard frog populations are found in side canyons of Lake Powell above the fluctuating reservoir elevations (Gloss et. al. 2005). These populations are above elevation 3,700 feet msl and would not be impacted by reduced elevations of Lake Powell. However, continued fluctuations of Lake Powell elevations would likely limit marsh and riparian vegetation at the shoreline, or only allow it to establish temporarily, thus continuing to limit the potential for leopard frogs and other amphibians to utilize areas below the full-pool elevation of Lake Powell.

Action Alternatives.

Fish. Flannelmouth suckers, razorback sucker, Colorado pikeminnow and bonytail chub occur in the inflow areas of the Colorado River and the San Juan River but do not spawn in Lake Powell, and changing elevations would be unlikely to affect habitat within the reservoir for any individuals remaining in the reservoir.

The lower elevations under the Water Supply, Conservation Before Shortage and Basin States alternatives would increase the amount of riverine habitat for these species in the river inflow areas, which may be a temporary benefit. The amount of lowering would generally be less than 20 feet for the 50th percentile elevation in March, 12 feet in July, and 17 feet in September (Figures P-7, P-8, P-9 in Appendix P). For the 10th percentile reservoir elevations, the elevation changes could range from 16 feet higher to 13 feet lower, with most of the elevations being lower, than under the No Action Alternative in all three months (March, July, and September). The lower elevations would provide a small benefit to razorback sucker, bonytail, Colorado pikeminnow and flannelmouth sucker in the river inflow areas by increasing the amount of flowing water habitat, though this is expected to be a minor benefit. These impacts may occur during the interim period and the modeling period.

The Reservoir Storage Alternative tends to result in higher lake elevations of less than approximately 8 feet relative to the No Action Alternative for the 50th percentile elevation in March, July, and September. For the 10th percentile reservoir elevations, the elevation may be up to 26 feet higher in all three months. This would reduce the amount of riverine habitat for razorback sucker, bonytail, Colorado pikeminnow and flannelmouth sucker in the river inflow areas compared to the No Action Alternative and create a minor negative impact. These impacts may occur during the interim period and the modeling period.

Birds. Since bald eagles, peregrine falcons, California condor and osprey are all wide ranging species that utilize many different habitat types in the area, none of the action alternatives differ substantially enough to impact these species at Lake Powell.

Clark's grebe would be impacted predominantly by impacts to marsh habitats. As indicated in the Vegetation and Wildlife section, the Water Supply Alternative would have a minor negative impact on vegetation, including marshes (at the inflow areas), and the Reservoir Storage Alternative would have a minor-positive impact on vegetation. Conservation Before Shortage and Basin States alternatives would not impact Clark's grebe. These impacts may occur during the interim period and the modeling period.

Belted kingfishers would be most impacted by potential changes in fish food supplies. Substantial impacts to fish food supplies at Lake Powell are not anticipated with any action alternative, thus no impacts to belted kingfishers are anticipated.

Amphibians. Northern leopard frog populations are found in side canyons above elevation 3,700 feet msl, so none of the action alternatives would impact special status amphibians at Lake Powell.

Table 4.8-2 summarizes the impacts to special status species by alternative.

Table 4.8-2
Lake Powell Special Status Species Impact Summary
Comparison of Action Alternatives to No Action Alternative

Species	Alternative	Impact	Rationale
Razorback sucker, bonytail, Colorado Pikeminnow, flannelmouth sucker	Water Supply, Conservation Before Shortage, Basin States	Minor - positive	Reservoir elevations tend to be lower than under the No Action Alternative, increasing riverine conditions at the inflows.
	Reservoir Storage	Minor- negative	Reservoir elevations tend to be higher than under the No Action Alternative, decreasing riverine conditions at the inflows.
Bald eagle, peregrine falcon, osprey, California Condor, belted kingfisher	All Action Alternatives	No impact	Wide ranging species and action alternatives do not differ substantially enough to cause indirect impacts.
Clark's grebe	Conservation Before Shortage and Basin States	No impact	Reservoir elevations trend close to the No Action Alternative. Impacts to marsh not anticipated.
	Water Supply	Minor - negative	Lower reservoir elevations would have minor negative impact on marshes at inflows, by increased likelihood of headcutting sediment deltas.
	Reservoir Storage	Minor – positive	Higher reservoir elevations would have minor positive impact on marshes at inflows, by decreased likelihood of headcutting sediment deltas.
Mammals	All Action Alternatives	No impact	Wide ranging species and action alternatives do not differ substantially enough to cause indirect impacts.
Northern leopard frog	All Action Alternatives	No Impact	Known populations above level of lake fluctuation.

4.8.4.2 Glen Canyon Dam to Lake Mead

No Action Alternative. Releases from Glen Canyon Dam would remain relatively stable during the interim period, but would be reduced over the later years of the modeling period. Reduced river flows have the potential to affect phreatophytes, marshes, and associated special status species.

Plants. Grand Canyon evening primrose grows on beaches along or near the mainstream Colorado River in the vicinity of Separation Canyon and downstream of Diamond Creek (Reclamation 2000). Lower releases could allow this species to colonize lower beaches exposed during reduced releases. Reduced high flows would favor encroachment of riparian vegetation towards the Colorado River, which would compete with the species. High flows and sediment, which are needed to maintain beach habitats and discourage riparian vegetation encroachment, would continue to be limited in the future. Beach habitat occupied by this species is also utilized by recreationists, which limits Grand Canyon evening primrose establishment.

Invertebrates. The Kanab ambersnail occurs in semi-aquatic habitat associated with springs and seeps. In the Grand Canyon, Kanab ambersnail were originally known to occur only at Vasey's Paradise, a large perennial spring. As part of an effort to recover the species, Kanab amber snails were translocated from Vasey's Paradise to three other locations. One of the criteria used to select these sites was that it be above the elevation of any potential future flood flows past Glen Canyon Dam. These translocated populations would not be affected by the proposed federal action. The Vasey's Paradise population and vegetation are not flooded until flows exceed 17,000 cfs (Reclamation 2002, EA, FONSI Proposed Experimental Releases from Glen Canyon Dam). Future conditions under the No Action Alternative may exceed 17,000 cfs for more than a single year in January, February, May, June, July, August, September, and December at the 90th percentile release (Figures P-13 to P-24 in Appendix P).

Niobrarra ambersnail occur in wetland habitats at several locations below Glen Canyon Dam. The population near Lees Ferry is subject to inundation from even moderate flows of the Colorado River (>25,000 cfs), and more than 90 percent of the entire habitat is inundated at 45,000 cfs or more. The Indian Gardens population persisted through the 1996 experimental flow. The population has not been monitored since May 1998 and March 1999 at which time it was abundant. However, flows exceeded 22,000 cfs for extended periods in the summer of 1998 and in May 1999, and no snails were found during habitat searches in those periods. Flows over 20,000 cfs inundate the Indian Gardens habitat (Arizona Game and Fish 2004). Future conditions under the No Action Alternative release may exceed 20,000 cfs at the 90th percentile releases in June, July, August, September, and December, which could cause a loss of wetland vegetation and individual snails.

MacNeill's sootywing skipper is a butterfly found along the Colorado River from southern Utah and Nevada to Arizona and southeastern California (Reclamation 1996a). Confirmed records of this species are reported for the Arizona counties of Mohave, La Paz, Yuma, Yavapai, Maricopa and Pinal. The MacNeill's sootywing skipper is also present in San Bernardino, Riverside and Imperial counties in California. This species also occurs along the Muddy River above Lake Mead (Austin & Austin 1980).

The larval host plant for MacNeill's sootywing skipper is quailbrush (*Atriplex lentiformis*). Quailbrush is the largest salt bush found in Arizona and forms dense thickets along the drainage system of the Colorado River (Emmel and Emmel 1973). Quailbrush is associated with floodplains located in alkaline soil areas with adequate water resources (Kearney and Peebles 1951). Specific surveys for this species and larval host plants have not been conducted in the lower Grand Canyon; however, the documented occurrence of MacNeill's sootywing skipper along the Muddy River above Lake Mead indicates there is a likelihood of occurrence in the lower Grand Canyon. Suitable habitat for this species likely requires stands of more than one host plant (W. Wiesenborn 1999). Future conditions under the No Action Alternative are not expected to affect floodplains where quailbrush is typically found.

Fish. Water releases from Glen Canyon Dam would continue to follow the guidelines provided in the 1996 Glen Canyon Dam ROD under the No Action Alternative, although the annual water releases may decrease in the future. Thus, the amount and physical characteristics of habitat available to native special status fish species (humpback chub, bluehead sucker, flannelmouth sucker) may vary over time under the No Action Alternative. Little information is available to quantitatively assess the potential effects of monthly release trends on the habitat of these fish. In general, the daily operations and Glen Canyon Dam releases will continue to be consistent with the 1996 Glen Canyon Dam ROD, therefore, the proposed federal action is not expected to substantially affect daily fluctuation overall. For example, a study of backwaters in the Grand Canyon (Goeking et al. 2003) found that the number and area of backwaters present varied with river discharge between years at any given site and varied among sites within one year. Given that there is little information to correlate differences in monthly releases to impacts on the physical characteristics of special status fish habitat availability, water temperature was selected as a better metric to analyze the impacts to special status fish species. Cold river temperatures and the presence of non-native fish species appear to be the key reasons for adverse native fish conditions in this reach.

Temperature of water released from Glen Canyon Dam would vary depending on the reservoir elevation, and these changes have been modeled (Section 4.5 and Appendix P). Native fish, such as the humpback chub, flannelmouth sucker and bluehead sucker could benefit from warmer water temperatures during their spawning season, because releases of cold water from Lake Powell generally keep water temperature downstream to Lake Mead below that needed for spawning to occur. Thus, spawning could only occur in warmer tributaries or backwaters. When reservoir elevations in Lake Powell fall below about 3,600 feet msl (approximately 10^{th} percentile level), water above 15 ºC (59 ºF) could be released. This water may warm approximately 2 ºC (35.6 ºF) by the time it reaches the Little Colorado River confluence and by up to 5 ºC (41 ºF) near the Diamond Creek confluence. For the 10^{th} percentile, water temperatures could be warm enough for humpback chub spawning and egg incubation from approximately May through July near Diamond Creek and from June through July below the Little Colorado River confluence. Figures P-62 through P-79 in Appendix P provide information on modeled water temperatures at selected locations for the No Action Alternative and the action alternatives.

Flannelmouth and bluehead suckers are also present in this reach of the Colorado River although they use the warmer tributaries for spawning (Table 4.8-3). Only under low Lake Powell elevations (10^{th} percentile), could suitable temperatures for spawning occur in the river for the bluehead sucker over a portion (about June to October) of their spawning season above the Little Colorado River confluence, and from about May to October near Diamond Creek. Egg incubation requires temperatures about 2 ºC (35.6 ºF) warmer than for spawning and thus would not occur for up to a month later in the spring, and then primarily near Diamond Creek.

For the 50th percentile elevations, water temperatures near Diamond Creek could be warm enough for their spawning from about June to October, while the 90th percentile elevation could result in suitable temperatures from about June through August. However, temperatures may only be suitable for egg incubation in August to early September for the 50th percentile and periodically in July and August for the 90th percentile. For flannelmouth suckers, water temperatures could be warm enough for spawning below the Little Colorado River in May and June, and in June at Lees Ferry under 10th percentile reservoir elevations, while egg incubation could occur only in June. Near Diamond Creek, temperatures could be warm enough for flannelmouth spawning from about late April through June during their spawning season at the 10th, 50th, and 90th percentiles and egg incubation could occur in May and June. Water temperatures may be adequate to support growth of these three fish species as summarized in Table 4.8-3.

Table 4.8-3
Months When Water Temperatures may be Adequate to Support Growth of Fish Under the No Action Alternative

Location	Species		
	Humpback Chub	Flannelmouth Sucker	Bluehead Sucker
Lees Ferry	June through October at 10th percentile	June through October at 10th percentile	June through mid November at 10th percentile
Below Little Colorado River	June through October at 10th percentile	June through October at 10th percentile	June through October at 10th percentile September and October at 50th percentile
Diamond Creek	May through October at 10th percentile June through October at 50th percentile June through August at 90th percentile	May through October at 10th percentile June through October at 50th percentile June through August at 90th percentile	May through October at 10th percentile June through October at 50th percentile May through August at 90th percentile

At lower Lake Powell elevations, which may occur in the future under the No Action Alternative, there is a higher potential for non-native fish to be released from Lake Powell into the Glen Canyon Dam to Lake Mead reach. Warmer temperatures in the future under No Action Alternative conditions at the Diamond Creek confluence could create conditions that would favor the upstream migration of non-native fish into the Grand Canyon. Warmer river temperatures may also promote the migration of non-native warmwater fish from tributaries that provide inflow to this river reach. These conditions would be a temporary occurrence. Since many non-native fish prey on native fish, the potentially increased number of non-native warmwater fish may adversely affect native species in this reach. However, there are many species of non-native fish species already present in this reach (Table 3.8-4).

Glen Canyon Dam releases made when Lake Powell water levels are drawdown to levels coinciding with the 10th Percentile Lake Powell water elevation values (under the No Action Alternative), could potentially result in warmer river flow temperatures. Under the No Action Alternative, these warmer river flow temperatures may exceed 20 °C (68 °F) and may reach 25 °C (77 °F). These warmer river flow temperatures could increase the potential for expansion of the Asian tapeworm (*Bothriocephalus acheilognathi*) and anchorworm (*Lernaea cyprinacea*) in the mainstream Colorado River in some years. Currently, these non-native fish parasites are found primarily in fish in the Little Colorado River and other side tributaries and mostly affect native fish. Under current conditions, these parasites are less likely to infect fish in the Colorado River because water temperatures are less than optimal for these parasites. The increased potential for these parasites to infect fish when Glen Canyon Dam releases occur at low Lake Powell elevations could adversely affect native fish including the humpback chub. Glen Canyon Dam releases made when Lake Powell water levels are at the higher 50^{th} and 90^{th} percentile Lake Powell elevation values result in cooler downstream temperatures and are mostly below 20 °C.

Historically, the release temperatures from Glen Canyon Dam have exhibited a relatively narrow seasonal variability and typically ranged from approximately 7 °C to 12 °C (44.6 ºF to 53.6 ºF) between 1990 and 2002 (Appendix F, Figure F-5). After 2002, the temperatures began to increase and the seasonal variability widened and ranged from approximately 8 °C to 16 °C (46.4 ºF to 60.8 ºF). Modeled future release temperatures for the No Action Alternative at the 50^{th} percentile Lake Powell elevations indicate similar potential conditions to those that began in 2002. Modeled release temperatures at the 10^{th} percentile Lake Powell elevation indicate the possibility of warmer release temperatures and a wider seasonal variability (a range of 11 °C to 22 °C) (Table 4.5-5). These warmer release temperatures under the No Action Alternative could affect the aquatic foodbase below Glen Canyon Dam. However, larval chironomids, larval simuliids, *Cladophora* and *Gammarus* are key components of the aquatic foodbase below Glen Canyon Dam and they are tolerant of a wide range in temperature. No potential effects on the aquatic foodbase due to changes in the water clarity, particularly algae, are expected as a result of the implementation of the proposed federal action.

The favorable temperature ranges are 8 °C to 25 °C (46.4 °F to 77 °F) for larval chironomids (LeSage and Harrison 1980; Laville and Vincon 1991; Sublette et. al. 1998; Stevens et. al. 1998; Danks 1978; Maier et. al. 1990), 10 °C to 26 °C (50 °F to 78.8 °F) for larval simuliids (Becker 1973; Ross and Merritt 1978; Colbo and Porter 1981; Hauer and Benke 1987), 13 °C to 17 °C (55.4 °F to 62.6 °F) for *Cladophora* (Graham et. al. 1982; Wong et. al. 1978), and 7 °C to 29 °C (44.6 °F to 84.2 °F) for *Gammarus* (Smith 1973; Pennak and Rosine 1976; Macneil et. al. 1997). The potential future release temperatures for the No Action Alternative should be similar to or higher than historic release temperatures. The warmer releases that may occur at the 10^{th} percentile Lake Powell elevations may be warmer than the preference of *Cladophora* in some years, but in general, these potential warmer releases may provide some overall benefit to the aquatic foodbase. This potential benefit is anticipated to benefit special status fish that rely on these organisms as their food source. Effects of the No Action Alternative on the aquatic foodbase and special status fish would be similar to historic effects. Substantial temperature-related effects to the aquatic foodbase are not anticipated with the No Action Alternative.

Mammals. Western small-footed myotis, pale Townsend's big eared bat, spotted bat, Allen's big-eared bat, western red bat, Yuma myotis, occult little brown bat, and Fringed myotis all may utilize this reach. Colorado River flows do not directly impact these species as they generally roost in caves and trees well above potential flow-related impacts. They are not obligate riparian species but may utilize such habitats for hunting. Impacts to these bat species from changes in vegetation, insect populations, from flow and water temperature changes are not likely under the No Action Alternative or the action alternatives. Accordingly, these species are not discussed further for this reach.

Amphibians. For the leopard frog population above Lees Ferry, reduced flows would not affect the spring-fed site. Inundation at this site occurs at approximately 21,000 cfs (Figures P-18 through P-21 in Appendix P). Inundation of this site would potentially occur under the No Action Alternative from June through September, as the 90th percentile releases in these months could exceed 21,000 cfs. Leopard frog reproduction has only been observed in warm (ca. 20 °C or 68 °F) pool and marsh areas, away from the direct influence of the river (Drost 2005). Colder pools (10 °C to 15 °C [50 °F to 59 °F]) that receive water from the Colorado River appear to be avoided. Water temperature at the spring site remains above 15 °C throughout the year and above 20 °C for several months (Spence 1996). Most of the warmer pools are located above the 21,000 cfs level; larvae and any remaining eggs still present during spring release peak flows would only infrequently be exposed to Colorado River flows. Lake Powell release temperatures under the No Action Alternative may exceed 15 °C (59 °F) when the reservoir is at the 10th percentile elevation. At the 50th and 90th percentiles, the Lake Powell release temperatures are expected to remain predominantly below 15 °C (59 °F) under the No Action Alternative (Figures P-68, P-69, P-70 in Appendix P). Thus, release temperatures would continue to remain below ideal temperatures for leopard frog under the No Action Alternative for most of the time.

Birds. Special status birds in this reach include bald eagle, California condor, southwestern willow flycatcher, Clark's grebe, osprey, belted kingfisher, snowy egret, and American Peregrine falcon. For the same reasons that California condor, osprey, belted kingfisher, and American peregrine falcon would be unaffected in Lake Powell, the proposed federal action would not impact these species between Glen Canyon Dam and Lake Mead. Between Glen Canyon Dam and Lake Mead, steep shorelines limit the establishment of significant marshes. It is unlikely that Clark's grebe or snowy egret would be impacted in this reach. Accordingly, only the bald eagle and southwestern willow flycatcher are discussed further in this reach.

Bald eagles in this area are primarily winter residents and they feed largely on fish, waterfowl and carrion. Bald eagles feed on trout in the Lees Ferry area, and often congregate at Nankoweap Creek. Less than ideal river temperatures for trout may occur in the future in some years; however, despite such potential adverse effects on trout in some years, it is anticipated that trout will remain a food source for eagles under the No Action Alternative. Potential increases in river flow temperatures under the No Action Alternative or action alternatives may result in an increase in the warmwater fish population which could serve as a supplemental food source for eagles. Future conditions under the No Action Alternative are not anticipated to affect roost or nest sites.

Southwestern willow flycatchers nest in riparian shrub habitats of tamarisk and willow downstream of Glen Canyon Dam. Reduced flows in the future would tend to continue favoring the establishment of riparian shrub vegetation in this reach. These conditions benefit southwestern willow flycatchers since they inhabit willow and tamarisk plant communities and have generally benefited from post-Glen Canyon Dam conditions. This trend would continue into the future.

Action Alternatives. Releases will only deviate from No Action Alternative conditions during the interim period for this reach. Though conditions causing potential impacts would cease after the interim period, effects on vegetation communities from interim period conditions may be observed beyond the interim period.

Plants. At the 90^{th} percentile June Glen Canyon Dam releases, the Reservoir Storage Alternative may have spill avoidance releases that would exceed the No Action Alternative. June releases are the highest for the year at the 90^{th} percentile and were used to gage potential impacts to Grand Canyon primrose habitat (Figure P-18 in Appendix P). These higher releases have a greater potential to adversely impact beach habitat and thus Grand Canyon evening primrose. These high flows may approach 34,000 cfs, which is still less than recent experimental releases that have exceeded 40,000 cfs, so the impacts should be negligible. The Conservation Before Shortage, Water Supply and Basin States alternatives sometimes exceed the No Action Alternative at the 90^{th} percentile, but they are typically in months that are not the annual high release and they still remain relatively close to the No Action Alternative. Therefore, the action alternatives are not expected to result in impacts on Grand Canyon evening primrose. The Reservoir Storage Alternative could potentially have a minor negative impact on Grand Canyon primrose due to occasional spill avoidance releases.

Invertebrates. Kanab ambersnail habitat is impacted when flows exceed 17,000 cfs. During the interim period, the Conservation Before Shortage and Basin States alternatives may exceed the flows observed under the No Action Alternative and 17,000 cfs in April and May at the 90^{th} percentile (Figures P-16, P-17). The other two action alternatives have only a few isolated years above the No Action Alternative and 17,000 cfs in these months. July releases at the 90^{th} percentile under the Conservation Before Shortage and Basin States Alternatives would be above 17,000 cfs, but lower than the No Action Alternative, therefore possibly inundating less Kanab ambersnail habitat in this month. The Conservation Before Shortage and Basin States alternatives could also be above the No Action Alternative and 17,000 cfs at the 50^{th} percentile in August, thus inundating more Kanab ambersnail habitat. The Water Supply Alternative could also have 50^{th} percentile flows that are higher than the No Action Alternative and above 17,000 cfs in August, though this is the only month where this may occur for the Water Supply Alternative, and most of the time flows would be similar to the No Action Alternative when above 17,000 cfs. In June, the Reservoir Storage Alternative's occasional spill avoidance releases up to 6,000 cfs above the No Action Alternative (to 29,500 cfs) would flood additional Kanab ambersnail habitat (Figure P-18 in Appendix P). The Kanab ambersnail population at Vasey's Paradise survived and recovered from innumerable similar and higher flows during the pre-dam era, and has survived six flows in excess of 45,000 cfs during the post-dam era (1965, 1980, 1983, and 1986). The Reservoir Storage Alternative could also exhibit flows above 17,000 cfs and exceeding the flows observed under the No Action Alternative in December.

At the 10th percentile, all the action alternatives may have lower releases from Glen Canyon Dam in some months. Though it is not possible to accurately project under which months those release levels would occur or how many months in a row this would occur, these lower releases would allow spring vegetation at Vasey's Paradise to develop lower down on the canyon. Ambersnail's could move into this lower habitat if releases are lower for long enough for such habitat to develop. When releases rise again, this habitat would be inundated and could impact ambersnails. However, this type of impact also occurs under the No Action Alternative. Accordingly, these potential impacts are expected to be minor and the action alternatives should not impact the population that occurs above the zone of fluctuating releases. Reclamation has consulted with the FWS (FWS 1994) on the effects to the Vasey's Paradise population from the operations of Glen Canyon Dam.

The Reservoir Storage Alternative may exceed the No Action Alternative release and 20,000 cfs in June and December at the 90th percentile and would thus have a greater potential for a negative impact on Niobrarra ambersnail habitat. When Glen Canyon Dam releases are above 20,000 cfs at the 90th percentile release level, the frequency and magnitude of releases under the Conservation Before Shortage, the Basin States and Water Supply alternatives are equal or less than those under the No Action Alternative, which has a greater potential for a positive impact on Niobrarra ambersnail habitat.

The Conservation Before Shortage, Basin States and Water Supply alternatives are not expected to affect the alluvial floodplain in the lower Grand Canyon area and would thus not impact MacNeill's sooty-winged skipper habitat. Occasional spill avoidance releases in June under the Reservoir Storage Alternative have the greatest potential to impact floodplains and quailbrush, and therefore would have the greatest potential impact on MacNeill's sooty-winged skipper habitat.

Fish. Water temperatures in the Colorado River below Glen Canyon Dam under the Conservation Before Shortage and Basin States alternatives should be similar to those for the No Action Alternative, although the water may be warmer a few weeks earlier under 10th percentile below the Little Colorado River and near Diamond Creek. This would allow the humpback chub and bluehead sucker to spawn and egg incubation to occur a little earlier, which would provide conditions that could benefit these species.

Flannelmouth potentially could spawn under 50th percentile levels below the Little Colorado River, but egg incubation would not occur. Temperatures suitable for growth may occur for about one month longer below the Little Colorado River at 10th percentile elevations and at Diamond Creek under 50th percentile elevations for all three species. Some growth could potentially occur under 50th percentile elevations for all three species below the Little Colorado River as well.

Under the Reservoir Storage Alternative, water temperatures in the river would usually be as cold as or sometimes colder than under the No Action Alternative. For the 10th percentile elevation, lower water temperatures could occur in January and February as well as in June through July (near Diamond Creek) or August (at Lees Ferry and below the Little Colorado River). For the 50th percentile elevation, lower water temperatures could occur from September through February at Lees Ferry, from August through March below the Little Colorado River confluence, and from August through February near Diamond Creek. These lower temperatures would not improve spawning or incubation temperatures for any of the native fish. Lower temperatures would have the potential to reduce growth rates for native fish in the Colorado River but would not affect those individuals residing in tributaries.

Under the Water Supply Alternative, water released to the Colorado River could be warmer at times. From about May through September, water temperatures at and below the Little Colorado River confluence may be 2 ºC to 5 ºC (35.6 ºF to 41 ºF) warmer than under the No Action Alternative and could be warm enough for humpback chub, flannelmouth, and bluehead sucker spawning to occur in the Colorado River. For the humpback chub, water temperatures near Diamond Creek could be warm enough for spawning and egg incubation May through July under 10th percentile elevations and in June and July under 50th and 90th percentile elevations. Just below the Little Colorado River confluence, temperatures have the potential to be warm enough for humpback chub spawning and egg incubation in May through July under 10th percentile elevations. These 10th percentile temperatures would increase the spawning and incubation time by about one month near the Little Colorado River and provide a greater likelihood of warmer temperatures than under the No Action Alternative.

For bluehead sucker, 10th percentile water temperatures could be warm enough for spawning below the Little Colorado River from about June through October and near Diamond Creek from May through October under the Water Supply Alternative. Water temperatures suitable for flannelmouth sucker spawning may occur near Diamond Creek in May and June and under 10th percentile levels in May and June below the Little Colorado River. The timing of these temperatures is similar to that for the No Action Alternative, but the likelihood of their occurrence is greater than under the No Action Alternative. How much of a benefit this could be to these species would depend on the frequency of these warmer temperatures, which is not known.

For the Water Supply Alternative, water temperatures may support growth of all three species for one to two months longer from Glen Canyon Dam to Lake Mead than under the No Action Alternative. Near the Little Colorado River, some growth could occur under 50th percentile elevations in the late summer to fall (August to October) for all three species.

The warmer water temperatures under the Water Supply Alternative would also benefit existing populations of non-native, non-game warmwater species such as carp, fathead minnows, catfish, and red shiner. This could increase competition for resources or predation on the native species that would have a negative impact on the native species, thereby at least partially offsetting the benefits of the warmer temperatures on the native species.

The passage of non-native fish through Glen Canyon Dam may occur as the lake levels drop, and the greatest potential for this to occur is under the Water Supply Alternative, which tends to have lower lake levels than all the other alternatives. The Reservoir Storage Alternative has the least potential for non-native fish passage because the lake levels tend to be higher than those under the other alternatives. The Conservation Before Shortage and Basin States alternatives tend to have Lake Powell elevations that are close but somewhat lower than the No Action Alternative, which would result in a small increase in the potential to pass non-native fish through Glen Canyon Dam. These trends occur during the interim period and for varied lengths of time into the modeling period. The Water Supply Alternative could take the longest to return to No Action Alternative conditions after the interim period. As indicated in the No Action Alternative discussion, the increased potential to pass non-native fish could adversely affect native fish below Glen Canyon Dam.

The Water Supply Alternative may result in higher Glen Canyon Dam release temperatures than the No Action Alternative. This has the potential to create conditions favorable for upstream migration of warmwater non-native fish into the Grand Canyon and the migration of non-native warmwater fish into the Colorado River from warmer side tributaries. The Reservoir Storage Alternative may have the lowest water temperatures at the Diamond Creek confluence, but similar to the No Action Alternative. The Conservation Before Shortage and Basin States alternatives would have effects similar to the No Action Alternative on conditions favoring upstream migration of non-native warmwater fish into the Grand Canyon and the migration of non-native warmwater fish into the Colorado River from warmer side tributaries. However, there are numerous non-native warmwater fish species that already inhabit the Grand Canyon.

Temperatures potentially favoring expansion of the Asian tapeworm and anchorworm into the Colorado River may occur when Lake Powell water levels are drawdown and warmer water is released from Glen Canyon Dam. As noted before, these warmer water temperatures generally coincide with Lake Powell water levels coinciding with the 10th Percentile lake elevation values observed under the No Action Alternative and the action alternatives, a condition that has a low probability of occurrence. Glen Canyon Dam releases made when the Lake Powell water levels are higher, at levels coinciding with the 50th and 90th Percentile elevation values, typically result in cooler downstream river flow temperatures. Under these latter conditions, the river flow temperatures typically remain below 20 °C the majority of the time and these cooler temperatures are less conducive for migration of the non-native parasites into the mainstream of the Colorado River. The Water Supply Alternative has a greater probability of providing favorable conditions for the migration of the Asian tapeworm and anchorworm into the mainstream of the Colorado River because this alternative provides the lowest Lake Powell water levels and potentially, warmer Glen Canyon Dam release temperatures. The Reservoir Storage Alternative provides higher Lake Powell water levels and generally cooler Glen Canyon Dam release temperatures. As such, the Reservoir Storage Alternative has a lower potential to increase Asian tapeworm and anchorworm expansion into the mainstream Colorado River, compared to the No Action Alternative. The Conservation Before Shortage and Basin States alternatives will have a similar effect as that as of the No Action Alternative.

The Conservation Before Shortage and Basin States alternatives should have very similar release temperatures as the No Action Alternative. Temperatures at Lees Ferry, Little Colorado River, and Diamond Creek would also be similar to the No Action Alternative (Appendix P). Therefore, these two alternatives should not have temperature-related impacts on the aquatic foodbase or the food sources for special status fish. The Water Supply Alternative may have warmer releases than No Action at the 10^{th} percentile Lake Powell elevations, which may potentially result in warmer temperatures downstream. The Reservoir Storage Alternative may have colder releases than No Action Alternative at the 10^{th} percentile Lake Powell elevations, which results in colder temperatures downstream. The warmer releases under the Water Supply Alternative may trend further from the preferences of *Cladophora*, which could affect the other invertebrates which feed on it. However, *Cladophora* should remain present despite the potential release temperatures above its preferred thermal range, and invertebrates may benefit from warmer temperatures overall. The predominance of *Cladophora* below Glen Canyon Dam appears to be linked to water clarity. The action alternatives are not expected to have any substantial effects on river clarity trends in the river reach between Glen Canyon Dam and Lake Mead. The Reservoir Storage Alternative tends to create conditions for the aquatic foodbase closer to historic conditions, though still potentially warmer at the 10^{th} percentile lake level releases. Future river flow temperatures are expected to remain within the preferred temperature range for larval chironomids, simuliids, and *Gammarus* in most years. None of the action alternatives are expected to result in substantial temperature-related impacts to the aquatic foodbase below Glen Canyon Dam, despite the potential differences indicated above.

Amphibians. Because leopard frogs preferentially select warmer water for breeding, occasional introduction of warmer water would presumably benefit the frogs. Lake Powell releases and temperatures at Lees Ferry at the 50^{th} percentile reservoir elevations may be almost always colder than 15 °C for all of the alternatives, so there would be no temperature impact to leopard frogs at the 50^{th} percentile Lake Powell elevation releases. The Water Supply Alternative may result in temperatures above 15 °C starting in May at the 10^{th} percentile Lake Powell elevations, which would provide a thermal benefit from less thermal shock to eggs and larvae. Modeling indicates this may occur at Glen Canyon Dam and at Lees Ferry. Lake Powell 10^{th}

percentile release temperatures for the Conservation Before Shortage, Basin States and Reservoir Storage alternatives do not exhibit significant increases in temperature and would result in similar conditions as the No Action Alternative. Following Atkinson (1996), it is possible that the warmer water would increase the rate of metamorphosis but result in a smaller size class of metamorphs.

Action alternative flows may inundate the Lees Ferry leopard frog habitat from June through September at 90th percentile releases from Glen Canyon Dam. During the interim period, these high releases may differ from the No Action Alternative. There are no differences from the No Action Alternative beyond the interim period at these higher end releases. When above 21,000 cfs, occasional June spill avoidance releases under the Reservoir Storage Alternative may exceed the releases that occur under the No Action Alternative by up to 6,000 cfs. Though these higher flows would presumably have a greater impact on the Lees Ferry leopard frog habitat, they occur in years where the No Action Alternative may also exceed 21,000 cfs, so the inundation impacts would be similar, though the habitat may be under deeper water than the No Action Alternative. The Conservation Before Shortage, Basin States and Water Supply alternatives may have lower 90th percentile flows in July and September, but still above 21,000 cfs, so the inundation impacts would be similar to that under the No Action Alternative, though the habitat may be under shallower water.

Birds. Bald eagles may be indirectly impacted by alterations to the trout fishery. At the 10th percentile, the greatest potential temperature impact to the trout fishery would occur under the Water Supply Alternative. However, these potential temperature effects are mitigated by trout's ability to move to thermal refugia at different water levels in the Colorado River and because warmer temperatures will occur in some years. Accordingly, despite these potential occasional changes in temperature, population-level impacts to the Lees Ferry trout fishery are not anticipated as a result of the proposed federal action. As noted before, warmer river flow temperatures may affect trout in some years and may benefit warmwater fish which could provide an alternative food source for eagles. The levels of potential flow impacts to vegetation communities anticipated under some alternatives are not likely to cause significant impact to bald eagles. Given bald eagle's mobility, varied diet, lack of impacts to roost or nest sites, none of the action alternatives would substantially impact bald eagles that inhabit areas downstream of Glen Canyon Dam.

Though higher flows, particularly with the Reservoir Storage Alternative in June, may flood riparian habitats, these would not be expected to impact southwestern willow flycatcher populations. Nests are typically above the 45,000 cfs stage. Reclamation concluded that long-term effects of the 42,000 to 45,000 cfs test flow in 2002 on Southwestern willow flycatcher habitat are expected to be beneficial (Reclamation 2002). Tamarisk are expected to withstand potential increased flows that may occur under Reservoir Storage peaks in June. The Conservation Before Shortage, Basin States and Water Supply alternatives are higher than the No Action Alternative by up to a few thousand cfs in some months, though these higher flows would not inundate southwestern willow flycatcher nests. When the action alternatives (all at least in some months) are lower than the No Action Alternative (typically at 10th percentile), these levels would not be expected to kill tamarisk, which is what southwestern willow flycatcher typically nest in below Glen Canyon Dam.

The Conservation Before Shortage, Basin States and Water Supply alternatives would have lower 10th percentile releases from April through September and the Reservoir Storage Alternative would have lower 10th percentile releases from June through September. These lower releases may reduce moist soil conditions below nesting sites, which is a preference of southwestern willow flycatcher. Lack of moist soil below nest sites may degrade the habitat for this species, at least temporarily. A lack of moist soil conditions is more likely for all of the action alternatives than for the No Action Alternative at the 10th percentile releases. At the 50th percentile release, the action alternatives would be at or above the No Action Alternative during the southwest willow flycatcher nesting season. So potential impacts to southwest willow flycatcher are only expected at lower releases.

Table 4.8-4 displays impacts to special status species in the Glen Canyon Dam to Lake Mead reach for all alternatives.

Table 4.8-4
Glen Canyon Dam to Lake Mead Special Status Species Impact Summary
Comparison of Action Alternatives to No Action Alternative

Species	Alternative	Impact	Rationale
Mammals	All Action Alternatives	No impact	Flow differences not expected to rise to the level of indirectly impacting special status mammals.
Grand canyon evening primrose	Conservation Before Shortage, Basin States, Water Supply	No impact	Similar 90th percentile releases to the No Action Alternative.
	Reservoir Storage	Minor-negative	Higher 90th percentile releases than the No Action Alternative may affect beach habitat more than the No Action Alternative. Interim period only. High flows still less than experimental releases.
Kanab ambersnail	All Action Alternatives	Minor-negative	90th percentile releases exceed the No Action Alternative and 17,000 cfs. Interim period only. High flows still less than past high flows from which Kanab ambersnail has recovered from.
Niobrarra ambersnail	Reservoir Storage	Minor-negative	90th percentile releases exceed the No Action Alternative and 20,000 cfs. Interim period only. High flows still less than past high flows.
	Conservation Before Shortage, Basin States and Water Supply	Minor-positive	When above 20,000 cfs at the 90th percentile release, the alternatives are equal or less than the No Action Alternative.

Table 4.8-4
Glen Canyon Dam to Lake Mead Special Status Species Impact Summary
Comparison of Action Alternatives to No Action Alternative

Species	Alternative	Impact	Rationale
MacNeill's sooty-winged skipper	Conservation Before Shortage, Basin States and Water Supply	No impact	High releases do not differ substantially from the No Action Alternative. Interim period only.
	Reservoir Storage	Minor - negative	90^{th} percentile releases in June have greatest potential to impact quailbrush along Colorado River. Interim period only.
Humpback chub, bluehead sucker, flannelmouth sucker	Conservation Before Shortage and Basin States	No impact	Release temperatures similar to those for the No Action Alternative but warming a little earlier in the year.
	Reservoir Storage	Minor-negative	Release temperatures may be as cold or colder that under the No Action Alternative most of the time which would adversely affect spawning, swimming ability, and reduce growth of humpback chub, bluehead sucker, and flannelmouth sucker.
	Water Supply	Minor-positive	Release temperature may be warmer than for the No Action Alternative sometimes, a benefit for native fish spawning, incubation, swimming ability, and growth. Temperature benefits to native species tempered because non-native warmwater fish competitors, Asian tapeworm, and anchorworm fish parasites may also benefit.
Northern leopard frog	Conservation Before Shortage, Basin States and Reservoir Storage	No Impact	Release temperatures trend close to the No Action Alternative. High flows inundate Lees Ferry frog habitat, but the No Action Alternative also inundates habitat.
	Water Supply	Minor-positive	Release temperatures higher than 15°C at 10^{th} percentile releases may provide thermal benefit to frog reproduction. High flows inundate Lees Ferry frog habitat, but the No Action Alternative also inundates habitat.
Bald eagle	All Action Alternatives	No impact	Substantial indirect impacts through impacts to food sources not anticipated. Wide ranging species with the varied diet. Impacts to roost or nest sites are not anticipated.
Southwestern willow flycatcher	All Action Alternatives	Minor-negative	Lower 10^{th} percentile flows may impact willow but not tamarisk. Lower 10^{th} percentile flows may reduce moist soil conditions below nest sites and degrade habitat value. Occurs under all action alternatives at 10^{th} percentile release.

4.8.4.3 Lake Mead

No Action Alternative.

Birds. Lake Mead water levels may exhibit a downward trend into the future under the No Action Alternative. This trend would have effects on the riparian and marsh habitats at the inflow areas and on the special status bird species that utilize such habitats for breeding, roosting or foraging. The downward trend would increase the potential for dewatering and headcutting of the sediment deltas, which would adversely affect riparian and marsh vegetation that has developed on the deltas. This has the greatest potential to adversely affect special status birds that utilize cottonwood-willow and marsh habitats such as the bald eagle, southwestern willow flycatcher, yellow-billed cuckoo, long-eared owl, American kestrel, osprey, Cooper's hawk, American peregrine falcon, northern harrier, Clark's grebe, snowy egret, Yuma clapper rail, California black rail, American bittern, western least bittern, great egret, white-faced ibis, belted kingfisher and American white pelican.

Mammals. Townsend's big-eared bat, pale Townsend's big-eared bat, occult little brown bat, spotted bat, Allen's big-eared bat, western red bat, Yuma myotis, western yellow bat, cave myotis, greater western mastiff bat, and small-footed myotis may utilize the riparian and marsh habitats at Lake Mead for foraging and roosting. These bat species utilize a variety of habitats for roosting, including dead trees, so potential vegetation effects should not substantially impact roosting opportunities for these bats. Substantial effects to insect food sources for special status bats is not expected because the Lake Mead water levels will continue to experience annual fluctuations and the downward trend will be gradual over time. The No Action Alternative conditions at Lake Mead would not impact the Yuma hispid cotton rat or Colorado River cotton rat as these species are found further south along the lower Colorado River.

Amphibians. Relict leopard frog populations at Lake Mead would not be affected under the No Action Alternative because the known populations are at springs above the influence of Lake Mead's fluctuation. Colorado River toads are not known at Lake Mead. The No Action Alternative conditions are not expected to affect special status amphibians at Lake Mead.

Plants. Sticky buckwheat, Geyer's milkvetch and Las Vegas bear poppy all occur at the shorelines of Lake Mead. These species typically benefit from lower reservoir levels that expose additional shoreline habitat. Lake Mead would continue to experience lake level fluctuation under the No Action Alternative, which would result in varied levels of exposed shoreline through the year. The general downward lake level trend of Lake Mead that may occur under the No Action Alternative would generally result in increased shoreline exposure which would benefit these species while this trend continues.

Invertebrates. MacNeill's sooty-winged skipper is not known at Lake Mead and would thus not be affected by future conditions under the No Action Alternative.

Fish. Under the No Action Alternative, special status fish would experience Lake Mead elevations less than 1,120 feet msl all year for the 50th and 10th percentile conditions. The 90th percentile elevations are generally projected to be near or above 1,200 feet msl all year. Modeled Lake Mead elevations for end of March, July and September are provided in Figures P-10 through P-12 in Appendix P. Razorback sucker spawning is known to occur between elevations 1,120 feet msl and 1,150 feet msl, and as elevations have dropped within this range and exposed areas used for spawning in earlier years, the fish have moved their spawning to nearby suitable areas

(Albrecht and Holden 2006). Based on the modeled reservoir elevations under the No Action Alternative, the preferred spawning sites would be out of the water over 50 percent of the time. Razorback sucker would have to move to suitable spawning habitat at lower reservoir elevations, where such habitat is available.

Action Alternatives. Lake Mead elevations will deviate from the No Action Alternative conditions during the interim period and the modeling period.

Birds. No impacts to riparian or marsh habitats were anticipated at Lake Mead for the Conservation Before Shortage or Basin States alternatives because the Lake Mead elevations under these action alternatives trend close to the No Action Alternative. Therefore, the action alternatives would not impact special status bird species at Lake Mead.

The Water Supply Alternative would result in a minor negative impact to cottonwood-willow, tamarisk and marsh vegetation at Lake Mead inflow areas and sediment deltas. These negative impacts would be caused by lower reservoir elevations, increased dewatering of the sediment deltas and delta erosion. However, depending on duration of the lower elevations, the impact may be offset by new vegetation growing on the newly exposed sediments. These vegetation impacts would cause minor negative impact to those special status bird species that forage, breed or roost in cottonwood-willow, tamarisk and marsh habitats. Impacted species include: southwestern willow flycatcher, Clark's grebe, snowy egret, Yuma clapper rail, yellow-billed cuckoo, California black rail, American bittern, western least bittern, great egret, white faced ibis, long-eared owl, American kestrel, osprey, northern harrier, Cooper's hawk, bald eagle, belted kingfisher, American peregrine falcon, and American white pelican.

The Reservoir Storage Alternative would result in a minor positive impact to vegetation at Lake Mead, primarily at the inflow areas and sediment deltas. These positive impacts would be caused by higher reservoir elevations than under the No Action Alternative, and thus less potential dewatering or sediment delta headcutting than under the No Action Alternative. Positive impacts are anticipated for the southwestern willow flycatcher, Clark's grebe, snowy egret, Yuma clapper rail, yellow-billed cuckoo, California black rail, American bittern, western least bittern, great egret, white faced ibis, long-eared owl, American kestrel, osprey, northern harrier, Cooper's hawk, bald eagle, belted kingfisher, American peregrine falcon, and American white pelican.

Mammals. Impacts to special status mammals at Lake Mead are not expected to occur for the same reasons provided under the No Action Alternative discussion.

Amphibians. Impacts to special status amphibians at Lake Mead are not expected for the reasons described under the No Action Alternative.

Plants. Sticky buckwheat, Geyer's milkvetch and Las Vegas bear poppy all occur at the shorelines of Lake Mead. These species typically benefit from lower reservoir elevations that expose additional shoreline habitat. The Conservation Before Shortage and Basin States alternatives would not impact these species since reservoir elevations trend close to the elevations under the No Action Alternative. The Water Supply Alternative would provide a minor beneficial impact to these species through lowered elevations. The Reservoir Storage Alternative would cause a minor negative impact to these species through raised elevations and inundation of shoreline habitats.

Invertebrates. MacNeill's sooty winged skipper is not known at Lake Mead, and would thus not be impacted by any action alternative.

Fish. Under the Basin States and Conservation Before Shortage alternatives, reservoir elevations may vary from 16 feet above to 12 feet below 50^{th} percentile levels under the No Action Alternative (Figures P-10, P-11, P-12 in Appendix P). The maximum elevation may be 1,128 feet msl with most elevations below 1,100 feet msl. These two alternatives could have minor positive impacts in years when the reservoir elevation is above 1,120 feet msl and no impacts to minor negative impacts when elevations are below that of the No Action Alternative. The Water Supply Alternative would have 50^{th} percentile reservoir elevations near or below those under the No Action Alternative, and a minor negative impact compared to the No Action Alternative. The Reservoir Storage Alternative, however, would have 50^{th} percentile elevations above those under the No Action Alternative with many occurrences of elevations above 1,125 feet msl and the maximum at elevation 1,139 feet msl. Thus, the Reservoir Storage Alternative would maintain reservoir elevations within the range currently used by razorback suckers for spawning more than 50 percent of the time, a moderate positive impact. At the 10^{th} percentile reservoir elevations, all action alternatives would have elevations near or above those under the No Action Alternative but none would be near the current elevations used for razorback spawning. Impacts could range from no effect to a minor positive impact but overall would likely be no impact.

Lowered reservoir elevations are known to allow vegetation to grow on the exposed lake bed, and these areas are then inundated at higher reservoir elevations. These submerged vegetated areas can provide cover for juvenile razorback suckers and enhance their survival. Thus, periodic lower reservoir elevations may have some benefits (minor positive impact) to razorback sucker spawning success and recruitment after the reservoir elevations rise and inundate the vegetation growing on the edge.

Lowered reservoir elevations under the No Action Alternative and all of the action alternatives would extend the riverine habitat where the Colorado River and the Virgin River enter the reservoir. This would increase habitat for the humpback chub, razorback sucker, flannelmouth sucker, and bluehead sucker that could move downstream and for the woundfin and the Virgin River chub in the Virgin River. Under 50^{th} percentile elevations, the Water Supply Alternative would provide the greatest benefit to those species while the Reservoir Storage Alternative would provide the least benefit. Both alternatives would provide minor positive impacts for these species. The other two action alternatives would provide little benefit (essentially no impact) relative to the No Action Alternative. At the 90th percentile elevations, none of the action alternatives differ substantially from the No Action Alternative, i.e., no impact, while under 10th percentile elevations, all but the Reservoir Storage Alternative are similar to the No Action Alternative resulting in no impact. The Reservoir Storage Alternative would provide the least riverine habitat increase, a minor negative impact. The Virgin River chub and bonytail are not known to be present in Lake Mead.

Table 4.8-5 describes potential special status species impacts of the action alternatives at Lake Mead.

Table 4.8-5
Lake Mead Special Status Species Impact Summary
Comparison of Action Alternatives to No Action Alternative

Species	Alternative	Impact	Rationale
Birds	Conservation Before Shortage, Basin States	No impact	Reservoir elevations trend close to the No Action Alternative.
	Reservoir Storage	Minor-positive	Reservoir elevations trend higher than the No Action Alternative.
	Water Supply	Minor-negative	Reservoir elevations trend lower than the No Action Alternative.
Mammals	All Action Alternatives	No Impact	Substantial impacts to insect food sources for bats not anticipated.
Relict leopard frog	All Action Alternatives	No impact	Overton arm population is located at a spring above Lake Mead's influence.
MacNeill's sooty-winged skipper	All Action Alternatives	No impact	Species not known at Lake Mead.
Sticky buckwheat, Geyer's milkvetch and Las Vegas bearpoppy	Conservation Before Shortage and Basin States	No impact	Reservoir elevations trend close to the No Action Alternative.
	Reservoir Storage	Minor-negative	Reservoir elevations trend higher than the No Action Alternative, inundating shoreline habitat. Habitats below full pool elevation considered temporary due to reservoir fluctuation.
	Water Supply	Minor-positive	Reservoir elevations trend lower than the No Action Alternative, exposing additional shoreline habitat. Habitats below full-pool elevation considered temporary due to reservoir elevation fluctuation.

Table 4.8-5
Lake Mead Special Status Species Impact Summary
Comparison of Action Alternatives to No Action Alternative

Species	Alternative	Impact	Rationale
Fish	Conservation Before Shortage and Basin States	No impact	Elevations above 1,120 feet msl could have a slight benefit to razorback sucker spawning while lower elevations could be less valuable; at 10th percentile elevations, these alternatives would be similar to the No Action Alternative. Essentially no increased amount of riverine habitat at 10th, 50th, or 90th percentile elevations.
	Water Supply	Minor negative Minor positive	Reservoir elevations would be near to or less than that under the No Action Alternative under 50th percentile elevations. Lower reservoir elevation would provide more riverine habitat for fish from Separation Canyon and the Virgin River under 50th percentile elevations.
	Reservoir Storage	Moderate positive Minor positive Minor negative	Reservoir elevations would be above 1,120 feet msl over 50 percent of the time; at 10th percentile elevations, no impact. Lower reservoir elevation would provide more riverine habitat for fish from Separation Canyon and the Virgin River under 50th percentile elevations. The 10th percentile elevations would provide less riverine habitat than under the No Action Alternative.

4.8.4.4 Hoover Dam to Davis Dam and Lake Havasu to Parker Dam

Due to lack of differences among alternatives in these reaches, and the lack of change in vegetation or habitat, there will be no impacts to special status species at these locations.

4.8.4.5 Davis Dam to Lake Havasu

No Action Alternative. Monthly releases from Davis Dam exhibit a downward trend in the future at the 90th percentile (Figures P-37 through P-48 in Appendix P). While special status species along the Colorado River are constantly making minor adjustments as flows fluctuate, downward trending releases could result in special status species habitat impacts.

Birds. Downward trending Davis Dam releases in the future under the No Action Alternative may have gradual adverse effects on cottonwood-willow and marsh habitats, which are utilized by many special status bird species. These species include: bald eagle, osprey, belted kingfisher, peregrine falcon, southwestern willow flycatcher, vermillion flycatcher, Clark's grebe, snowy egret, Yuma clapper rail, western yellow-billed cuckoo, California black rail, elf owl, gilded flicker, Gila woodpecker, Arizona Bell's vireo, Sonoran yellow warbler, summer tanager, American white pelican, double crested cormorant, American least bittern, Western bittern, great egret, black-crowned night heron, white faced ibis, black tern, long-eared owl, brown crested flycatcher, Lucy's warbler, yellow-breasted chat, northern cardinal, northern harrier, Cooper's hawk and American kestrel. Since lower flows are more likely to affect cottonwood willow than tamarisk, the No Action Alternative conditions are expected to favor continued tamarisk expansion along the lower Colorado River.

Mammals. Townsend's big-eared bat, Pale Townsend's big-eared bat, spotted bat, Allen's big-eared bat, Western red bat, occult little brown bat, Yuma myotis, Western Yellow bat, cave myotis, greater western mastiff bat and small-footed myotis utilize riparian and marsh habitats in this reach for foraging and roosting. Downward trending Davis Dam releases under No Action Alternative conditions are expected to be gradual, though they may affect the composition of riparian habitats. Such gradual changes are not expected to substantially affect insect food sources for special status bats. Since these bats typically utilize a variety of roost sites, including live and dead trees, substantial impacts to these species roost sites are not anticipated under the No Action Alternative.

The Yuma hispid cotton rat and Colorado River cotton rat are only known from Yuma south. The No Action Alternative will not affect these species in this reach.

Amphibians. Relict leopard frogs are known below Hoover Dam at several springs to the north of this reach and are above the influence of the Colorado River. The Lowland Leopard frog is known along the Bill Williams River, but not in this reach. Though potential Colorado River toad occurs in this reach, the species is not known here. The No Action Alternative will have no effects on special status amphibians in this reach.

Invertebrates. MacNeill's sooty-winged skipper is known at scattered sites along the lower Colorado River and is associated with quailbrush (*Atriplex*) and mesquite communities. The Atriplex land cover type is present in this reach (Table 3.8-2). However, quailbrush typically grows on alluvial floodplains and flow-related impacts from the No Action Alternative are not anticipated to affect alluvial floodplains. Downward trending releases may result in groundwater table impacts in the future. However, because the declines will likely be gradual and that mesquite and quailbrush are not obligate phreatophytes, groundwater-related effects under No Action Alternative conditions are not anticipated. The No Action Alternative should not affect MacNeill's sooty-winged skipper in this reach.

Fish. In the Colorado River between Davis Dam and Lake Havasu, some backwaters are present that could be used by razorback suckers, bonytail, and flannelmouth suckers, the only special status fish species present. Reduced flows in the future in this reach may result in more frequent dewatering of backwaters, resulting in a reduction of habitat for these special status fish species. Backwaters may become vegetated with marsh plants under reduced flow conditions. Non-native fish would continue to be present in this reach and compete with native fish.

Action Alternatives. The Conservation Before Shortage and Basin States alternatives would not impact any special status species in this reach because Davis Dam monthly releases trend close to the No Action Alternative. These two action alternatives are not discussed further for this reach. Flow deviations from the No Action Alternative under the Water Supply Alternative and Reservoir Storage alternatives generally return to No Action conditions at the end of the interim period, though the vegetation and associated special status species effects of interim period conditions may be observed beyond the interim period.

Birds. The Reservoir Storage and Water Supply alternatives may result in lower and higher monthly releases respectively. Respective impacts to special status birds would be similar to impacts discussed at Lake Mead. However, a higher number of species may be impacted since this reach includes California special status birds not considered at Lake Mead. The Reservoir Storage Alternative would have a minor negative impact on the following special status birds through flow-related negative impacts to their habitats: bald eagle, osprey, belted kingfisher, peregrine falcon, southwestern willow flycatcher, vermillion flycatcher, Clark's grebe, snowy egret, Yuma clapper rail, western yellow-billed cuckoo, California black rail, elf owl, gilded flicker, Gila woodpecker, Arizona Bell's vireo, Sonoran yellow warbler, summer tanager, American white pelican, double crested cormorant, American least bittern, Western bittern, great egret, black-crowned night heron, white faced ibis, black tern, long-eared owl, brown crested flycatcher, Lucy's yellow warbler, yellow-breasted chat, northern cardinal, northern harrier, Cooper's hawk and American kestrel. The Water Supply Alternative is expected to have a minor positive impact on these same species. The groundwater changes anticipated for this reach may be on the order of 0.5 feet or less (Section 4.3), which contributes to these impacts being minor.

Mammals. Though there may be higher and lower Davis Dam releases under the Water Supply and Reservoir Storage alternatives, respectively, these differences are not expected to substantially impact foraging or roosting conditions for special status bats. Impacts from the action alternatives on special status mammals are expected to be similar to the conditions expected under the No Action Alternative.

Yuma hispid cotton rat and Colorado River cotton rat are only known along the Colorado River from Yuma south. Therefore, this proposed federal action would not impact these species in this reach.

Amphibians. There will be no impacts from the Water Supply and Reservoir Storage alternatives to the Colorado River Toad, relict leopard frog or lowland leopard frog in this reach for the same reasons as described for the No Action Alternative.

Invertebrates. There will be no impacts from the Water Supply and Reservoir Storage alternatives to MacNeill's sooty-winged skipper in this reach for the same reasons as described for the No Action Alternative.

Fish. The Reservoir Storage alternative may result in slightly less flow while the Water Supply alternative may result in slightly more flow than under the No Action Alternative in most months of the year under 50^{th} and 10^{th} percentile elevations. Reductions in Colorado River flow below Davis Dam could affect the flannelmouth sucker through loss of spawning habitat in the riverine sections and rearing habitat in backwaters. This would be a minor negative impact for this species. Reduced flows could also have a minor negative impact on razorback sucker and bonytail through loss of rearing habitat. The slightly higher flows under the Water Supply Alternative could have a minor positive impact on all three species. Under the 90th percentile, higher releases in the winter for the Reservoir Storage Alternative could have potential benefits or detriments to backwater habitats depending on the amount of sediment scour or deposition. Overall, however, no impact would be expected from higher winter releases.

Table 4.8-6 provides a summary of potential impacts that may occur under the action alternatives to special status species in the Davis Dam to Lake Havasu reach.

Table 4.8-6
Davis Dam to Lake Havasu Special Status Species Impact Summary
Comparison of Action Alternatives to No Action Alternative

Location	Alternative	Impact	Rationale
Birds	Conservation Before Shortage and Basin States	No Impact	Monthly releases closely follow the No Action Alternative.
	Water Supply	Minor-positive	Monthly releases higher than the No Action Alternative at 10th and 50th percentiles.
	Reservoir Storage	Minor-negative	Monthly releases lower than the No Action Alternative at 10th and 50th percentiles.
Mammals	All Action Alternatives	No impact	Conservation Before Shortage and Basin States alternatives monthly releases trend close to the No Action Alternative. Reservoir Storage and Water Supply alternatives differences are not substantial enough to cause indirect impacts to special status mammals.
Amphibians	All Action Alternatives	No Impact	Species not known in this reach.
Invertebrates	All Action Alternatives	No impact	Action alternatives not expected to adversely impact quailbrush or mesquite communities on alluvial floodplains.
Fish	Conservation Before Shortage and Basin States	No impact	Davis Dam releases trend close to the No Action Alternative.
	Water Supply	Minor- positive	Increased releases at 10th and 50th percentile elevations could benefit razorback sucker, bonytail, and flannelmouth sucker.
	Reservoir Storage	Minor-negative	Decreased releases at 10th and 50th percentile elevations could result in habitat reduction for razorback sucker, bonytail, and flannelmouth sucker.

4.8.4.6 Parker Dam to NIB

No Action Alternative. Monthly flows from Parker Dam to Imperial Dam exhibit a level to slightly downward trend in the future mostly because of a reduction in magnitude of 90th percentile flows in some months (Figures P-49 through P-60 in Appendix P). While special status species along the Colorado River are constantly adjusting as flows fluctuate, the slight downward trend in the future could adversely affect cottonwood and marsh communities and the special status species that rely on such habitats. Under the No Action Alternative, shortage conditions would occur without specific operating criteria. The gradual nature of this slight downward trend is such that terrestrial special status species and habitat conditions would not change abruptly or substantially. The No Action Alternative will not affect the Colorado River below Imperial Dam because flows between Imperial Dam and the NIB consist primarily of leakage from Imperial Dam and return flows from water diverted at Imperial Dam. Accordingly there will be no effects from the proposed federal action on special status species below Imperial Dam. The following discussion applies only to the Colorado River reach between Parker Dam and Imperial Dam.

Birds. The gradual and slight downward trend of flows in this reach in the future may adversely affect cottonwood-willow and marsh habitats and thus the special status birds that utilize such habitats. These species include: bald eagle, osprey, belted kingfisher, peregrine falcon, southwestern willow flycatcher, vermillion flycatcher, Clark's grebe, snowy egret, Yuma clapper rail, western yellow-billed cuckoo, California black rail, elf owl, gilded flicker, Gila woodpecker, Arizona Bell's vireo, Sonoran yellow warbler, summer tanager, American white pelican, double crested cormorant, American bittern, Western least bittern, great egret, black-crowned night heron, white faced ibis, black tern, long-eared owl, brown crested flycatcher, Lucy's warbler, yellow-breasted chat, northern cardinal, northern harrier, Cooper's hawk, and American kestrel. Lower flows would continue to favor expansion of tamarisk along this reach, which tends to reduce the value of the habitats the species invades.

Mammals. The gradual and slight downward trend of flows in this reach in the future under the No Action Alternative would have similar effects on special status bats as was described for the No Action Alternative for the Davis Dam to Lake Havasu reach.

The Yuma hispid cotton rat and Colorado River cotton rat do occur in this reach and they inhabit moist grassy areas along the lower Colorado River, including wetlands (Arizona Game and Fish 2004) from Yuma and downstream. The downward trend of releases from Parker Dam under the No Action Alternative may have minor effects on the moist riparian habitats these two species prefer. However, since these species also utilize agricultural fields and the downward release trend is gradual and small, effects under the No Action Alternative on these two rat species is expected to be minor.

Amphibians. Special status amphibians do not occur in this reach, thus no effects from the No Action Alternative are anticipated.

Invertebrates. MacNeill's sooty-winged skipper may occur in the quailbrush and mesquite communities that are present in this reach. However, the No Action Alternative is not expected to affect alluvial floodplains or otherwise impact these vegetation communities through groundwater effects. The No Action Alternative will not affect MacNeill's sooty-winged skipper in this reach.

Fish. The only listed fish species present in the Colorado River or in-stream reservoirs from Parker Dam to the NIB are the razorback sucker and bonytail chub. The effects of the No Action Alternative on these fish below Parker Dam would be similar to effects below Davis Dam.

Action Alternatives. Between Parker Dam and the NIB, the Water Supply Alternative flows from Parker Dam to Imperial Dam are similar to the No Action Alternative flows. Therefore, the Water Supply Alternative would have no impacts to special status species and is not discussed further for this reach. Flow deviations from No Action Alternative under the remaining action alternatives generally return to No Action Alternative conditions at the end of the interim period, though the vegetation and associated special status species effects of interim period conditions may be observed beyond the interim period.

Birds. Between Parker Dam and Imperial Dam, flows of the Conservation Before Shortage, Basin States, and Reservoir Storage alternatives would be lower than under the No Action Alternative at the 10th and 50th percentiles. The Reservoir Storage Alternative results in the greatest reduction from the No Action Alternative, while the Basin States Alternative results in the least reduction. These lower releases would have a minor negative impact on cottonwood-willow and marsh habitats and thus a correspondingly minor negative impact to special status birds that rely on those habitats. Impacted species include the following: bald eagle, osprey, belted kingfisher, peregrine falcon, southwestern willow flycatcher, vermillion flycatcher, Clark's grebe, snowy egret, Yuma clapper rail, western yellow-billed cuckoo, California black rail, elf owl, gilded flicker, Gila woodpecker, Arizona Bell's vireo, Sonoran yellow warbler, summer tanager, American white pelican, double crested cormorant, American bittern, Western least bittern, , great egret, black-crowned night heron, white faced ibis, black tern, long-eared owl, brown crested flycatcher, Lucy's yellow warbler, yellow-breasted chat, northern cardinal, northern harrier, Cooper's hawk, and American kestrel.

Mammals. The special status bat species would not be impacted in this reach for the same reasons as described for the Davis Dam to Lake Havasu reach.

Departures of the action alternatives from the No Action Alternative may be at most 0.25 feet stage reduction in the reach from Parker Dam to Imperial Dam. The action alternatives would not alter the historic operational methodology or range of flow volumes in the river channel below Imperial Dam. Therefore, none of the action alternatives would impact the Yuma hispid cotton rat or Colorado River cotton rat, which occur below Imperial Dam.

Amphibians. Special status amphibians do not occur in this reach.

Invertebrates. MacNeill's sooty-winged skipper would not be impacted in this reach because alluvial floodplains with quailbrush and mesquite are not expected to be substantially impacted by any alternative.

Fish. The Conservation Before Shortage, Basin States and Reservoir Storage alternatives have monthly releases that would be less than those under the No Action at the 10th and 50th percentiles. These lower flows could have impacts on Razorback Sucker and Bonytail chub similar to those described for the Reservoir Storage Alternative in the Davis Dam to Lake Havasu reach. The use of High Levee Pond on the Cibola NWR for native fishes would not be affected by changes in releases from Parker Dam.

Table 4.8-7 summarizes the potential impacts to special status species in the Parker Dam to NIB reach for the action alternatives.

Table 4.8-7
Parker Dam to NIB Special Status Species Impact Summary
Comparison of Action Alternatives to No Action Alternative

Location	Alternative	Impact	Rationale
Birds	Water Supply	No Impact	Monthly releases closely follow the No Action Alternative. No flow-related impacts anticipated below Imperial Dam.
	Conservation Before Shortage, Basin States, Reservoir Storage	Minor-negative	Monthly releases lower than the No Action Alternatives at 10th and 50th percentiles. Small anticipated groundwater level impacts. No flow-related impacts anticipated below Imperial Dam.
Mammals	All Action Alternatives	No impact	Monthly flows for Water Supply alternative are similar to No Action Alternative. Reservoir Storage, Conservation Before Shortage and Basin States alternatives are not substantially different than No Action Alternative to cause indirect impacts to special status bats. Two cotton rat species occur below Imperial Dam, where flow impacts are not anticipated.
Amphibians	All Action Alternatives	No Impact	Species not known in this reach.
Invertebrates	All Action Alternatives	No impact	Action alternatives not expected to adversely impact quailbrush or mesquite communities on alluvial floodplains.
Razorback Sucker and Bonytail chub	Water Supply	No Impact	Monthly flows closely follow the No Action Alternative.
	Conservation before Shortage, Basin States and Reservoir Storage	Minor-negative	Monthly flows are lower than No Action Alternative at the 10th and 50th percentiles and could result in habitat reduction.

4.8.4.7 NIB to SIB

No Action Alternative. The lack of flows precludes the presence of a significant river fishery in the Colorado River reach between Morelos Diversion Dam and the SIB (Limitrophe Division) and the riparian, marsh habitats, and the special status species that rely on those habitats are adversely affected by this condition. Flows past Morelos Diversion Dam tend to benefit downstream vegetated habitats and associated special status species. The probability of these excess flows occurring in the future under the No Action Alternative is relatively low, typically less than 20 percent. The infrequency of flows under the No Action Alternative would continue to maintain less than ideal conditions for cottonwood-willow and marsh habitats and the species that rely on such habitats. The special status bird and mammal species identified in the Parker Dam to the NIB reach will continue to experience these adverse effects on their habitat below

Morelos Diversion Dam under the No Action Alternative. The No Action Alternative will not have effects on special status amphibians, plants or fish because none are present in this reach. Infrequent flows in this reach under the No Action Alternative will continue to favor the expansion of tamarisk which may compete with mesquite and quailbrush communities, thus limiting the habitat potential for MacNeill's sooty-winged skipper in this reach.

Action Alternatives. The likelihood of flood control excess flows passing Morelos Diversion Dam under the Basin States and Water Supply alternatives is approximately equal to the No Action Alternative. Therefore these action alternatives would have no impact on special status species in this reach. The Reservoir Storage and Conservation Before Shortage alternatives have a higher likelihood of flood control excess flows passing Morelos Diversion Dam than under the No Action Alternative (Figure P-61 in Appendix P). In addition, due to modeling assumptions under the Reservoir Storage and Conservation Before Shortage alternatives, water is delivered to Mexico through this reach via periodic flows[2] of about 40 kafy to 200 kafy (Section 2.4). These pulse flows would occur approximately every other year during the interim period only. The probability of flows past Morelos Diversion Dam under these two action alternatives returns to flows under No Action Alternative conditions after the interim period. These flows would have overall benefits to river flow, riparian and marsh vegetation and special status species that utilize these habitats since substantial flow in this reach is relatively rare. The Reservoir Storage and Conservation Before Shortage alternatives would have a moderate, positive impact on special status species between Morelos Diversion Dam and the SIB.

Birds. The species identified as impacted in the Parker Dam to the NIB would be positively impacted by the increased likelihood of flows past Morelos Diversion Dam under the Reservoir Storage and Conservation Before Shortage alternatives. The Basin States and Water Supply alternatives would not impact special status birds since these action alternatives are just as likely as the No Action Alternative to have flows past Morelos Diversion Dam.

Amphibians, Plants and Fish. There are no special status amphibians, plants or fish in this reach.

Mammals. The increased likelihood of flows past Morelos Diversion Dam under the Reservoir Storage and Conservation Before Shortage alternatives would provide a moderate benefit to riparian and marsh habitats below Morelos Diversion Dam, which

[2] These flows were modeled as part of the storage and delivery mechanism under the Conservation Before Shortage and Reservoir Storage alternatives. The modeling assumptions were utilized in this Draft EIS in order to analyze the potential impacts to environmental resources of the storage and delivery mechanism, particularly with regard to reservoir elevations and river flow impacts. The use of these modeling assumptions does not represent any determination by Reclamation as to whether, or how, these releases could be made under current administration of the Colorado River.

would potentially benefit special status bats and the Yuma hispid cotton rat and Colorado River cotton rat in this reach.

Invertebrates. The *Atriplex* land cover type is present in this reach, which may provide habitat for MacNeill's sooty-winged skipper. Though not specifically known in this reach, the species has been documented in Yuma County, Arizona. The Basin States and Water Supply alternatives are as likely as the No Action Alternative to result in flows past Morelos Diversion Dam. The Reservoir Storage and Conservation Before Shortage alternatives are more likely to have flows past Morelos Diversion Dam. Though an overall benefit to habitat conditions, flows past Morelos Diversion Dam could scour riparian vegetation, potentially including *Atriplex*, which serves as potential habitat for MacNeill's sooty-winged skipper. Thus these alternatives would potentially have a minor negative impact on this species, despite overall benefits to the conditions in this reach.

Table 4.8-8 summarizes the impacts to special status species in the NIB to the SIB reach for the action alternatives.

Table 4.8-8
NIB to SIB Special Status Species Impact Summary
Comparison of Action Alternatives to No Action Alternatives

Location	Alternative	Impact	Rationale
Birds	Basin States and Water Supply	No Impact	Flows past Morelos Diversion Dam just as likely under the No Action Alternative.
	Reservoir Storage and Conservation Before Shortage	Moderate – positive	Flows past Morelos Diversion Dam more likely than under the No Action Alternative. Flows are rare in this reach, so increased likelihood would benefit the riparian corridor and associated special status species.
Mammals	Basin States and Water Supply	No impact	Flows past Morelos Diversion Dam just as likely under the No Action Alternative.
	Reservoir Storage and Conservation Before Shortage	Moderate-positive	Flows past Morelos Diversion Dam more likely than the No Action Alternative. Flows are rare in this reach, so increased likelihood would benefit the riparian corridor and associated special status species.
Amphibians, Plants and Fish	All Action Alternatives	No Impact	Fish occurrence is problematic due to lack of steady flows. No special status plants or amphibians are known from this reach.
MacNeill's sooty-winged skipper	Basin States and Water Supply	No impact	Flows past Morelos Diversion Dam just as likely under the No Action Alternative.
	Reservoir Storage and Conservation Before Shortage	Minor-negative	Atriplex vegetation occurs in this reach and could be impacted from scouring by increased likelihood of flow past Morelos Diversion Dam.

4.8.5 Summary

4.8.5.1 Vegetation and Wildlife

Lake Powell and Lake Mead. The Water Supply Alternative may have a minor negative impact on obligate phreatophytes, marsh and the wildlife that use such habitats because lake levels tend to be lower than under the No Action Alternative. The Reservoir Storage Alternative may have a minor positive impact on obligate phreatophytes, marsh and associated wildlife because lake levels tend to be higher than under the No Action Alternative.

Glen Canyon Dam to Lake Mead. All four action alternatives tend to have lower 10^{th} percentile releases from Glen Canyon Dam than under the No Action Alternative. These lowered releases may negatively impact obligate phreatophytes, marsh and associated wildlife below Lake Powell. The impacts are expected to be minor because though lower, they are within the range of recent history and are anticipated for the interim period only.

Hoover Dam to Davis Dam and Lake Havasu to Parker Dam. All four action alternatives would have no impact to vegetation or wildlife in these areas because there may be only small differences in Lake Mead releases and these areas are dominated by Lake Mohave and its backwater and Lake Havasu. Vegetated habitats potentially affected by flow changes between Hoover Dam and Lake Mohave are limited. Lake Mohave and Lake Havasu are operated on monthly rule curves so vegetation and wildlife effects at the lakes under the action alternatives are identical to those under the No Action Alternative.

Davis Dam to Lake Havasu. The Water Supply Alternative may have higher 10^{th} and 50^{th} percentile monthly releases from Davis Dam and this may cause a minor positive impact to obligate phreatophytes, marsh and associated and wildlife compared to the No Action Alternative. The Reservoir Storage Alternative may have lower 10^{th} and 50^{th} percentile monthly releases from Davis Dam and this may cause a minor negative impact to obligate phreatophytes, marsh and wildlife compared to the No Action Alternative. These differences remain within the range of annual fluctuation that has occurred and may occur during the interim period only.

Parker Dam to Imperial Dam. The Conservation Before Shortage, Basin States and Reservoir Storage alternatives all have lower 10^{th} and 50^{th} percentile releases and may thus have a minor negative impact on obligate phreatophytes, marsh and associated wildlife.

Imperial Dam to NIB. All of the action alternatives will have no impact to vegetation and wildlife in this reach. Flow changes in this reach will show up in the AAC rather than in the Colorado River below Imperial Dam. No impacts to vegetation or wildlife are anticipated from flow differences in the AAC.

NIB to SIB. Mexico diverts its water at Morelos Diversion Dam (at the NIB) and flows below this dam are rare. There is a higher probability of excess flows passing Morelos Diversion Dam under the Conservation Before Shortage and Reservoir Storage alternatives than under the No Action Alternative, which is expected to cause a moderate positive benefit to river flow, obligate phreatophytes, marsh and associated wildlife below Morelos Diversion Dam. These benefits were deemed moderate because flows in this reach are currently rare and any additional flow in this reach is assumed to be beneficial.

4.8.5.2 Special Status Species

Lake Powell. Lower Lake Powell elevations under the Conservation Before Shortage, Basin States and Water Supply alternatives may increase the amount of riverine habitat available at the inflow areas to Lake Powell. This may provide a minor positive benefit to Razorback sucker, bonytail, Colorado pikeminnow and flannelmouth sucker found in the lake. The higher lake levels under the Reservoir Storage Alternative may decrease the amount of riverine habitat at the inflow areas, which may not provide this benefit.

Clark's grebe that may inhabit Lake Powell could be impacted by water level changes in Lake Powell that affect marsh habitat at the inflow areas. The Reservoir Storage and Water Supply alternatives may have higher and lower lake levels respectively, which translate into a minor positive and minor negative impact respectively to Clark's grebe.

Glen Canyon Dam to Lake Mead. The Reservoir Storage and Water Supply alternatives may result in lower and higher river temperatures respectively below Glen Canyon Dam. Higher temperatures may provide a minor positive impact to humpback chub, bluehead sucker and flannelmouth sucker. However, these warmer temperatures also benefit non-native fish species, which compete with native fish. Lower temperatures may provide a minor negative impact to these native fish species. The warmer river temperatures that may occur under the Water Supply Alternative may have a minor positive impact on Leopard Frogs from reduced thermal shock. Higher 90^{th} percentile releases under the Reservoir Storage Alternative have the potential to have increased impact to beach habitat in the lower Grand Canyon, which could adversely impact Grand Canyon Evening primrose that may inhabit such beaches. All four action alternatives may have flows that could exceed the No Action Alternative and 17,000 cfs in some months, which may cause additional impact to Kanab ambersnail habitat at Vasey's paradise. The Reservoir Storage Alternative may have flows in June that could exceed the No Action Alternative and exceed 20,000 cfs, thus causing greater impact to Niobrarra ambersnail habitat. The Conservation Before Shortage, Basin States and Water Supply alternatives may have 90^{th} percentile flows that when above 20,000 cfs are equal or less than No Action Alternative, which would provide a minor positive benefit to the Niobrarra ambersnail. High flows in June under the Reservoir Storage Alternative have the greatest potential to impact quailbrush in the Grand Canyon, which could impact MacNeill's sooty winged-skipper. All four action alternatives may have a minor negative impact on the Southwestern Willow Flycatcher because 10^{th} percentile releases trend lower than No Action Alternative. These lower potential flows could adversely impact Southwestern Willow Flycatcher habitat in the Grand Canyon.

Lake Mead. The lower and higher Lake Mead elevations that may occur under the Water Supply and Reservoir Storage Alternatives, respectively, could cause minor negative and minor positive impacts, respectively, to special status bird species. Bird impacts may be caused by increased or decreased potential for dewatering of riparian habitats and headcutting at the Lake Mead inflow areas. Higher lake levels under the Reservoir Storage Alternative may inundate additional shoreline habitat for the sticky buckwheat, Geyer's milkvetch and Las Vegas Bearpoppy and be a minor negative impact. Lower Lake Mead water levels under the Water Supply Alternative may expose additional shoreline habitat for these plants and be a minor positive impact. These impacts were deemed minor because all habitats below the full-pool elevation of Lake Mead are subject to periodic inundation and exposure as the lake fluctuates in the future. The Reservoir Storage and Water Supply alternatives may have both minor positive and negative impacts to special status fish species. This may occur because the amount of riverine habitat for these species at the inflow areas are more and less than under the No Action Alternative at the 10^{th} and 50^{th} percentile levels, respectively. The Reservoir Storage Alternative may result in water levels over elevation 1,120 feet msl 50 percent of the time, which may benefit special status fish spawning in the lake.

Hoover Dam to Davis Dam and Lake Havasu to Parker Dam. There is no substantial difference between any of the alternatives in this reach. Accordingly, there will be no special status species impacts here.

Davis Dam to Lake Havasu. Lower monthly releases from Davis Dam under the Reservoir Storage Alternative may have a minor negative impact on obligate phreatophytes, marsh and the associated special status bird species. Impacts to these species may occur through adverse effects to their habitats from reduced dam releases. Razorback sucker, flannelmouth sucker and bonytail may experience a minor negative impact because lower potential releases could have adverse impacts to riverine spawning habitat and backwater rearing habitats that these species utilize. Higher monthly releases from Davis Dam under the Water Supply Alternative may have a minor positive impact on obligate phreatophytes, marsh and the associated special status bird species. Razorback sucker, flannelmouth sucker and bonytail may also benefit from these higher flows because there is a reduced likelihood that spawning and rearing habitats may be adversely impacted from flow-related effects.

Parker Dam to Imperial Dam. Lower monthly flows under the Conservation Before Shortage, Basin States and Reservoir Storage alternatives may have minor negative impacts to the habitats of the special status bird species. Obligate phreatophytes, marsh and the associated special status bird species would be negatively impacted by lower releases. Razorback sucker and bonytail chub may be negatively impacted by lower flows under the Conservation Before Shortage, Basin States and Reservoir Storage alternatives. Lower flows may negatively impact spawning and rearing habitats for these species.

Imperial Dam to NIB. The No Action Alternative and the action alternatives will have no impact to special status species in this reach. Flow changes in this reach will show up in the AAC rather than in the Colorado River below Imperial Dam. No impacts to special status species are anticipated from flow differences in the AAC.

NIB to SIB. Flows past Morelos Diversion Dam are more probable under the Reservoir Storage and Conservation Before Shortage alternatives. The increased probability of flows may have a moderate positive impact on the special status bird species through positive impacts to riparian and marsh habitats these species utilize. These higher probabilities of flows may also positively impact the special status bat species listed in Section 4.8.3.7, the Yuma hispid cotton rat and the Colorado River cotton rat through positive impacts to their riparian and marsh habitats. Though these flows are an overall benefit to the riparian corridor below the NIB, the increased probability of high flows could increase the likelihood of scouring *Atriplex* vegetation in this reach, which would be a minor impact.

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4.9 Cultural Resources

This section describes the methods used in the analysis and potential effects to cultural resources, including historic properties, Indian sacred sites, and issues of Tribal concern as a result of implementing the alternatives developed under the proposed federal action.

4.9.1 Methodology

This section provides a general analysis that considers how cultural sites might be exposed and affected by implementation of the proposed federal action. However, the specifics about current integrity of the submerged sites and the impacts that might occur to these sites once they are exposed are mostly unknown. Because of this, Reclamation and the NPS will work together to develop an agreement (acceptable to the consulting parties) that implements an appropriate strategy to identify, analyze, and address potential effects to cultural sites as they are exposed in the future as a consequence of implementing the proposed federal action.

For Lake Powell, the 10th percentile was selected as the basis for effect determination because it represents the "worst case" that still has a reasonable probability of occurring. At Lake Mead, elevation 1,080 feet msl was selected as the basis for effect determination.[1] Processes that might result in a loss of integrity vary by reach and property type; consequently, methods of assessing effects differ by reach.

4.9.2 Lake Powell and Glen Canyon Dam

4.9.2.1 No Action Alternative

For the No Action Alternative, the lowest projected elevation of Lake Powell under the 10th percentile modeled Lake Powell elevations would be 3,540 feet msl (Appendix P, Figure P-7). Some 193 unexcavated archaeological sites are at or above this elevation.

4.9.2.2 Basin States Alternative and Conservation Before Shortage Alternatives

For the Basin States and Conservation Before Shortage alternatives, the lowest projected elevation of Lake Powell under the 10th percentile modeled Lake Powell elevations is projected to be 3,550 feet msl. Some 190 unexcavated archaeological sites are at or above this elevation and would therefore be subject to erosion or visitor impacts. This is essentially the same effect as under the No Action Alternative.

[1] Elevation 1,083 feet msl is the lowest elevation historically observed since Lake Mead filled

4.9.2.3 Water Supply Alternative

For the Water Supply Alternative, the lowest projected elevation of Lake Powell under the 10th percentile modeled Lake Powell elevations is projected to be 3,505 feet msl. Some 222 unexcavated archaeological sites are at or above this Lake Powell elevation and would therefore be subject to erosion or visitor impacts. This is a greater number of affected sites than under the No Action Alternative.

4.9.2.4 Reservoir Storage Alternative

For the Reservoir Storage Alternative, the lowest projected elevation of Lake Powell under the 10th percentile modeled Lake Powell elevations is projected to be 3,540 feet msl. Some 193 unexcavated archaeological sites are at or above this elevation and would therefore be subject to erosion or visitor impacts. This is essentially the same result as under the No Action Alternative.

4.9.3 Glen Canyon Dam To Lake Mead

The Colorado River corridor between Glen Canyon Dam and Separation Canyon contains 336 NRHP-eligible properties. These are actively managed by the NPS, Navajo Nation and Hualapai Indian Tribe. In addition, Reclamation's NHPA Section 106 responsibilities for effects of Glen Canyon Dam operations are managed through a programmatic agreement. A treatment plan for mitigation of adverse impacts to historic properties is in development and will be implemented in 2008. The Grand Canyon Protection Act of 1992 ensures long-term mitigation of effects. Thus, the alternatives currently under analysis pose no additional threat to historic properties not already considered by existing programs.

4.9.4 Lake Mead and Hoover Dam

Some 32 previously recorded cultural resources are located at or below elevation 1,080 feet msl, although many more undocumented cultural resources are probably submerged in Lake Mead at or below this elevation. If these cultural resources were to emerge, additional impacts would be anticipated as a result of invasion by invasive species of plants and animals (specifically as seen at St. Thomas by tamarisk and Asiatic freshwater clams), cracking and fissuring of sediments as a result of repeated wetting and drying and freeze/thaw cycles (Wyskup 2006), and as a result of visitor impacts. Resources like the B-29 Bomber aircraft and the aggregate classification plant are currently at depths where they cannot be reached without specialized breathing-gas mixture and diving equipment, but a lowering of the reservoir elevation would bring these resources into the range of recreational scuba divers.

4.9.4.1 No Action Alternative

The probability of Lake Mead pool elevation falling below 1,080 feet msl was analyzed in Section 4.3 (Table 4.3-21). Figure 4.3-21 presents the probabilities of Lake Mead elevation falling below 1,080 feet msl over the period of analysis for all alternatives. Under the No Action Alternative, the probability begins at zero percent in 2008 and increases to 41 percent in 2060. From 2017 through 2040, the probability fluctuates between 38 percent and 44 percent.

4.9.4.2 Basin States and Conservation Before Shortage Alternatives

In 2008, the probability of the Lake Mead elevation falling below elevation 1,080 feet msl is zero under these alternatives. In years 2017 through 2040, the probability is slightly lower than under the No Action Alternative for several years and ranges between 36 percent and 47 percent. Given these small differences compared to the No Action Alternative, the differential effect on cultural resources would be negligible.

4.9.4.3 Water Supply Alternative

In 2008, the probability of the Lake Mead elevation falling below elevation 1,080 feet msl is zero. From 2017 through 2040, the probability fluctuates between 39 percent and 51 percent, a relative difference of about one to seven percent under the Water Supply Alternative compared to the No Action Alternative. Consequently, there is a higher probability that cultural resources submerged at or below elevation 1,080 feet msl would emerge under the Water Supply Alternative.

4.9.4.4 Reservoir Storage Alternative

In 2008, the probability of the Lake Mead elevation falling below elevation 1,080 feet msl is zero. The probability of the Lake Mead elevation falling below elevation 1,080 feet msl is substantially lower (one percent to 23 percent) under this alternative compared to the No Action Alternative. Consequently, there is a lower probability that cultural resources submerged at or below elevation 1,080 feet msl would emerge under the Reservoir Storage Alternative.

4.9.5 Hoover Dam to Davis Dam

Under all alternatives, Lake Mohave would continue to be operated to meet monthly target elevations. Because there would be no change in reservoir operations, there is no potential for adverse effects to occur to cultural resources submerged in Lake Mohave as a result of the proposed federal action.

4.9.6 Davis Dam to Parker Dam

Geomorphic processes in lacustrine and fluvial environments differ so the Havasu Reach has been subdivided into sub-reaches for this analysis, a river reach and Lake Havasu.

4.9.6.1 Davis Dam to Upper Lake Havasu.

There are 10 previously recorded cultural resources located along the reach of the Colorado River from Davis Dam to the upper end of Lake Havasu. Three of these cultural resources span the Colorado River with their end-points anchored in positions well above the river surface. A lowering of the elevation of the river in the area of these sites would have no direct or indirect effect on these resources. Examination of the site forms and map plots for two other previously recorded cultural resources (both segments of railroads) indicate these sites are located in elevated positions back from the riverbank. No direct or indirect effects to these resources are anticipated as a result of the proposed federal action due to their elevated locations.

Of the five additional cultural resources in this reach, only two would be directly affected by a drop in river elevation. These two sites represent the remnants of two bridges used by contractors during the construction of Davis Dam.

Although the proposed federal action may result in reductions in the annual volume released from Davis Dam and the corresponding mean daily releases, the hourly releases will continue to fluctuate between the historical minimum and maximum ranges due to operational considerations and constraints. The corresponding river flows and associated elevations would also continue to fluctuate between the historical minimum and maximum ranges and therefore it is unlikely there would be any changes in depositional or erosional processes along tributary streams or washes, or the Colorado River itself. Furthermore, it is highly unlikely that daily or hourly changes in elevation would result in conditions that would allow for more ready access to cultural resources located immediately adjacent to or in the river.

4.9.6.2 Lake Havasu and Parker Dam.

Under the alternatives, Lake Havasu will continue to be operated to meet monthly target elevations. Because there will be no change in the manner in which the reservoir has been operated historically, there is no potential for effects to occur to cultural resources submerged in Lake Havasu.

4.9.7 Parker Dam to Imperial Dam

The IA FEIS identified several cultural resource sites within or proximal to the Parker Dam to Imperial Dam reach. However, most of the historic resources that may be present in the APE, as suggested from plats and site records, have been destroyed by meandering and relocation of the mainstream channel of the Colorado River and agricultural development. Further, the proposed federal action will have no effect on Parker Dam, Imperial Dam or the Old Parker Road.

Although the proposed federal action may result in reductions in the annual volume released from Parker Dam and the corresponding mean daily releases, the hourly releases will continue to fluctuate between the historical ranges due to operational considerations and constraints. The corresponding river flows and associated elevations would also continue to fluctuate between the historical minimum and maximum ranges and therefore it is unlikely there would be any changes in depositional or erosional processes along tributary streams or washes, or the Colorado River. Eleven of the twelve sites located proximate to the APE are situated in locations above the river channel, its connected lakes and backwaters, and floodplain. The anticipated changes in elevations would therefore not impact these sites. Also, the prehistoric habitation site listed on the National Register would not be directly impacted by a drop in river elevation. It is conceivable that it could be indirectly impacted by better accessibility if the river drops in elevation more frequently or for longer periods of time. The probability of this occurring is small and would be countered by the emergence of impenetrable vegetation behind the retreating water line. Furthermore, it is highly unlikely that daily or hourly changes in elevation would result in conditions that would allow for more ready access to cultural resources located immediately adjacent to or in the river.

4.9.8 Sacred Sites and Other Issues of Tribal Concern

As a result of prior government-to-government consultations, several tribes had identified Indian sacred sites located on federal lands within the affected environment. During consultations regarding this proposed federal action, the Hualapai Indian Tribe was the only tribe who specifically raised a concern regarding how the alternatives might adversely affect the physical integrity of sacred sites. The Hualapai Indian Tribe also raised concerns regarding biological resources located in the Grand Canyon and on Hualapai Tribal land.

Reclamation, the NPS, and the FWS (federal agencies who manage lands within the affected environment) remain committed to accommodating access to and ceremonial use of Indian sacred sites by Indian religious practitioners. The agencies also remain committed to avoiding any adverse effects to the physical integrity of such sites in compliance with Exec. Order No. 13007. None of the alternatives are believed to adversely affect any identified Indian sacred site or alter access to such a site.

During consultation for this proposed federal action, several tribes expressed concern that the alternatives might result in inadvertent discoveries of Native American human remains or cultural items as defined under the Native American Graves Protection and Repatriation Act of 1990 (NAGPRA). Reclamation and the federal land-managing agencies remain committed to compliance with both the inadvertent discovery and museum inventory sections of this law and its implementing regulations.

With respect to museum inventories from the original Glen Canyon archaeological project, Reclamation is working on cultural affiliation determinations on behalf of tribes seeking repatriation of inventory items from the Glen Canyon archaeological project.

4.9.9 Summary

For Lake Powell, under the Water Supply Alternative at the 10^{th} percentile, there are at least 222 unexcavated sites subject to effect, as compared to about 193 sites under the other alternatives. Consultation is underway regarding eligibility and effect.

For the reach from Glen Canyon to Lake Mead, the alternatives pose no additional threat to cultural resources because of the programs already underway.

For Lake Mead, there are at least 32 cultural resources located below elevation 1,080 feet msl. The probability of exposing sites below this elevation vary by alternative, with the Reservoir Storage Alternative having the lowest probability (up to 23 percent lower compared to the No Action Alternative) and the Water Supply Alternative having the highest probability (up to seven percent higher compared to the No Action Alternative). The Basin States and Conservation Before Shortage alternatives have probabilities similar to those of the No Action Alternative.

For reaches below Lake Mead, no adverse effects are anticipated from any of the alternatives. However, consultation regarding eligibility and effect will be undertaken.

For Indian sacred sites and other issues of Tribal concern (not including ITAs), none of the alternatives are expected to restrict access or result in loss of physical integrity to sacred sites. Consultations with Indian tribes are ongoing with respect to these issues and other issues and concerns.

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4.10 Indian Trust Assets

4.10.1 Water Rights and Trust Lands

No vested water right of any kind, quantified or unquantified, including federally reserved Indian rights to Colorado River water, rights pursuant to the Consolidated Decree or Congressionally-approved water right settlements utilizing CAP water, will be altered as a result of any of the alternatives under consideration.

To the extent that additional Tribal water rights are developed, established or quantified during the interim period of the proposed federal action, the United States will manage Colorado River facilities to deliver water consistent with such additional water rights, if any, pursuant to federal law. Thus, modifications to system operation, in accordance with pertinent legal requirements, will be considered as Tribal water rights and will be exercised in accordance with applicable law.

Water deliveries to the Fort Mojave, Chemehuevi, CRIT, and Fort Yuma Indian Reservations will not be affected by the proposed federal action due to their early priority dates. For the Cocopah Indian Reservation, its 1915 and 1917 PPRs would also not be affected. However, the 1974 priority date of 2,026 afy of the Cocopah Indian Reservation may be reduced during certain shortage conditions, as summarized in the Water Delivery Section 4.4. Similarly, the CAP Settlement tribes, with their post-1968 CAP Priority, would also be subject to shortages. However, even when water deliveries are reduced to these Indian Reservations, the underlying water right would not be affected.

Water delivery reductions may result in fallowing of some Indian lands; however, these changes in land-use are expected to be temporary and no permanent changes in land-use would occur. In terms of effects to the shorelines of reservations, the fluctuations that might occur as a result of this action downstream of Lake Mead are within historic levels.

For the No Action Alternative under the 10^{th} and 50^{th} percentiles, monthly releases from Glen Canyon Dam would range from approximately 9,000 to 14,000 cfs past the Navajo and Hualapai Indian Reservation boundaries. Under the action alternatives, flows would occasionally be reduced by approximately 700 to 2,000 cfs. These slight reductions in flow and concomitant sediment transport differences would not affect Indian trust lands.

4.10.2 Hydroelectric Power Generation and Distribution

As described in Section 4.11, the energy generated at Headgate Rock Powerplant under the Basin States, Conservation Before Shortage, and Reservoir Storage alternatives could potentially be less than under the No Action Alternative. These reductions in energy generated range from 1.3 percent to 2.5 percent. However, Reclamation has determined that the water appropriated to non-CRIT entities that flows through Headgate Rock Dam and generates electricity is not an ITA.

4.10.3 Cultural Resources

As discussed in the Cultural Resources section (Section 4.9), Reclamation is currently in the process of identifying cultural resources and evaluating potential effects. However, based on what is currently known of Hualapai Indian Tribe historic and traditional cultural properties, there would be no effect on cultural resources of concern to the tribe. Furthermore, under Exec. Order No. 13007, there will be no change in access to Hualapai Indian Tribe or other Indian tribe sacred sites as a result of the proposed federal action.

4.10.4 Biological Resources

While not necessarily ITAs, the Navajo Nation and Hualapai Indian Tribe have expressed concern over biological resources located on their reservations and in the intervening Grand Canyon. As discussed in the Biological Resources Section (Section 4.8), the action alternatives would result in occasional reductions of approximately 700 to 2,000 cfs past the Navajo Nation and the Hualapai Indian Reservations, compared with the No Action Alternative. These flows would have some potential to impact obligate native phreatophytes such as willow (a plant of concern to many tribes); however the effects on vegetation are likely to be short-term, especially in comparison to the long-term trends favoring tamarisk expansion.

The Navajo Nation and the Hualapai Indian Tribe also expressed concern over native fish. The Hualapai Indian Tribe is particularly concerned with razorback sucker in the upper end of Lake Mead. As discussed in the Biology Resources Section, the modeling of Lake Mead elevations indicate that the minimum Lake Mead water levels under the action alternatives would be similar to those under the No Action Alternative. Therefore, the proposed federal action is expected to have either no effects or only minor effects on razorback sucker and other fish of Tribal concern.

4.10.5 Summary

After analyzing each resource, it is concluded that Tribal trust resources identified in the study area would not be adversely affected by any of the anticipated environmental impacts stemming from the proposed federal action.

4.11 Electrical Power Resources

This section analyzes the potential effects of the proposed federal action on electrical power (or hydropower) resources. The following issues are addressed:

- change in electrical power generated and the associated change in economic value;
- effect on Upper and Lower Colorado funds that pay for operation, maintenance, replacements of power facilities, and other programs supported by these funds;
- financial implications associated with implementation of surcharge;
- potential impact to ancillary services; and
- change in annual cost of electrical power for pumping water associated with the Navajo Generating Station, City of Page water supply system, SNWA water supply system, and CAP pumping load.

4.11.1 Methodology

Reclamation conducted a study of the potential effects of the action alternatives on electrical power resources of the Colorado River system that included all major facilities with the exception of generation capacity at Glen Canyon Powerplant. Western conducted a parallel analysis of the potential effects of the action alternatives only on Glen Canyon Powerplant (Appendix O). The two studies show very similar trends among the alternatives and the relative findings of each study are comparable. Western's analytical methodology includes a more detailed hourly analysis of capacity of the Glen Canyon Powerplant because of operational limitations of hydropower facilities resulting from the 1996 Glen Canyon Dam ROD. The results of Reclamation's analysis are used throughout this section with the exception of the analysis of generation capacity and the economic value of generation capacity of the Glen Canyon Powerplant, which uses the results of the hourly analysis conducted by Western.

4.11.1.1 Electrical Energy Generated

The basis for the electrical power analysis is the CRSS model described in Section 4.2 and Appendix A. Among other variables, the model simulates monthly turbine release (af) and end-of-month (EOM) reservoir elevation (feet above msl) and calculates monthly generation (MWh) and monthly capacity (MW). The monthly generation data were then aggregated to produce estimates of annual generation. Using the resulting annual data, the mean, median, 90^{th} percentile, and 10^{th} percentile annual energy generation statistics were calculated for each year for Glen Canyon, Hoover, Davis, and Parker Powerplants.

Since the elevation behind Headgate Rock Dam is maintained at a relatively constant elevation, electrical power generation at the Headgate Rock Powerplant was calculated based on modeling changes in river flows provided by the CRSS model for the No Action Alternative and action alternatives. The modeled flows available to pass through the

Headgate Rock Powerplant were first reduced by a 5.96 percent factor to account for water that is likely to be bypassed through the river gates. This factor was derived from actual data from 2001 through 2005. Energy was then calculated using a conversion factor of 12.97 kWh /af, derived by averaging the monthly kWh/af values for the Headgate Rock Powerplant from 1996 through 1998.

In general, mean values provide an assessment of the overall impact to hydropower. The mean is the average of all modeled traces, which includes all hydrologic extremes, while the median is the midpoint of all values. Mean energy values higher than median values reflect water released from Glen Canyon Dam for equalization and the existence of the minimum objective release. Mean energy values lower than median values at the Hoover Powerplant are likely due to extreme dry conditions when the Hoover Powerplant may not be generating power.

4.11.1.2 Generation Capacity

Using the capacity relationships for each powerplant, their respective monthly availability factors and the monthly forebay elevations simulated by the CRSS model, the monthly capacity for each powerplant was computed. The mean, median, 90^{th} percentile and 10^{th} percentile capacity values were then computed for the No Action Alternative and the action alternatives for the Hoover, Davis, and Parker Powerplants. For the Glen Canyon Powerplant, the analysis was conducted by Western (Appendix O) and only the mean, median, and 10^{th} percentile values are presented. The 90^{th} percentile values were not calculated for the Glen Canyon Powerplant because at this level there is no substantial difference among the alternatives. Capacity was not calculated for Headgate Rock Powerplant because no changes in capacity are anticipated.

4.11.1.3 Economic Values

The economic value of operating an existing hydroelectric powerplant varies considerably with time of day. The cost of meeting demand varies on a second-by-second basis depending on the load, the mix of powerplants being operated to meet load, and their output levels. During off-peak periods, demand is typically satisfied with lower-cost coal, run-of-river hydropower, and nuclear units. During on-peak periods, the additional load is met with more expensive sources such as gas turbine units. Consequently, the economic value of hydropower is greatest during the hours when the demand for electricity, and the variable cost of meeting demand, is the highest.

The electrical energy prices used in this analysis were developed from both an hourly price forecast keyed to the Palo Verde Interchange and mean monthly reported price indices for the Palo Verde Interchange obtained from Dow Jones, Inc. The hourly forecast of 2004 electricity prices at the Palo Verde Interchange was developed using the AURORA model (Electric Power Information Solutions, Inc. 2005).

AURORA model simulations used in this analysis were developed for and used in the Northwest Power and Conservation Council's (NWPCC) Fifth Northwest Electric Power and Conservation Plan (NWPCC 2005). The NWPCC is primarily interested in Northwestern electricity markets. Relatively less attention is devoted to characterizing market conditions in other areas. Consequently, the forecast described in this analysis primarily reflects the default data supplied with the AURORA model.

For purposes of this analysis, the hourly prices developed using the AURORA model were scaled to match the mean monthly reported prices purchased from Dow Jones, Inc. The resulting (scaled) hourly prices exhibit the expected daily, weekly and monthly patterns of price behavior and reflect the mean values actually observed in each month.

The underlying hourly prices yielded by this process are for 2004. These prices were escalated by 2.2 percent per year to estimate 2008 prices. For this analysis, estimation of the economic value for the No Action Alternative and each of the action alternatives were analyzed using monthly generation data simulated by the CRSS model as described previously. The value of the monthly generation was then analyzed using the escalated mean price of electricity for that month. The monthly economic value was then aggregated to produce estimates of annual economic value.

The costs and benefits associated with electrical power generation are incurred at different times over a long period of time. Because the timing of these costs and benefits differ across the alternatives, the present value of the future stream of costs and benefits for each alternative was computed as a means of assessing the economic value of electrical power for each alternative.

All economic value estimates reported in this Draft EIS are measured in present value 2008 dollars (PV 2008 $). All annual costs and benefits subsequent to 2008 were escalated at 2.2 percent per year and discounted back to the 2008 base year using a discount rate of 4.875 percent.

Similar to the process used in the economic analysis of electrical energy generation, the present value of generation capacity was analyzed. In this instance, the capacity was valued at $6.32/kW-month based upon the alternative market cost of capacity.

For Glen Canyon Powerplant, the economic value of electrical energy generated was derived from Reclamation's analysis, whereas the value of generation capacity was derived from Western's analysis.

4.11.2 Electrical Power Generation Facilities

4.11.2.1 Glen Canyon Powerplant

No Action Alternative. The No Action Alternative values for annual energy generation, monthly generation capacity, and economic value at Glen Canyon Powerplant for the mean, median, 90th percentile, and 10th percentile values are presented in Table 4.11-1.

Table 4.11-1
No Action Alternative Values at Glen Canyon Powerplant

Measure	Mean	Median	90th Percentile	10th Percentile
Annual Energy Generation (MWh)	4,265,749	3,795,040	6,315,161	3,197,806
Monthly Capacity (MW)	603	546	Not available	455
Economic Value of Electrical Power Generation - Total (PV 2008 $ millions)	6,808	6,823	Not available	5,881

Comparison of Action Alternatives to No Action Alternative. Table 4.11.2 shows the change in annual electrical energy generation for each alternative in MWh in comparison to the No Action Alternative, for the mean, median, 90th percentile and 10th percentile values.

Table 4.11-2
Change in Glen Canyon Powerplant Annual Energy Generation (MWh)

Alternatives	Mean	Median	90th Percentile	10th Percentile
Basin States	(10,516)	24,121	(39,058)	(68,219)
Conservation before Shortage	(9,093)	24,121	(37,368)	(64,149)
Water Supply	(95,799)	6,768	(67,401)	(219,755)
Reservoir Storage	26,668	23,265	55,966	(24,324)

Table 4.11-3 shows the percent change in annual energy generation for each alternative, in comparison to the No Action alternative, for each hydrologic level.

Table 4.11-3
Percent Change in Glen Canyon Powerplant Annual Generation

Alternatives	Mean	Median	90th Percentile	10th Percentile
Basin States	(0.25)	0.64	(0.62)	(2.1)
Conservation before Shortage	(0.21)	0.64	(0.59)	(2.0)
Water Supply	(2.2)	0.18	(1.1)	(6.9)
Reservoir Storage	0.63	0.61	0.89	(0.76)

Figure 4.11-1
Glen Canyon Powerplant
Average Values of Annual Electrical Energy Production

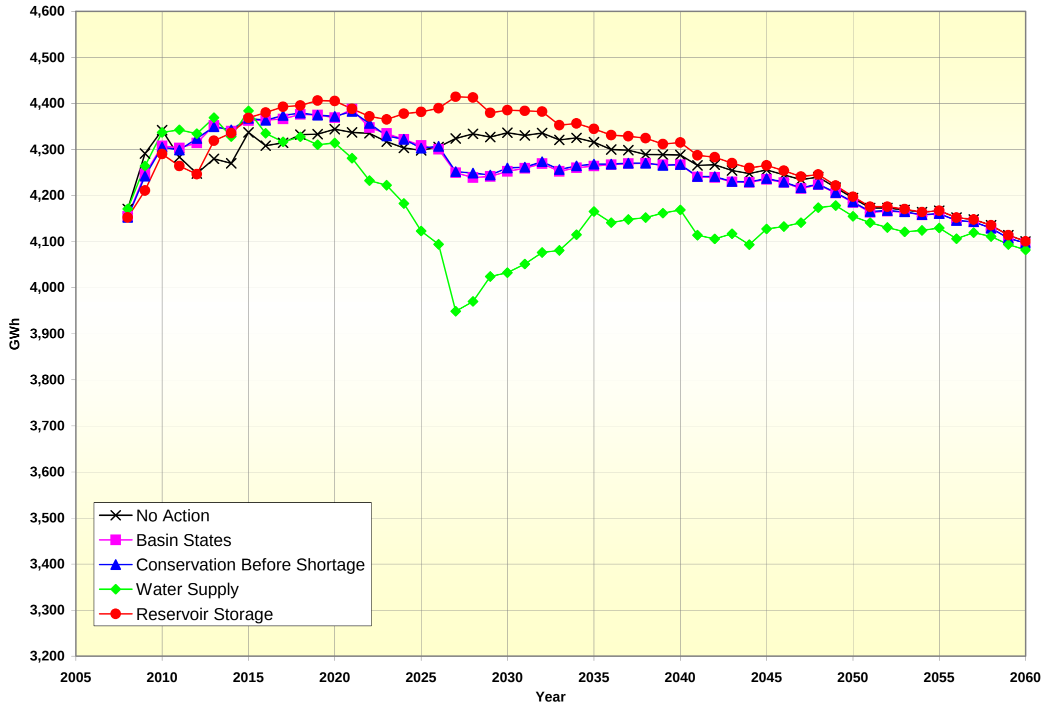


Figure 4.11-1 shows average values of annual electrical energy production for the Glen Canyon Powerplant, over the period of study, for each alternative, including the No Action Alternative. Differences in mean generation values between the No Action Alternative and the action alternatives are the greatest from 2020 through 2050.

As noted above, Western conducted a complementary study of energy generation and associated economic value using an hourly time step to simulate hourly Glen Canyon Powerplant generation levels. Western's model was used to determine the hourly operation schedule that maximized the economic value of the hydropower resource. Hourly pricing data, inflation and discount rates used in Western's study were the same as those used by Reclamation.

The Western study also included an analysis of the impacts to generation capacity at Glen Canyon Powerplant. Table 4.11-4 shows the change in generation capacity for each alternative, as compared to the No Action Alternative, for the mean, median, and 10^{th} percentile hydrologic levels. The corresponding percentage changes are identified in Table 4.11-5.

Table 4.11-4
Change in Glen Canyon Powerplant Generation Capacity

Alternatives	Change in Capacity (Megawatts)		
	Mean	Median	10th Percentile
Basin States	3.44	6.18	(12.67)
Conservation Before Shortage	3.63	6.20	(11.45)
Water Supply	(11.21)	4.08	(30.11)
Reservoir Storage	9.59	2.85	(2.48)

Table 4.11-5
Change in Glen Canyon Powerplant Generation Capacity (Percent)

Alternatives	Change in Generation Capacity		
	Mean	Median	10th Percentile
Basin States	0.57	1.1	(2.8)
Conservation Before Shortage	0.60	1.1	(2.5)
Water Supply	(1.9)	0.75	(6.6)
Reservoir Storage	1.6	0.52	(0.55)

Table 4.11-6 shows the change in total economic value of electrical power generation for each alternative, as compared to the No Action Alternative, for the mean, median and 10th percentile values. Table 4.11-7 shows the corresponding percentage change in net present value for each alternative as compared to the No Action Alternative for the same hydrologic levels.

Table 4.11-6
Change in Glen Canyon Powerplant Total Economic Value of Electrical Power Generation (PV 2008 $ million)

Alternatives	Mean	Median	10th Percentile
Basin States	(4.72)	59.52	(129.49)
Conservation Before Shortage	(2.79)	61.10	(135.88)
Water Supply	(139.27)	36.04	(427.83)
Reservoir Storage	62.43	63.06	42.86

Table 4.11-7
Change in Glen Canyon Powerplant Total Economic Value of Electrical Power Generation (Percent)

Alternatives	Mean	Median	10th Percentile
Basin States	(0.07)	0.87	(2.20)
Conservation Before Shortage	(0.04)	0.90	(2.31)
Water Supply	(2.05)	0.53	(7.27)
Reservoir Storage	0.92	0.92	0.73

Under all the action alternatives, the greatest impact to power would occur in the dry years. The Reservoir Storage Alternative provides an increased electrical power generation value, a result of higher reservoir elevations, while the other action alternatives show generally decreased electrical power generation values.

4.11.2.2 Hoover Powerplant

No Action Alternative. The No Action Alternative values for annual energy generation, monthly generation capacity, and economic value at Hoover Powerplant for the mean, median, 90th percentile and 10th percentile values are presented in Table 4.11-8.

Table 4.11-8
No Action Alternative Values at Hoover Powerplant

Measure	Mean	Median	90th Percentile	10th Percentile[1]
Annual Energy Generation (MWh)	3,156,820	3,680,235	5,233,791	0.0
Monthly Capacity (MW)	1,201	1,428	2,067	0.0
Economic Value of Electrical Power Generation - Total (PV 2008 $ millions)	7,351	8,472	10,503	3,592

1 The 10th percentile value for capacity and energy is zero on cumulative distribution function graphs of end-of-December capacity and energy, a result of Lake Mead elevation being less than 1,050 feet msl (the assumed minimum power head). This result cascades in calculating total generation and percentage changes in Tables 4.11-9 through 4.11-14.

Comparison of Action Alternatives to No Action Alternative. Table 4.11-9 presents the change in annual electrical energy generation for each action alternative, in comparison to the No Action Alternative, for the mean, median, 90th percentile and 10th percentile values.

Table 4.11-9
Change in Hoover Powerplant Annual Electrical Energy Generation (MWh)

Alternatives	Mean	Median	90th Percentile	10th Percentile
Basin States	14,369	(29,186)	(15,301)	0.0
Conservation Before Shortage	18,570	(35,081)	(1,313)	0.0
Water Supply	(48,281)	(19,062)	(66,444)	0.0
Reservoir Storage	274,019	(29,970)	56,864	0.0

Table 4.11-10 presents the percent change in annual electrical energy generation for each action alternative, in comparison to the No Action Alternative, for the mean, median, 90th percentile and 10th percentile values.

Table 4.11-10
Change in Hoover Powerplant Annual Electrical Energy Generation (Percent)

Alternatives	Mean	Median	90th Percentile	10th Percentile
Basin States	0.46	(0.79)	(0.29)	0.0
Conservation Before Shortage	0.59	(0.95)	(0.02)	0.0
Water Supply	(1.5)	(0.52)	(1.27)	0.0
Reservoir Storage	8.7	(0.81)	1.1	0.0

Figure 4.11-2 depicts average values of annual electrical energy production for the Hoover Powerplant over the period of study for each alternative, including the No Action Alternative. Differences in mean generation values between the No Action Alternative and the action alternatives are the greatest from 2020 through 2050.

Figure 4.11-2
Hoover Powerplant
Average Values of Annual Electrical Energy Production

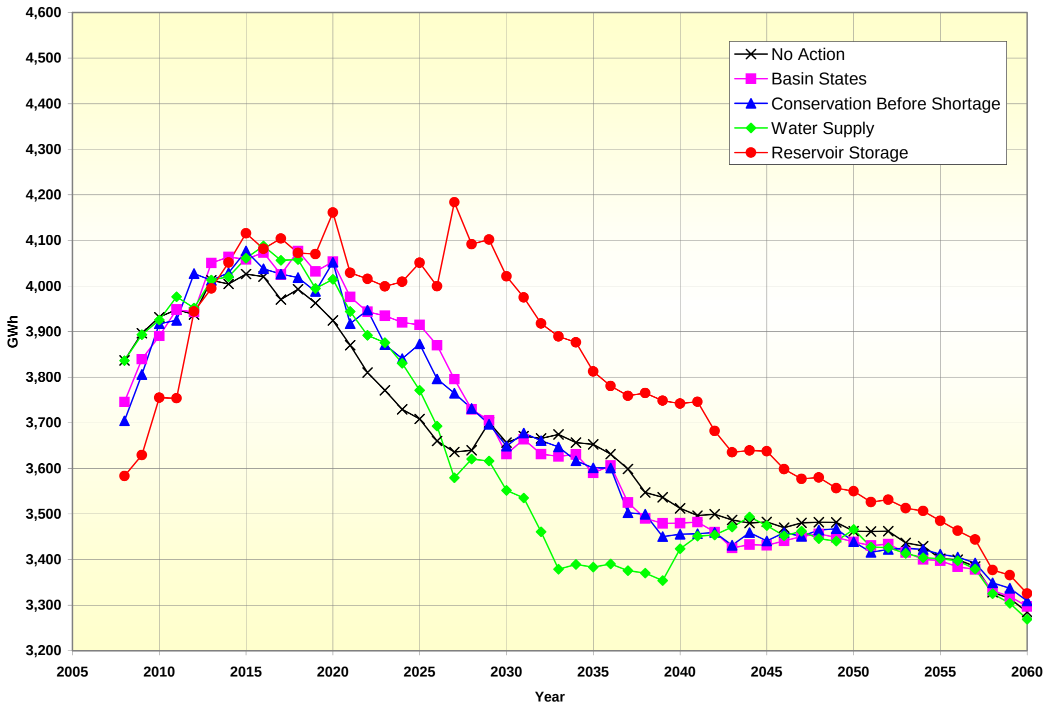


Table 4.11-11 shows the change in the Hoover Powerplant monthly generation capacity (MW) for the action alternatives compared to the No Action Alternative.

Table 4.11-11
Change in Hoover Powerplant Monthly Generation Capacity (MW)

Alternatives	Mean	Median	90th Percentile	10th Percentile
Basin States	12.7	6.1	1.4	0.0
Conservation Before Shortage	15.5	8.7	1.5	0.0
Water Supply	(22.9)	(14.5)	(2.5)	0.0
Reservoir Storage	136.0	60.4	5.8	0.0

Table 4.11-12 presents the percentage change in Hoover Powerplant monthly capacity for each of the action alternatives as compared to the No Action Alternative.

Table 4.11-12
Change in Hoover Powerplant Monthly Generation Capacity (Percent)

Alternatives	Mean	Median	90th Percentile	10th Percentile
Basin States	1.1	0.43	0.06	0.0
Conservation Before Shortage	1.3	0.61	0.07	0.0
Water Supply	(1.9)	(1.0)	(0.12)	0.0
Reservoir Storage	11.3	4.2	0.28	0.0

Table 4.11-13 presents the change in each of the action alternatives as compared to the net present value of the total electrical power generation under the No Action Alternative. Table 4.11-14 presents the corresponding percentage change in net present value for each alternative as compared to the No Action Alternative for the same hydrologic levels.

Table 4.11-13
Change in Hoover Powerplant Total Economic Value of Electrical Power Generated (PV 2008 $ million)

Alternatives	Mean	Median	90th Percentile	10th Percentile
Basin States	75.39	(250.17)	(12.23)	144.33
Conservation Before Shortage	89.97	(226.51)	(5.53)	162.20
Water Supply	(88.36)	(420.49)	(41.62)	38.76
Reservoir Storage	742.48	272.25	34.90	1,417.97

Table 4.11-14
Change in Hoover Powerplant Total Economic Value of Electrical Power Generated (Percent)

Alternatives	Mean	Median	90th Percentile	10th Percentile
Basin States	1.03	(2.95)	(0.12)	4.02
Conservation Before Shortage	1.22	(2.67)	(0.05)	4.52
Water Supply	(1.2)	(4.96)	(0.40)	1.08
Reservoir Storage	10.10	3.21	0.33	39.48

In general, the Reservoir Storage Alternative provides the greatest increase in electrical power generation value at Hoover Powerplant, while the Water Supply Alternative proves most adverse to power generation. The Basin States and Conservation Before Shortage alternatives show similar results and they are ranked between the Reservoir Storage Alternative and the Water Supply Alternative in their effect on power resources at Hoover Powerplant.

4.11.2.3 Parker and Davis Powerplants

No Action Alternative. The No Action Alternative values for annual energy generation, monthly generation capacity, and total economic value for Parker and Davis Powerplants for the mean, median, 90th percentile and 10th percentile values are presented in Table 4.11-15.

Table 4.11-15
No Action Alternative Values at Parker and Davis Powerplants

Measure	Mean	Median	90th Percentile	10th Percentile
Annual Energy Generation (MWh)	1,618,736	1,559,622	1,812,884	1,483,907
Monthly Capacity (MW)	331	364	364	286
Economic Value of Electrical Power Generation - Total (PV (2008 $ millions)	2,243	2,258	2,357	2,129

Comparison of Action Alternatives to No Action Alternative. Table 4.11-16 presents the change in annual electrical energy generation in MWh for each action alternative, in comparison to the No Action Alternative, for the mean, median, 90th percentile and 10th percentile values.

Table 4.11-16
Change in Parker and Davis Powerplants Annual Electrical Energy Generation (MWh)

Alternatives	Mean	Median	9^{0th} Percentile	10th Percentile
Basin States	(9,318)	(8,328)	(3,969)	(10,010)
Conservation Before Shortage	(11,210)	(12,258)	(846)	(10,392)
Water Supply	1,593	14,085	(13,162)	2,728
Reservoir Storage	(18,252)	(24,034)	25,035	(22,156)

Table 4.11-17 presents the percent change in generation between the No Action Alternative and the action alternatives for the Parker and Davis Powerplants.

Table 4.11-17
Change in Parker and Davis Powerplants Annual Electrical Energy Generation (Percent)

Alternatives	Mean	Median	90th Percentile	10th Percentile
Basin States	(0.58)	(0.53)	(0.22)	(0.67)
Conservation Before Shortage	(0.69)	(0.79)	(0.05)	(0.70)
Water Supply	0.10	0.90	(0.73)	0.18
Reservoir Storage	(1.1)	(1.5)	1.4	(1.5)

Table 4.11-18 shows that no changes are anticipated in monthly generation capacity under the action alternatives.

Table 4.11-18
Change in Parker and Davis Powerplants Monthly Generation Capacity (MW)

Alternatives	Mean	Median	90th Percentile	10th Percentile
Basin States	0.0	0.0	0.0	0.0
Conservation Before Shortage	0.0	0.0	0.0	0.0
Water Supply	0.0	0.0	0.0	0.0
Reservoir Storage	0.0	0.0	0.0	0.0

Figure 4.11-3 and Figure 4.11-4 depict average values of annual electrical energy production for the Davis Powerplant and the Parker Powerplant, respectively, comparing the No Action Alternative and the action alternatives.

Figure 4.11-3
Davis Powerplant
Average Values of Annual Electrical Energy Production

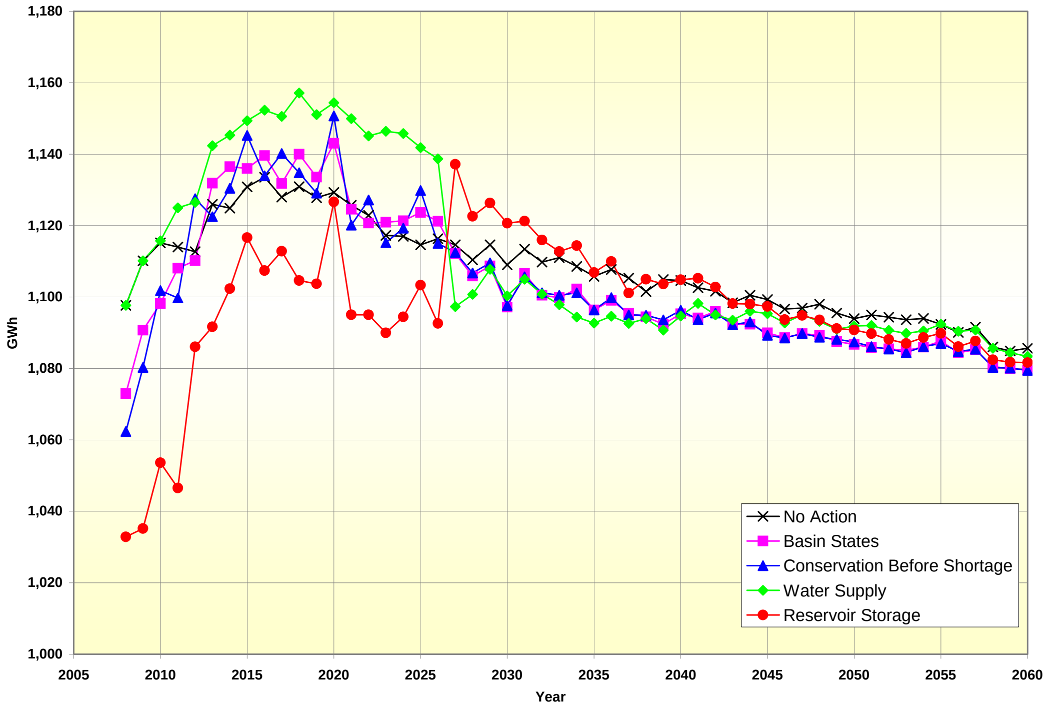
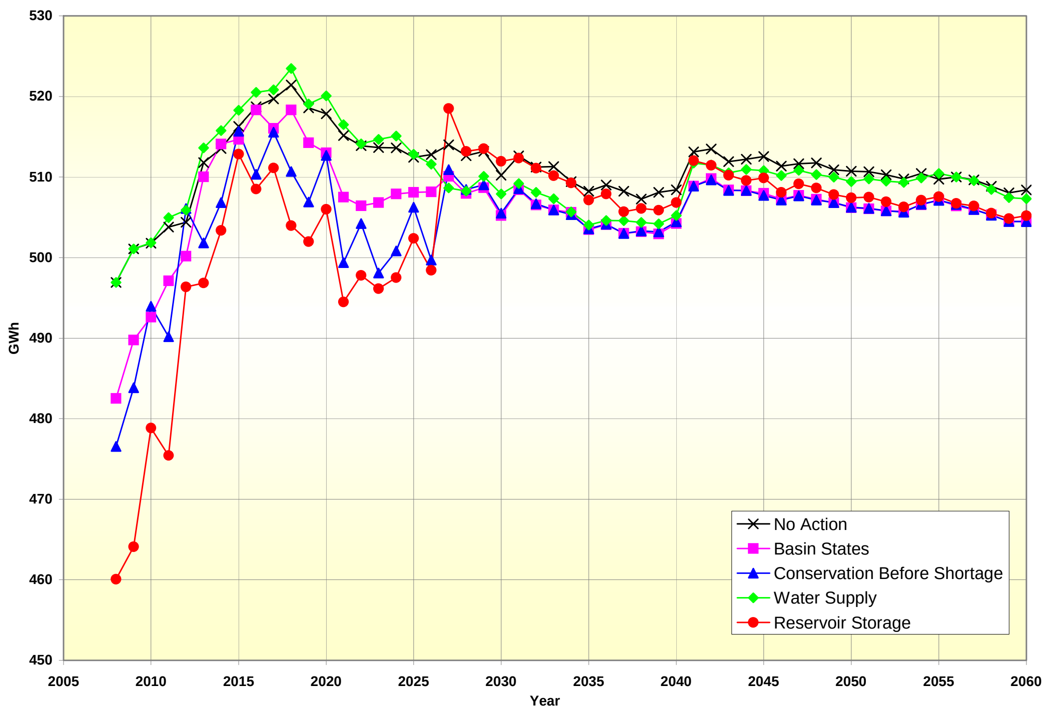


Figure 4.11-4
Parker Powerplant
Average Values of Annual Electrical Energy Production



Economic value comparisons between the No Action Alternative and the action alternatives are presented in Table 4.11-19.

Table 4.11-19
Change in Parker and Davis Powerplants Total Economic Value of Electrical Power Generation (PV 2008 $ million)

Alternatives	Mean	Median	90th Percentile	10th Percentile
Basin States	(12.39)	(11.32)	(10.17)	(12.05
Conservation Before Shortage	(16.43)	(18.14)	(11.09)	(16.26)
Water Supply	6.23	7.90	1.46	10.73
Reservoir Storage	(36.91)	(33.95)	(26.16)	(50.50)

Table 4.11-20 presents the change in economic value between the No Action Alternative and each of the action alternatives.

Table 4.11-20
Change in Parker and Davis Powerplants Total Economic Value of Electrical Power Generated (Percent)

Alternatives	Mean	Median	90th Percentile	10th Percentile
Basin States	(0.55)	(0.50)	(0.43)	(0.57)
Conservation Before Shortage	(0.73)	(0.80)	(0.47)	(0.76)
Water Supply	0.28	0.35	0.06	0.50
Reservoir Storage	(1.6)	(1.5)	(1.1)	(2.4)

In general, the Basin States and Conservation Before Shortage alternatives could potentially provide a slight decline in the economic value of electrical power generated at the Parker and Davis Powerplants. The Reservoir Storage Alternative is expected to result in a greater decline in economic values. The Water Supply Alternative results in slight increases in economic value for the Parker and Davis Powerplants.

Because of downstream requirements (i.e., environmental, plant operations and water requirements) the forebay elevations at Davis and Parker Dam Powerplants remain relatively constant and electrical power generation is proportional to inflow. Consequently, the maximum generation capacity at the Parker and Davis Powerplants will not be affected by the any of the action alternatives.

4.11.2.4 Headgate Rock Powerplant

No Action Alternative. The No Action Alternative values for annual generation and economic value at Headgate Rock Powerplant for the mean, median, 90th percentile and 10th percentile values are presented in Table 4.11-21.

Table 4.11-21
No Action Alternative Values at Headgate Rock Power Plant

Measure	Mean	Median	90th Percentile	10th Percentile
Annual Energy Generation (MWh)	77,386	73,666	85,452	69,634
Economic Value of Electrical Power Generation (PV 2008 $)	102,892,840	98,096,022	113,356,265	92,748,408

Comparison of Action Alternatives to No Action Alternative. Table 4.11-22 presents the change in annual generation for each action alternative relative to the No Action Alternative. The Water Supply Alternative provides higher median electrical energy generation due to the higher observed flows as compared to the No Action Alternative. The Basin States, Conservation Before Shortage, and Reservoir Storage alternatives provided lower electrical energy generation as compared to the No Action Alternative.

Table 4.11-22
Change in Headgate Rock Powerplant Annual Electrical Energy Generation (MWh)

Alternatives	Mean	Median	90th Percentile	10th Percentile
Basin States	(934)	(956)	(438)	(1,223)
Conservation Before Shortage	(1261)	(1,187)	(415)	(1,853)
Water Supply	(222)	161	(999)	69
Reservoir Storage	(1,366)	(2,084)	556	(2,371)

Table 4.11-23 presents the percent change in annual electrical energy generation for each action alternative relative to the No Action Alternative.

Table 4.11-23
Change in Headgate Rock Powerplant Annual Electrical Energy Generation (Percent)

Alternatives	Mean	Median	90th Percentile	10th Percentile
Basin States	(1.2)	(1.3)	(0.51)	(1.8)
Conservation Before Shortage	(1.6)	(1.6)	(0.49)	(2.7)
Water Supply	(0.29)	0.22	(1.2)	0.10
Reservoir Storage	(1.8)	(2.8)	0.65	(3.4)

Figure 4.11-5 depicts average values of annual electrical energy production for Headgate Rock Powerplant, comparing the No Action Alternative and the action alternatives.

Figure 4.11-5
Headgate Rock Powerplant
Average Values of Electrical Energy Production

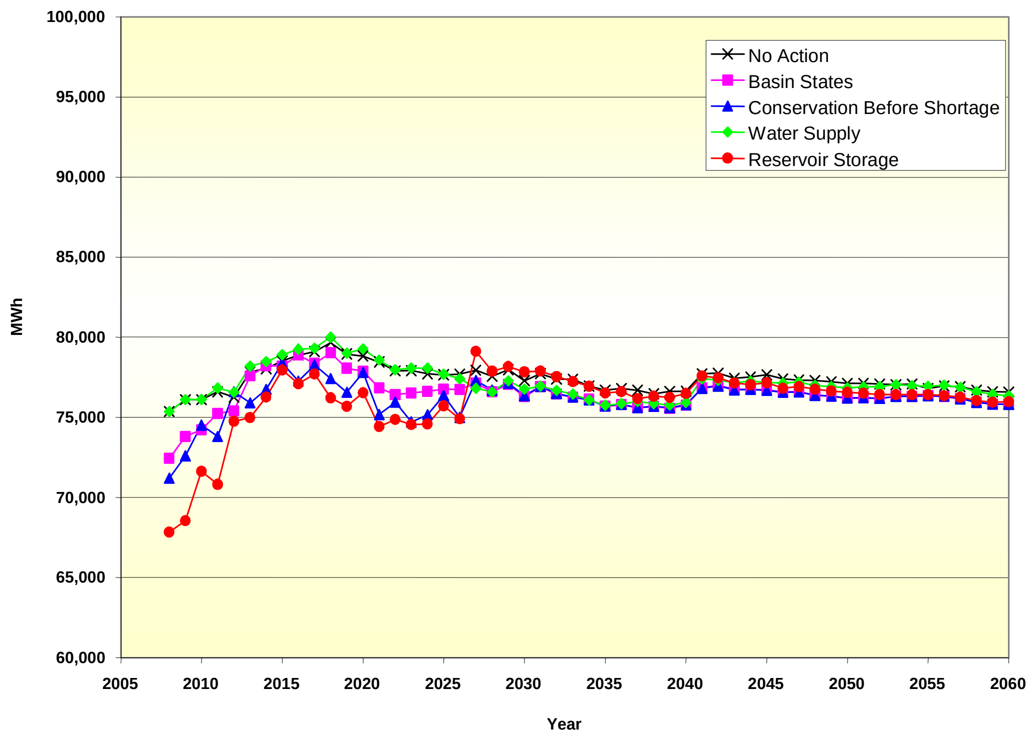


Table 4.11-24 provides an overview of the potential change in economic value of electrical power generated for each action alternative relative to the No Action Alternative.

Table 4.11-24
Change in Headgate Rock Powerplant Total Economic Value of Electrical Power Generated (PV 2008 $ million)

Alternatives	Mean	Median	90th Percentile	10th Percentile
Basin States	(1.3)	(1.4)	(0.5)	(1.9)
Conservation Before Shortage	(2.0)	(1.9)	(0.6)	(3.1)
Water Supply	(0.20)	0.26	(1.3)	0.18
Reservoir Storage	(2.6)	(3.7)	0.8	(4.3)

Table 4.11-25 provides an overview of the potential percent change in economic value of electrical power generated for each action alternative relative to the No Action Alternative.

Table 4.11-25
Change in Headgate Rock Powerplant Total Economic Value of Electrical Power Generated (Percent)

Alternatives	Mean	Median	90th Percentile	10th Percentile
Basin States	(1.3)	(1.4)	(0.44)	(2.0)
Conservation Before Shortage	(1.9)	(1.9)	(0.53)	(3.3)
Water Supply	(0.19)	0.27	(1.2)	0.20
Reservoir Storage	(2.5)	(3.8)	0.71	(4.6)

In general, the value of electrical power generated under the Water Supply Alternative could potentially be slightly higher than under the No Action Alternative. The value of electrical power generated under the Basin States, Conservation Before Shortage, and Reservoir Storage alternatives could potentially be less than under the No Action Alternative.

Currently the Headgate Rock Powerplant generates more electrical power than is needed by CRIT. Implementation of either of the action alternatives will not impact the Headgate Rock Powerplant's ability to meet CRIT's current electrical power demands. However, a reduction in Headgate Rock Powerplant generation could impact BIA's ability to meet new Tribal energy demands.

4.11.2.5 Basin Power Funds

Upper Colorado River Basin Fund. As noted in section 3.11, approximately $175 million is needed each year to fund Reclamation and Western operating needs. Western is responsible for transmission and marketing of CRSP power, collecting payment for the power, and the transfer of revenues for repayment to the General Treasury.

Implementation of the various alternatives could result in more variation in the Upper Colorado River Basin Fund (Basin Fund), and could lead to additional actions such as power rate adjustments, rate surcharges, or reductions to customer allocations to respond to shortfalls in revenue under dry conditions. Western and its power customers need to quickly respond to changing hydrological conditions to forestall possible financial problems.

In addition, if an alternative were to increase or decrease Glen Canyon Powerplant electrical power generation over an extended period of time, Western and its power customers might decide to increase or decrease allocations in response, which could, in turn, affect the rate Western charges for the power and its financial reserves in the Basin Fund. A rate increase could affect customers' generation and power purchase decisions as well as their overall financial condition.

An important aspect associated with power delivery is whether and how much one or more of the alternatives alters the probability of a total loss of generation from Glen Canyon Powerplant. Loss of Glen Canyon Powerplant generation would result in a loss of revenue to Western, Reclamation, and various environmental programs in the Upper Basin; loss of generation and replacement costs for power customers; and degradation to power system reliability.

Figure 4.11-6 shows the percentage of end-of-March elevations from Reclamation's CRSS modeling output that are less than or equal to elevation 3,490 feet msl. March typically has the lowest reservoir elevation of the year and elevation 3,490 feet msl is the point at which electrical power can no longer be produced at the Glen Canyon Powerplant. Using this measure, the Water Supply Alternative is more likely to provide conditions that would result in the Lake Powel elevation falling below the minimum power pool elevation of 3,490 feet msl, as compared to the No Action Alternative. The Reservoir Storage, Basin States, and Conservation Before Shortage alternatives have equal or slightly lower probabilities than the No Action Alternative. An analysis of end-of-July elevations indicated that these values are less pronounced than the end-of-March elevations, but similar.

Lower Colorado River Basin Development Fund. The functions of the Development Fund are to collect revenues and repayment associated with CAP, and to fund expenses related to the Colorado River Salinity Control Program and projects as directed by the Arizona Water Rights Settlements Act (P.L. 108-451).

An important aspect associated with power delivery is whether and how much one or more of the alternatives alters the probability of a total loss of generation from the Hoover Powerplant. Loss of Hoover Powerplant generation would result in a loss of revenue to Western, Reclamation and various environmental programs in the Lower Basin; loss of generation and replacement costs for power customers; and, degradation to power system reliability.

Figure 4.11-7 shows the percentage of end-of-December elevations from Reclamation's CRSS modeling output that are less than or equal to elevation 1,050 feet msl. This elevation is the point at which it is currently assumed that power can no longer be produced at the Hoover Powerplant.

Figure 4.11-6
Lake Powell End-of-March Elevations
Comparison of Action Alternatives to No Action Alternative
Percent of Values Less Than or Equal to Elevation 3,490 feet msl

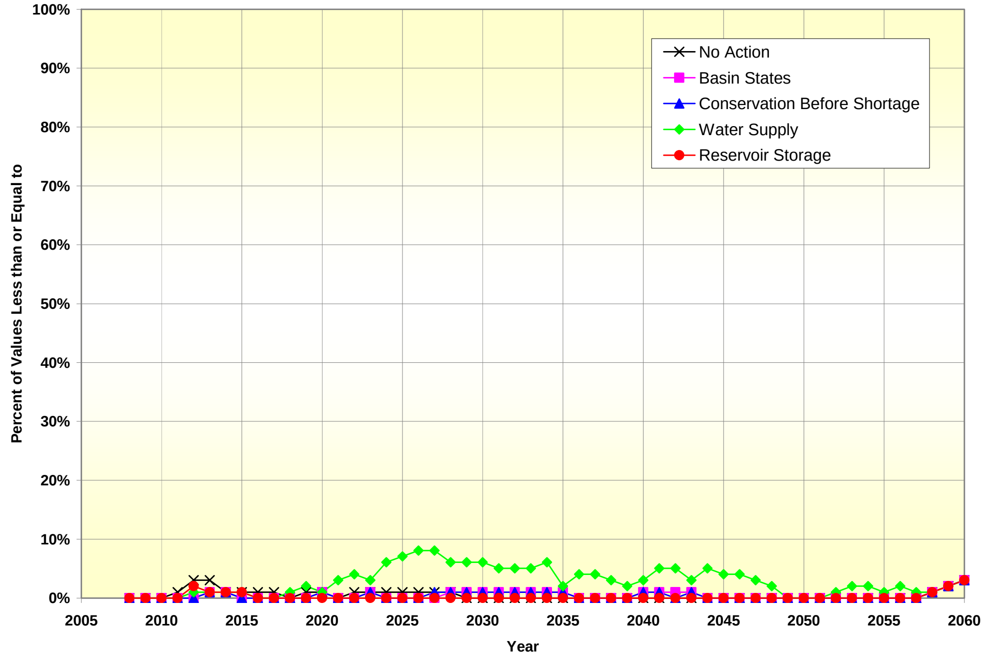
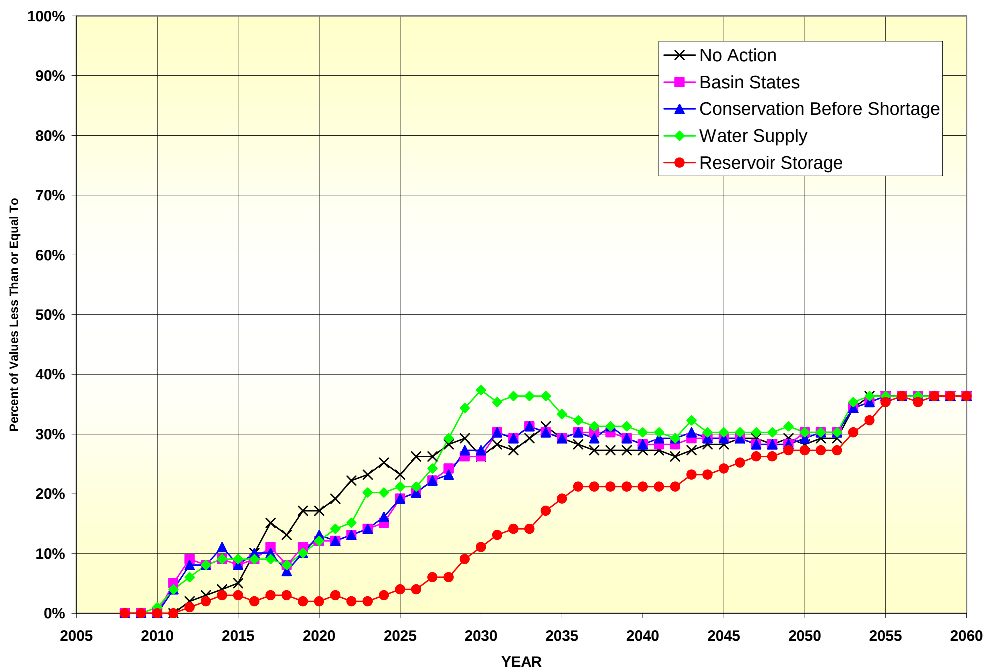


Figure 4.11-7
Lake Mead End-of-July Elevations
Comparison of Action Alternatives to No Action Alternative
Percent of Values Less Than or Equal to Elevation 1,050 feet msl



Using this measure, the Water Supply Alternative is slightly more prone to fall below the minimum power pool than the No Action Alternative, while the Basin States and Conservation Before Shortage alternatives have equal or slightly lower probabilities than the No Action Alternative. The Reservoir Storage Alternative has much lower probabilities of falling below this elevation. Values for end-of-December elevations are less pronounced, but similar.

Any of the alternatives that reduce electrical power production would reduce the surcharge revenues available to defray costs associated with the Colorado River Basin Salinity Control Act (Title II) and the CAP repayment.

Colorado River Dam Fund. The Colorado River Dam Fund (Dam Fund) is utilized to fund operation and maintenance payments to states, visitor services, up-rating program, replacements, investment repayment and interest expenses of the Boulder Canyon Project. The Annual Revenue Requirement is typically approximately $60 to $70 million per fiscal year.

Since implementation of the various alternatives could result in more variation in the Dam Fund cash reserves, this could lead to additional actions, such as power rate adjustments, or reductions to contractors allocations to respond to shortfalls in capacity, energy and revenues under dry conditions.

4.11.2.6 System-Wide Electrical Power Issues

Conservation Before Shortage Surcharge. The Conservation Before Shortage Alternative imposes a power customer surcharge that is expected to amount to between $1.5 million and $12.3 million depending on the level of a voluntary water conservation shortage implemented in a particular year (e.g. 400,000, 500,000, or 600,000 af) and the cost of conserved water. The surcharge on a 600,000 af declared shortage is to cover at a minimum the cost of 122,500 af of water. It is estimated that this would cost between $20 - $100 per af.

This surcharge is not included in the current economic analysis at any of the Upper or Lower Basin facilities or Basin Funds. Surcharges imposed are typically not included within Western's or Reclamation's electrical power rate structure. For example, the current 4.5 mil and the 2.5 mil rate imposed on Hoover Powerplant and P-DP power contractors to help repay Reclamation’s CAP project construction costs and to provide funding for salinity projects are a separate part of the contractor’s bill.

Imposing a surcharge on power revenues would require separate legislation. Rate making authority, except for Reclamation project use power, lies with Western, therefore such changes would be under the purview of the Secretary of the Department of Energy and the United States Congress.

Ancillary Service Impacts. In addition to generating electrical power, each of the power generation facilities in the study area provides other electrical products and services referred to as ancillary services. Ancillary services are those services necessary to keep the power grid functioning continuously, safely, and reliably.

Western, as an operator of multiple control areas (referred to also as balancing authorities), is required by the Federal Energy Regulatory Commission to offer ancillary services to entities purchasing transmission services in its control areas. Entities purchasing transmission are required to self supply ancillary services or purchase ancillary services from third parties. The Hoover Powerplant capacity and energy is dynamically scheduled to the contractors which allows certain ancillary services to be utilized in other control areas. The Hoover Powerplant is also a significant source of reserves, regulation and frequency control for non-Western control areas in California, Arizona, and Nevada.

Reserves. Because of low load factors at the Glen Canyon Powerplant and the Hoover Powerplant, at any given time there are hundreds of megawatts of spinning or supplemental reserves that can be called on to respond to generating unit outages and power system emergencies. The available unscheduled capacity at Davis Powerplant and Parker Powerplant is used primarily for reserves. In addition, the generation units at Davis Powerplant have a portion of their capacity that are used exclusively for reserves.

Action alternatives that reduce or eliminate capacity at the Glen Canyon Powerplant and the Hoover Powerplant will reduce or eliminate reserve capacity as well, impacting reliability of the power system, and impacting revenue to Western or specific projects. None of the proposed alternatives are expected to have a significant impact on reserves at Davis Powerplant and Parker Powerplant since the associated lake elevations are not affected. A reduction in electrical power production at these powerplants would create a slight increase in the average reserve capacity available.

Regulation and Frequency Control. Regulation and frequency control is needed to maintain power system stability and the moment-to-moment balance between load and generation. Reductions in electrical power generation from the Glen Canyon Powerplant and the Hoover Powerplant would impact the ability of the powerplants to provide regulation services. Although the generating units are able to regulate throughout most of their operating range, the amount of regulation available decreases as generating capability decreases.

The Hoover Powerplant is primarily used to provide regulation for the control area. However, the Davis Powerplant has some capability for regulation and frequency control, but the available unscheduled capacity at the Davis Powerplant is used almost exclusively for reserves.

Any of the alternatives that cause the Glen Canyon Powerplant or the Hoover Powerplant to stop generating completely due to low reservoir elevation (below the minimum power pool elevation), could potentially eliminate regulation as well. As shown on Figures 4.11-

6 and 4.11-7, the Water Supply Alternative poses the greatest risk to regulation and frequency control at the Glen Canyon and Hoover Powerplants.

Reactive Supply and Voltage Control. Reactive power is power required to "charge" the transmission lines and associated electrical equipment that comprise the power grid. Unlike other ancillary services that can assist the power system over large geographical areas, reactive supply and voltage control are limited to small areas. Glen Canyon Powerplant supplies reactive power to northern Arizona and southern Utah. For the Hoover Powerplant, that area would include northwestern Arizona, Southern Nevada and southeastern California. Without an adequate supply of reactive power and constant monitoring, power system voltages can increase or decrease beyond acceptable limits, leading to system instability, cascading outages, and damage to electrical equipment.

Black Start Capability. Black Start Service, also referred to as Startup Service consists of providing the electrical power needed to start up a generating plant, usually after a system emergency (e.g. large scale blackout) that causes loss of electricity from the generating station.

The Glen Canyon Powerplant is relied upon to provide black start capability to the power system. The Hoover Powerplant is relied upon to provide the same capability to the power system and also for Palo Verde Nuclear Generating Station located outside of Phoenix, Arizona. Similar to regulation and frequency control, the Water Supply Alternative is most prone to cause the Glen Canyon Powerplant and Hoover Powerplant to stop generating completely due to low reservoir elevation conditions. The Davis Powerplant and Parker Powerplant do not provide Black Start Service.

Contract Commitments. Western contracts with preference power customers to supply firm energy and capacity. Currently, about 243 municipalities, rural electric cooperatives, Indian tribes, irrigation districts, and state and federal facilities in Arizona, Nevada, New Mexico, Colorado, Utah, and Wyoming are served from Salt Lake City Area Integrated Project (SLCA/IP) power facilities, which includes the Glen Canyon Powerplant. The Hoover Powerplant contractors have an allocation from Western for a specific quantity of contingent capacity and associated firm energy.

At the Glen Canyon Powerplant, the current contracts went into effect in October, 2004 and extend through September, 2024. At the Hoover Powerplant, the current contracts went into effect in June, 1987 and extend through September, 2017. For the P-DP, current contracts went into effect in October, 1988 and extend through September, 2008. Western is near concluding the process of finalizing these contractual commitments through September 2028.

Each contractor has an allocation from Western for a specific quantity of energy and capacity each month. Western guarantees that the minimum quantity of energy will be available for contractors, and purchases power to meet that level whenever hydropower generation is insufficient to supply the required amount (referred to as firming purchases). Hydropower generation above the minimum level is also allocated to contractors on an as-available basis as operational and hydrological conditions allow.

As has been described earlier in this section, an alternative may increase or decrease energy generation and capacity at the Glen Canyon Powerplant or the Hoover Powerplant. Western has the ability to modify its contract commitments to its electrical power customers when a change in the volume of water released at these dams results in changes in electrical generation and capacity. For example, if an alternative reduced energy generation and capacity at the Glen Canyon Powerplant over the long-term average, Western would have the ability to lower its contract commitments to those customers who have contracts that include Glen Canyon Powerplant electrical power. The lower commitments would cause these customers (electrical utilities) to add new generating facilities, speed up planned construction of new generating facilities or take other action to make up for the reduction in Western's contract commitment. The estimated values of these actions by customers are what is portrayed in the tables in this section.

Energy and capacity allocations to contractors can be revised when the contracts are renewed. Allocations to contractors after contract terms expire will depend upon projections of future capacity and energy.

4.11.2.7 Electrical Power Use Associated with Water Supply Systems

This section discusses potential changes in pumping costs for the following entities that pump water from Lake Powell: the NGS which obtains cooling water from Lake Powell, the City of Page which obtains municipal water from Lake Powell; SNWA which obtains water from Lake Mead; and CAP and MWD which divert water from Lake Havasu. Incremental differences in pumping costs are associated with differences in modeled average Lake Powell, Lake Mead, and Lake Havasu elevations between the No Action Alternative and the action alternatives.

River system modeling provided the average elevations for Lake Powell, Lake Mead, and Lake Havasu under the No Action Alternative and the action alternatives. Increases or decreases in net effective pumping head correspond with decreases or increases in reservoir elevations. Estimates of the differences in pumping costs were calculated using these changes in pumping head, as well as estimates of annual pumping volumes, unit electrical power costs and pump efficiency.

Navajo Generating Station. The SRP estimates that water use at NGS will be approximately 29,000 afy in the future. Power for the intake pumps is obtained from auxiliary power units at the NGS at a cost of $0.0104 per kWh. Table 4.11-26 identifies changes in electrical power requirements for the alternatives and the associated increase or decrease in cost.

Table 4.11-26
Change in Navajo Generating Station Intake Electrical Power Requirements at Lake Powell [1]

Alternatives	Change in Annual Electrical Power Requirement (kWh)[2]	Change in Associated Annual Cost ($)
Basin States	124,365	$1,293
Conservation Before Shortage	114,167	$1,187
Water Supply	277,648	$2,888
Reservoir Storage	(75,925)	($790)

1. *Assumes 29,000 afy of Pumping, Cost = E (kWh) = $0.0104*
2. *E (kwh) = 1.024 * V (afy) * H (ft)/E (%)*

City of Page Water Supply. As noted in Section 3.12, the average annual water demand by the City of Page in recent years has been around 2,650 afy. Annual electrical power demand to deliver the water has averaged around 3,900,000 kWh per year over the past 10 years. Under the No Action Alternative, using the current rate of $.03286 per kWh (includes overhead), the annual cost of electrical power for pumping the water is around $130,000 per year.

Table 4.11-27 summarizes the differences in pumping costs for the Reclamation-operated raw water intake serving the City of Page. The greatest increase would be under the Water Supply Alternative which would be an average $829 per year or, in comparison to the total annual the No Action Alternative cost of $130,000, an approximate increase of less than one percent. In general the effect on City of Page pumping costs would be minor under all alternatives.

Table 4.11-27
Change in City of Page Intake Electrical Power Requirements at Lake Powell [1]

Alternatives	Change in Annual Electrical Power Requirement (kWh)[2]	Change in Associated Annual Cost ($)
Basin States	11,364	$371
Conservation Before Shortage	10,433	$341
Water Supply	25,371	$829
Reservoir Storage	(6,938)	($227)

1. *Assumes 2,650 afy of Pumping, Cost = E (kWh) = $0.03286*
2. *E (kWh) = 1.024 * V (afy) * H (ft) / E(%)*

SNWA Water Supply. Pumping costs under the No Action Alternative were not calculated. However, under the No Action Alternative, the average elevation of Lake Mead declines from 2008 through 2060. Also, the chance that lake elevations could drop below the minimum power pool elevation of 1,050 feet msl increases for all alternatives, with the Reservoir Storage Alternative resulting in the smallest increase in probability. These results also suggest that under the No Action Alternative, SNWA can expect pumping costs to increase due to the increase in net effective pumping head. The cost of pumping varies with each of the action alternatives as an increase or decrease compared to the No Action Alternative. Table 4.11-28 shows the potential differences between pumping costs under the action alternatives to those under the No Action Alternative.

Table 4.11-28
Change in Estimated SNWA Pumping Costs

Alternative	Change in Cost ($)
Basin States	(45,560.76)
Conservation Before Shortage	(68,341.14)
Water Supply	273,364.56
Reservoir Storage	(1,870,198.68)

The change in pumping costs shown in Table 4.11-28 consider the difference in the average of the 50th percentile (median) Lake Mead annual elevation values from 2008 to 2060 under each action alternative to that of the No Action Alternative. The differences in the average of the median elevations (between each action alternative and the No Action Alternative) was multiplied by the estimated annual SNWA combined pumping costs for the two SNWA intake pump stations (Levy 2006 personal communication) corresponding to the respective Lake Mead elevations. A positive number in Table 4.11-28 indicates an increase in annual SNWA pumping costs and a negative number (in parenthesis) indicates a potential savings in annual SNWA pumping costs.

CAP Pumping Load. Under all alternatives, when shortages are imposed on CAP there is an associated reduction in electrical power requirements to pump water and more of CAP's share of NGS generation is available to be marketed (after 2011). For a 500,000 af shortage (at $48/MWh), the annual market value of the electrical power available to be marketed is approximately $41 million.

This revenue would benefit all CAP users to the extent it would be used to offset CAWCD's repayment obligation, as well as Indian tribes that benefit from the AWSA. The Reservoir Storage Alternative would result in the greatest overall shortages, and therefore the greatest reduction in CAP pumping load.

4.11.2.8 Summary Comparison of Alternatives

Table 4.11-29 summarizes effects of each of the action alternatives compared to the No Action Alternative for electrical energy generation, generation capacity, and associated economic effects.

Table 4.11-29
Summary Comparison of Action Alternatives to No Action Alternative
Mean Values for Electrical Energy Generation, Generation Capacity, and Economic Value

	No Action	Basin States	Conservation Before Shortage	Water Supply	Reservoir Storage
Glen Canyon Powerplant					
Annual Energy Generation (MWh)	4,265,749	4,255,233	4,256,656	4,169,950	4,292,417
Change in Annual Energy Generation (MWh)	0.0	(10,516)	(9,093)	(95,799)	26,668
Change in Annual Energy Generation (Percent)	0.0	(0.25)	(0.21)	(2.2)	0.63
Monthly capacity (MW)	603	606	607	592	613
Change in Monthly Capacity (MW)	0.0	3.4	3.6	(11.2)	9.6
Change in Monthly Capacity (Percent)	0.0	0.57	0.60	(1.9)	1.6
Economic Value of Electrical Power Generation – Total (PV 2008 $ Million)	6,808	6,803	6,805	6,669	6,870
Change in present value of Electrical Power Generation (PV 2008 $ Million)	0.0	(4.72)	(2.79)	(139.27)	62.43
Change in Present Value of Electrical Power Generation (Percent)	0.0	(0.07)	(0.04)	(2.05)	0.92
Hoover Powerplant					
Annual Energy Generation (MWh)	3,156,820	3,171,189	3,175,390	3,108,539	3,430,839
Change in Annual Energy Generation (MWh)	0	14,369	18,570	(48,281)	274,019
Change in Annual Energy Generation (Percent)	0.0	0.46	0.59	(1.5)	8.7
Monthly capacity (MW)	1,201	1,214	1,217	1,178	1,337
Change in Monthly Capacity (MW)	0.0	12.7	15.5	(22.9)	136.0
Change in Monthly Capacity (Percent)	0.0	1.1	1.3	(1.9)	11.3
Economic Value of Electrical Power Generation – Total (PV 2008 $ Million)	7,351	7,426	7.441	7,263	8,093
Change in present value of Electrical Power Generation (PV 2008 $ Million)	0.0	75.4	90.0	(88.4)	742.5
Change in Present Value of Electrical Power Generation (Percent)	0.0	1.03	1.22	(1.2)	10.1

Table 4.11-29
Summary Comparison of Action Alternatives to No Action Alternative
Mean Values for Electrical Energy Generation, Generation Capacity, and Economic Value

	No Action	Basin States	Conservation Before Shortage	Water Supply	Reservoir Storage
Parker and Davis Powerplant					
Annual Energy Generation (MWh)	1,618,736	1,609,419	1,607,527	1,620,329	1,600,484
Change in Annual Energy Generation (MWh)	0	(9,318)	(11,210)	1,593	(18,253)
Change in Annual Energy Generation (Percent)	0.0	(0.58)	(0.69)	0.10	(1.1)
Monthly capacity (MW)	331.4	331.4	331.4	331.4	331.4
Change in Monthly Capacity (MW)	0	0	0	0	0
Change in Monthly Capacity (Percent)	0.0	0.0	0.0	0.0	0.0
Economic Value of Electrical Power Generation – Total (PV 2008 $ Million)	2,243	2,230	2,226	2,249	2,206
Change in present value of Electrical Power Generation (PV 2008 $ Million)	0.0	(12.4)	(16.4)	6.2	(36.9)
Change in Present Value of Electrical Power Generation (Percent)	0.0	(0.55)	(0.73)	0.28	(1.6)
Headgate Rock Powerplant					
Annual Energy Generation (MWh)	77,386	76,452	77,059	78,425	76,242
Change in Annual Energy Generation (MWh)	0	(934)	(1,261)	(222)	1,366
Change in Annual Energy Generation (Percent)	0.0	(1.2)	(1.6)	(0.29)	(1.8)
Economic Value of Electrical Power Generation – Total (PV 2008 $ Million)	103	102	101	103	100
Change in present value of Electrical Power Generation (PV 2008 $ Million)	0.0	(1.3)	(2.0)	(0.20)	(2.6)
Change in Present Value of Electrical Power Generation (Percent)	0.0	(1.3)	(1.9)	(0.19)	(2.5)

4.11.2.9 Generation Facilities

Glen Canyon and Hoover Powerplants. Table 4.11-29 presents the potential changes in generation, capacity, and economic value of electrical power. The Basin States, Conservation Before Shortage Alternative, and Water Supply alternative result in minor variations for each of these parameters. Because of generally lower elevations, the Water Supply Alternative would have the greatest adverse effect on electrical power production and value. Most of these changes are less than one percent, however, and these alternatives result in both positive and negative variations. Therefore, these impacts are considered minor. The Reservoir Storage Alternative generally results in greater positive changes with respect to electrical power production and value because of higher reservoir elevations and would result in moderate beneficial effects, particularly in the case of the Hoover Powerplant.

Parker-Davis Project and Headgate Rock Powerplants. These facilities are generally considered to be "run of the river" electrical power generation facilities and are affected primarily by release volumes from Hoover Dam. As shown in Table 4.11-29, the Basin States, Conservation Before Shortage, and Reservoir Storage Alternatives all generally result in minor decreases in electrical power production and value at these facilities as compared to the No Action Alternative because they result in lower release volumes downstream of Hoover Dam, with the Reservoir Storage Alternative having the greatest adverse effects. Again, these changes are relatively minor (most less than one percent). The Water Supply Alternative results in greater release volumes downstream and therefore slight increases in electrical power production and value as compared to the No Action Alternative. These increases are considered beneficial but also minor as compared to overall electrical power production at these facilities.

Water Supply Systems. As presented in Table 4.11-29, the Basin States, Conservation Before Shortage, and Water Supply alternatives would generally result in lower elevations at Lake Powell, as compared to the No Action Alternative, and therefore could potentially result in increased pumping costs for the NGS and City of Page, with the Water Supply Alternative resulting in approximately twice the increase in costs as compared to the other action alternatives

The Reservoir Storage Alternative would result in generally higher reservoir elevations and therefore reduced pumping costs as compared to the No Action Alternative. This beneficial effect is also considered minor.

Basin Power Funds. Reductions in power revenues could reduce the amount of money available to meet the intended uses of these funds, possibly leading to reductions in allocations to power contractors or power rate adjustments. The action alternatives generally have a minor impact on the economic value of electrical power generation at Glen Canyon and Hoover Powerplants. However, total loss of electrical power generation capabilities would have a substantial effect on the basin power funds. At the Glen Canyon Powerplant, the probability this type of loss in electrical power generation capability is very small (less than five percent) except for the Water Supply Alternative, which would result in as much as a nine percent probability. At the Hoover Powerplant, the probability of total loss of generation is higher, increasing from the current negligible probability to about 30 percent in 2026. As shown in Figure 4.11-7, the Reservoir Storage Alternative is the exception to this, while the remaining alternatives are very similar to the No Action Alternative.

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4.12 Recreation

This section discusses the recreational resources within the study area that may be affected by the proposed federal action. Topics include:

- ♦ Shoreline public use facilities;
- ♦ Reservoir boating;
- ♦ River and whitewater boating; and
- ♦ Sport fishing.

4.12.1 Methodology

The following methods were used to determine effects of the alternatives on recreation resources.

4.12.1.1 Method Used to Assess Shoreline Public Use Facilities

These sections examine the probabilities that reservoir elevations would decrease below critical thresholds for use of selected marinas, boat docks, and boat launch ramps. These sections also assess whether impacts would occur in access to or use of attraction features. Threshold reservoir elevations were determined by reviewing published sources and through personal communication with Reclamation, NPS, and resource specialists, and from public comments provided during scoping for this Draft EIS. The threshold elevations were used as indicators of recreational facilities that might be rendered inoperable or require relocation or modification to maintain their operation. Projections of reservoir elevations for 2008, 2016, 2025, 2040, 2050, and 2060 are provided in Section 4.3. The narrative of effects of the alternatives is provided below for selected facilities in July or September, representing relatively high visitation months for both Lake Powell and Lake Mead. These facilities are representative of potential effects of the alternatives on shoreline recreation opportunities at each reservoir. Results are described for 2026, representing the end of the interim period. For Lake Powell, Wahweap Marina was selected for description in the narrative due to its popularity with boaters. For Lake Mead, Pearce Ferry at the in-flow area to the reservoir is described. Effects on Echo Bay Public Launch Ramp are also described in the narrative because it represents a facility that closes at a relatively low reservoir elevation of 1,050 feet msl.

4.12.1.2 Method Used to Assess Reservoir Boating

This analysis assesses the probabilities that reservoir elevations would decrease below critical thresholds for boating navigation hazards and change navigable areas and passageways, and whether decreases in reservoir surface area might affect safe boating capacities. Threshold pool elevations were determined by reviewing published sources and through personal communication with Reclamation, NPS, and resource specialists, and from public comments.

In general, the surface area of the reservoirs available for boating is reduced when the reservoir elevation drops and this may affect the number of boats that can safely operate at one time referred to as safe boating density. Safe boating density could be used to assess the effects of each alternative on boating safety if daily boating levels for the reservoirs were available. However, recent and consistent information on the level of daily or peak boating use, such as whether the current boating densities on the reservoirs have approached or exceeded the safe boating density is not available. Without information on current reservoir boating densities, it cannot be determined whether any reductions in pool elevations at Lake Powell and Lake Mead associated with the alternatives would result in unsafe boating conditions due to a corresponding increase in boating density. Personal communications with boaters and NPS managers suggest that Lake Mead and Lake Powell have not exceeded safe boating densities.

Navigation hazards and shallow waters require boaters to take detours around inaccessible areas. This may add mileage to trips and may influence recreational boaters to remain in specific areas, which can result in congestion in those areas. Additionally, as reservoir elevations drop and surface area decreases, congestion may become more noticeable in popular areas that receive high-use or where narrow travel corridors exist.

4.12.1.3 Method Used to Assess River and Whitewater Boating

This analysis uses river flow data from Section 4.3 to analyze whether there would be increased exposures to boating navigation hazards, changes in access or use of rest areas and take-outs, or changes in trip durations resulting from the action alternatives compared to the No Action Alternative. Whitewater boating is the key recreational activity in the Grand Canyon below Lees Ferry and above Lake Mead. Other reaches do not provide whitewater boating opportunities and, therefore, are not addressed.

Threshold river flows were determined by reviewing published sources and through personal communication with river managers and from comments received during scoping. These representative river flows were chosen as indicators for whitewater boating safety and the availability of rest areas and take-out points.

This analysis also includes a discussion of areas on the river that could become unsafe for whitewater boating at certain flows due to hazards such as exposed rocks, changes in navigation patterns caused by obstructions, and increased or decreased river velocities. These flows were also analyzed to determine elevations at or below which various whitewater boating facilities (rest areas and take-out points) might be rendered inoperable or require modification to maintain their operation.

4.12.1.4 Method Used to Assess Sport Fishing

This analysis evaluates changes in sport fishing opportunities by reach among the action alternatives compared to the No Action Alternative. The assessment of sport fishing was based on a literature review to determine the current status of fish assemblages in the study area. No specific reservoir pool elevation thresholds related to sport fishing were found. A general discussion about changes in flow and salinity and possible effects on sport fish is also provided.

A more detailed analysis of effects to rainbow trout based on changes in water temperature is used for the Colorado River reach between Glen Canyon Dam and Lake Mead. Water temperature changes may affect sport fish. Rainbow trout were chosen for the analysis based on the importance of its recreational fishery in the Colorado River reach below Glen Canyon Dam.

Striped bass and threadfin shad in Lake Powell and Lake Mead were selected to represent the reservoir sport fishery; striped bass are a sports fish and threadfin shad are their food source. Striped bass feed on threadfin shad, and when shad are abundant, striped bass are able to reproduce and grow quickly. The resulting increased bass population continues feeding on the threadfin shad, and they deplete the shad populations. Striped bass decline in numbers and predation on shad decreases. This causes the threadfin population to increase again. This cycle has been occurring since the first introduction of striped bass into Lake Powell in 1974 and is expected to continue in the future (Gustaveson 1999).

Rainbow trout and its water temperature thresholds were used to analyze potential differences in impacts between the alternatives below Glen Canyon Dam. Minimum, maximum, and lethal water temperatures for various life history stages were determined and months that spawning, incubation and growth occur were established. The 10^{th} percentile data were used to analyze potential effects because the 50^{th} and 90^{th} percentile data are essentially identical between the alternatives and no meaningful differences exist. It is important to note that the 10^{th} percentile elevations are unlikely to occur in any given year or consistently over time (Section 4.2). Modeled temperature data at Glen Canyon Dam, the Little Colorado River confluence, and at Diamond Creek were used in the trout fishery analysis. A qualitative analysis of potential water temperature changes and effects on rainbow trout were made by comparing the differences between water temperatures under the No Action Alternative and the action alternatives.

Water Temperature Assessment. Surface minimum and maximum monthly water temperature data (up to 10 feet below the surface) for Lake Powell were provided and compared to striped bass and threadfin shad thresholds to determine whether potential surface temperatures would exceed the lethal tolerances of striped bass or threadfin. Striped bass lower lethal limit is 5°C and upper lethal limit is 33°C. Threadfin shad have an upper lethal limit of 37°C and a lower lethal limit of 5°C.

Modeled river temperatures (Section 4.5 and Appendix P) were used to assess the possible effects on rainbow trout in the river section from Glen Canyon Dam to Diamond Creek (Tables 4.5-4 to 4.5-9 and Appendix P). Conditions supporting rainbow trout spawning and incubation were assumed to deteriorate as temperature warms beyond 15ºC (Table 4.12-1). Trout eggs that are subjected to temperatures warmer than 15ºC are prone to increased mortality (Table 4.12-1). Juvenile rearing success is assumed to deteriorate at water temperatures ranging from 17ºC to 25ºC. Rainbow trout can be expected to show significant mortality at temperatures exceeding 25ºC (Myrick and Cech 2001; Raleigh et. al. 1984) (Table 4.12-1).

Table 4.12-1
Water Temperature Tolerances of Rainbow Trout (ºC)

Species	Species Code	Spawning			Incubation			Growth			Lethal	
		Minimum	Maximum	Optimum	Minimum	Maximum	Optimum	Minimum	Maximum	Optimum	Low	High
Rainbow Trout	RBT	8	13	10	7	15	10	12	21	16	0	25

In the Colorado River, rainbow trout are year-round residents. Spawning typically begins in January and continues into May, with peak spawning occurring in March and April (Korman et. al. 2005) (Table 4.12-2). During spawning, the female digs a redd (i.e., gravel nest) where the eggs are deposited, and they are then fertilized by the male. The optimal water temperature for trout spawning and incubation has been reported to fall between 7ºC and 15ºC (Table 4.12-1). Incubation lasts from 1.5 months to 4 months, depending on water temperature (Table 4.12-2).

Newly emerged fry move to shallow, protected areas along stream banks, but as they grow, they move to faster, deeper areas of the river. Shallow riffles are the most important channel type for trout during their first year (Barnhart 1986). Juvenile trout generally use riffles and runs in the main and secondary channels, along with the head and tail of pools. Juvenile rearing success is assumed to deteriorate at water temperatures ranging from 17ºC to 25ºC. Juvenile trout feed on a variety of aquatic and terrestrial insects and other small invertebrates.

Table 4.12-2
Life History of the Rainbow Trout, Phases by Months

Phases	Citations	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Spawning	2,4,5	■	■	■	■	■							
Egg Incubation	2,4,5	■	■	■	■	■	■	■	■				
Juvenile Rearing	2,4,5	■	■	■	■	■	■	■	■	■	■	■	■
Residence	1, 2, 3	■	■	■	■	■	■	■	■	■	■	■	■

1 *Lake Powell n.d. Available at: http://www.waterquality.utah.gov/watersheds/lakes/LAKEPOWL.pdf. Accessed October 27, 2006.*

2 *GCDAMP (Glen Canyon Dam Adaptive Management Program). n.d. Lees Ferry trout fishery. Available at: http://www.pn.usbr.gov/keyresc/tf.html. Accessed October 27, 2006.*

3 *Fishing in Laughlin, Nevada. 2006. Available at: http://www.laughlinnevadaguide.com/fish.htm. Accessed October 27, 2006.*

4 *Valdez 1993. Non-native fishes of Grand Canyon. Available at: http://www.gcrg.org/bqr/6-4/fishes.htm. Accessed: October 27, 2006.*

5 *Korman et. al. 2005, 21.*

Salinity Assessment. Salinity levels were assessed below Hoover Dam and it was determined that future salinity levels would not affect rainbow trout (Section 4.5). Striped bass are naturally a brackish to salt water species, so the slight increase in salinity should have no effect on striped bass or threadfin shad. Therefore this issue is not discussed further.

Flow Assessment. Flow reductions that occur outside of spawning periods of fish are expected to have minimal impacts on fish species because habitat is likely not a factor limiting their populations. Extreme reductions, however, could result in the loss of fish through stranding and reduction in water quality (e.g., dissolved oxygen, temperature). The abundance of sports fishes, however, would be expected to recover following flow reduction periods through natural reproduction and through augmentations under fish stocking programs.

Flow reductions during the spawning period could desiccate eggs or strand juvenile fish. Impacts on sport fishes are expected to be minimal because their populations are relatively large and would be expected to recover following reduced flow conditions through natural reproduction and through augmentations under fish stocking programs.

Given that releases from Glen Canyon Dam would remain within their historic range, its was concluded that changes in flow would not be a useful tool to analyze effects on sport fish in this reach of the river. The reaches below Hoover Dam are also expected to continue with operations similar to historic conditions. Therefore flow assessment was not used in this analysis.

4.12.2 Recreation at Lake Powell

Table 3.12-3 identifies the threshold elevations below which shoreline recreational facilities at Lake Powell could be affected. Below these elevations, facility adjustments or capital improvements would be required, creating potential impacts on recreation at Lake Powell. Figures 4.3-3 through 4.3-11 and Tables 4.3-2 through 4.3-10 show the percentage of values less than or equal to these threshold elevations during the study period.

4.12.2.1 Access or Use of Lake Powell Boating Facilities

No Action Alternative. In July 2026, there is a six percent chance that elevations will be less than 3,560 feet msl, resulting in the closure or modification of Wahweap and lower Bullfrog launch ramps. Table 4.3-7 and Figure 4.3-8 provide the data for all years and all alternatives.

Basin States and Conservation Before Shortage Alternatives. In July 2026, there is an eight percent chance of closing Wahweap and lower Bullfrog launch ramps under these two alternatives.

Water Supply Alternative. In July 2026, there is a 20 percent chance of closing Wahweap and lower Bullfrog launch ramps under this alternative.

Reservoir Storage Alternative. In July 2026, there is a two percent chance of closing Wahweap and lower Bullfrog launch ramps under this alternative.

4.12.2.2 Safe Boating Capacities and Exposure to Navigation Hazards

In general, as reservoir elevations drop, hazards such as submerged snags and boulders can become exposed or are closer to the surface, increasing the likelihood that boats can come in contact with such hazards. The elevations of such hazards are often unknown until they become exposed. At elevation 3,620 feet msl, hazardous obstructions result in the NPS prohibiting boating around Castle Rock and Gregory Butte. Table 4.3-5 and Figure 4.3-6 provide the data for all years and all alternatives.

No Action Alternative. In September 2026, there is a 29 percent chance the NPS would have to prohibit boating around Castle Rock and Gregory Butte due to navigational hazards.

Basin States and Conservation Before Shortage Alternatives. In September 2026, there is a 36 percent chance of boating restrictions around Castle Rock and Gregory Butte.

Water Supply Alternative. In September 2026, there is a 47 percent chance of boating restrictions around Castle Rock and Gregory Butte.

Reservoir Storage Alternative. In September 2026, there is a 21 percent chance of boating restrictions around Castle Rock and Gregory Butte.

4.12.2.3 Lake Powell Sport Fish Populations

Potential surface temperatures under any alternative could get close to the upper lethal limits for both striped bass and threadfin shad, especially in July and August when maximum temperatures could reach 29°C. However, the maximum lethal limits of 37°C and 33°C for threadfin shad and striped bass, respectively, would not be exceeded. Further, these water temperatures are for the upper 10 feet of the reservoir, and lower depths provide cooler water. It is assumed that striped bass and threadfin shad would be able to move into the cooler thermocline during the summer months (Gustaveson 1999). Water temperatures would not drop below the lower lethal limit of 5°C for striped bass or threadfin shad under any alternative. The coldest winter temperature could be 7°C. Because surface temperatures would not exceed the lethal tolerances of either species, and it is assumed that both species would have adequate thermal refugia, substantial temperature-related impacts to the reservoir sport fishery are not anticipated to occur under any of the alternatives.

The general trend for the alternatives indicates that Lake Powell water under the Conservation Before Shortage and Basin States alternatives do not differ substantially from the No Action Alternative. Therefore, Lake Powell conditions are expected to be similar to the No Action Alternative for lake sport fish under these two action alternatives. The Water Supply Alternative tends to have lower reservoir elevations, which makes the lake more susceptible to atmospheric temperature influence. The Reservoir Storage Alternative has generally higher Lake Powell elevations compared to the No Action Alternative, which makes the lake less susceptible to atmospheric temperature influence. However, threadfin shad and striped bass should still be able to survive potential winter and summer temperature variations.

4.12.2.4 Access or Use of Rainbow Bridge

Above a Lake Powell elevation of 3,650 feet msl, Rainbow Bridge is visible from the floating walkway and interpretive platforms at Rainbow Bridge National Monument. If Lake Powell elevations fall below 3,650 feet msl, Rainbow Bridge is no longer visible from the lake and the floating walkway and interpretive platforms are removed and stored. Under this circumstance, dock facilities would be moved to a lower elevation and connected to the land trail with a short walkway, and the old land trail through Bridge Canyon (submerged at full-pool elevation) would be used. Table 4.3-3 and Figure 4.3-4 provide the reservoir elevation data for all years and all alternatives.

No Action Alternative. In July 2026, there is a 41 percent chance that the NPS would have to close or modify facilities at Rainbow Bridge.

Basin States and Conservation Before Shortage Alternatives. In July 2026, there is a 51 percent chance that the NPS would have to close or modify facilities at Rainbow Bridge.

Water Supply Alternative. In July 2026, there is a 60 percent chance that the NPS would have to close or modify facilities at Rainbow Bridge.

Reservoir Storage Alternative. In July 2026, there is a 38 percent chance that the NPS would have to close or modify facilities at Rainbow Bridge.

4.12.3 Recreation from Glen Canyon Dam to Lake Mead

4.12.3.1 Boating

Current operation of Glen Canyon Dam requires a minimum flow release of 8,000 cfs between a.m. and 7 p.m., and 5,000 cfs at night. Therefore, daytime flows will not drop lower than the safe whitewater boating threshold flow of 5,000 cfs. In addition, flow releases from Glen Canyon Dam will be within historical operating range. As shown in Tables 4.3-12 through 4.3-14, releases from Glen Canyon Dam would generally be much higher than these minimum flows under all alternatives and hydrological conditions. Therefore, there would be no change in exposure to unsafe boating conditions caused by change in river elevation. Minor changes in exposure to boating navigation hazards caused by change in river velocity; changes in access or use of rest areas and take-out points; changes in trip duration caused by changes in river velocity; or ability to use sport fishing sites caused by change in flows may occur under all alternatives. These changes would not be substantial and would not affect recreation use or opportunities.

4.12.3.2 Sport Fish Populations

For the reach of the river between Glen Canyon Dam and Lake Mead, water temperatures were used (See Appendix P) from Glen Canyon Dam, Little Colorado River confluence, and below Diamond Creek gage to compare the No Action Alternative with the action alternatives. Rainbow trout are the major sport fish in this reach and are used for the assessment.

Glen Canyon Dam Releases and Lees Ferry Reach:

- **No Action Alternative.** As discussed in Section 4.8.4.2, the historical range of release temperatures from Glen Canyon Dam was relatively stable between 1990 and 2002 and typically ranged from 7 °C to12 °C (44.6 °F to 53.6 °F). These relatively stable cold temperatures were favorable for rainbow trout. Beginning in 2002, the range of release temperatures increased and the higher end of the range approached 16 °C (60.8 °F) (Appendix F, Figure F-5). Under the No Action Alternative for Glen Canyon Dam releases, the 10^{th} percentile water temperatures were compared against the preferred water temperatures for spawning, incubation, growth and mortality of rainbow trout. In all months (January through December) minimum potential temperatures are below the preferred lowest water temperature (12 °C) suitable for growth. The minimum potential temperatures are below the minimum suitable spawning temperature of 8 °C from January through April (Table 4.12-1). The potential temperature range for the Glen Canyon Dam release and river temperature at Lees Ferry are not expected to exceed 25° C but may reach 20 °C at the 10^{th} percentile Lake Powell elevation release. As indicated in Chapter 4.8, substantial impacts to the aquatic foodbase are not anticipated.

- **Action Alternatives.** While the action alternatives compared to the No Action Alternative are similar, the 10^{th} percentile water temperatures show a potential slight warming trend for all of the alternatives except the Reservoir Storage Alternative. The Reservoir Storage Alternative shows only November as being potentially above the preferred temperature for growth. The Water Supply Alternative shows the most potential warming and water temperatures in August and September may exceed the preferred growth temperature. Incubation temperatures may be exceeded from May through August, which could cause egg mortality. The amount of egg mortality would depend on the duration of water temperatures above the limits for incubation, which is not known. Lethal limits for rainbow trout are not exceeded in any month. The Water Supply Alternative may result in a shorter spawning season since the river flow temperatures in this river reach may increase and become too warm for spawning in May. As indicated in Chapter 4.8, substantial impacts to the aquatic foodbase are not anticipated.

Little Colorado River Confluence:

- **No Action Alternative.** Under the No Action Alternative, the 10^{th} percentile water temperatures were compared against the preferred water temperatures for spawning, incubation, growth and mortality of rainbow trout. In almost all months (January through June, October through December) minimum temperatures may be below the preferred ranges for growth. The minimum temperatures may be below the preferred minimum temperature for spawning (8 °C or 46 °F) in January and February (Table 4.12-1).

- **Action Alternatives.** While the action alternatives compared to the No Action Alternative are similar, the 10th percentile water temperatures show a slight potential warming trend for all of the alternatives except the Reservoir Storage Alternative, which is slightly cooler. The Reservoir Storage Alternative shows the least potential variation in temperatures. The Water Supply Alternative shows the most potential warming of water from June through October and may exceed suitable thresholds for growth and incubation. (Table 4.12-1 and Table 4.12-2). Preferred growth temperatures may be exceeded from June to October and incubation temperatures (> 15 °C) may be exceeded from April through August. The amount of egg mortality would depend on the duration of water temperatures above the limits for incubation, which is not known. All action alternatives may result in shorter spawning seasons since potential spring high temperatures may exceed the upper spawning threshold. The Water Supply Alternative could potentially provide the shortest spawning season. Lethal limits for rainbow trout are not exceeded in any month.

Diamond Creek:

- **No Action Alternative.** Under the No Action Alternative for Diamond Creek the 10th percentile water temperatures show that from January through May and November and December, minimum temperatures may be below the suitable range for growth. The minimum temperatures may be below the minimum temperature for spawning (8° C or 46.4 °F) in January and February (Table 4.12-1). Lethal water temperatures may be reached in the summer under the No Action Alternative though fish should be able to find thermal refugia.

- **Action Alternatives.** While the action alternatives compared to the No Action Alternative are similar, the 10th percentile water temperatures show a potential warming trend for all of the alternatives, except for the Reservoir Storage Alternative. The Reservoir Storage Alternative shows the least potential variation in temperatures but temperatures may exceed all life history thresholds for March, May, September, and December (Table 4.12-1 and Table 4.12-2). The Water Supply Alternative shows the most potential warming of water from April through October. Preferred growth temperatures may be exceeded from May to October and incubation temperatures (> 15 °C) may be exceeded from April through August. The amount of egg mortality would depend on the duration of water temperatures above the limits for incubation, which is not known. Lethal water temperature limits above 25 °C, may be reached in July, August and September. These summer high temperatures would be greater than under the No Action Alternative for these months. The potential spawning season in this reach may be the most limited because the water warms above 13 °C (55.4 °F) earlier in the year than other reaches. The Water Supply and Reservoir Storage alternatives may potentially provide the shortest and longest spawning seasons, respectively, of the action alternatives. However, juvenile and adult fish are able to find thermal refugia by moving upstream into cooler water habitats such as pools and may not be substantially affected by warmer water temperatures. Further, this section of river is not as important for trout as the Lees Ferry reach is.

4.12.4 Recreation at Lake Mead

Table 3.12-7 identifies the threshold elevations below which shoreline recreational facilities at Lake Mead could be affected. Below these elevations, facility adjustments or capital improvements would be required, creating potential impacts on recreation at Lake Mead. Figures 4.3-18 through 4.3-23 and Tables 4.3-18 through 4.3-23 show the percentage of values less than or equal to these thresholds during the study period.

4.12.4.1 Access or Use of Lake Mead Boating Facilities

No Action Alternative. In July 2026, there is a 76 percent probability that Lake Mead elevations may be lower than elevation 1,175 feet msl, resulting in the closure of the Pearce Bay Launch Ramp and the addition of another 16 miles that boaters would have to travel downstream to take-out. Table 4.3-17 and Figure 4.3-17 provide the data for all years and all alternatives. The Echo Bay Public Launch Ramp would close at an elevation of 1,050 feet msl (Figure 4.3-21 and Table 4.3-21). In July 2026, there is a 26 percent chance that this facility would close under the No Action Alternative.

Basin States and Conservation Before Shortage Alternatives. In July 2026, there is a 76 and 77 percent chance of closing the Pearce Bay Launch Ramp under these two alternatives, respectively. In July 2026, there is a 20 percent chance under both these alternatives that the Echo Bay Public Launch Ramp would close due to low reservoir elevations.

Water Supply Alternative. In July 2026, there is a 78 percent chance of closing the Pearce Bay Launch Ramp and adding 16 miles to river trips. In July 2026, there is a 21 percent chance that the Echo Bay Public Launch Ramp would close due to low reservoir elevations.

Reservoir Storage Alternative. In July 2026, there is a 68 percent chance of closing the Pearce Bay Launch Ramp and adding 16 miles to river trips. In July 2026, there is a four percent chance that the Echo Bay Public Launch Ramp would close.

4.12.4.2 Safe Boating and Navigation Hazards

Over the years, sediment has built up in the section of the reservoir between Grand Wash Cliffs and Pearce Ferry. When the Lake Mead elevation drops below elevation 1,170 feet msl, there is no well-defined river channel in this upper portion of Lake Mead, making it dangerous for boaters (NPS 2005a).

No Action Alternative. In July 2026, there is a 74 percent probability that boaters may encounter navigational hazards in upper Lake Mead.

Basin States and Conservation Before Shortage Alternatives. In July 2026, there is a 73 percent probability that boaters may encounter navigational hazards in upper Lake Mead.

Water Supply Alternative. In July 2026, there is a 77 percent probability that boaters may encounter navigational hazards in upper Lake Mead.

Reservoir Storage Alternative. In July 2026, there is a 65 percent probability that boaters may encounter navigational hazards in upper Lake Mead.

4.12.4.3 Sport Fish Populations

No Action Alternative. Rainbow trout (and razorback suckers) are raised in the Lake Mead Fish Hatchery by Nevada Department of Wildlife (NDOW). NDOW obtains its water supply for the fish hatchery from Lake Mead. Their water comes from the Basic Management, Inc. (BMI) intake at reservoir elevation 1,060 feet msl. Under recent conditions, the hatchery has experienced problems with water temperature and total dissolved solids in its water from the intake (Parke 2006). Water temperatures taken from the intake are approximately 24°C (75°F), which is too warm for trout. NDOW has noticed the increase in water temperatures starts when Lake Mead's elevation is less than 100 feet above the BMI intake (elevation 1,160 feet msl and less). The 50th and 10th percentile monthly elevations are never above elevation 1,160 feet msl so temperature problems are likely to persist for future hatchery operations. The 90th percentile elevations are identical for all alternatives and would alleviate the hatchery's temperature problems. The 50th percentile elevations are always above elevation 1060 feet msl, but the 10th percentile elevations for all alternatives will fall below 1,060 feet msl in the future. Thus, the hatchery may have water supply problems at the 10th percentile elevation values.

The situation for striped bass and threadfin shad in Lake Powell is expected to be similar at Lake Mead. However, threadfin shad are near the northern limit of their range at Lake Powell so threadfin shad are less likely to be affected by cold winter temperatures at Lake Mead.

Action Alternatives. The Basin States and Conservation Before Shortage alternatives would be similar to the No Action Alternative. The Reservoir Storage Alternative is the most beneficial to the hatchery's water supply and the Water Supply Alternative would have the most adverse effects on water temperature. Effects on threadfin shad and striped bass are expected to be similar to the effects at Lake Powell.

4.12.5 Recreation from Hoover Dam to SIB

Flow releases from Hoover Dam, Davis Dam, Parker Dam, and Imperial Dam will all be within historical operating range. Therefore, there would be minimal changes in exposure to boating navigation hazards caused by changes in river elevation; changes in exposure to boating navigation hazards caused by changes in river velocity; changes in access or use of rest areas and take-out points; changes in trip duration caused by changes in river velocity; or decrease in access or use of sport fishing sites caused by changes in flows. The sport fishery in this reach is primarily warm water. The minor changes in water temperatures that may occur below Hoover Dam are not expected to affect warmwater sport fish.

4.12.6 Summary

4.12.6.1 Shoreline Facilities

For shoreline public use facilities at Lake Powell, the No Action, Basin States, Conservation Before Shortage, and Reservoir Storage alternatives provide a two to eight percent probability that the Wahweap and Lower Bullfrog Launch ramps may close in 2026, while the Water Supply Alternative provides a 20 percent probability of this occurrence. Other marinas and launch ramps are similarly affected under the different alternatives.

For Rainbow Bridge National Monument, in 2026 there is a 41 percent probability under the No Action Alternative that the NPS would have to close or modify recreational facilities at this location. The action alternatives provide a 38 to 60 percent probability of facility closures.

At Lake Mead, all of the alternatives provide a 76 to 78 percent probability that the Pearce Bay launch ramp would be closed to boaters, except for the Reservoir Storage Alternative, which provides a 68 percent probability. Similarly, all of the alternatives provide a 20 to 26 percent probability of closure of the Echo Bay Public Launch Ramp (in the north end of the reservoir), except for the Reservoir Storage Alternative which provides only a four percent probability of this occurrence.

4.12.6.2 Safe Boating and Navigation

For safe boating at Lake Powell, under the No Action Alternative and Reservoir Storage Alternative, probabilities range from 21 to 29 percent that the NPS would have to prohibit boating around Castle Rock and Gregory Butte. Under the Basin States and Conservation Before Shortage alternatives, there is a 36 percent probability that boating prohibitions would need to be put in place. Under the Water Supply Alternative, the probability of this occurrence is 47percent.

For Lake Mead, all the alternatives in July 2026 provide a 73 to 77 percent probability that boaters may encounter navigational hazards in the upper end of Lake Mead due to reservoir elevations being drawn down below elevation 1,170 feet msl. The Reservoir Storage Alternative provides a 65 percent probability of a similar recreational impact. Similar effects would occur in the Overton Arm of Lake Mead.

For whitewater boating through Grand Canyon, the Glen Canyon Dam ROD flows will be maintained. Even in a 7.0 maf Glen Canyon Dam release year, the minimum daily flow will remain at or above 5,000 cfs, a safe boating threshold.

4.12.6.3 Sport Fish Populations

Sport fish populations would not be adversely affected at Lake Powell under any of the alternatives. Although water surface temperatures may approach lethal levels in the upper 10 feet of the reservoir under any alternative, lethal levels for striped bass and threadfin shad should not be exceeded by any alternative. Moreover, cooler temperatures below the lake surface would serve as a refuge for the fish. The situation for striped bass and threadfin shad in Lake Mead is similar to Lake Powell. Higher water temperatures could impair the Lake Mead Fish Hatchery, particularly under the Water Supply Alternative.

High water temperatures could affect the rainbow trout in the Lees Ferry reach. Under the No Action Alternative, 10^{th} percentile temperatures are suitable for growth, spawning, and incubation in the months shown in Table 4.12-2. Under the action alternatives, 10^{th} percentile modeling results indicate there could be minor impacts to rainbow trout due to warmer temperatures. The Water Supply Alternative shows the most warming from April through November. The Reservoir Storage Alternative shows only November as being higher than the growth threshold.

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4.13 Transportation

This section describes the methods of analysis and potential effects on transportation, focusing on ferry services, and river taxis.

4.13.1 Methodology

4.13.1.1 Effects on Lake Powell Ferry Service

The John Atlantic Burr Ferry becomes inoperable when the Lake Powell elevation falls below elevation 3,550 feet msl, requiring additional driving of approximately 130 miles between the Bullfrog and Halls Crossing marinas. Consequently, for each action alternative, the analysis evaluates the probability the ferry would be inoperable and compares that to the probability under the No Action Alternative. These comparisons were based on the Lake Powell end-of-September elevations between years 2008 through 2060.

4.13.1.2 Effects on Laughlin River Taxis and Tour Boats

Changes in releases from Davis Dam have the potential to impact the operations of the river taxi services and tour boats in Laughlin, Nevada. The projected discharges or flows in cfs were compared to the flows required by the river taxis and the tour boats.

4.13.1.3 Effects on Lake Havasu Ferry Service

Changes in Lake Havasu elevations could affect the existing ferry service and recreational uses. Effects of changes in Lake Havasu elevations on recreational uses are discussed in the recreational impacts discussion (Section 4.12). The discussion presented below is limited to the potential effects on ferry service provided on Lake Havasu.

4.13.2 Lake Powell Ferry Service

Table 4.13-1 lists the range of probabilities of Lake Powell elevations being less than or equal to elevation 3,550 feet msl for each alternative. An analysis for each alternative is provided below.

Table 4.13-1
Range of Probabilities of Lake Powell Elevations Less Than or Equal to Elevation 3,550 feet msl

Alternative	2008 through 2025	2026 through 2060
No Action	0% to 8.1%	3% to 10.1%
Basin States	0% to 6.1%	5.1% to 10.1%
Conservation Before Shortage	0% to 6.1%	5.1% to 10.1%
Water Supply	0% to 17.1%	7.1% to 17.2%
Reservoir Storage	0% to 5.1%	0.1% to 10.1%

4.13.2.1 No Action Alternative

The likelihood that Lake Powell elevations would fall below 3,550 feet msl under the No Action Alternative is not greater than 10 percent for all years until 2060 (zero to 10 percent; Figure 4.3-10 and Table 4.13-1). Consequently, the Lake Powell Ferry Service would be able to operate about 90 percent of the time under No Action Alternative conditions.

4.13.2.2 Basin States Alternative

The Basin States Alternative would result in very similar or slightly lower probabilities (zero to six percent) of Lake Powell elevations being less than 3,550 feet msl when compared to the No Action Alternative from the period 2008 through 2025 (Figure 4.3-10 and Table 4.13-1). For the period 2026 through 2060, the Basin States Alternative would result in similar or slightly higher probabilities (five to 10 percent) as compared to the No Action Alternative. The net effect under this alternative is minor.

4.13.2.3 Conservation Before Shortage Alternative

The Conservation Before Shortage Alternative would result in very similar or slightly lower probabilities (zero to 6.1 percent) of Lake Powell elevations being less than elevation 3,550 feet msl when compared to the No Action Alternative for the period 2008 through 2025 (Figure 4.3-10 and Table 4.13-1). For the period 2026 through 2060, the Conservation Before Shortage Alternative would result in similar or slightly higher probabilities (five to 10 percent) as compared to the No Action Alternative. The net effect under this alternative is minor.

4.13.2.4 Water Supply Alternative

The Water Supply Alternative would result in similar or higher probabilities (zero to 17 percent) of Lake Powell elevations being less than elevation 3,550 feet msl when compared to the No Action Alternative for the period 2008 through 2025 (Figure 4.3-10 and Table 4.13-1). For the period 2026 through 2060, the Water Supply Alternative would result in higher probabilities (seven to 17 percent) as compared to the No Action Alternative. The net effect under this alternative is moderately adverse.

4.13.2.5 Reservoir Storage Alternative

The Reservoir Storage Alternative would result in similar or slightly lower probabilities (zero percent to five percent) of Lake Powell elevations being less than 3,550 feet msl compared to the No Action Alternative for the period 2008 through 2025 (Figure 4.3-10 and Table 4.13-1). For the period 2026 through 2060, the Reservoir Storage Alternative would result in similar or slightly lower probabilities (zero percent to 10 percent) as compared to the No Action Alternative. The net effect under the Reservoir Storage Alternative is beneficial.

4.13.3 Laughlin River Taxis and Tour Boats

The minimum future flow under the No Action Alternative and under the action alternatives will continue to be 2,300 cfs, the minimum flow needed to run one turbine of Davis Powerplant at about one-half capacity. The duration of flows in the 2,300 to 4,600 cfs range would not be affected by the proposed federal action. However, the duration of flows in the 4,600 cfs to 9,200 cfs range may be affected by the proposed federal action. For example, due to changes in annual releases, the duration of hourly flows in the 4,600 to 9,200 cfs range may increase during some days under the Water Supply Alternative and decrease during some days under the Reservoir Storage Alternative. These potential effects would be minor effects on transportation. The duration of hourly flows in the 4,600 cfs to 9,200 cfs range under the Basin Sates Alternative and the Conservation Before Shortage Alternative are expected to be nearly the same as those under the No Action Alternative.

4.13.4 Lake Havasu Ferry Service

Lake Havasu will continue to be operated to meet monthly elevation targets; therefore, adoption of any of the alternatives would not affect the operation of the Lake Havasu ferry service.

4.13.5 Summary

For the Lake Powell ferry, the Basin States and Conservation Before Shortage alternatives would have minor effects on ferry service; the Water Supply Alternative would result in moderate adverse effects; and the Reservoir Storage Alternative would have beneficial effects. The probability varies from year to year, but there is up to a 17 percent probability that the Lake Powell ferry may become inoperable under the Water Supply Alternative for some period of time. Conversely, the ferry remains operable with the highest probabilities and greatest durations of time under the Reservoir Storage Alternative.

For the Colorado River ferry service below Davis Dam, only under the Reservoir Storage Alternative are there measurable effects and these potential effects would most likely be minor. The other alternatives show no difference from the No Action Alternative.

The Lake Havasu ferry service would be unaffected under all of the action alternatives.

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4.14 Socioeconomics and Land Use

This section describes the environmental consequences related to socioeconomics, agricultural production and other land uses for the alternatives considered in the proposed federal action, and describes the methods used to determine the effects resulting from each alternative. The study area and issues associated with these resources are described in Section 3.14. Additional information on the assessment of socioeconomic and land use effects is provided in Appendix H. Cumulative impacts related to socioeconomics and land use are discussed in Chapter 5.

4.14.1 Methodology

This section describes the methods used to estimate the effects on socioeconomics resulting from the proposed federal action. The assessment focused on estimating the socioeconomic effects that would occur as a result of potential changes in agricultural production, reservoir-related and river-related recreation, and the change in M&I water availability.

4.14.1.1 Agriculture

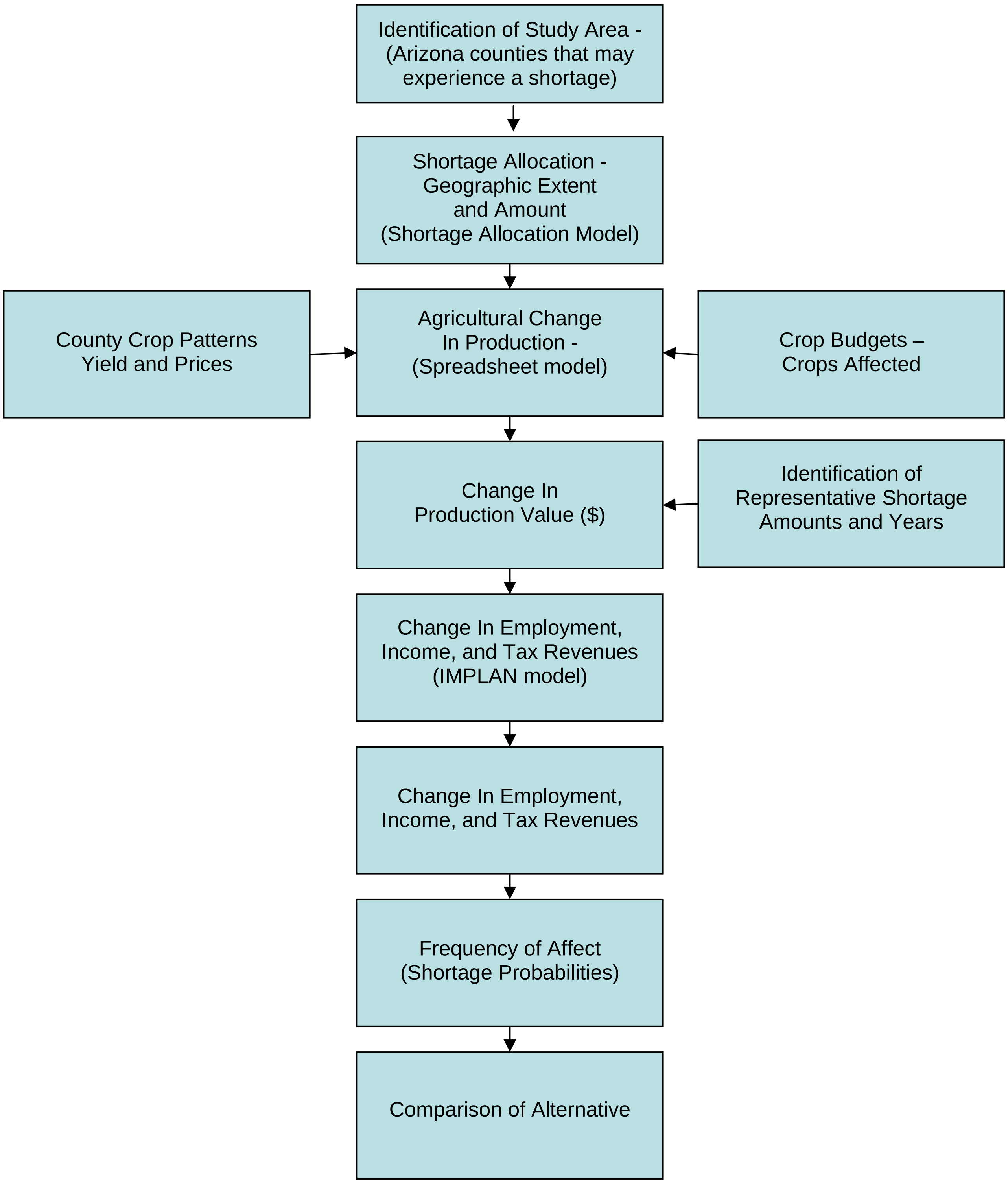
The socioeconomic effects of changes in agricultural production were quantitatively and qualitatively assessed. A quantitative assessment was conducted for Arizona counties that may experience a shortage whereas a qualitative assessment was conducted for California and Nevada counties. The quantitative assessment was limited to Arizona counties since a shortage event would potentially have the greatest effect on the CAP service area and the CAP has a large amount of agriculture within its service area. In contrast, Nevada has very little agricultural production, and shortages to California would be unlikely to occur and would only affect the M&I sector.

The quantitative assessment was conducted in three major steps:

- estimating changes in agricultural production as the result of reduced water deliveries;
- estimating the potential changes in employment, income, and tax revenue as a result of reduced water deliveries; and
- applying the shortage probabilities for a particular shortage amount and year to understand the likelihood that the potential changes would occur.

Figure 4.14-1 provides an overview of the steps followed in conducting the assessment of changes in agricultural production and resulting changes in employment, income, and tax revenues.

Figure 4.14-1
Steps in Analyzing Changes in Agricultural Production
and Resulting Changes in Employment, Income, and Tax Revenue



4.14.1.2 Estimating Changes in Agricultural Production Value

Involuntary Shortages. The purpose of the impact assessment for agriculture is to estimate the change in agricultural production values as a result of the proposed federal action. Specifically, this section focuses on the incidence of these impacts on non-Indian and Indian agricultural production in Pinal, Maricopa, Pima, Mojave, La Paz, Yuma, and Graham Counties for 2008, 2017, 2026, 2027, 2040, and 2060. The seven counties were selected because the irrigation districts that may experience shortages are located within these counties. Impacts to agriculture in the seven-county area were examined by observing modeled changes in industry output and acreage of fallowed lands for agriculture. The years 2008, 2017, and 2026, were selected because they represent the beginning, midpoint, and end of the interim period. The years 2027, 2040, and 2060 were selected because they represent the beginning, midpoint, and end of the recovery period.

The objectives of this study were to quantify potential:

- changes in agricultural production for various levels of shortage; and
- amounts of fallowed land for various levels of shortage.

Key to this impact analysis is the assumption that the most conservative way to estimate impacts is to assume that, if a shortage occurs, farmers would react by fallowing irrigated lands. The decision to fallow lands would rest on the ability of the farmer to cover the variable costs of production for crops grown in the study area. These assumptions are discussed in more detail later in this section.

While fallowing of lands may occur during shortages, there are other sources of water that may be used by farmers in order to offset shortages. For example, a farmer may have a groundwater well available and may be able to mitigate shortages in surface water supply by pumping additional groundwater. Other farmers may be able to take delivery of groundwater that is recovered from a groundwater bank. It is difficult, if not impossible, to project exactly how individual farmers, irrigation districts, or the Lower Division states may mitigate potential, future agricultural impacts from shortages. Therefore, for the purposes of this analysis, the projected change in agricultural production was based on the conservative assumption that other sources of water would not be available.

The crops considered included cotton, wheat, alfalfa, vegetables and melons, and trees and vines. The primary focus is on cotton, wheat, and alfalfa because these crops have lower earnings per af of water than fruit, vegetable, and nut crops and, therefore, are more vulnerable to changes in water costs and shortages. Farm budgets were developed for cotton, wheat, and alfalfa to determine the maximum water cost a farmer can pay and still produce a particular crop. These budgets represent a generalization of the variable production costs for a particular crop exclusive of water costs. When the cost of water exceeds the maximum water cost a farmer can pay or if water is not available, a crop is taken out of production and the land is fallowed for the year in which a shortage occurs. The data from all of the model runs were compared to the No Action Alternative.

4.14.1.3 General Assumptions and Data Sources

Crop Patterns, Yields, and Prices. Crop patterns, yield per acre, and prices were assumed to remain constant for non-Indian and Indian agricultural output for all alternatives during the study period. Crop patterns for the CAP and other irrigation districts in this study are based on historical crop patterns that were reported by irrigation districts to Reclamation for the years 1999 through 2004. These data were averaged and aggregated at the county level for the impact analysis. Cropping patterns for Indian agriculture come from a variety of sources and may be incomplete. Accordingly, it was assumed that cropping patterns on Indian lands were similar to that of nearby irrigation districts. Appendix H includes information on cropping patterns for CAP and other irrigation districts.

Yield data was based on five-year average county-level yields for the period 2000 through 2005. Prices are based on five-year average statewide prices for Arizona for the period 2000 to 2005. The yield and price data are published by the USDA's National Agricultural Statistics Service (NASS) for Arizona. Information on county-level yield and price data is provided in Appendix H.

Water Costs. The cost of water used in the analysis of agricultural impacts is a blended cost that reflects the price of CAWCD excess water pools, groundwater pumping, and other water. The price of CAWCD excess water was obtained directly from the CAWCD. Cost estimates for groundwater pumping and other water were obtained from various irrigation districts. These data were aggregated to a county-level basis for use in the agricultural impacts analysis. The blended cost of water data for each county is included in Appendix H.

Crop Budgeting and Impacts upon Crop Selection due to Water Cost and Water Shortages. Crop budgets were developed to determine the crop types that would be affected as a result of water shortages. A detailed description of how the crop budgets were developed is included in Appendix H.

Assessment of Changes in Agricultural Production. It is assumed that the agricultural impacts for involuntary shortages are the same for various levels of shortage for each alternative. As an example, a 600,000 af shortage occurring under the Reservoir Storage Alternative would result in the same change in agricultural production as a 600,000 af shortage occurring under the Basin States Alternative. Shortages may occur more or less frequently under various alternatives, but the change in agricultural production during a particular volume of shortage was assumed to be the same across the alternatives. This is due to the modeling assumptions made with regard to how shortages might be distributed to various water users (Section 4.2, Appendix A, and Appendix G). These assumptions are the same across all alternatives. Changes in agricultural production and resulting changes in production value due to voluntary shortages would likely be different than the changes due to involuntary shortages, discussed in additional detail below.

Output from Reclamation's Shortage Allocation Model (Section 4.2 and Appendix G) was used as input for assessing changes in agricultural production during the involuntary fallowing of agricultural lands. The various levels of shortage were input into the model and the amount of shortage that would be allocated to various agricultural users was generated. These results were aggregated on a county-level basis for use in the agricultural impacts analysis.

Agricultural impacts for both non-Indian and Indian agriculture were analyzed independently. For both analyses, the amount of shortage allocated to non-Indian and Indian water users in each county for various levels of overall shortage were input into a spreadsheet model developed by Reclamation that estimates changes in agricultural production and production value. Model input includes output from the partial crop budgets, the amount of available surface water in each county, county-wide shortage amounts from the water allocation model, the amount of water applied per acre for each crop, and county-wide water distribution patterns with respect to cotton, wheat, and alfalfa production. Based on the amount of shortage realized in each county, the model estimates the amount of land that would be fallowed using the relative profitability of each crop. The model assumes that the least profitable crops are fallowed first. Once all of the irrigated land associated with the least profitable crop is fallowed, the model assumes that fallowing of the next-least profitable crop would commence. The irrigated acreage associated with fallowing is estimated based on the amount of water allocated to various crops and the crop water use per acre associated with those crops. The resulting direct economic impacts are calculated by multiplying the number of acres fallowed for various crops by the gross output for those crops.

The federal government has reserved a volume of CAP water in the range of 47,000 to 67,000 af for future water settlements. At some time, this water may be allocated to tribes in Arizona for agricultural or M&I use. Once allocated, this water would potentially be vulnerable to shortages. However, it is not known where or when this water may be allocated. Because of this uncertainty, the reserved federal water has not been included in the analysis.

Shortages. The partial farm budgets used in the analysis of involuntary shortages are a potential means to estimate the minimum amount of compensation a farmer would accept to fallow agricultural ground. However, compensation rates included in recently established fallowing programs do not reflect these minimum amounts. It appears that market forces have contributed significantly to the compensation rates paid in fallowing programs for conserved water. As a result, available data from several fallowing programs were used to estimate a range of costs for conserved water and to estimate potential amounts of land that would be fallowed under various levels of shortage.

Data from several sources suggest that fallowing agricultural lands would result in a reduction in the consumptive use of water ranging between 4.2 and 6.9 af per acre (Colby et. al. 2006). The amount of acreage that would be fallowed would be dependent on the crops grown and the consumptive use of those crops. However, again, it is difficult to project which irrigators or districts would fallow their land and what crops would not be grown. In lieu of attempting to project the crops that would not be grown, for the purposes of this study, it was assumed that the amount of fallowed land per af of conserved water would be similar to the range shown above. It was assumed that all of the potentially conserved water results from agricultural water conservation.

Voluntary shortages may result in a beneficial effect on farmers rather than a detriment. The minimum amount of water a farmer would likely accept would be at a break-even price. However, given the demand for water conservation under voluntary shortages, a farmer would be less likely to accept a minimum payment and would be more likely to attempt to maximize economic gain.

Implementation of voluntary shortages is the focus of the Conservation Before Shortage Alternative. The water conservation (voluntary shortage) prior to involuntary shortage included in this alternative assumes that farmers would be paid to initiate voluntary water conservation measures. These conservation measures could be implemented in a variety of ways such as on-farm efficiency improvements, canal lining, etc. It is, however, very difficult to project what actions individual farmers or irrigation districts might take in the future to conserve water. Land fallowing programs have frequently been used as a means to voluntarily conserve water and fallowing would likely result in the most significant impacts with regard to land use. For the purposes of this study, it is assumed that land fallowing would be the means of conserving water for the Conservation Before Shortage Alternative.

Estimating Changes in Employment, Income, and Tax Revenue. The socioeconomic effects of changes in agricultural production in Arizona were analyzed using the IMPLAN model (Minnesota IMPLAN Group 2006). IMPLAN is a regional economic model that describes the flows from producers to intermediate and final consumers using a series of economic multipliers. The IMPLAN model describes for each county the transfers of money between all industries and institutions. This model of county-level economic interactions is used to project, using the input-output multipliers, total regional economic activity based on a change in expenditures.

In addition to the direct loss in agricultural output, reduced expenditures occur from a drop in business-to-business purchases and in reduced household expenditures. These changes, known as indirect and induced economic effects and were also estimated using IMPLAN. The resulting socioeconomic effects were quantified as changes in employment, income, and tax revenue.

The qualitative assessment for changes in agricultural production and resulting changes in employment, income, and tax revenues was based on the probability of shortages occurring in the agricultural sector in California and Nevada.

Municipal and Industrial Water Uses. The potential socioeconomic consequences of shortages occurring in the M&I sector were qualitatively assessed for Arizona, California, and Nevada. The effects were qualitatively assessed because it was not known to what degree a specific economic sector considered an M&I use would be affected. The analysis was based on the shortage amounts and shortage allocations reported in Section 4.4.

The analysis first examined the probability of a range of water shortages occurring in different years. The shortages analyzed included 400,000 af, 500,000 af, 600,000 af, 800,000 af, 1 maf, 1.2 maf, 1.8maf, and 2.5 maf. Consistent with the assessment of the effects to agriculture, the M&I analysis examined years 2008, 2017, 2026, 2027, 2040, and 2060 for each of the shortage amounts.

The analysis focused on those years and shortage levels having the highest probability of occurring and where the probability was substantially different compared to the No Action Alternative. The analysis then examined whether a particular shortage event would affect the M&I sector as compared to the No Action Alternative. For example, a shortage in Arizona would affect the agricultural sector first. In contrast, a shortage in Nevada would affect M&I, primarily because Nevada has a small agricultural sector.

For situations likely to have an effect on the M&I sector, the ability of each state to manage shortages to the M&I sector were analyzed. The M&I shortages allocated to each state were compared to the drought plans or actions that state or local agencies could institute during a shortage. The analysis then qualitatively discussed whether such drought planning mechanisms are adequate to address shortages to the M&I sector.

Recreation. The recreation-related socioeconomic effects resulting from changes in Lake Powell and Lake Mead elevations and flows in the Colorado River downstream of Lake Powell and Lake Mead were qualitatively assessed. The conclusions regarding the extent of changes in reservoir elevations and river flows reported in Section 4.3 and recreation opportunities reported in Section 4.12 were used to help determine the magnitude of socioeconomic effects.

Lake Powell and Lake Mead. The assessment of changes in recreation-related economic activity was based on changes in Lake Powell and Lake Mead elevations. As indicated in Sections 4.3 and 4.12, particular months representative of the primary recreational season were selected for each lake to analyze the potential elevation changes (September for Lake Powell; July for Lake Mead).

Figure 4.14-2 depicts the end-of-September Lake Powell elevations and Figure 4.14-3 depicts the end-of-July Lake Mead elevations used in this analysis. The years considered in the assessment are 2008, 2016, 2026, and 2060. For each year, lake elevations for each alternative were compared to the No Action Alternative. This comparison was conducted for the 90^{th}, 50^{th}, and 10^{th} percentiles shown in Figures 4.14-2 and 4.14-3.

Colorado River Downstream of Lake Powell and Lake Mead. The assessment of socioeconomic effects as result of changes in recreation-related economic activity was based on the results of the recreation assessment. The results of this assessment are provided in Section 4.12.

Figure 4.14-2
Lake Powell End-of-September Elevations
Comparison of Action Alternatives to No Action Alternative
90th, 50th, and 10th Percentile Values

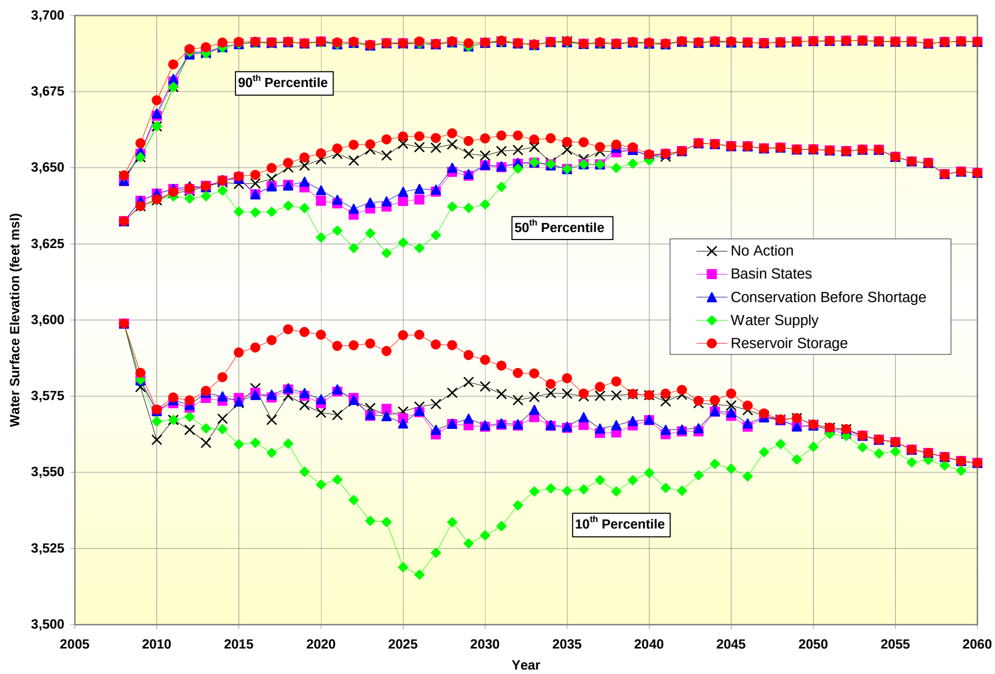
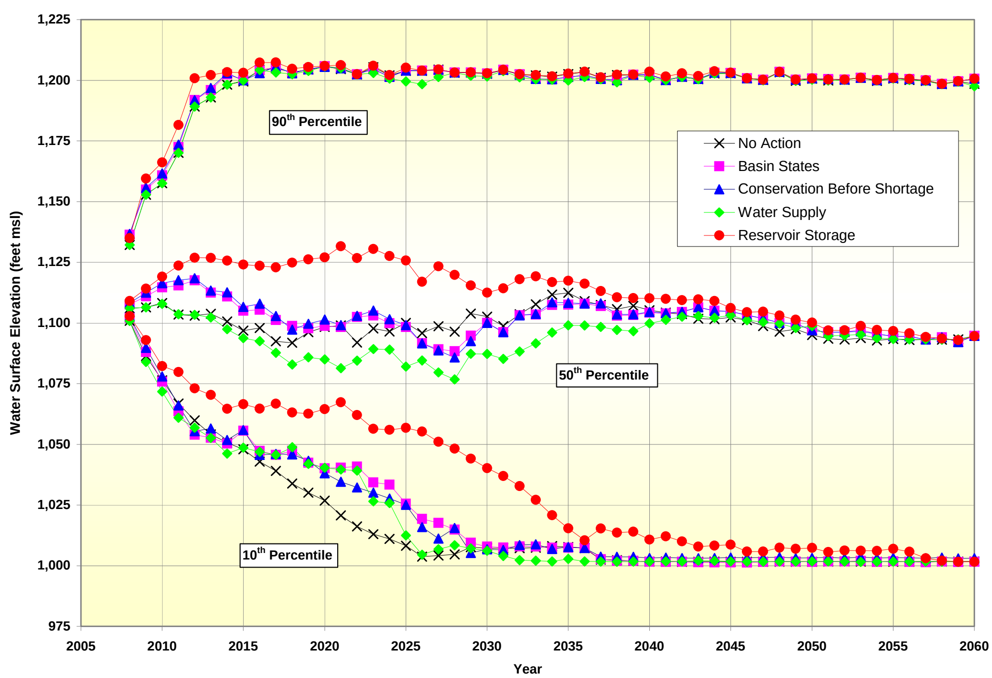


Figure 4.14-3
Lake Mead End-of-July Elevations
Comparison of Action Alternatives to No Action Alternative
90th, 50th, and 10th Percentile Values



4.14.2 Agriculture

This section provides the assessment of potential effects on agricultural production and resulting changes in employment, income, and taxes. Table 4.14-1 provides estimates of involuntary fallowed agricultural land for each shortage amount. Table 4.14-2 provides estimates of changes in agricultural production value for each shortage amount. The change in production value was used as input to IMPLAN to estimate changes in employment, income, and tax revenue.

Table 4.14-1
Estimate of Involuntarily Fallowed Acres
in Arizona under Various Levels of Shortage for Various Years

Shortage (af)	Non-Indian Agriculture					
	2008	2017	2026	2027	2040	2060
400,000	-	75,824	28,940	-	-	-
500,000	-	77,150	30,255	17,667	6,034	6,099
600,000	-	78,476	31,569	18,986	7,383	7,460
800,000	-	80,945	34,012	21,436	9,887	9,989
1,000,000	-	83,094	36,134	23,551	11,960	12,043
1,200,000	-	-	-	25,582	14,083	14,183
1,800,000	-	-	-	-	26,447	26,590
2,500,000	-	-	-	-	-	-
Shortage (af)	Indian Agriculture					
	2008	2017	2026	2027	2040	2060
400,000	-	1,015	21,912	-	-	-
500,000	-	3,697	35,403	40,621	38,773	44,185
600,000	-	18,961	40,876	45,692	45,497	49,322
800,000	-	40,824	53,122	56,460	56,469	68,407
1,000,000	-	50,883	62,228	66,832	66,820	72,673
1,200,000	-	-	-	79,265	78,904	84,723
1,800,000	-	-	-	-	110,010	114,911
2,500,000	-	-	-	-	-	-
Shortage (af)	Total Agriculture					
	2008	2017	2026	2027	2040	2060
400,000	-	76,840	50,852	-	-	-
500,000	-	80,847	65,658	58,288	44,808	50,283
600,000	-	97,437	72,446	64,678	52,880	56,782
800,000	-	121,769	87,134	77,897	66,356	78,396
1,000,000	-	133,978	98,361	90,383	78,780	84,716
1,200,000	-	-	-	104,847	92,987	98,906
1,800,000	-	-	-	-	136,457	141,501

Note: a dash indicates that a shortage of the given magnitude did not occur in the particular year

Table 4.14-1 provides the total estimated fallowed acreage for each shortage amount for 2008, 2017, 2026, 2027, 2040, and 2060. No change in production would occur in 2008 because no shortages are projected to occur in that year. In general, for each shortage amount, the amount of fallowed non-Indian agricultural land decreases between 2017 and 2060 reflecting the trend of fewer acres of agricultural land being in production in the future. No permanent change in land uses would occur under any of the alternatives because shortages would be of a temporary nature and agricultural lands would likely not be permanently removed from production.

The changes in agricultural production values are shown in Table 4.14-2. These changes are a direct result of the amount of land fallowed for each shortage amount. Similar to the acreages of fallowed land, the changes in production value is expected to decrease as a result of less land being fallowed in the future for non-Indian agriculture.

Table 4.14-2
Estimated Change in Agricultural Production Value Resulting from Involuntary Land Fallowing in Arizona under Various Levels of Shortage for Various Years

Shortage (af)	Non-Indian Agriculture					
	2008	2017	2026	2027	2040	2060
400,000	-	$51,195,179	$12,387,806	-	-	-
500,000	-	$51,953,661	$13,149,411	$8,006,656	$3,270,691	$3,296,452
600,000	-	$52,712,002	$13,910,889	$8,770,989	$4,051,276	$4,082,213
800,000	-	$54,433,982	$15,643,948	$10,510,445	$5,830,923	$5,872,090
1,000,000	-	$56,268,414	$17,322,373	$12,192,218	$7,566,566	$7,652,684
1,200,000	-	-	-	$13,929,676	$9,340,389	$9,443,813
1,800,000	-	-	-	-	$16,709,801	$16,857,520
2,500,000	-	-	-	-	-	-
Shortage (af)	Indian Agriculture					
	2008	2017	2026	2027	2040	2060
400,000	-	$414,478	$9,312,403	-	-	-
500,000	-	$1,519,888	$14,973,885	$17,968,660	$17,145,722	$22,004,969
600,000	-	$7,647,965	$17,934,942	$20,962,163	$20,778,353	$23,911,269
800,000	-	$17,103,947	$25,412,798	$28,397,854	$28,403,141	$40,722,440
1,000,000	-	$23,748,789	$33,894,540	$38,696,649	$38,675,888	$44,848,932
1,200,000	-	-	-	$51,659,413	$51,279,840	$57,414,819
1,800,000	-	-	-	-	$83,717,890	$88,879,486
2,500,000	-	-	-	-	-	-

Table 4.14-2
Estimated Change in Agricultural Production Value Resulting from Involuntary Land Fallowing in Arizona under Various Levels of Shortage for Various Years

Shortage (af)	Total Agriculture					
	2008	2017	2026	2027	2040	2060
400,000	-	$51,609,657	$21,700,209	-	-	-
500,000	-	$53,473,550	$28,123,296	$25,975,317	$20,416,414	$25,301,421
600,000	-	$60,359,967	$31,845,830	$29,733,152	$24,829,629	$27,993,482
800,000	-	$71,537,929	$41,056,747	$38,908,299	$34,234,064	$46,594,531
1,000,000	-	$80,017,202	$51,216,914	$50,888,868	$46,242,454	$52,501,616
1,200,000	-	-	-	$65,589,088	$60,620,229	$66,858,632
1,800,000	-	-	-	-	$100,427,690	$105,737,006
2,500,000	-	-	-	-	-	-

Note: a dash indicates that a shortage of the given magnitude did not occur in the particular year

4.14.2.1 Changes in Agricultural Production and Resulting Changes in Employment and Income in Arizona

This section describes the potential changes in employment and income for each alternative as a result of changes in agricultural production. The discussion is a summary of the impact analysis conducted for the Arizona counties that may experience a shortage resulting in changes in agricultural production. The results of this county-level assessment of changes in employment and income for each shortage amount, year, and county are provided in Appendix H. The counties analyzed are Maricopa, Pinal, Pima, Mohave, La Paz, Yuma, and Graham. A summary comparison of the effects on employment and income among the alternatives is provided at the end of this subsection.

Table 4.14-3 presents a comparison of the shortage amounts with the estimated changes in employment and income and lists the probabilities of occurrence for each alternative, based on Tables 4.4-5 through 4.4-9. Shortages generated by the alternatives that were not exactly equal to the amounts shown in Table 4.14-3 were counted at the next highest value for the probabilities listed in Table 4.14-3.

Table 4.14-3
Estimated Changes in Employment as a Result of Shortages to Agricultural Lands for the No Action, Basin States, and Conservation Before Shortage, Water Supply and Reservoir Storage Alternatives, by Selected Years and Shortage Amounts

Shortage Amount (af)	2017						
	Shortage Probabilities for Each Alternative (percent)					Jobs	Income ($ million)
	NA	BS	CBS	WS	RS		
400,000	-	18	-	-	-	(534)	(21.0)
500,000	39	7	-	-	-	(597)	(21.3)
600,000	-	2	-	-	22	(707)	(25.3)
800,000	-	-	-	-	9	(853)	(29.4)
1,000,000	1	-	1	-	2	(929)	(32.8)
1,200,000	-	-	-	-	-	-	-
1,800,000	-	-	-	-	-	-	-
2,500,000	-	-	-	-	-	-	-
Shortage Amount (af)	**2026**						
	Shortage Probabilities for Each Alternative (percent)					Jobs	Income ($ million)
	NA	BS	CBS	WS	RS		
400,000	-	16	2	9	-	(316)	(8.8)
500,000	39	12	-	-	-	(406)	(11..4)
600,000	1	7	-	-	19	(453)	(12.9)
800,000	3	-	4	-	14	(561)	(16.7)
1,000,000	2	-	1	-	4	(656)	(21.7)
1,200,000	-	-	-	-	-	-	-
1,800,000	1	-	1	-	-	(1,206)	(42.5)
2,500,000	-	-	-	-	-	-	-
Shortage Amount (af)	**2027**						
	Shortage Probabilities for Each Alternative (percent)					Jobs	Income ($ million)
	NA	BS	CBS	WS	RS		
400,000	-	-	-	-	-	-	-
500,000	39	48	45	43	37	(356)	(10.5)
600,000	1	1	1	-	-	(402)	(11.7)
800,000	3	-	-	1	-	(515)	(16.0)
1,000,000	3	-	3	-	-	(634)	(21.1)
1,200,000	1	1	1	1	-	(780)	(29.2)
1,800,000	1	-	-	3	-	(1,204)	(43.8)
2,500,000	-	-	-	4	-	-	-

Table 4.14-3
Estimated Changes in Employment as a Result of Shortages to Agricultural Lands for the No Action, Basin States, and Conservation Before Shortage, Water Supply and Reservoir Storage Alternatives, by Selected Years and Shortage Amounts

Shortage Amount (af)	2040						
	Shortage Probabilities for Each Alternative (percent)					Jobs	Income ($ million)
	NA	BS	CBS	WS	RS		
400,000	-	-	-	-	-	-	-
500,000	42	41	40	37	46	(221)	(5.7)
600,000	1	1	1	1	-	(352)	(10.2)
800,000	2	2	2	4	-	(454)	(14.2)
1,000,000	1	1	1	2	2	(571)	(18.4)
1,200,000	3	3	7	4	-	(715)	(25.2)
1,800,000	4	5	2	5	3	(1,066)	(41.6)
2,500,000	-	-	-	-	-	-	-
Shortage Amount (af)	2060						
	Shortage Probabilities for Each Alternative (percent)					Jobs	Income ($ million)
	NA	BS	CBS	WS	RS		
400,000	-	-	-	-	-	-	-
500,000	55	53	49	53	54	(354)	(10.1)
600,000	1	-	3	1	-	(388)	(11.6)
800,000	4	5	5	4	5	(569)	(19.2)
1,000,000	3	2	2	3	1	(640)	(21.8)
1,200,000	3	3	4	3	4	(783)	(27.9)
1,800,000	4	4	3	4	3	(1,164)	(42.9)
2,500,000	-	-	-	-	-	-	-

Note:

NA = No Action Alternative

WS = Water Supply Alternative

CBS = Conservation Before Shortage Alternative

BS = Basin States Alternative

RS = Reservoir Storage Alternative

- = No shortage occurring

No Action Alternative. Potential decreases in employment attributable to a shortage occurring under the No Action Alternative for the period 2008 through 2026 would range from a low of 406 jobs during a 500,000 af shortage in 2026 to a high of 1,206 jobs during a 1.8 maf shortage in 2026. Resulting losses in personal income range from a low of approximately $11.4 million to a high of approximately $42.5million (Table 4.14-3).

For the period 2008 through 2026, a shortage of approximately 500,000 af would have the greatest probability of occurring, estimated at 39 percent. This shortage amount would result in an estimated loss of up to 597 jobs and resulting reduction in personal income of approximately $21.3 million (Table 4.14-3). Even if considered to be permanent, these potential changes in jobs and personal income are not considered substantial because the changes represent less than one percent of total employment and personal income generated within the seven-county study area in Arizona.

Potential decreases in employment attributable to a shortage occurring under the No Action Alternative for the period 2027 through 2060 would range from a low of 221 jobs during a 500,000 af shortage in 2040 to high of 1,164 jobs during a 1.8 maf shortage in 2060. Resulting losses in personal income over the same period would range from a low of approximately $5.7 million to a high of approximately $42.9 million (Table 4.14-3).

For the period 2027 through 2060, a shortage of approximately 500,000 af would have the greatest probability of occurring, ranging from 39 percent in 2027 to 55 percent in 2060. In 2060, a 500,000 af shortage would result in an estimated loss of 354 jobs and reduction in personal income of approximately $10.1 million (Table 4.14-3). Even if considered to be permanent, these potential changes in jobs and personal income are not considered substantial because the changes represent less than one percent of total employment and personal income within the seven-county study area in Arizona.

Basin States Alternative. Potential decreases in employment attributable to a shortage occurring under the Basin States Alternative for the period 2008 through 2026 would range from a low of 316 jobs during a 400,000 af shortage in 2026 to a high of 707 jobs during a 600,000 af shortage in 2017 resulting in a loss in personal income ranging from approximately $8.8 million to $25.3 million (Table 4.14-3).

For the period 2008 through 2026, a shortage of 400,000 af would have the greatest probability of occurring, 18 percent in 2017 and 16 percent in 2026, with corresponding estimated losses of 534 and 316 jobs respectively, and reductions in personal income of approximately $21.0 and 8.8 million respectively. Even if considered to be permanent, these potential changes in jobs and personal income are not considered substantial because the changes represent less than one percent of total employment and personal income within the seven-county study area in Arizona. As with the No Action Alternative, the probabilities of shortages of 600,000 af or greater occurring between 2008 and 2026 are very low for the Basin States Alternative.

Potential decreases in employment attributable to a shortage occurring under the Basin States Alternative between 2027 and 2060 would range from a low of 221 jobs during a 500,000 af shortage in 2040 to a high of 1,164 jobs during a 1.8 maf shortage in 2060. Resulting losses in personal income would range from a low of approximately $5.7 million to a high of approximately $42.9 million (Table 4.14-3).

For the period 2027 through 2060, a shortage of 500,000 af would have the greatest probability of occurring, ranging from 41 to 53 percent. The 500,000 af shortage amount would result in an estimated loss of up to 354 jobs and reduction in personal income of up to $10.1 million (Table 4.14-3). Even if considered to be permanent, these changes in jobs and personal income are not considered substantial because the changes represent less than one percent of total employment and personal income within the seven-county study area in Arizona. The probabilities of shortages of 600,000 af or greater occurring for the period 2027 through 2060 for the Basin States Alternative are higher than during the period 2008 to 2026, but are very similar to the No Action Alternative.

Conservation Before Shortage Alternative. It should be noted that the results of the analysis reported in this discussion may underestimate the socioeconomic effects of particular shortages occurring under the Conservation Before Shortage Alternative. This analysis assumes that the voluntary conservation targets (400 kaf, 500 kaf, and 600 kaf at Lake Mead elevations 1,075 feel msl, 1,050 feel msl, and 1,025 feet msl respectively) would be met, assuming that farmers would participate voluntarily in the program and that losses resulting from voluntary shortages would be offset by payments made to farmers to forgo raising crops. With these assumptions, the only the potential impacts of involuntary shortages have been analyzed in this section.

Potential decreases in employment attributable to an involuntary shortage occurring under the Conservation Before Shortage Alternative for the period 2008 through 2026 would range from a low of 316 jobs during a 400,000 af shortage in 2026 to a high of 1206 jobs during a 1.8 maf shortage in 2017. Similarly, estimated losses in personal income would range from a low of approximately $8.8 million to a high of approximately $42.5 million (Table 4.14-3).

Shortages of 500,000 af have a much greater probability of occurring under the No Action Alternative than under than under the Conservation Before Shortage Alternative. This suggests for the period 2008 through 2026 the probability of adverse socioeconomic effects occurring under the Conservation Before Shortage Alternative would be much less when compared to the No Action Alternative.

Potential decreases in employment attributable to a shortage occurring under the Conservation Before Shortage Alternative for the period 2027 through 2060 would range from a low of 221 jobs during a 500,000 af shortage in 2040 to a high of 1,164 jobs during a 1.8 maf shortage in 2060. Similarly, estimated losses in personal income over the same period would range from a low of approximately $5.7 million to a high of approximately $42.9 million (Table 4.14-3).

For the period 2027 through 2060, a shortage of 500,000 af would have the greatest probability of occurring, ranging from 40 percent to 49 percent. This 500,000 af shortage amount would result in an estimated loss of up to 356 jobs and reduction in personal income of approximately $10.5 million (Table 4.14-3). Even if considered permanent, these job losses and reductions in personal income are not considered substantial because the changes represent less than one percent of total employment and personal income within both the seven-county study area in Arizona.

When compared to the No Action Alternative, the probabilities of shortages in 2027 under the Conservation Before Shortage Alternative are higher for shortages of 500,000 af and less for greater shortages. However, in 2060 shortages of 500,000 af have a slightly lower probability of occurring under the Conservation Before Shortage Alternative and similar probabilities for higher shortage levels.

Water Supply Alternative. For the period 2008 through 2026, potential decreases in employment attributable to a shortage under the Water Supply Alternative would occur only during a 400,000 af shortage in 2026. This would result in an estimated loss of 316 jobs and reduction in personal income of $8.8 million (Table 4.14-3). This lack of shortages is a result of this alternative's strategy to provide full water deliveries until no water remains in Lake Mead, a reservoir draw down situation which has a low probability of occurring during the interim period.

Potential decreases in employment attributable to a shortage occurring under the Water Supply Alternative for the period 2027 through 2060 would range from a low of 221 jobs during a 500,000 af shortage in 2040 to a high of 1,164 jobs during a 1.8 maf shortage in 2060. Resulting losses in personal income over the same period would range from a low of approximately $5.7 million to a high of approximately $42.9 million (Table 4.14-3).

For the period 2040 through 2060, the probability of shortages under the Water Supply Alternative are very similar to those of the other alternatives, and shortages of 500,000 af would have the greatest probability of occurring, ranging from 37 percent to 53 percent. A 500,000 af shortage would result in an estimated loss of up to 356 jobs and reduction in personal income of up to $10.5 million. Even if considered to be permanent, these changes in jobs and personal income are not considered substantial because the changes represent less than one percent of total employment and personal income within the seven-county study area in Arizona.

Reservoir Storage Alternative. Potential decreases in employment attributable to a shortage occurring under the Reservoir Storage Alternative for the period 2008 through 2026 would range from a low of 453 jobs during a 600,000 af shortage in 2026 to a high of 929 jobs during a one maf shortage in 2017. Resulting losses in personal income over the same period would range from a low of approximately $12.9 million to a high of approximately $32.8 million (Table 4.14-3).

For the period 2008 through 2026, a shortage of 600,000 af would have the greatest probability of occurring, ranging from 19 percent to 22 percent. A 600,000 af shortage would result in an estimated loss of up to 707 jobs and reduction in personal income of approximately $25.3 million (Table 4.14-3). Even if considered to be permanent, these changes in jobs and personal income are not considered substantial because the changes represent less than one percent of total employment and personal income within the seven-county study area in Arizona.

When compared to the No Action Alternative, the probabilities of shortages of one maf or greater occurring for the period 2008 through 2026 are similar. However, shortages of 500,000 af have a much greater potential of occurring under the No Action Alternative whereas shortages of 600,000 af and 800,000 af have a greater probability of occurring under the Reservoir Storage Alternative. This suggests that for the period 2008 through 2026 the probability of adverse socioeconomic effects occurring under the Reservoir Storage Alternative may be slightly less than the No Action Alternative, but when shortages do occur, they are greater in magnitude with increased socioeconomic effects.

Potential decreases in employment attributable to a shortage occurring under the Reservoir Storage Alternative for the period 2027 through 2060 would range from a low of 221 jobs during a 500,000 af shortage in 2040 to a high of 1,164 jobs during a 1.8 maf shortage in 2060 (Table 4.14-3). Resulting losses in personal income would range from a low of approximately $5.7 million to a high of approximately $42.9 million (Table .14-3).

For the period 2027 through 2060, a shortage of 500,000 af would have the greatest probability of occurring, ranging from 37 percent to 54 percent. A 500,000 af shortage would result in an estimated loss of up to 356 jobs and reduction in personal income of up to $10.5 million (Table 4.14-3). Even if considered to be permanent, these changes in jobs and personal income are not considered substantial because the changes represent less than one percent of total employment and personal income within the seven-county study area and Arizona.

When compared to the No Action Alternative, the probabilities of shortages occurring under the Reservoir Storage Alternative are lower than the other alternatives in 2027 but very similar in 2060.

4.14.2.2 Changes in Tax Revenues in Arizona

This section describes the potential changes in tax revenue for each alternative as a result of changes in agricultural production. Changes in tax revenue would result from the direct reduction in agricultural production, from reduced business-to-business activity, and from reductions in personal income. The tax revenue discussion summarizes the impacts for those Arizona counties that may experience a water shortage resulting in changes in agricultural production. The results of the county-level assessment on tax revenues for each shortage amount, year, and county are provided in Appendix H. The counties analyzed are Maricopa, Pinal, Pima, Mohave, La Paz, Yuma, and Graham. A summary comparison of the effects on tax revenue is provided at the end of this subsection.

Table 4.14-4 presents a comparison of the shortage amounts with the estimated changes in tax revenues and lists the probabilities of occurrence for each alternative. Shortages generated by the alternatives that were not exactly equal to the amounts shown in Table 4.14-4 were counted at the next highest value for the probabilities listed in Table 4.14-4.

Table 4.14-4
Estimated Changes in Tax Revenues as a Result of Shortages to Agricultural Lands under the No Action, Basin States, Conservation Before Shortages, Water Supply, and Reservoir Storage Alternatives, by Selected Year and Shortages

Shortage Amount (af)	2017					
	Shortage Probabilities for Each Alternative (percent)					Changes in Tax Revenues ($ million)
	NA	BS	CBS	WS	RS	
400,000	-	18	-	-	-	(7.3)
500,000	39	7	-	-	-	(7.5)
600,000	-	2	-	-	22	(8.6)
800,000	-	-	-	-	9	(10.1)
1,000,000	1	-	1	-	2	(11.3)
1,200,000	-	-	-	-	-	-
1,800,000	-	-	-	-	-	-
2,500,000	-	-	-	-	-	-
Shortage Amount (af)	2026					
	Shortage Probabilities for Each Alternative (percent)					Changes in Tax Revenues ($ million)
	NA	BS	CBS	WS	RS	
400,000	-	16	2	9	-	(3.1)
500,000	39	12	-	-	-	(4.0)
600,000	1	7	-	-	19	(4.5)
800,000	3	-	4	-	14	(5.8)
1,000,000	2	-	1	-	4	(7.3)
1,200,000	-	-	-	-	-	-
1,800,000	1	-	1	-	-	(14.3)
2,500,000	-	-	-	-	-	-
Shortage Amount (af)	2027					
	Shortage Probabilities for Each Alternative (percent)					Changes in Tax Revenues ($ million)
	NA	BS	CBS	WS	RS	
400,000	-	-	-	-	-	-
500,000	39	48	45	43	37	(3.5)
600,000	1	1	1	-	-	(4.1)
800,000	3	-	-	1	-	(5.5)
1,000,000	3	-	3	-	-	(7.2)
1,200,000	1	1	1	1	-	(9.3)
1,800,000	1	-	-	3	-	(14.8)
2,500,000	-	-	-	4	-	-

Table 4.14-4
Estimated Changes in Tax Revenues as a Result of Shortages to Agricultural Lands under the No Action, Basin States, Conservation Before Shortages, Water Supply, and Reservoir Storage Alternatives, by Selected Year and Shortages

Shortage Amount (af)	2040					
	Shortage Probabilities for Each Alternative (percent)					Changes in Tax Revenues ($ million)
	NA	BS	CBS	WS	RS	
400,000	-	-	-	-	-	-
500,000	42	41	40	37	46	(2.0)
600,000	1	1	1	1	-	(3.5)
800,000	2	2	2	4	-	(4.9)
1,000,000	1	1	1	2	2	(6.6)
1,200,000	3	3	7	4	-	(8.7)
1,800,000	4	5	2	5	3	(11.3)
2,500,000	-	-	-	-	-	-
Shortage Amount (af)	2060					
	Shortage Probabilities for Each Alternative (percent)					Changes in Tax Revenues ($ million)
	NA	BS	CBS	WS	RS	
400,000	-	-	-	-	-	-
500,000	55	53	49	53	54	(3.6)
600,000	1	-	3	1	-	(4.0)
800,000	4	5	5	4	5	(6.6)
1,000,000	3	2	2	3	1	(7.5)
1,200,000	3	3	4	3	4	(9.4)
1,800,000	4	4	3	4	3	(14.6)
2,500,000	-	-	-	-	-	-

Note:

NA = No Action Alternative

WS = Water Supply Alternative

CBS = Conservation Before Shortage Alternative

BS = Basin States Alternative

RS = Reservoir Storage Alternative

- = No Shortage Occurring

Arizona reported a total of $8.477 billion in state taxes collected and $5.943 billion in local government taxes collected for 2001–2002 (<http://ftp2.census.gov/govs/estimate/02slsstab1a.xls>). These values are compared to the tax impacts associated with the project alternatives, discussed in the following paragraphs and referring to Table 4.14-4 and Appendix H.

No Action Alternative. Potential decreases in tax revenue for the period 2008 through 2026 would range from a low of $4 million during a 500,000 af shortage in 2026 to a high of $14.3 million during a 1.8 maf shortage in 2026. For the period 2008 through 2026, a shortage of approximately 500,000 af would have the greatest probability of occurring, estimated at 39 percent.

Potential decreases in tax revenue for the period 2027 through 2060 would range from a low of $2 million during a 500,000 af shortage in 2040 to a high of $14.8 million during a 1.8 maf shortage in 2027. For the period 2027 through 2060, a shortage of 500,000 af would have the greatest probability of occurring, estimated at between 39 percent in 2027 to 55 percent in 2060. These changes in tax revenues represent a small percentage of total state and local taxes collected.

Basin States Alternative. Potential decreases in tax revenue occurring under the Basin States Alternative for the period 2008 through 2026 would range from a low of $3.1 million during a 400,000 af shortage in 2026 to a high of $8.6 million during a 600,000 af shortage in 2017. For the period 2008 through 2026, a shortage of 400,000 af would have the greatest probability of occurring, estimated at 16 to 18 percent.

Potential decreases in tax revenue attributable to a shortage occurring during the Basin States Alternative during the period 2027 through 2060 would range from a low of $2 million during a 500,000 af shortage in 2040 to a high of $14.6 million during a 1.8 maf shortage in 2060. For the period 2027 through 2060, a shortage of 500,000 af would have the greatest probability of occurring, estimated at between 41 percent in 2040 to 53 percent in 2060. Although these tax effects are substantial, they represent a small percentage of total state and local taxes collected.

Conservation Before Shortage Alternative. This analysis assumes that the voluntary conservation targets (400 kaf, 500 kaf, and 600 kaf at Lake Mead elevations 1,075 feet msl, 1,050 feel msl, and 1,025 feet msl respectively) would be met and therefore only the potential impacts of involuntary shortages have been analyzed. Potential decreases in tax revenue due to an involuntary shortage occurring under the Conservation Before Shortage Alternative during the period 2008 through 2026 would range from a low of $3.1 million during a 400,000 af shortage in 2026 to a high of $11.3 million during a 1 maf shortage in 2017. For the period 2008 through 2026, a shortage of 800,000 af would have the greatest probability of occurring, estimated at only four percent.

Potential decreases in tax revenue attributable to a shortage occurring under the Conservation Before Shortage Alternative during the period 2027 through 2060 would range from a low of $2 million during a 500,000 af shortage in 2040 to a high of $14.6 million during a 1.8 maf shortage in 2060. For the period 2027 through 2060, a shortage of 500,000 af would have the greatest probability of occurring, estimated at between 40 percent in 2040 to 49 percent in 2060. Although these tax effects are substantial, they represent a small percentage of total state and local taxes collected.

Water Supply Alternative. Potential decreases in tax revenue occurring under the Water Supply Alternative during the period 2008 through 2026 would be limited to a loss of $3.1 million during a 400,000 af shortage in 2026. This lack of shortages is a result of this alternative's strategy to provide full water deliveries until no water remains in Lake Mead, a reservoir draw down situation which has a low probability of occurring during the interim period.

Potential decreases in tax revenue attributable to a shortage occurring under the Water Supply Alternative during the period 2027 through 2060 would range from a low of $2 million during a 500,000 af shortage in 2040 to a high of $14.6 million during a 1.8 maf shortage in 2060. For the period 2027 through 2060, a shortage of 500,000 af would have the greatest probability of occurring, estimated at between 37 percent in 2040 to 53 percent in 2060. Although these tax effects are substantial, they represent a small percentage of total state and local taxes collected.

Reservoir Storage Alternative. Potential decreases in tax revenue attributable to a shortage occurring under the Reservoir Storage Alternative during the period 2008 through 2026 would range from a low of $4.5 million during a 600,000 af shortage in 2026 to a high of $11.3 million during a 1 maf shortage in 2017. For the period 2008 through 2026, a shortage of 600,000 af in 2017 would have the greatest probabilities of occurring, estimated at 19 to 22 percent.

Potential decreases in tax revenue attributable to a shortage occurring under the Reservoir Storage Alternative during the period 2027 through 2060 would range from a low of $2 million during a 500,000 af shortage in 2040 to a high of $14.6 million during a 1.8 maf shortage in 2060. For the period 2027 through 2060, a shortage of 500,000 af would have the greatest probability of occurring, estimated at between 37 percent in 2027 to 54 percent in 2060. Although these tax effects are substantial, they represent a small percentage of total state and local taxes collected.

4.14.2.3 Changes in Agricultural Production in California and Resulting Changes in Employment and Income in California

The results of the water allocation modeling indicate that although a portion of the shortages may be shared by California, agricultural users would not be affected in the event a shortage occurs. In California, agricultural rights are senior enough that they are not expected to share in a shortage. None of the alternatives are expected to result in a change in agricultural production.

4.14.2.4 Changes in Agricultural Production in Nevada and Resulting Changes in Employment and Income in Nevada

The results of the water allocation modeling indicate that although a portion of the shortages may be shared by Nevada, agricultural users would not be affected in the event a shortage occurs. There are very few agricultural users that receive part of Nevada's Colorado River water allocation. None of the alternatives are expected to result in a change in agricultural production.

Shortages occurring in Nevada are expected to be limited to the M&I sector. No changes in employment and income as a result of changes in agricultural production in Nevada are expected under any of the alternatives.

4.14.3 Municipal and Industrial Water Uses

This section provides the results of the assessment of potential changes in M&I water use and resulting socioeconomic effects. The analysis is a qualitative discussion supported by the assessment of the shortage probabilities and volumes described in Section 4.4.

For the period 2008 through 2060 the probability of a shortage occurring is highest for shortages ranging from 400,000 to 800,000 af and the probabilities of shortages occurring greater than 800,000 af are very similar among all the alternatives, including the No Action Alternative. Accordingly, the focus of the M&I analysis was to describe the effects of shortages that range from 400,000 af to 800,000 af.

For the period 2008 through 2026, the greatest differences in shortage probabilities would occur under the Basin States Alternative and the Reservoir Storage Alternative. In 2017, a 600,000 af shortage would have a 22 percent chance of occurring under the Reservoir Storage Alternative compared to a zero percent chance under the No Action Alternative. Conversely, a 500,000 af shortage would have a much greater likelihood of occurring under the No Action Alternative compared to all the action alternatives.

For the period 2027 through 2060, the probability of a shortage occurring under each alternative is highest at the 500,000 af shortage level. When compared to the No Action Alternative, shortages of 500,000 af in 2027 have a greater probability of occurring under all the action alternatives. Conversely, in 2040 and in 2060 shortages of 500,000 af have a slightly lower probability of occurring under all the action alternatives when compared to the No Action Alternative.

4.14.3.1 Changes in Municipal and Industrial Water Uses In Arizona

This section describes the potential socioeconomic effects that would result from changes in deliveries to M&I users in Arizona. As described above, the analysis is based on an analysis of shortage amounts in the range of 400,000 af to 800,000 af.

Arizona’s Drought Management Plan serves as an umbrella that provides direction to Arizona state agencies and guidance to regional and local agencies regarding responses to drought conditions (Arizona 2004). Shortages to the Arizona M&I sector would be addressed through the state’s and each local jurisdiction’s drought responses and plans. These responses include supply-side and demand-side actions. Supply-side actions may include groundwater recharge, water purchase agreements, and alternative water supplies such as brackish water and reclaimed water. Demand-side strategies focus on implementing different stages of water conservation measures as a drought progresses. Shortages to the Arizona M&I sector would be addressed through each entity’s supply-side and demand-side drought response actions and programs.

Arizona M&I shortages of up to 283,000 af could occur during shortages in the range of 400,000 af to 800,000 af. Implementing statewide and local demand-side and supply-side strategies are expected to minimize adverse socioeconomic effects occurring during the maximum M&I shortage.

4.14.3.2 Changes in Municipal and Industrial Water Uses In California

The section provides the results of the analysis of changes of potential socioeconomic effects as a result of changes in deliveries to M&I users. The conclusion is based on information provided in the water supply section. In summary, deliveries to MWD are not anticipated to be adversely affected for the Lower Basin shortages up to 1.8 maf because of California's higher priority relative to Arizona's and Nevada's Colorado River water supply priorities. In addition, shortages of 1.8 maf or greater have a low probability of occurring. MWD has or is working on putting in place storage and transfer programs that are expected to provide full supplies when needed even when Colorado River surplus supplies are not available. MWD has implemented and continues to expand storage and transfer programs that could be implemented to make up for water supply shortfalls in the event of a shortage. Examples of MWD actions include agreements with irrigation districts and individual landowners to reduce water use by fallowing lands, funding water efficiency improvements, and banking and exchange programs.

MWD is not expected to experience a substantial reduction in deliveries to M&I users during a shortage because of the priority of California's water rights in combination with the availability of alternative water supplies. The action alternatives are not expected to result in a substantial change in economic activities dependent on M&I deliveries.

4.14.3.3 Changes in Municipal and Industrial Water Uses in Nevada

This section describes the potential socioeconomic effects that would result from changes in deliveries to M&I users in Nevada. The analysis is based on a comparison of the action alternatives to the No Action Alternative.

Shortages to the M&I sector of Southern Nevada would mostly be borne by the SNWA, which has prepared a drought plan (SNWA Drought Plan 2005) to address water shortages. That plan includes two levels – a drought watch and a drought alert and calls for landscape watering restrictions to private lawns, community use recreational turf areas, and golf courses. The plan also includes restrictions on surface, building, equipment, and vehicle washing.

Each action alternative would have shortage allocations that are less than or almost equivalent to those under the No Action Alternative. The largest differential would occur under the Water Supply Alternative in 2027, where the shortage would equal 84,290 af as compared to 60,565 af under the No Action Alternative. Even under this most extreme scenario, however, the drought plan would be used to make up the water supply shortfall of less than 25,000 af. For each scenario, the probability of shortages in southern Nevada would not be substantially different than under the No Action Alternative. In addition, with Nevada's drought plan in place, shortages to the M&I sector (under the No Action Alternative or under either of the action alternatives) would be minimized. Consequently, socioeconomic effects on southern Nevada's M&I sector resulting from the proposed alternatives would not be substantial.

4.14.4 Recreation

This section describes the changes in reservoir-related and river-related economic activity attributable to implementing the shortage criteria alternatives. The assessment is based, in part, on the conclusions provided in Section 4.3 and Section 4.12.

4.14.4.1 Change in Economic Activity as a Result of Changes in Recreation Occurring at Lake Powell

The following qualitative assessment of changes in recreation-related economic activity is based on a comparison of Lake Powell elevations modeled for the No Action Alternative and each action alternative.

As shown in Figure 4.14-2, at the 90th percentile, there are no differences in Lake Powell end-of-September lake elevations between the alternatives. This suggests that at higher lake elevations there would be no differences in recreation opportunities and associated economic activity among the alternatives.

At the 50th percentile, end-of-September reservoir elevations under the Reservoir Storage Alternative would be nearly the same as conditions under the No Action Alternative. This suggests that recreation opportunities and resulting economic activity would not change. Reservoir elevations would be lower under the Conservation Before Shortage, Basin States, and the Water Supply Alternatives when compared to the No Action Alternative, with the Water Supply Alternative showing the lowest 50th percentile elevations. Because the reservoir would have substantial storage under all alternatives at the 50th percentile level, these lower elevations are not expected to result in substantial change in recreation opportunities at Lake Powell and would not result in a substantial change in recreation-related economic activity.

The greatest differences in Lake Powell elevations would occur at the 10th percentile. Lake Powell elevations would be higher under the Reservoir Storage Alternative when compared to the No Action Alternative. These higher elevations would benefit recreation opportunities at Lake Powell and resulting economic activity. Reservoir levels would be nearly the same for the Basin States, Conservation Before Shortage, and the No Action Alternative. This suggests that recreation-related economic activity would be the same among these three alternatives. Reservoir elevations would be lowest under the Water Supply Alternative and would result in the greatest adverse effect on recreation opportunities and associated reduction in economic activity.

4.14.4.2 Change in Economic Activity as a Result of Changes in Recreation Occurring in the Colorado River Below Lake Powell

Recreation opportunities and use would not be adversely affected on the Colorado River reach below Lake Powell because flows would not drop below safe boating thresholds for all of the alternatives. There would be no resulting changes in recreation-related economic activity among the alternatives because recreation use is not expected to change.

4.14.4.3 Change in Economic Activity as a Result of Changes in Recreation Occurring at Lake Mead

The following qualitative assessment of changes in recreation-related economic activity is based on a comparison of Lake Powell elevations modeled for the No Action Alternative and each action alternative.

As illustrated in Figure 4.14-3, at the 90th percentile, there are essentially no differences in Lake Mead end-of-July lake elevations among the alternatives. This suggests that at the higher lake elevations there would no differences in recreation opportunities and associated economic activity.

At the 50th percentile, end-of-July reservoir elevations under the Reservoir Storage Alternative would be higher when compared to the No Action Alternative. This suggests that recreation opportunities and resulting economic activity would be greater under the Reservoir Storage Alternative. Reservoir levels for the Basin States, Conservation Before Shortage, and No Action alternatives would be nearly the same. No substantial differences in economic activity would occur under the Conservation Before Shortage, Basin States, and Water Supply alternatives.

The greatest differences in Lake Mead elevations would occur at the 10th percentile. The Lake Mead elevations under the Basin States, Conservation Before Shortage, and Water Supply alternatives would be slightly higher during the interim period when compared to the No Action Alternative. This suggests that there would be only a small, if any, increase in economic activity when compared to the No Action Alternative. The Reservoir Storage Alternative would result in the greatest increase in Lake Mead elevations compared to the No Action Alternative. These higher elevations would benefit recreation opportunities and resulting economic activity.

4.14.4.4 Changes in Economic Activity as a Result of Changes in Recreation Occurring in the Colorado River Below Lake Mead

Recreation opportunities and use would not be adversely affected on the reach of the Colorado River below Lake Mead because releases from Hoover Dam, Davis Dam, Parker Dam, and Imperial Dam would remain within historical ranges. As a result, there would be no change in recreation-related economic activity among the alternatives because recreation opportunities and use are not expected to change.

4.14.5 Summary

4.14.5.1 Employment and Income

When compared to the No Action Alternative, none of the action alternatives would result in a substantial change in employment or income attributable to changes in agricultural production. Although a loss in employment and income would occur under each alternative, the probability of shortages occurring would be greater under the No Action Alternative. This suggests that the loss in employment and income estimated for the No Action Alternative would be reduced under each of the action alternatives. Among the action alternatives, shortages would have the greatest probability of occurring under the Reservoir Storage and Basin States alternatives, with the Reservoir Storage Alternative producing larger shortages during the interim period. This indicates that these alternatives could potentially result in the greatest loss in employment and income. However, none of the changes in employment and income are considered substantial when compared to total employment and income generated within the study area.

For the period 2027 through 2060, the change in employment and income would be similar between the No Action Alternative and the action alternatives. The greatest difference would be in 2027 in which the probabilities would be slightly higher when compared to the No Action Alternatives. However, by 2040, the probabilities of shortages occurring under all alternatives are very similar.

4.14.5.2 Tax Revenues

When compared to the No Action Alternative, none of the action alternatives would result in a greater change in tax revenues attributable to changes in agricultural production. Although a reduction in tax revenues would occur under each alternative, the probability of a shortage occurring would be greatest under the No Action Alternative. The loss in tax revenue estimated for the No Action Alternative would be lower under each of the action alternatives. Among the action alternatives, shortages would have the greatest probability of occurring under the Reservoir Storage and Basin States alternatives, suggesting that these alternatives would result in the greatest loss in tax revenues. However, none of the changes in tax revenues are considered substantial when compared to total tax revenue generated within the study area.

For the period 2027 through 2060, the change in tax revenue would be similar between the No Action Alternative and the action alternatives. The greatest difference would be in 2027 in which the shortage probabilities would be slightly higher when compared to the No Action Alternative. However, by 2040, the probabilities of shortages occurring under all alternatives are very similar, suggesting that the change in tax revenues among all alternatives would be similar.

4.14.5.3 Municipal and Industrial Water Uses

Adverse effects on employment and income in Arizona and Nevada during shortages would be minimized as a result of drought plans being in place. No adverse effects are expected in California because of priority of apportionment and the availability of alternative water supplies.

4.14.5.4 Recreation

Recreation opportunities and associated economic activity at Lake Powell are not expected to be substantially different between the No Action, Basin States, and Conservation Before Shortage alternatives. Recreation opportunities and associated economic activity would be adversely affected under the Water Supply Alternative. Conversely, recreation opportunities and associated economic activity would benefit under the Reservoir Storage Alternative as a result of higher Lake Powell elevations.

Recreation opportunities and associated economic activity at Lake Mead are not expected to be substantially different between the No Action Alternative or the Basin States, Conservation Before Shortage, and Water Supply alternatives. Recreation opportunities and associated economic activity would benefit under the Reservoir Storage Alternative as a result of higher Lake Mead elevations.

Because flows in the Lake Powell to Lake Mead reach and in the reach downstream of Lake Mead would remain within ranges suitable for boating, there would be no change in river-related economic activity.

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4.15 Environmental Justice

This section describes the methods of analysis, and potential effects on environmental justice communities at the county level.

4.15.1 Methodology

The nine environmental justice counties were examined by resource to identify whether any of the alternatives are likely to have disproportionate and adverse human health or environmental impacts.

4.15.2 Hydrology, Water Deliveries, and Socioeconomics

Potential water shortages will not impact water deliveries in Utah (Section 3.2) and would only rarely affect water deliveries in California (Table 4.4-16 and Table 4.4-17). Five of the eight Arizona counties are environmental justice communities. Two of the three counties served by the CAP are environmental justice communities (Pinal and Pima). Under all alternatives, a shortage would cause the reduction of water deliveries first to the CAP and other post-1968 Colorado River contractors in Arizona. While some would consider this a disproportionate impact on these Arizona counties as compared to other Colorado River contractors, this shortage allocation is mandated under the CRBPA, and would occur under all of the action alternatives as well as under the No Action Alternative.

As an example of the magnitude of potential socioeconomic impacts, in 2026 a 500,000 af shortage has a 39 percent chance of occurring under the No Action Alternative. This would potentially result in a loss of about 270 jobs. In comparison, under the Basin States Alternative, the probability of occurrence is approximately 12 percent and would result in a loss of the same number of jobs. Under the Conservation Before Shortage Alternative and the Water Supply Alternative, there would be a zero percent probability of this shortage in 2026. Under the Reservoir Storage Alternative, there is a zero percent probability of shortage in 2026. The biggest difference in the probability of shortage occurs in 2017 with a 22 percent probability of occurrence under the Reservoir Storage Alternative and a zero percent probability of occurrence under the No Action Alternative. Even so, this effect is projected to only result in the loss of approximately 215 jobs. The loss in the number of jobs is so small compared to the total number of jobs in the environmental justice counties that the effects of the alternatives are negligible.

Accordingly, there is no substantive difference among the alternatives with respect to environmental justice impacts from water deliveries and socioeconomics.

4.15.3 Water Quality

Potential changes to water quality were evaluated for salinity, temperature, metals, and perchlorate. Effects on these parameters would be minor and would not disproportionately affect any environmental justice communities in the study area. For example, in Imperial County, California, the predicted salinity values would range from 740 mg/L to 764 mg/L. All values are below the 879 mg/L numeric criterion established by the Colorado River Salinity Control Forum.

4.15.4 Air Quality

Potential changes to fugitive dust emissions due to exposed shoreline are minor at Lake Powell (San Juan County) and there is no significant difference among alternatives at Lake Mead or downstream. Therefore, the proposed federal action would not disproportionately impact any environmental justice communities.

4.15.5 Visual Resources

Potential impacts to visual resources were considered for calcium carbonate rings, attraction features, and sediment deltas. While some of these features are located within San Juan County, Utah, (e.g. Rainbow Bridge) an environmental justice community, effects are not disproportionate or unique to any environmental justice community.

4.15.6 Biological Resources

Potential impacts to biological resources would not disproportionately impact any environmental justice community identified within the study area. Potential impacts to vegetation, wildlife, and fish due to the action alternatives would be minor.

Scoping and subsequent consultation did not result in the identification of any environmental justice community for whom indigenous fish, vegetation, or wildlife constituted a significant portion of their diet. There will not be any difference in rates or patterns of subsistence consumption by environmental justice communities, including Indian tribes, in comparison to the general population in the study area.

4.15.7 Cultural Resources

Potential impacts or access to cultural resources are not expected to be unique to the environmental justice communities identified in the study area. Reclamation and the cooperating agencies are committed to compliance with all laws and regulations associated with historic properties, sacred sites, and cultural resources. Consultations are ongoing with concerned Indian tribes.

4.15.8 Indian Trust Assets

Reclamation has concluded that the proposed federal action will have no significant impacts on ITAs. Reclamation is committed to protecting and maintaining ITAs and rights reserved by or granted to Indian tribes or individual Indians by treaties, statutes, and executive orders.

4.15.9 Electrical Power Resources

Changes to electrical power production among the alternatives have the potential to affect environmental justice communities disproportionately through possible minor increases in electricity rates resulting from decreased electrical power generation under some of the action alternatives. However, these changes in electrical power production are generally very minor (less than one percent) and the facilities potentially affected produce less than four percent of the total power produced in the region. Therefore no substantial environmental justice effects are anticipated.

4.15.10 Recreation

Potential recreational impacts are primarily associated with shoreline facilities around Lake Powell and Lake Mead. San Juan County, Utah, which is greater than 50 percent minority, includes a portion of Lake Powell and could be affected by these recreational impacts; however, the effect would not be disproportionate to the recreational impacts experienced by other counties adjacent to Lake Powell and Lake Mead.

4.15.11 Transportation

Potential transportation impacts are associated primarily with ferry services on Lake Powell and on the Colorado River below Davis Dam. At Lake Powell, both San Juan County and Kane County would be equally affected by any disruption to the ferry service due to low reservoir levels. San Juan County would not be disproportionately affected. Below Davis Dam, the ferry service across the river serves two non-environmental justice counties.

4.15.12 Summary

After evaluating each resource, it is concluded that the environmental justice communities identified in the study area would not be disproportionately affected by any of the anticipated environmental impacts stemming from the proposed federal action.

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