Appendix G

Technical Memorandum No. 1
Analysis of River Operations and Water Supply

TECHNICAL MEMORANDUM NO. 1
ANALYSIS OF RIVER OPERATIONS AND WATER SUPPLY

Prepared as Part of the

ENVIRONMENTAL IMPACT STATEMENT FOR THE IMPLEMENTATION AGREEMENT, INADVERTENT OVERRUN AND PAYBACK POLICY, AND RELATED FEDERAL ACTIONS

October 18, 2002

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1.0 RIVER SYSTEM OPERATIONS

This section presents an overview of the operation of the Colorado River system, with particular emphasis on the operation of Glen Canyon and Hoover Dams. The term *operation of the Colorado River system* refers to how the water is managed once it enters the Colorado River system and includes operation of the system reservoirs, dams and other Colorado River system facilities.

1.1 OPERATION OF THE COLORADO RIVER SYSTEM OVERVIEW

Operation of the Colorado River system and delivery of Colorado River water to the seven Basin States and Mexico are conducted in accordance with a body of documents often referred to as the *Law of the River*, which is discussed in Section 1.2.2 of the Environmental Impact Statement for the Implementation Agreement, Inadvertent Overrun and Payback Policy, and Related Federal Actions (EIS). The *Law of the River* provides that water cannot be released from storage unless there is a reasonable beneficial use for the water. The exceptions to this are releases required for flood control, river regulation or dam safety. In the Lower Basin, water is released from the system to satisfy approved water delivery orders and to satisfy other stated purposes. The principal facilities that were built to manage the water in the Colorado River System include Glen Canyon Dam and Hoover Dam.

The Colorado River system is operated by the Bureau of Reclamation (Reclamation) pursuant to the Long Range Operating Criteria (LROC) and the Annual Operating Plan (AOP). The AOP is required by the Colorado River Basin Project Act of 1968 (CRBPA). The AOP is formulated for the upcoming year under a variety of potential scenarios or conditions. The plan is developed based on projected demands, existing storage conditions and probable inflows. The AOP is prepared by Reclamation, acting on behalf of the Secretary, in consultation with the Basin States, the Upper Colorado River Commission, Indian tribes, appropriate federal agencies, representatives of the academic and scientific communities, environmental organizations, the recreation industry, water delivery contractors, contractors for the purchase of federal power, others interested in Colorado River operations, and the general public.

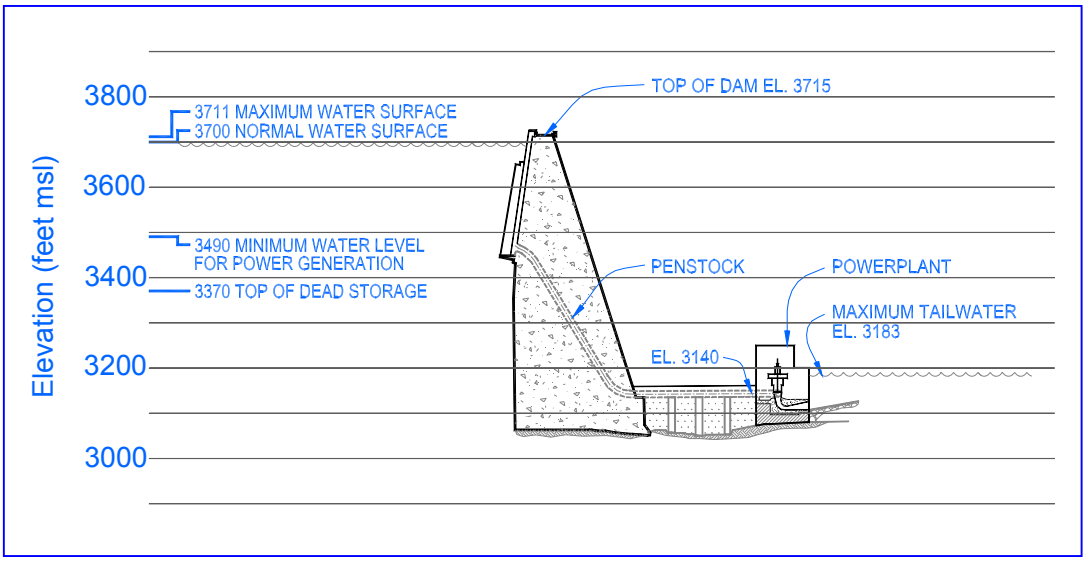
Prior to the beginning of the calendar year, Lower Basin diversion schedules are requested from major water users entitled to use Colorado River water as discussed in Section 4.4. These schedules are estimated monthly diversions and return flows that allow Reclamation to determine a tentative schedule of monthly releases through the Hoover Powerplant. Actual monthly releases are determined by the demand for water downstream of Hoover Dam. Daily changes in water releases are made to accommodate emergencies and weather.

A minimum of 1.5 million acre feet (maf) is delivered annually to Mexico in accordance with the US-Mexican Water Treaty of 1944. The Treaty contains provisions for delivery of up to 200,000 acre feet (af) above the 1.5 maf when there exists water in excess of that necessary to satisfy the uses in the United States and the guaranteed quantity of 1.5 maf to Mexico. Additionally, excess flows above the 200,000 af may become available to Mexico coincident with Lake Mead flood control releases and Gila River flood flows provided that the reasonable beneficial uses of the Lower Division states have been satisfied.

1.2 DESCRIPTION AND OPERATION OF GLEN CANYON DAM

Glen Canyon Dam is a concrete arch dam rising approximately 700 feet above the level of the Colorado River streambed. A profile of the dam is depicted on Figure 1.2-1. Except during flood conditions, the "full reservoir" water level is 3700 feet above mean sea level (msl), corresponding to the top of the spillway gates. Under normal operating conditions, releases from Glen Canyon Dam are made through the Glen Canyon Powerplant by means of gates on the upstream face of the dam. The minimum water level at which hydropower can be generated is elevation 3490 feet msl. Releases in excess of the powerplant capacity may be made when flood conditions are caused by high runoff in the Colorado River Basin, or when needed to provide Beach/Habitat Building Flows (BHBF) downstream of the dam (Reclamation, 2000).

Figure 1.2-1
Lake Powell and Glen Canyon Dam Important Operating Elevations



Flows below Glen Canyon Dam are primary influenced by storage and release decisions that are scheduled and implemented on an annual, monthly and hourly basis at Glen Canyon Dam. Other sources of water below Glen Canyon Dam include inflows from the Paria and Little Colorado rivers.

The annual volume of water released from Glen Canyon Dam is made according to the provisions of the LROC that includes a minimum objective release of 8.23 maf, storage equalization between Lake Powell and Lake Mead under prescribed conditions and the avoidance of spills. Annual releases from Lake Powell greater than the minimum occur if Upper Basin storage is greater than the storage required by Section 602(a) of the CRBPA and the storage in Lake Powell is greater than the storage in Lake Mead. Annual release volumes greater than the minimum objective of 8.23 maf are also made to avoid anticipated spills.

Monthly operational decisions are generally intermediate targets needed to systematically achieve the annual operating requirements. The actual volume of water released from Lake Powell each month depends on the forecasted inflow, storage targets, and annual release requirements described above. Demand for energy is also considered and accommodated as long as the annual release and storage requirements are not affected.

The National Weather Service Colorado Basin River Forecast Center (CBRFC) provides the monthly forecasts of expected inflow into Lake Powell. The CBRFC uses a satellite-telemetered network of hundreds of data collection points within the Upper Colorado River Basin that gather data on snow water content, precipitation, temperature and streamflow. Regression and real-time conceptual computer models are used to forecast inflows that are then used by Reclamation to plan future release volumes. Due to the variability in climatic conditions, modeling and data errors, these forecasts are based, in part, on large uncertainties. The greatest period of uncertainty occurs in early winter and decreases as the snow accumulation period progresses into the snowmelt season, often forcing modifications to the monthly schedule of releases.

An objective in the operation of Glen Canyon Dam is to attempt to safely fill Lake Powell each summer. When carryover storage from the previous year in combination with forecasted inflow allows, Lake Powell is targeted to reach storage of about 23.8 maf in July (0.5 maf from full pool). In years when Lake Powell fills or nearly fills in the summer, releases in the late summer and early winter are generally made to draw the reservoir level down, so that there is at least 2.4 maf of vacant space in Lake Powell on January 1. Storage targets are always reached in a manner consistent with the LROC.

Daily and hourly releases are made according to the parameters of the Record of Decision (ROD) for the Operation of Glen Canyon Dam Final Environmental Impact

Statement and published in the *Glen Canyon Dam Operating Criteria* (62 CFR 9447, Mar. 3, 1997), as shown in Table 1.2-1.

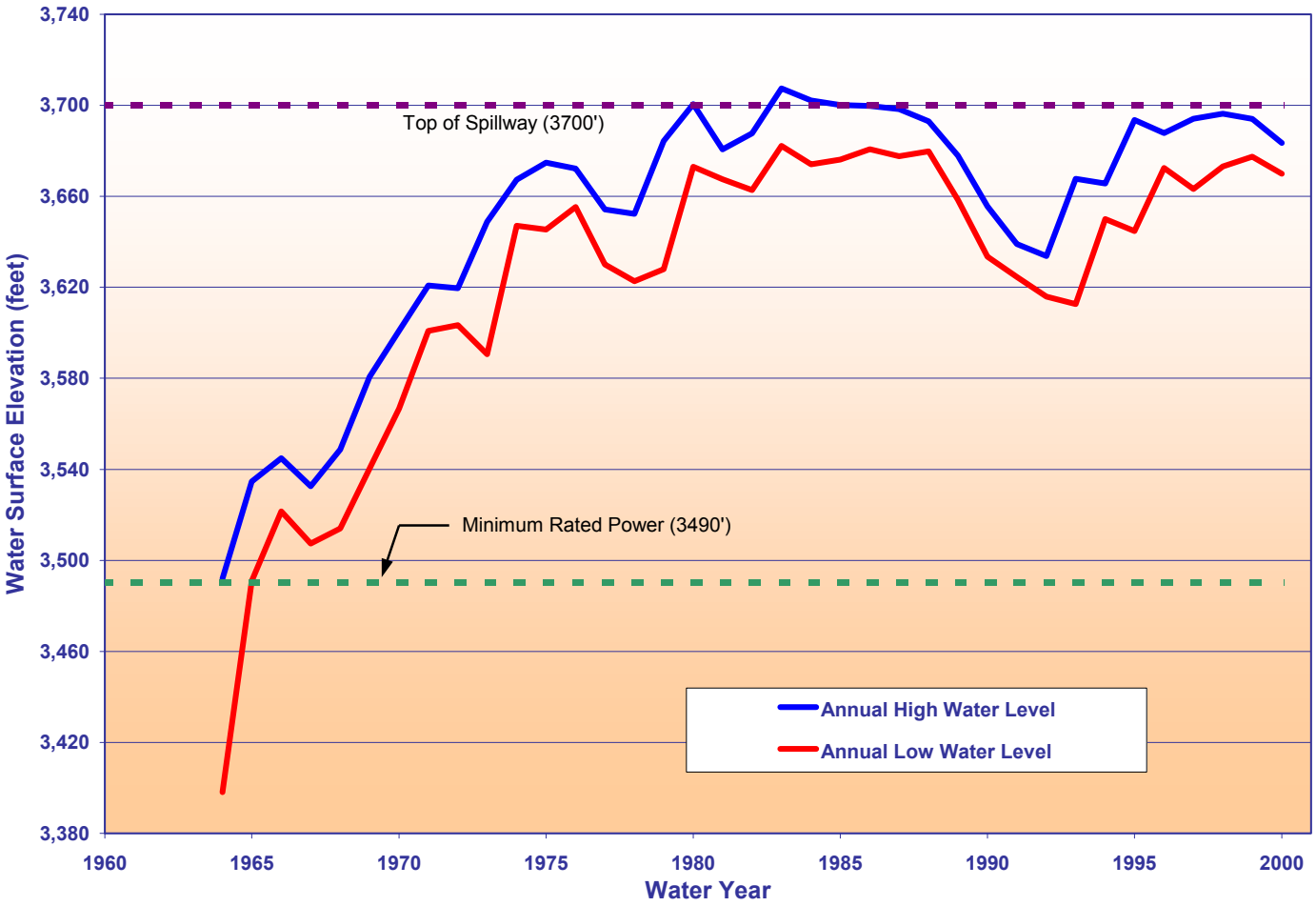
Table 1.2-1
Glen Canyon Dam Release Restrictions

Parameter	Cubic Feet per Second	Conditions
Maximum Flow[1]	25,000	
Minimum Flow	5,000	Nighttime
	8,000	7:00 a.m. to 7:00 p.m.
Ramp Rates		
Ascending	4,000	Per hour
Descending	1,500	Per hour
Daily Fluctuations[2]	5,000 to 8,000	

[1] To be evaluated and potentially increased as necessary and in years when delivery to the Lower Basin exceeds 8.23 maf.
[2] Daily fluctuation limit is 5,000 cfs for months with release volumes less than 0.6 maf; 6,000 cfs for monthly release volumes of 0.6 maf to 0.8 maf; and 8,000 cfs for monthly volumes over 0.8 maf.

Glen Canyon Dam and Lake Powell were designed to operate from a normal maximum water surface elevation of 3700 feet msl to a minimum elevation of 3490 feet msl, the minimum for hydropower production. During flood conditions, the water surface elevation of Lake Powell can exceed 3700 feet msl by raising the spillway radial gates. Since first reaching equalization storage with Lake Mead in 1974, the reservoir water level has fluctuated from a high of 3708 feet msl to a low of approximately 3612 feet msl, as shown on Figure 1.2-2. The "water year" is cited to correspond with Upper Basin water accounting.

Figure 1.2-2
Historic Lake Powell Water Levels



1.3 DESCRIPTION AND OPERATION OF HOOVER DAM

Hoover Dam and Lake Mead are operated with the following three main priorities: 1) river regulation, improvement of navigation, and flood control, 2) irrigation and domestic uses, including the satisfaction of present perfected water rights, and 3) power. The Boulder Canyon Project Act of 1928 specified flood control as the project purpose having first priority for operation of Hoover Dam and Lake Mead.

Hoover Dam is the northernmost Reclamation facility on the lower Colorado River and is located 326 miles downstream of Lee Ferry. Hoover Dam provides flood control protection and Lake Mead provides the majority of the storage capacity for the Lower Basin as well as significant recreation opportunities. Lake Mead storage capacity is 27.38 maf at a maximum water surface elevation of 1229.0 feet msl. At this elevation, Lake Mead's water surface area would equal 163,000 acres. The dam's four intake towers draw water from the reservoir at elevations above 895 feet to drive 17 generators within the dam's powerplant. The minimum water surface elevation for efficient power generation is 1083 feet msl.

Flood control regulations for Lake Mead were established to manage potential flood events arising from rain and snowmelt. Lake Mead's uppermost 1.5 maf of storage capacity, between elevations 1219.61 and 1229.0 feet, is defined as exclusive flood control. Within this capacity allocation, 1.218 maf of flood storage is above elevation 1221.0 feet, the top of the raised spillway gates. Figure 1.3-1 illustrates some of the important Hoover Dam and Lake Mead water surface elevations that are referenced in subsequent sections.

Lake Mead is usually at its maximum water level in November and December. If required, system storage space-building is achieved between August 1 and January 1. Hoover Dam storage space-building releases are limited to 28,000 cfs, while the mean daily releases to meet the water delivery orders of Colorado River water entitlement holders normally range between 8000 cfs to 18,000 cfs.

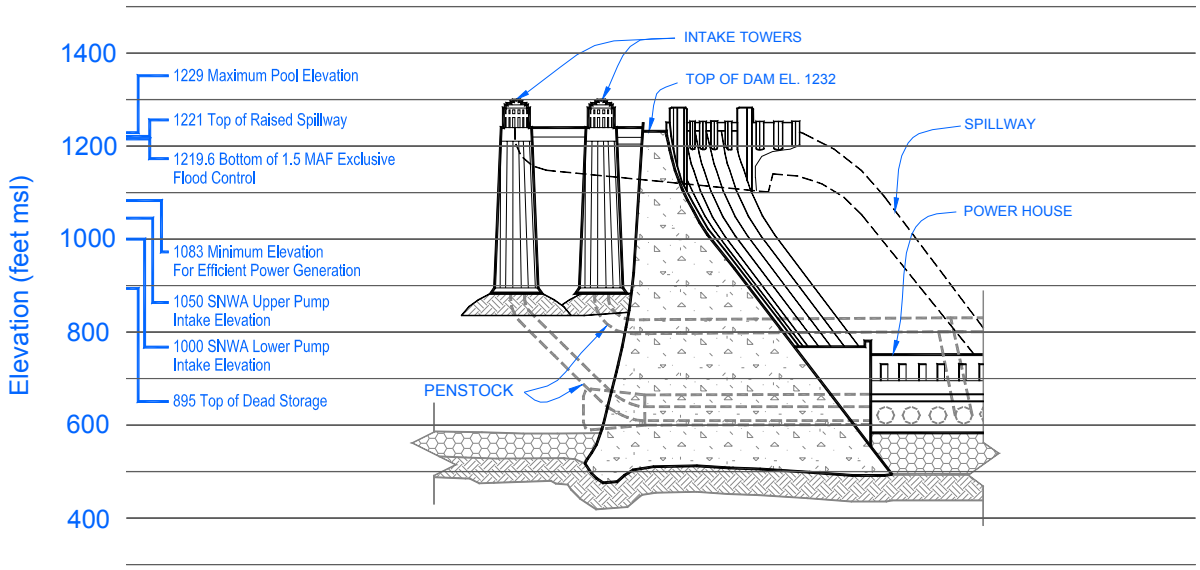
In addition to controlled releases from Lake Mead to meet water supply and power requirements, water is also diverted from Lake Mead at the Southern Nevada Water Authority (SNWA) Saddle Island intake facilities, Boulder City's Hoover Dam intake, and the Basic Management, Inc.'s (BMI) intake facility for use in the Las Vegas area for domestic purposes by SNWA, BMI and other users.

The diversions by SNWA at its Saddle Island intake facilities entail pumping the water from the intake to SNWA's transmission facilities for treatment and further conveyance to the Las Vegas area. The elevation of the original SNWA intake is approximately 1000 feet msl. However, the minimum required Lake Mead water level necessary to operate the pumping units at SNWA's original intake facility is 1050 feet msl. SNWA recently constructed a second pumping plant with an intake elevation of 950 feet msl. The minimum required Lake Mead water level necessary to operate the pumping units

at SNWA's second intake facility is 1000 feet msl. The new SNWA intake provides only a portion of the capacity required by SNWA to meet its Lake Mead water supply needs. Therefore, the intake elevation of SNWA's original pumping plant is critical to its ability to divert its full Colorado River water entitlement.

Hoover Dam is managed to provide at least 7.5 maf annually for consumptive use by the Lower Division states plus the United States' 1.5 maf obligation to Mexico. Hoover Dam releases are managed on an hourly basis to maximize the value of generated power by providing peaking during high-demand periods. This results in fluctuating flows below Hoover Dam that can range from 1,000 cubic feet per second (cfs) to 49,000 cfs. The upper value is the maximum flow-through capacity through the powerplant at Hoover Dam (49,000 cfs). However, because these flows enter Lake Mohave downstream, the affected zone of fluctuation is only a few miles.

Figure 1.3-1
Lake Mead and Hoover Dam Important Operating Elevations



Releases of water from Hoover Dam may also be affected by the Secretary's determinations relating to normal, surplus or shortage water supply conditions, as provided in the LROC. Another type of release includes flood control releases. For Hoover Dam, flood control releases are defined in this report as releases in excess of downstream demands.

Flood control was specified as a primary project purpose by the Boulder Canyon Project Act of 1928 (BCPA), the act authorizing Hoover Dam. The Corps is responsible for developing the flood control operation plan for Hoover Dam and Lake Mead as indicated in 33 CFR 208.11. The plan is the result of a coordinated effort by the Corps and Reclamation. However, the Corps is responsible for providing the flood control

regulations and has authority for final approval of the plan. Any deviations from the flood control operating instructions provided by the plan must be authorized by the Corps. The Secretary is responsible for operating Hoover Dam in accordance with these regulations.

The flood control regulations specify that once Lake Mead flood releases exceed 40,000 cfs, the releases shall be maintained at the highest rate until the reservoir drops to elevation 1221.0 feet msl. Releases may then be gradually reduced to 40,000 cfs until the prescribed seasonal storage space is available. The regulations set forth two primary criteria for flood control operations related to snowmelt: 1) preparatory reservoir space requirements, and 2) application of runoff forecasts to determine releases.

In preparation for each annual season of snow accumulation and associated runoff, progressive expansion of total Colorado River system reservoir space is required during the latter half of each year. Minimum available flood control space increases from 1.5 maf on August 1 to 5.35 maf on January 1. Required flood storage space can be accumulated within Lake Mead and in specified upstream reservoirs: Powell, Navajo, Blue Mesa, Flaming Gorge and Fontenelle. The minimum required to be reserved exclusively for flood control storage in Lake Mead is 1.5 maf. Table 1.3-1 presents the amount of required flood storage space within the Colorado River system by date:

Table 1.3-1
Minimum Required Colorado River System Storage Space

Date	Storage Space (maf)
August 1	1.50
September 1	2.27
October 1	3.04
November 1	3.81
December 1	4.58
January 1	5.35

Normal space-building releases from Lake Mead to meet the required August 1 to January 1 flood control space are limited to a maximum of 28,000 cfs. Releases in any month based on water entitlement holders' demand are less than 28,000 cfs (on the order of 20,000 cfs or less).

Between January 1 and July 31, flood control releases based on forecasted inflow may be required to prevent filling Lake Mead beyond its 1.5 maf minimum space requirement. Beginning on January 1 and continuing through July, the CBRFC issues monthly runoff forecasts. These forecasts are used by Reclamation in estimating releases from Hoover Dam. The release schedule contained in the Corps' regulations is based on increasing releases in six steps as shown on Table 1.3-2.

Table 1.3-2
Minimum Flood Control Releases at Hoover Dam

Step	Amount of Cubic Feet/Second
Step 1	0
Step 2	19,000
Step 3	28,000
Step 4	35,000
Step 5	40,000
Step 6	73,000

The lowest step, zero cfs, corresponds to times when the regulations do not require flood control releases. Hoover Dam releases are then made to meet water and power objectives. The second step, 19,000 cfs, is based on the powerplant capacity of Parker Dam. The third step, 28,000 cfs, corresponds to the Davis Dam powerplant capacity. The fourth step in the Corps release schedule is 35,000 cfs. This flow corresponds to the powerplant flow-through capacity of Hoover Dam in 1987. However, the present powerplant flow-through capacity at Hoover Dam is 49,000 cfs. At the time Hoover Dam was completed, 40,000 cfs was the approximate maximum flow from the dam considered to be nondamaging to the downstream streambed. The 40,000 cfs flow now forms the fifth step. Releases of 40,000 cfs and greater would result from low-probability hydrologic events. The sixth and final step in the series (73,000 cfs) is the maximum controlled release from Hoover Dam that can occur without spillway flow.

Flood control releases are required when forecasted inflow exceeds downstream demands, available storage space at lakes Mead and Powell and allowable space in other Upper Basin reservoirs. This includes accounting for projected bank storage and evaporation losses at both lakes, plus net withdrawal from Lake Mead by the SNWA. The Corps regulations set the procedures for releasing the volume that cannot be impounded, as discussed above.

Average monthly releases are determined early in each month and apply only to the current month. The releases are progressively revised in response to updated runoff forecasts and changing reservoir storage levels during each subsequent month throughout the January 1–July 31 runoff period. If the reservoirs are full, drawdown is accomplished to vacate flood control space as required. Unless flood control is necessary, Hoover Dam is operated to meet downstream demands.

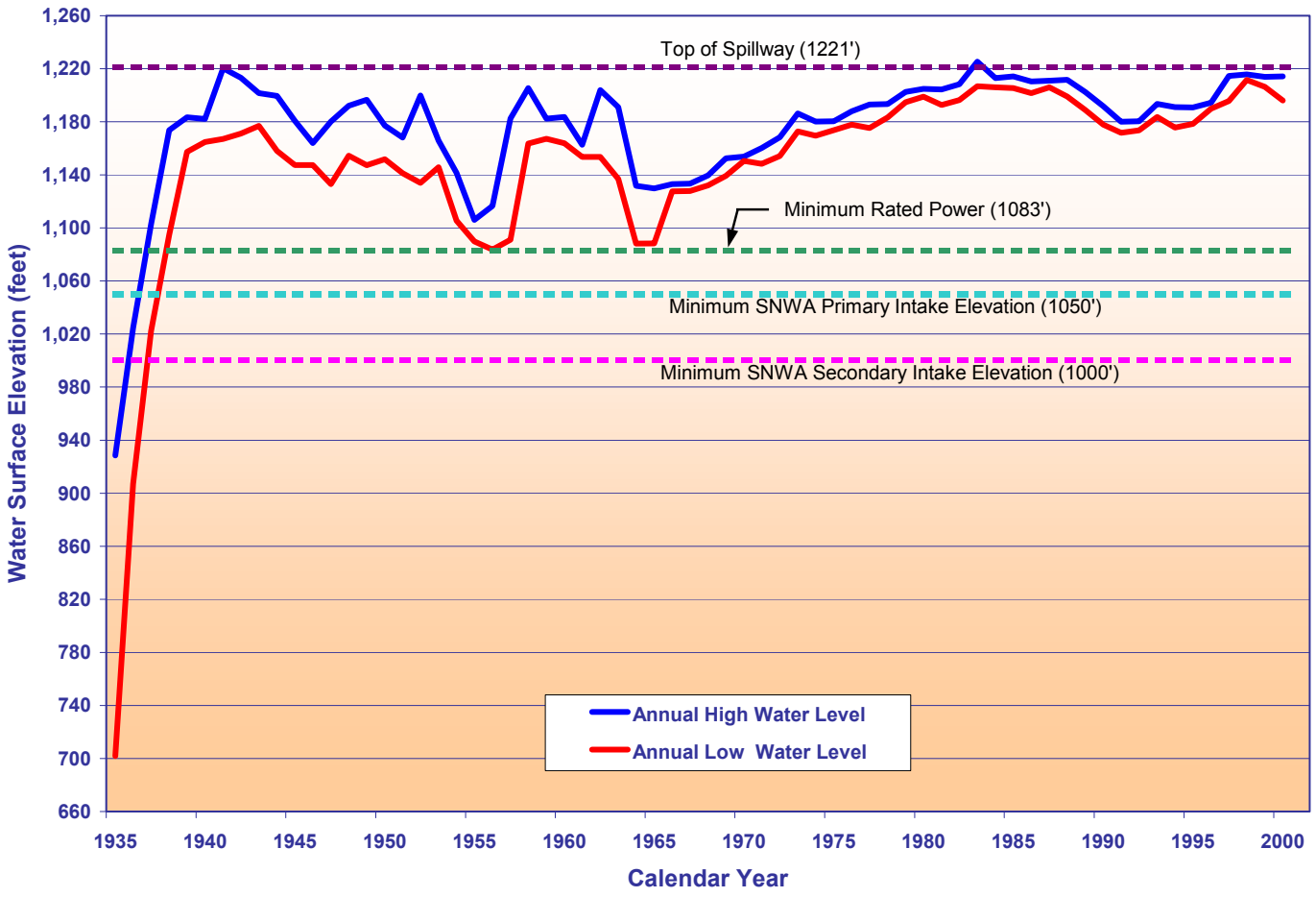
During non-flood operations, the end-of-month Lake Mead elevations are driven by consumptive use needs, Glen Canyon Dam releases and Treaty deliveries to Mexico. Lake Mead end-of-month target elevations are not fixed as are the end-of-month target elevations for Lake Mohave and Lake Havasu. Normally, Lake Mead elevations decline with increasing irrigation deliveries through June or later and then begin to rise again. Lake Mead's storage capacity provides for the majority of Colorado River regulation from Glen Canyon Dam to the International Boundary with Mexico. Figure

1.3-2 presents the historic annual water levels (annual maximum and minimum) of Lake Mead. The annual change in elevations of Lake Mead has ranged from less than ten feet to as much as 75 feet msl. The calendar year is cited to correspond with Lower Basin water accounting.

The decrease in the range of the elevations within a year observed after the mid-1960s can be attributed to the regulation provided by Lake Powell. Historic Lake Mead low water levels have dropped to the minimum rated power elevation (1083 feet msl) of the Hoover Powerplant during two periods (1954 to 1957 and 1965 to 1966). The maximum Lake Mead water surface elevation of approximately 1225.6 feet msl occurred in only one year, 1983.

Four Lake Mead water surface elevations of interest are also shown in Figure 1.3-2. The first elevation is 1221 feet msl, the top of the spillway gates. The second elevation is 1083 feet msl, the minimum elevation for the effective generation of power. The third elevation is 1050 feet msl, the minimum elevation required for the operation of SNWA's original intake facility. The final elevation is 1000 feet msl, the minimum elevation required for the operation of SNWA's second intake facility.

Figure 1.3-2
Historic Lake Mead Water Levels
(Annual Highs and Lows)



1.4 NATURAL RUNOFF AND STORAGE OF WATER

Most of the natural flow in the Colorado River system originates in the Upper Basin and is highly variable from year to year. The natural flow represents an estimate of runoff flows that would exist without storage or depletion by man and was used in the modeling of the baseline conditions and interim surplus criteria alternatives. About 86 percent of the Colorado River System annual runoff originates in only 15 percent of the watershed—in the mountains of Colorado, Utah, Wyoming and New Mexico. While the average annual natural flow at Lees Ferry is calculated at 15.1 maf, annual flows in excess of 23.8 maf and as little as 5.0 maf have occurred. The flow in the Colorado River above Lake Powell reaches its annual maximum during the April through July period. During the summer and fall, thunderstorms occasionally produce additional peaks in the river. However, these flows are usually smaller in volume than the snowmelt peaks and of much shorter duration. Flows immediately below Glen Canyon Dam consist almost entirely of water released from Lake Powell. Downstream of Glen Canyon Dam, the annual river gains from tributaries, groundwater discharge and occasional flash floods from side canyons average 900,000 af. Immediately downstream of Hoover Dam, the river flows consist almost entirely of water released from Lake Mead. Downstream of Hoover Dam, the river gains additional water from tributaries such as the Bill Williams River and the Gila River, groundwater discharge, and return flows.

Total storage capacity in the Colorado River system is nearly four times the river's average natural flow. The various reservoirs that provide storage in the Colorado River system and their respective capacities are discussed in Section 1.2.4 of the EIS.

Figure 1.4-1 presents the annual natural flow calculated at Lees Ferry for calendar years 1906 through 2000. The natural flow represents an estimate of the flows that would occur at Lees Ferry without storage or depletion by human activity. This is different than the recorded or historical stream flows that represent actual measured flows. Figure 1.4-2 presents the annual historical flows recorded at Lees Ferry for the period 1922 through 2000 (calendar year).

Figure 1.4-1
Natural Flow at Lees Ferry Stream Gage

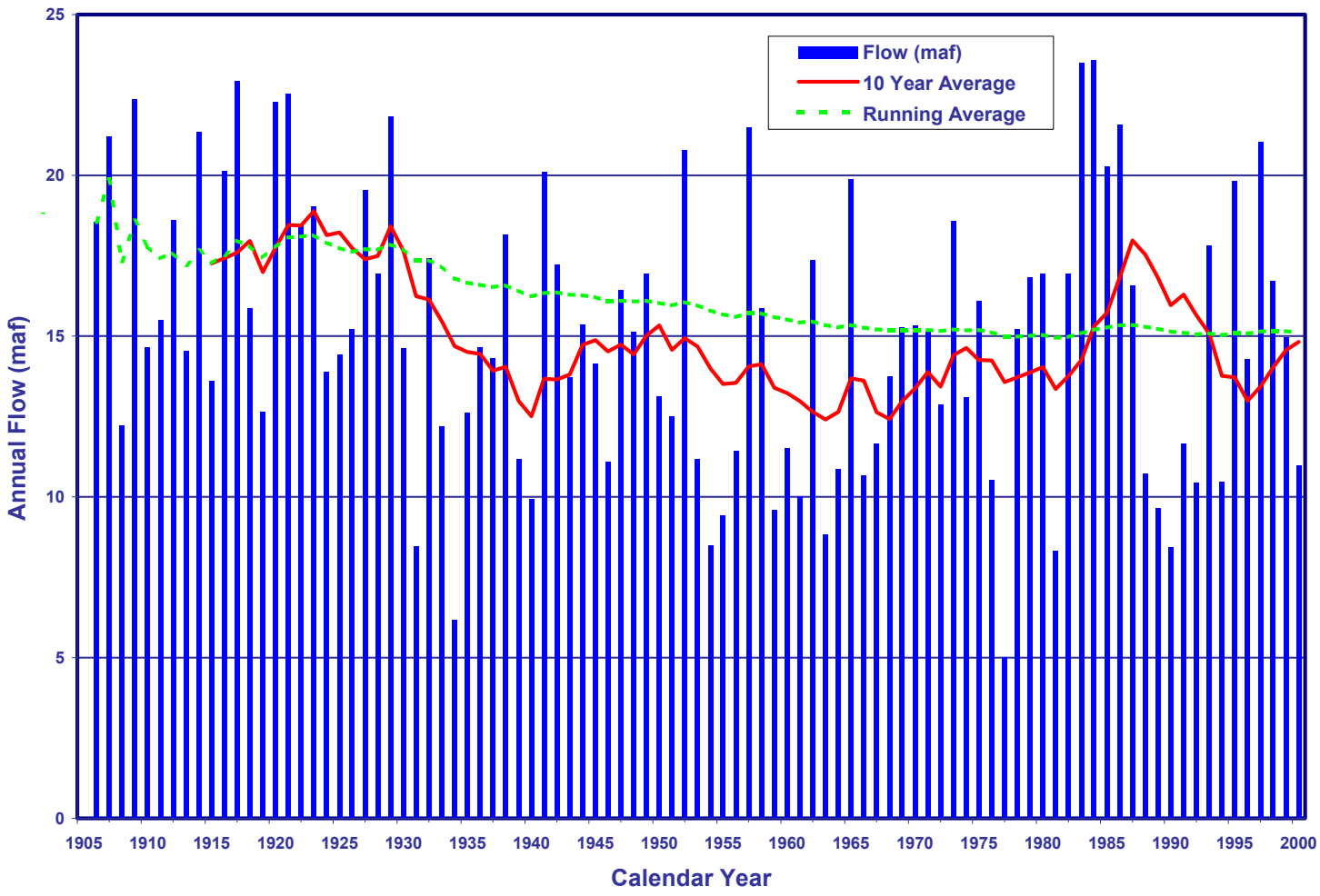
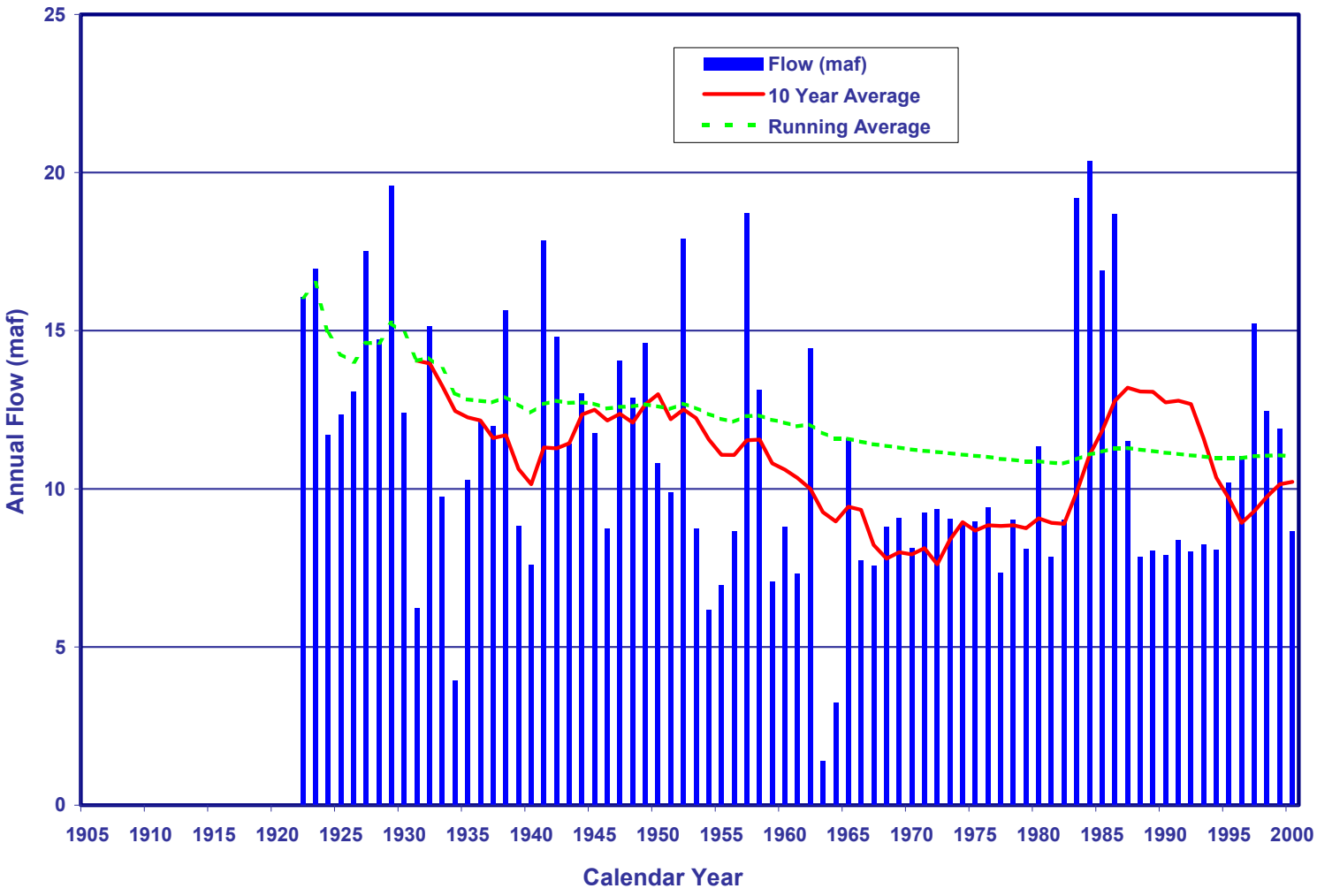


Figure 1.4-2
Historic Annual Flow at Lees Ferry Stream Gage



2.0 RIVER SYSTEM MODELING

This section addresses the modeling and analysis procedures used to simulate river system operation for various operational scenarios. The scenarios were chosen to analyze hydrologic changes that are likely to occur due to execution of the Secretarial Implementation Agreement (IA), which is necessary to implement the water transfers and exchanges proposed in the Quantification Settlement Agreement (QSA). Additional scenarios were modeled to analyze the cumulative effects of the combined Interim Surplus Guidelines (ISG) and QSA.

2.1 MODEL CONFIGURATION

Future river system conditions for each scenario were simulated using a computerized model. The model framework used for this process is the commercial river modeling software called RiverWare (Zagona et al, 2001). RiverWare was developed by the University of Colorado in cooperation with Reclamation and the Tennessee Valley Authority. RiverWare was configured to simulate the Colorado River System and its operation and integrates the Colorado River Simulation System (CRSS) model that was developed by Reclamation in the 1970s. River operation parameters modeled by CRSS on a monthly basis include the water entering the river system, storage in system reservoirs, releases from storage, river flows, and the water demands of and deliveries to the Basin States and Mexico. The water supply used by the model consists of the natural inflow in the river system over the 85-year period from 1906 through 1990, at 29 individual inflow points on the system.

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. Return flow credits are applied when a portion of the diverted water is returned to the river system. In cases where there are no return flow credits associated with the diversions, the depletion is equal to the diversion. The simulated operation of Glen Canyon Dam, Hoover Dam and other elements of the Colorado River system was consistent with the LROC, applicable requirements for storage and flood control management, water supply deliveries to contractors and federal establishments in the Basin States, Indian tribes, and Mexico, and flow regulation downstream of the system dams.

2.2 CRITERIA MODELED AND ANALYZED

Four Colorado River operational scenarios are considered in this report and are listed in Table 2.2-1. A more detailed description of the assumptions of the four operation scenarios can be found in Section 2.3.

Table 2.2-1
Colorado River Operational Scenarios Modeled

Operational Scenario	Assumptions
No Action (NA)	1988/89 agreement (110 kaf transfer from IID to MWD) No other California water transfers (i.e., no QSA) Interim Surplus Guidelines 2002-2016, 70R 2017-2076 MWD meets ISG ROD benchmarks, permitting the Interim Surplus Guidelines to remain in place.
Implementation Agreement (IA)	1988/89 agreement (110 kaf transfer from IID to MWD) QSA (388 kaf transfer by 2026) Interim Surplus Guidelines 2002-2016, 70R 2017-2076 ISG ROD benchmarks are met via QSA
Baseline for Cumulative Analysis (Baseline)	1988/89 agreement (110 kaf transfer from IID to MWD) No other California water transfers (i.e., no QSA) No Interim Surplus Guidelines (70R for entire period 2002-2076) No ISG ROD benchmarks to be met
Cumulative Analysis (CA)	1988/89 agreement (110 kaf transfer from IID to MWD) QSA (388 kaf transfer by 2026) Additional reduction in diversion by PVID of up to 111 kafpermitting the Secretary to make an equivalent amount of water available to MWD. Interim Surplus Guidelines 2002-2016, 70R 2017-2076 ISG Rod benchmarks are met via QSA

The 1988/89 agreement cited in Table 2.2-1 provides for a 110 kaf reduction in diversion by IID from water conservation to permit the Secretary to make an equivalent amount of water available to MWD.

The operational scenarios in Table 2.2-1 were used in two separate analyses as follows:

1. An analysis that evaluates the potential effects resulting from the implementation of the proposed water transfers (i.e., QSA). Under this analysis, the results of the modeled No Action and Implementation Agreement modeled operational scenarios were compared. The focus of this analysis was to ascertain the potential cumulative impacts to the river system and water deliveries to the Basin states and Mexico resulting from the implementation of the proposed water transfers.

2. An analysis that evaluates the potential cumulative effects from the implementation of the Interim Surplus Guidelines, water transfers proposed in the QSA, and the Palo Verde Irrigation District Land Management, Crop Rotation and Water Supply Program (PVID/MWD program). Under this analysis, the results of the modeled Baseline for Cumulative Analysis and Cumulative Analysis modeled operational scenarios were compared. The focus of this analysis was to ascertain the potential cumulative impacts to the

river system and water deliveries to the Basin states and Mexico resulting from the implementation of these water management programs.

2.3 MODELING ASSUMPTIONS

Due to the high degree of uncertainty in future inflows, projecting the future state of the Colorado River system is also highly uncertain. For this report, this uncertainty is dealt with in two ways. First, the uncertainty due to hydrologic variability is quantified by running many simulations, each with a different assumption of the future inflows. This technique is explained more fully in Section 2.5. Secondly, when comparing operational scenarios, the majority of modeling assumptions is kept consistent between the scenarios, and only those assumptions that are specific to the particular scenario are changed. This allows a relative comparison of the effects of one scenario to another.

The important modeling assumptions used for the scenarios studied are detailed below.

2.3.1 ASSUMPTIONS CONSISTENT FOR ALL OPERATIONAL SCENARIOS

For all scenarios, system conditions were simulated for the period 2002-2076, using the same initial reservoir elevations for January 1, 2002. Reclamation's 24 month study model (a model also implemented in RiverWare) was used to project these elevations, using actual elevations as of April 2001 (the month in which these studies began) and projected operations for the remainder of the 2001 calendar year. These elevations and the corresponding reservoir storage are shown on Table 2.3-1.

Table 2.3-1
Projected Jan 1, 2002 Reservoir Elevations Used as Initial Conditions for Modeling Study

Reservoir	Elevation, feet msl	Storage, kaf
Fontenelle	6,484.89	197.32
Flaming Gorge	6,023.21	3,052.16
Taylor Park	9,309.50	62.79
Blue Mesa	7,486.72	582.68
Morrow Point	7,153.73	112.18
Crystal	6,746.05	15.00
Navajo	6,074.60	1,487.66
Powell	3,669.91	24,256.50
Mead	1,182.01	20,441.65
Mohave	638.71	1,582.96
Havasu	445.78	539.15
Total	**NA**	**52,330.05**

The operation of the Upper Basin reservoirs including Lake Powell, was consistent for all scenarios, as were the Upper Division States depletion projections. These projections were

provided by the Upper Colorado River Commission (December 1999) and include new Indian tribe schedules as documented in the Interim Surplus Criteria FEIS. These schedules are detailed in Attachment B.

The operation of the Lower Basin reservoirs, including Lake Mead was consistent for all scenarios with the exception of the depletion schedules for specific California entities and the criteria under which surplus conditions were determined. These exceptions are discussed in detail in Section 2.3.2. Particular modeling assumptions for the Lower basin that were consistent for all scenarios include:

- Lake Mead is operated to meet downstream demand, (including Mexico), except when additional releases are necessary to meet the Corps flood control regulations.
- Lakes Mohave and Havasu are operated in accordance with their existing rule curves.
- Lower Basin shortage conditions are determined by the strategies detailed in Section 2.4.
- Water deliveries to Mexico are pursuant to the requirements of the US-Mexico Water Treaty of 1944, which provide annual deliveries of 1.5 maf to Mexico under normal conditions, up to 1.7 maf under Lake Mead flood control release conditions, and less than 1.5 maf under conditions of extreme shortage when California's delivery is also cut.

Several other modeling assumptions may be of interest. First, Mexico's principal diversion is at Morelos Dam where most of its Colorado River apportionment of 1.5 maf is diverted. In practice, up to 140 thousand acre-feet (kaf) is delivered to Mexico near the Southerly International Boundary (SIB). The model, however, extends to just south of the Northerly International Boundary (NIB) to include the diversion at Morelos Dam and accounts for the entire Treaty delivery at that point. Under normal conditions, the model sets the diversion and depletion schedule for the Mexican Treaty delivery at Morelos Dam to 1.515 mafy. The additional 15,000 af accounts for typical scheduling errors and over-deliveries.

Secondly, the Yuma Desalting Plant was assumed to remain in ready reserve status with 120,000 acre-feet per year (afy) bypassed to the Cienega de Santa Clara in Mexico from 2002-2004. For modeling purposes, this depletion is not counted as part of the Treaty delivery. The desalting plant is assumed to operate beginning in 2005, reducing the bypass to 52,000 afy. Similarly, for modeling purposes, this bypass is not counted as part of the Treaty delivery. It should be noted that the United States recognizes that it has an obligation to replace, as appropriate, the bypass flows and that 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 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.

Lastly, all Arizona shortages are assumed to be absorbed by the Central Arizona Project (CAP). Reclamation acknowledges that under the current priority framework, there would be some sharing of Arizona shortage between the Central Arizona Project and other Priority 4 users. However, the basis or formula for the sharing of Arizona shortages is the subject of current negotiations and thus could not be adequately modeled. The water supply conditions modeled were used to evaluate the relative differences in water deliveries to users in each state under each operational scenario. The normal, surplus and shortage condition water depletion schedules modeled are consistent with the depletion schedules prepared by the Basin states for this purpose.

2.3.2 MODELING ASSUMPTIONS SPECIFIC TO EACH OPERATIONAL SCENARIO

As previously mentioned, the differences in modeling assumptions between the operational scenarios involve the depletion schedules for specific California entities and the criteria used to determine surplus conditions. A description of these differences follows.

No Action Scenario

In this scenario, no water transfers specified in the QSA are in effect. However, the existing conservation program implemented by IID and funded by MWD (the 1988/89 Agreements) is assumed to continue throughout the study period (2002-2076) at 110 kaf per year. Detailed schedules for the Lower Division state entities under normal conditions for the No Action scenario are presented and discussed in Attachment A.

Surplus conditions are determined under the No Action Scenario using the Interim Surplus Guidelines for the period 2002-2016. For the period 2017-2076, surplus conditions are determined using the "70R" strategy. An overview of these strategies and the corresponding surplus depletion schedules are presented in Attachment C.

One additional assumption should be noted here. In the Interim Surplus Guidelines Record of Decision (ISG ROD), benchmarks for reductions of agricultural use of Colorado River water in California were specified. Since these benchmarks are not met from QSA water transfers under the No Action scenario, it was assumed that the Metropolitan Water District (MWD) would reduce its use to meet the benchmarks and therefore, keep the ISG in effect. Further explanation and the resulting MWD surplus schedules are detailed in Attachment C.

Implementation Agreement Scenario

In this scenario, water transfers consistent with the QSA are assumed under normal conditions. These transfers are in addition to the 110 kafy due to the 1988/89 Agreement between IID and MWD. Most of these transfers are assumed to "ramp up" over the first 25 years. The total amount of water transferred from California agricultural use to MWD is 388.2 kaf by the year 2026 and remains at that amount for the period 2027 – 2047.

In 2047, the total amount of water transferred to MWD is assumed to drop to 338.2 kaf per year and remain at that level through 2076. This 50 kaf drop is the result of assuming that the "Second 50 kafy" transfer (see section 2.2.1.1 of the EIS) from IID does not occur. This assumption was made to model the "worst case" with regard to reduced river flows in the Parker to Imperial reach.

Further details of the water transfers assumed under the IA scenario can be found in Attachment A.

Surplus conditions are determined under the IA scenario identical to those of the No Action Scenario (i.e., ISG 2002-2016, 70R 2017-2076). The surplus depletion schedules are also identical, with the exception of the MWD schedules, since the ISG ROD benchmarks are met with the QSA water transfers. These schedules are detailed in Attachment C.

Baseline for Cumulative Analysis Scenario

In this scenario, the normal depletion schedules are identical to those used for the No Action scenario (i.e., no water transfers except for the 1988/89 Agreements).

Surplus conditions are determined under this scenario using the 70R strategy for the entire period, 2002-2076. Interim Surplus Guidelines are not in effect, and therefore, there are no benchmark reductions to meet. A further explanation of this strategy and the corresponding surplus schedules are detailed in Attachment C.

Cumulative Analysis Scenario

In this scenario, the normal depletion schedules are identical to those used for the IA scenario (i.e., 388 kaf of transfers by 2026), but with the addition of approximately 110 kaf/year of transfers from PVID to MWD under the PVID/MWD program. These schedules are detailed in Attachment A.

Surplus conditions are determined under this scenario identical to those of the IA scenario. The surplus depletion schedules are also identical to those used for the IA scenario.

2.4 LAKE MEAD WATER LEVEL PROTECTION ASSUMPTIONS

There are no established shortage criteria for the operation of Lake Mead. However, it was necessary to include some shortage criteria in the model simulation to address concerns related to low Lake Mead water levels. Three important Lake Mead water elevations were selected for analysis. The significance of these selected elevations relates to known economic and/or socioeconomic impacts that would occur if Lake Mead water levels were lowered below the selected water levels. Elevation 1083 feet msl is the minimum water level for efficient power generation at the Hoover Powerplant based on its existing turbine configuration. Elevation 1050 feet msl is the minimum water level necessary for operation of SNWA's upper water intake. Water withdrawn from the Lake Mead through this intake is delivered to Las Vegas Valley, Boulder City and other parts of Clark County. Even though SNWA has constructed a second intake at a lower elevation, the original intake at elevation 1050 feet msl is needed to meet full SNWA summer diversions. Elevation 1000 feet msl is the minimum water level necessary for operation of SNWA's lower water intake.

In the absence of specific shortage criteria, the Lake Mead level protection assumptions listed below were assumed for all operational scenarios modeled.

First Level Shortage:

- The Lake Mead water level of 1083 feet msl was designated as a level that should be protected. The "protection line" (to prevent the water level from declining below elevation 1083 feet msl with approximately an 80 percent probability) used for the Interim Surplus Criteria Final Environmental Impact statement (Reclamation, 2000) was extrapolated from 2050 through 2076 and used for this study. A graph of this protection line is presented in Attachment D. Sensitivity analysis of using a 1050-foot protection line is also discussed in Attachment D.
- A "first-level" shortage would be determined to exist for any year in which the Lake Mead water level was below the protection line at the beginning of the year.
- During first level shortage conditions, the annual water delivery to CAP was set to 1.0 maf, and the Southern Nevada Water Authority (SNWA) was assigned four percent of the total shortage.

Second Level Shortage:

- A second level shortage would be determined to exist for any year if the Lake Mead water surface elevation was projected at the beginning of the year to fall below 1000 feet msl by the end of the year.

- During second level shortage conditions, the CAP and SNWA consumptive use would be reduced as needed to maintain the Lake Mead water level at 1000 feet msl. Once the delivery to the CAP is reduced to zero, deliveries to MWD and to Mexico would be reduced to maintain the Lake Mead water level at 1000 feet msl.

2.5 COMPUTATIONAL PROCEDURES

As previously discussed, the model was used to simulate the future state of the Colorado River system on a monthly basis, in terms of reservoir levels, releases from the dams, hydroelectric energy generation, flows at various points along the system and diversions to and return flows from various water users. The input data for the model included the monthly tributary inflows, various physical process parameters (such as the evaporation rates for each reservoir) and the diversion and depletion schedules for entities in the Basin States and Mexico. The common and specific modeling assumptions were also input for each scenario being studied.

Despite the differences in the modeling assumptions for each scenario, the future state of the Colorado River system (i.e., water levels at Lake Mead and Lake Powell) is most sensitive to the future inflows. As discussed in Section 1.4, observations over the period of historical record (1906–present) show that inflow into the system has been highly variable from year to year. Predictions of the future inflows, particularly for long-range studies, are highly uncertain. Although the model does not predict future inflows, it can be used to analyze a range of possible future inflows and to quantify the probability of particular events (i.e., lake levels being below or above certain levels).

Several methods are available for ascertaining the range of possible future inflows. On the Colorado River, a particular technique (called the Indexed Sequential Method) has been used since the early 1980s and involves a series of simulations, each applying a different future inflow scenario (USBR, 1985; Ouarda, *et al.,* 1997). Each future inflow scenario is generated from the historical natural flow record by "cycling" through that record. Currently, the natural flow record from water years 1906-1990 is utilized, although work is on-going to compute the natural flows for all 29 inflow points from 1991 to present. For example, the first simulation assumes that the inflows for 2002 through 2076 will be the 1906 through 1980 record, the second simulation assumes the inflows for 2002 through 2076 will be the 1907 through 1981 record, and so on. As the method progresses, the historical record is assumed to "wrap-around" (i.e., after 1990, the record reverts back to 1906), yielding a possible 85 different inflow scenarios. The result of the Indexed Sequential Method is a set of 85 separate simulations (referred to as "traces") for each operating criterion that is analyzed. This enables an evaluation of the respective criteria over a broad range of possible future hydrologic conditions using standard statistical techniques.

2.6 POST-PROCESSING AND DATA INTERPRETATION PROCEDURES

The various hydrologic, environmental and socioeconomic analyses in the EIS requires the sorting and arranging of various types of model output data into tabulations or plots of specific operational conditions, or parameters, at various points on the system. This was done through the use of statistical methods and other numerical analyses.

The model generates data on a monthly time step for some 300 points (or nodes) on the river system. Furthermore, through the use of the Indexed Sequential Method, the model generates 85 possible outcomes for each node for each month over the time period 2002 through 2076. These very large data sets are generated for each surplus alternative and baseline conditions and 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 are typically aggregated to reduce the volume of data and to facilitate comparing the operational scenarios. The type of aggregation varies depending upon the needs of the particular resource analysis. The post-processing techniques used for this report fall into two basic categories: those that aggregate in time, space or both, and those that aggregate the 85 possible outcomes.

For aggregation in time and space, simple techniques are employed. For example, deliveries of Colorado River water to all California diversion nodes in the model are summed to produce the total delivery to the state for each calendar year. Similarly, lake elevations may be chosen on an annual basis (i.e., end of December) to show long-term lake level trends as opposed to short-term fluctuations. For comparison purposes, three time periods are routinely used in this analysis. They are the 15-year period that coincides with the interim surplus guidelines period (2002 through 2016), the 60 year period of time that follows (2017 through 2076), and the entire 75-year period of analysis. The particular time period used will be noted in the methodology section for each resource.

Once the appropriate temporal and spatial aggregation is chosen, standard statistical techniques are used to analyze the 85 possible outcomes for a fixed time. Statistics that may be generated include the mean and standard deviation. However, the most common technique simply ranks the outcomes at each time (from highest to lowest) and uses the ranked outcomes to compute other statistics of interest. For example, if end-of-calendar year Lake Mead elevations are ranked for each year, the median outcome for a given year is the elevation for which half of the values are below and half are above the median value, which is also referred to as the 50th percentile value. Similarly, the elevation for which 10 percent of the values are less than or equal to, is the 10th percentile outcome.

Several presentations of the ranked data are then possible. A graph (or table) may be produced that compares the 90th percentile, 50th percentile, and 10th percentile outcomes from 2002 through 2076 for the cases analyzed. 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).

3.0 RIVER SYSTEM MODELING RESULTS

This section presents general and specific discussions of the Colorado River System operation modeling results. The following sequence of topics is used to address the potentially affected river system components:

- Lake Powell water levels,
- River flows between Glen Canyon Dam and Lake Mead,
- Lake Mead water levels, and
- River flows below Hoover Dam.

Two separate analyses are presented in this section, each covering the four topics listed above. These analyses are as follows:

- An analysis of the Implementation Agreement. This analysis compares conditions under the Implementation Agreement with No Action.
- A cumulative analysis of the Implementation Agreement and other projects affecting river operation. This analysis compares conditions under the Cumulative Analysis with a specific Baseline for Cumulative Analysis.

The operational scenarios used for these two analyses were described in Section 2.2.

As noted previously, the focus of this analysis is the potentially affected portion of the Colorado River system extending from Lake Powell to the SIB. Although lakes Mohave and Havasu are within the potentially affected area, it has been determined that the Implementation Agreement would have no effect on the operation of these facilities. Lakes Mohave and Havasu are operated pursuant to monthly target elevations that are used to manage the storage, water release, and power production at these facilities. Under the respective target elevations, the annual water level fluctuation is approximately 14 feet for Lake Mohave and approximately four feet for Lake Havasu. Under all future operating scenarios considered under this analysis, lakes Mohave and Havasu would continue to be operated under their current respective monthly target elevations.

3.1 GENERAL OBSERVATIONS CONCERNING MODELING RESULTS

The following general observations apply to the results of operational modeling of the Implementation Agreement and the cumulative analysis:

- Future water levels of Lakes Powell and Mead will probably be lower than historical levels due to increasing Upper Basin depletions under the No Action conditions and the Implementation Agreement.

- Median Lake Mead water levels decline throughout the period of analysis for the No Action conditions and the Implementation Agreement because Lower Division depletions and evaporation exceed long-term inflow. Median Lake Powell levels decline for a number of years and then stabilize under the No Action conditions as well as under the Implementation Agreement. The declining median trend in Lake Powell levels under the No Action and Implementation Agreement conditions is due to increasing Upper Division depletions. Lake Powell water levels eventually stabilize under the No Action and Implementation Agreement conditions. This behavior is caused by less frequent equalization releases from Lake Powell to Lake Mead (due to the 602(a) storage requirements) as the Upper Division states continue to increase their use of Colorado River water.
- Under normal conditions, deliveries to the Lower Basin users are always equal to the normal depletion schedules, including those for the Indian tribes. Under shortage conditions, only CAP and SNWA share in the shortage until CAP goes to zero. All tribes in the 10 Tribe Partnership in the Lower Basin receive their scheduled depletion, with the exception of the Cocopah Tribe which holds a right to some Arizona Priority 4 water. As discussed above, as a modeling assumption, all Arizona shortages were assigned to CAP for this FEIS.
- As expected, changes in storage in Lakes Powell and Mead due to the IA are minor. The IA allows transfers of water between California entities within the State's total apportionment of 4.4 MAF. Therefore under normal conditions, these transfers would have no impact on Lake Mead's storage. However, under surplus conditions, the total delivery to California would be somewhat less under the IA compared to baseline conditions, the result of reduced agricultural use due to transfers and the ISG, which do not provide surplus water to the agricultural entities at the "full" and "Partial Domestic" surplus levels (see attachment C). The impact of the reduced California deliveries under these surplus levels would be a slight increase in Lake Mead's contents, and under equalization conditions, a corresponding minor increase in Lake Powell.

The Cumulative Analysis covers the effects of the recently implemented interim surplus guidelines, the proposed Implementation Agreement, and the certain other proposed water transfers within California. The modeling study indicated that the cumulative effects would be as follows, when measured at the median of the values produced (50th percentile) unless otherwise noted.

- The water levels of lakes Powell and Mead would be lower during and immediately after the interim surplus period but after several decades water levels would be the same as those under baseline conditions.

- The probability of minimum releases from Lake Powell during the interim surplus period would be lower under Cumulative Analysis conditions than under Baseline for Cumulative Analysis.

- The annual river flows below the Havasu National Wildlife Refuge would be greater under Cumulative Analysis conditions than under the Baseline for Cumulative Analysis through 2016, after which flow conditions would be essentially the same as under the baseline.

- The annual river flows below Parker Dam and below the Palo Verde Irrigation District diversion would be lower under Cumulative Analysis conditions than under the Baseline for Cumulative Analysis through 2016, after which flow conditions would remain lower than under the baseline.

- The flows in the Colorado River below Morelos Dam, which lie in the realm of the 90th percentile of annual flow, would be approximately the same under Cumulative Analysis conditions as under the Baseline for Cumulative Analysis, although the cumulative values would vary above and below the baseline from year to year.

3.2 ANALYSIS OF WATER TRANSFERS

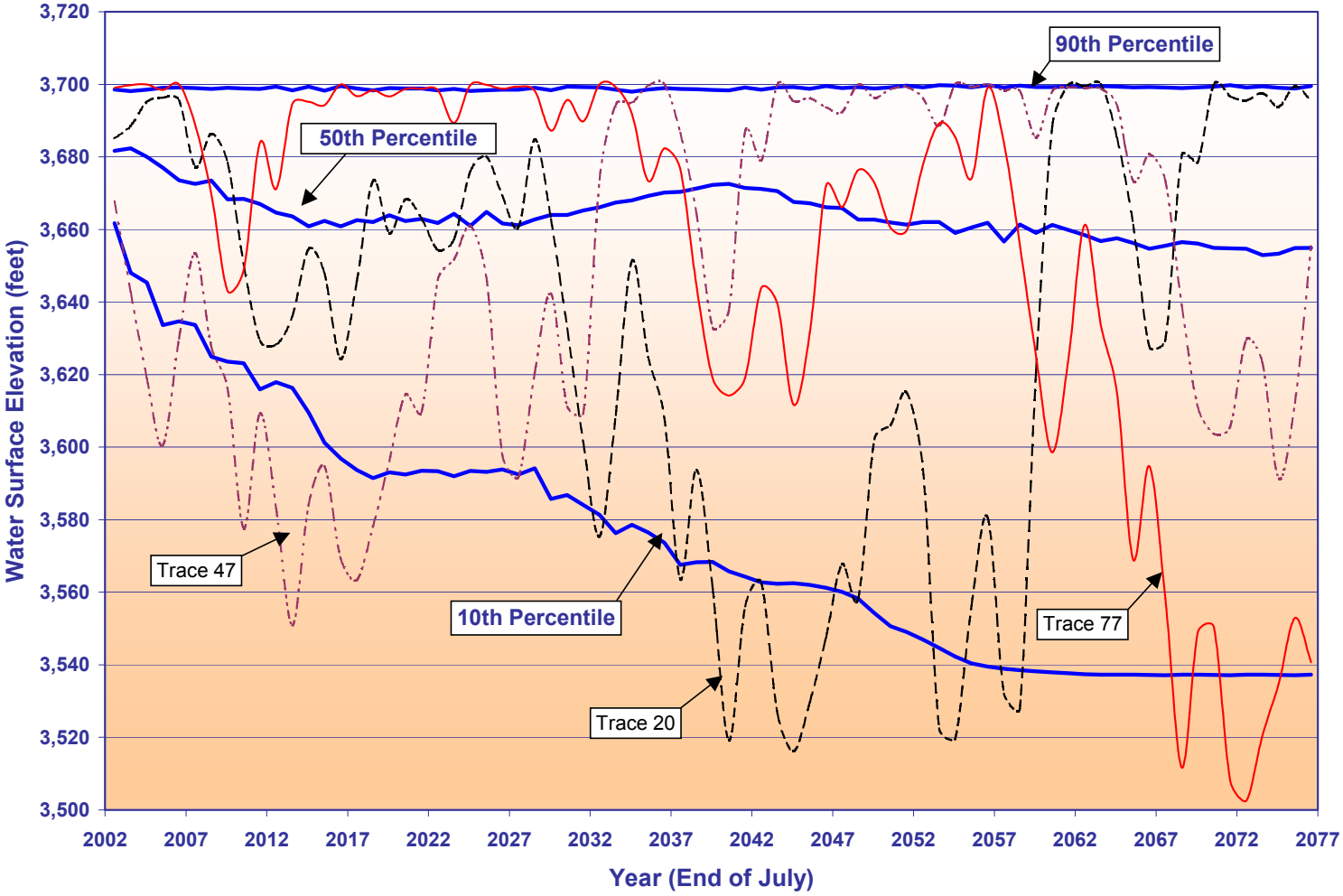
3.2.1 LAKE POWELL WATER LEVELS

3.2.1.1 MODELING RESULTS OF NO ACTION

Under the No Action conditions, the water surface elevation of Lake Powell is projected to fluctuate between full level and decreasingly lower levels during the period of analysis (2002 to 2076). Figure 3.2-1 illustrates the range of water levels by three lines, labeled 90th Percentile, 50th Percentile and 10th Percentile. The 50th percentile line shows the median water level for each future year. The median water level under No Action conditions is shown to decline to approximately 3665 feet msl by 2016 and then vary gradually between approximately 10 feet higher and lower than that elevation through 2076. The 10th percentile line shows there is a 10 percent probability that the water level would drop to 3597 feet msl by 2016 and to 3537 feet msl by 2076.

Generally, there is about a 20-foot difference between the annual high and low water levels at Lake Powell. It should also be noted that the Lake Powell elevations depicted in Figure 3.2-1 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 low occurs at the end of the year. The high summer levels were analyzed because of their importance to water-based recreation at Lake Powell.

Figure 3.2-1
Lake Powell End-of-July Water Elevations Under No Action
90th, 50th and 10th Percentile Values and Representative Traces



Three distinct traces were added to Figure 3.2-1 to illustrate what was actually simulated under the various traces and respective hydrologic sequences and to highlight that the 90th, 50th and 10th percentile lines do not represent actual traces, but rather the ranking of the data from the 85 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 10th percentile line. The trace identified as Trace 20 represents the hydrologic sequence that begins in year 1925. The trace identified as Trace 47 represents the hydrologic sequence that begins in year 1952. The trace identified as Trace 77 represents the hydrologic sequence that begins in year 1982.

In Figure 3.2-1, the 90th and 10th percentile lines bracket the range where 80 percent of the water levels simulated for the No Action conditions occur. 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 between the highs and the lows, 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 3.2-2 presents a comparison of the 90th, 50th and 10th percentile plots under No Action conditions and those under the Implementation Agreement. This figure is best used for comparing the relative differences in the general lake level trends that result from the simulation of No Action and Implementation Agreement conditions.

Figure 3.2-3 shows the frequency that future Lake Powell end-of-July water elevations would exceed elevation 3695 feet msl under the No Action and Implementation Agreement conditions. When the Lake Powell water level is at or exceeds 3695 feet msl, the reservoir is considered to be essentially full. In year 2016, under No Action conditions, the percentage of values greater than or equal to elevation 3695 feet msl is 19 percent. After 2016 the annual percentages of values equal to or greater than elevation 3695 feet msl increase gradually to 29 percent and then decrease to 24 percent in 2076 under No Action conditions.

Figure 3.2-2
Lake Powell End-of-July Water Elevations
Comparison of Implementation Agreement to No Action Conditions
90th, 50th and 10th Percentile Values

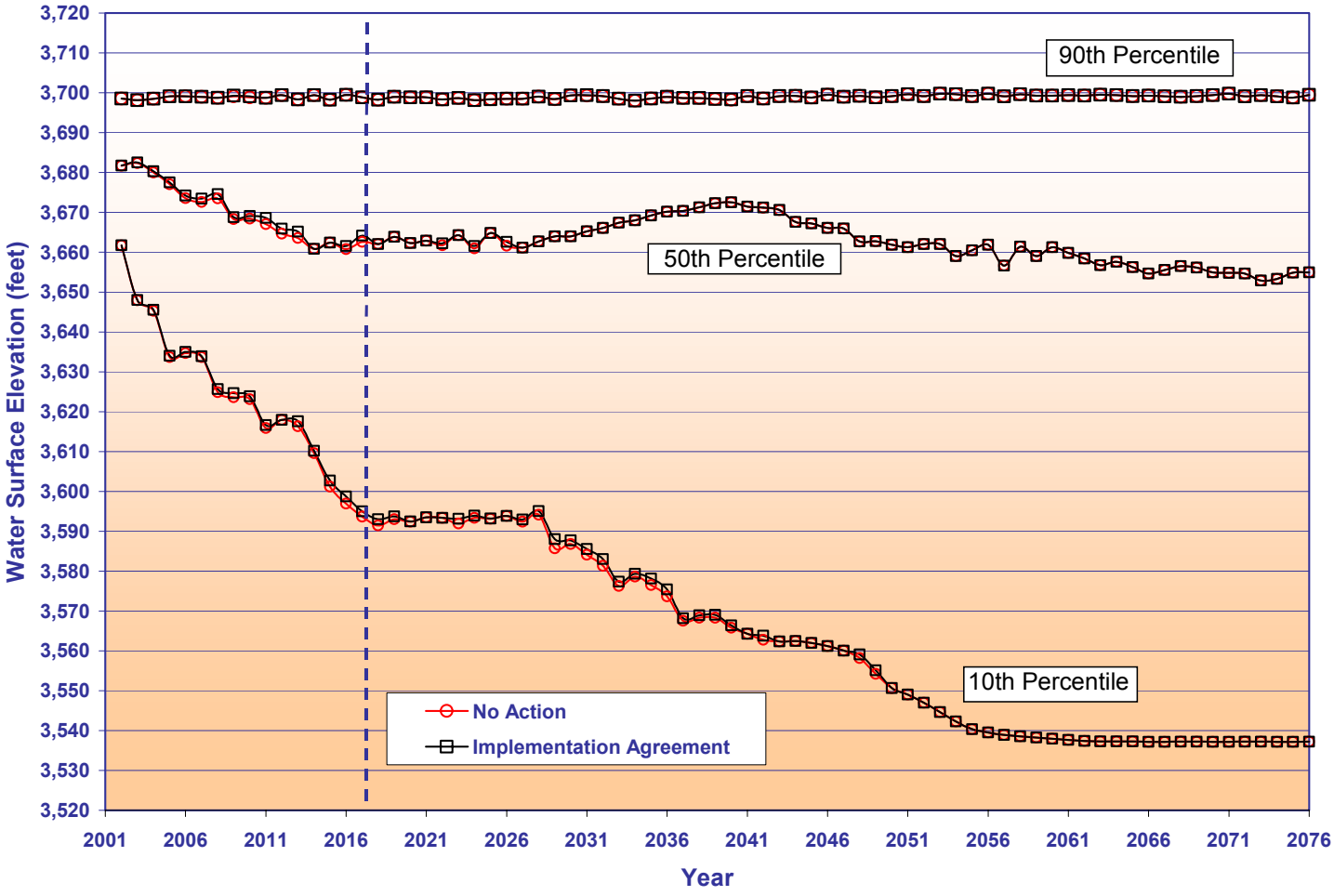


Figure 3.2-3
Lake Powell End-of-July Water Elevations
Comparison of Implementation Agreement to No Action Conditions
Percentage of Values Greater than or Equal to Elevation 3695 Feet

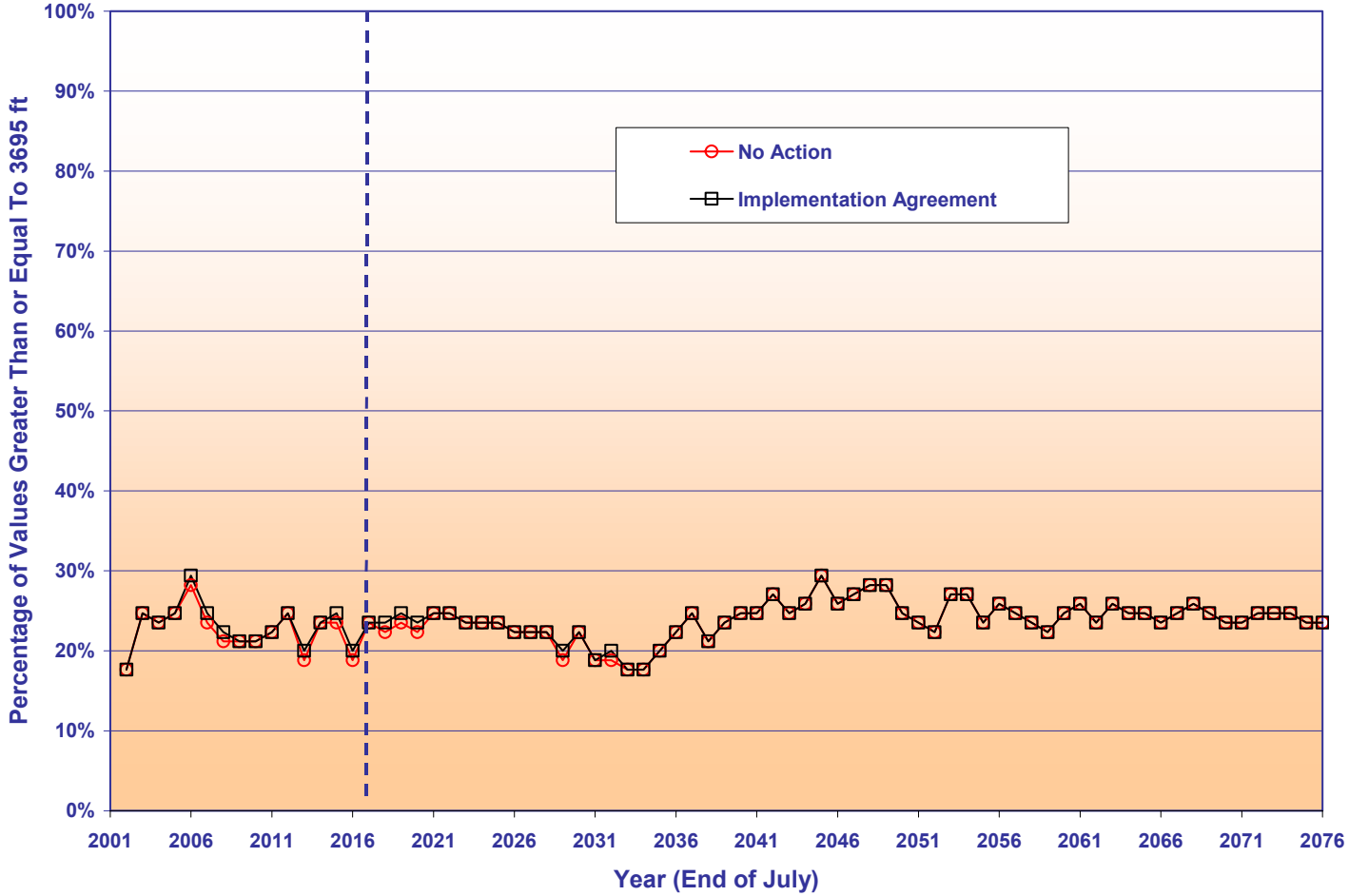


Figure 3.2-4 shows the frequency that future Lake Powell end-of-July water elevations under No Action conditions and the Implementation Agreement would be at or exceed a lake water elevation of 3612 feet msl. Lake Powell water surface elevation 3612 feet msl is used in this analysis as the low threshold elevation for marina and boat ramps at Lake Powell. This threshold elevation of 3612 feet msl is used to evaluate the No Action conditions and the effects of the Implementation Agreement on shoreline facilities at Lake Powell. The lines represent the percentage of values greater than or equal to the lake water elevation of 3612 feet msl under the No Action conditions and the Implementation Agreement. In year 2016, under the No Action conditions, the percentage of values greater than or equal to elevation 3612 feet msl is 88 percent. Between 2016 and 2076, the annual percentages of values greater than or equal to elevation 3612 feet msl decrease gradually to 68 percent.

3.2.1.2 COMPARISON OF IMPLEMENTATION AGREEMENT TO NO ACTION CONDITIONS

Figure 3.2-2 compared the 90th, 50th and 10th percentile water levels under the Implementation Agreement to those under No Action conditions. As discussed above, under No Action conditions, future Lake Powell water levels at the upper and lower 10th percentiles would likely be temporary and the water level would fluctuate between them in response to multi-year variations in basin runoff conditions. The same would apply to Implementation Agreement conditions.

Table 3.2-1 presents a comparison of the 90th percentile, median (50th percentile) and 10th percentile values of the Implementation Agreement to those of the No Action conditions. The values presented in this table are for years 2016, 2026, 2036, 2046 and 2076.

Table 3.2-1
Lake Powell End-of-July Water Elevations
Comparison of Implementation Agreement to No Action Conditions
90th, 50th and 10th Percentile Values

Year	No Action			Implementation Agreement		
	90th Percentile	50th Percentile	10th Percentile	90th Percentile	50th Percentile	10th Percentile
2016	3700	3661	3597	3699	3662	3599
2026	3699	3662	3594	3699	3663	3594
2036	3699	3670	3574	3699	3670	3575
2046	3700	3666	3561	3699	3666	3561
2076	3700	3655	3537	3699	3655	3537

Figure 3.2-3 compared the percentage of Lake Powell elevations that exceeded 3695 feet msl for the Implementation Agreement and No Action conditions. Table 3.2-2 provides a summary of that comparison for years 2016, 2026, 2036, 2046 and 2076.

Figure 3.2-4
Lake Powell End-of-July Water Elevations
Comparison of Implementation Agreement to No Action Conditions
Percentage of Values Greater than or Equal to Elevation 3612 Feet

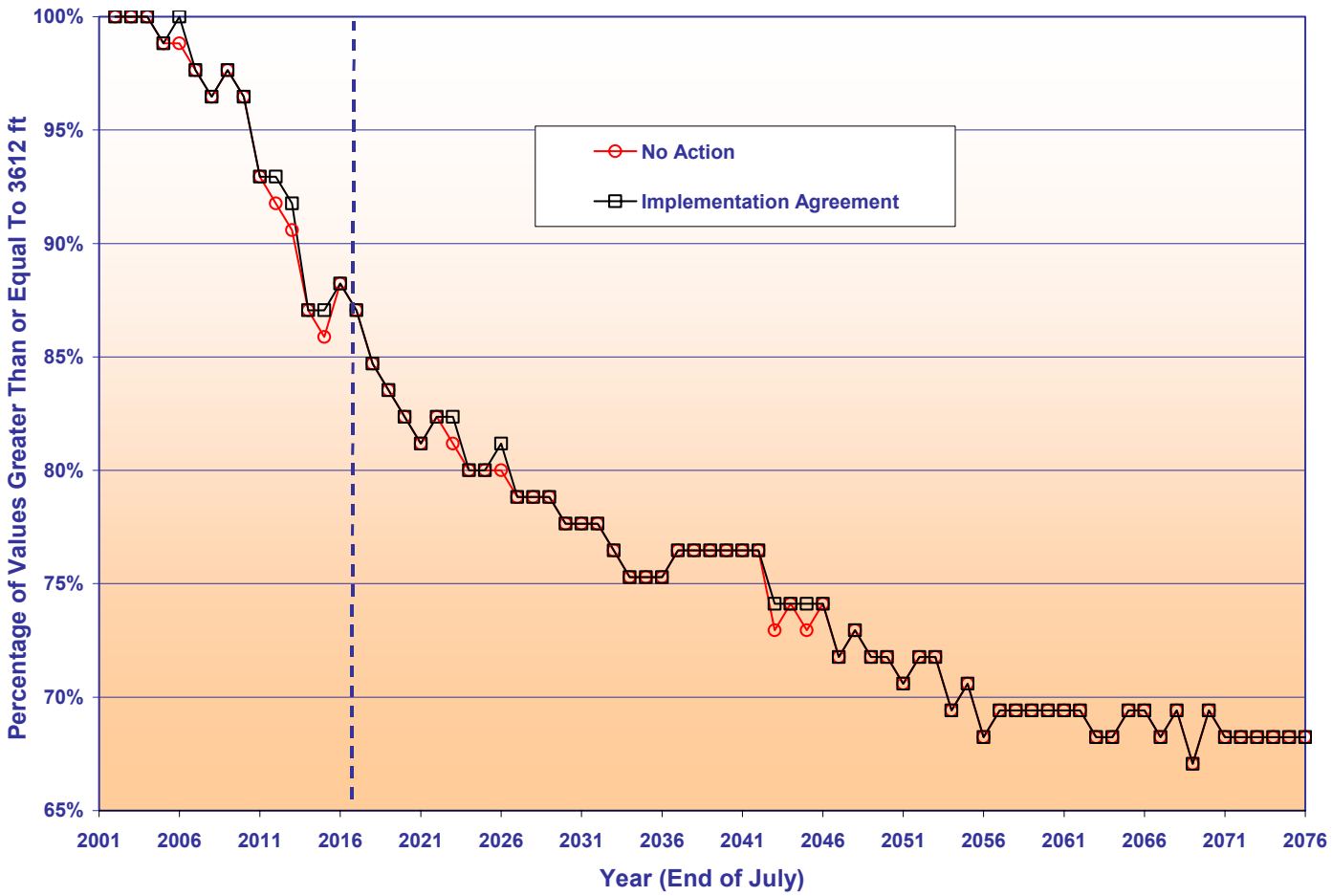


Table 3.2-2
Lake Powell End-of-July Water Elevations
Comparison of Implementation Agreement to No Action Conditions
Percentage of Values Greater than or Equal to Elevation 3695 Feet

Year	No Action	Implementation Agreement
2016	18%	20%
2026	22%	22%
2036	22%	22%
2046	26%	26%
2076	24%	24%

Figure 3.2-4 compared the percentage of Lake Powell elevations that exceeded 3612 feet msl under the Implementation Agreement and No Action conditions. Table 3.2-3 provides a summary of that comparison for years 2016, 2026, 2036, 2046 and 2076.

Table 3.2-3
Lake Powell End-of-July Water Elevations
Comparison of Implementation Agreement to No Action Conditions
Percentage of Values Greater than or Equal to Elevation 3612 Feet

Year	No Action	Implementation Agreement
2016	88%	88%
2026	80%	81%
2036	75%	75%
2046	74%	74%
2076	68%	68%

3.2.1.3 SENSITIVITY ANALYSIS

The water surface elevations of Lake Powell presented above are based on model operations in which the Lake Mead water surface elevation of 1083 feet msl was assumed to be the shortage protection level. In order to test the sensitivity of that assumption on the results of the model operation, model runs were also conducted with an assumed Lake Mead protection level of 1050 feet msl. With the 1050-foot protection level on Lake Mead, the water levels on Lake Powell were essentially the same as those based on the 1083-foot protection level under Implementation Agreement Conditions. Lake Mead water levels were observed to be lower under the 1050-foot level protection criteria. However, the relative differences between the Action and No Action alternatives were similar. A discussion of the results of this sensitivity analysis is presented in Attachment D.

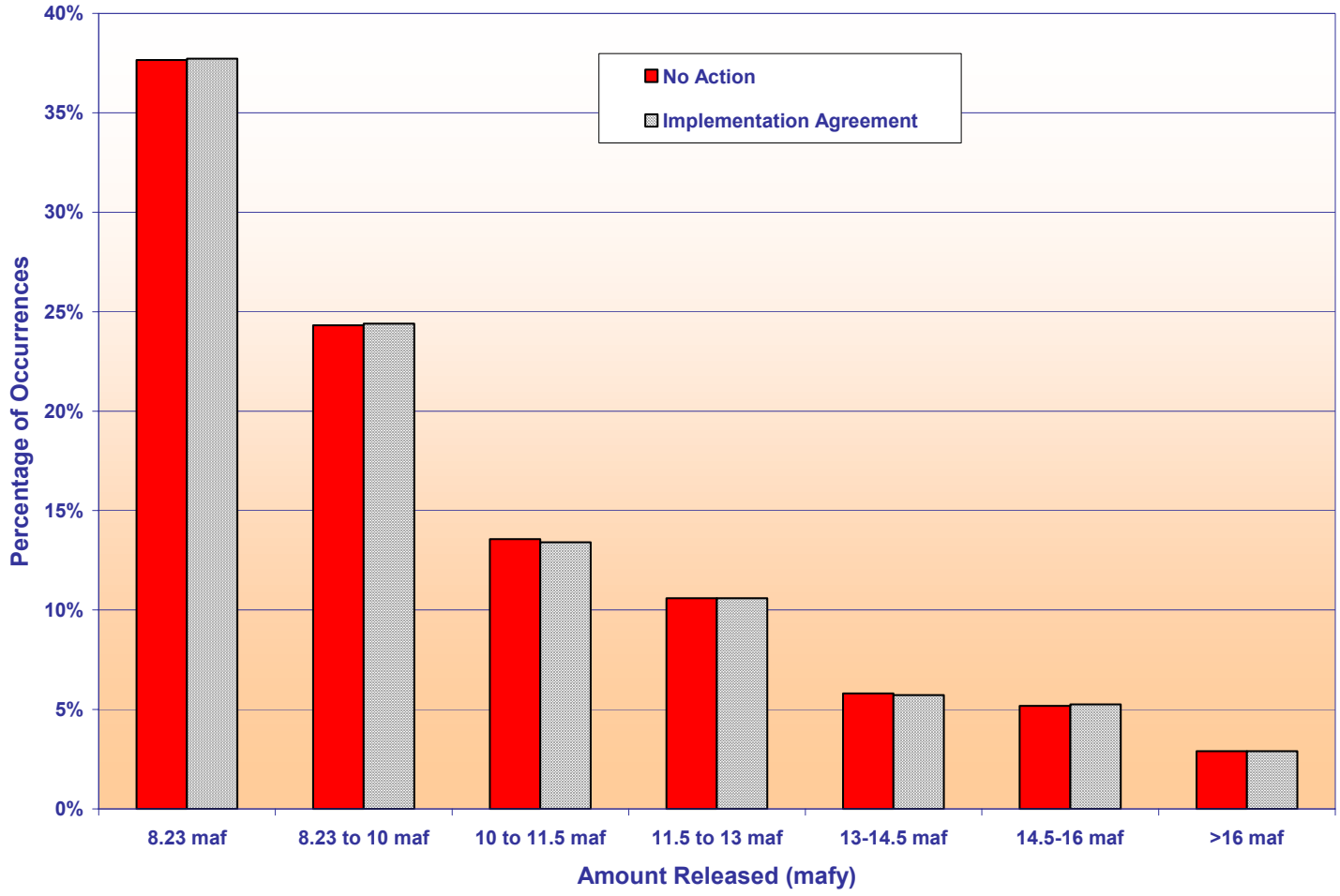
3.2.2 RIVER FLOWS BETWEEN LAKE POWELL AND LAKE MEAD

The river flows between Glen Canyon Dam and Lake Mead result from controlled releases from Glen Canyon Dam (Lake Powell) and include gains from tributaries in this reach of the river. Releases from Glen Canyon Dam are managed as previously discussed in Sections 1.1.1. The most significant gains from perennial streams include

inflow from the Little Colorado River and Paria River. However, inflow from these streams is concentrated over very short periods of time, and on average, make up approximately two percent of the total annual flow in this reach of the river.

Figure 3.2-5 provides a comparison of the relative frequency of occurrence of annual releases from Lake Powell under the No Action conditions and Implementation Agreement, during the interim surplus guidelines period (through 2016). Releases between 8.23 and 11.5 maf generally correspond to years where equalization releases are being made from Lake Powell. The surplus water deliveries from Lake Mead associated with the interim surplus guidelines tend to increase the relative frequency of equalization during that period compared to No Action conditions.

Figure 3.2-5
Histogram of Modeled Lake Powell Annual Releases (Water Years)
2002 to 2016 (85 Traces)



3.2.3 LAKE MEAD WATER LEVELS

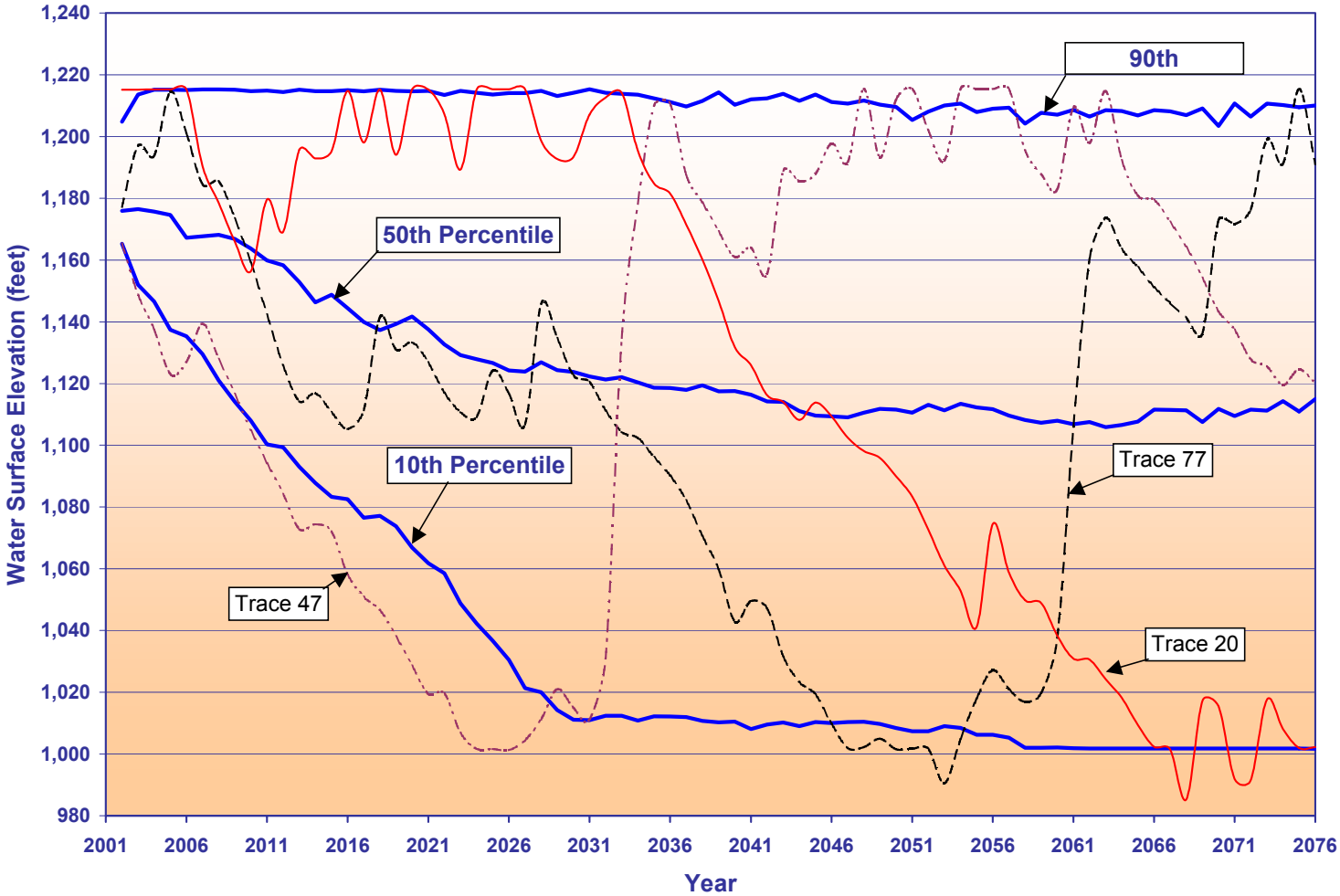
This section summarizes the results of the future Lake Mead water level simulations under No Action conditions and Implementation Agreement conditions.

3.2.3.1 MODELING RESULTS OF NO ACTION

Under the No Action conditions, the water surface elevation of Lake Mead is projected to fluctuate between full level and decreasingly lower levels during the period of analysis (2002 to 2076). Figure 3.2-6 illustrates the range of water levels (end of December) by three lines, labeled 90th Percentile, 50th Percentile and 10th Percentile. The 50th percentile line shows the median water level for each future year. The median water level under No Action conditions is shown to decline to 1144 feet msl by 2016 and to 1115 feet msl by 2076. The 10th percentile line shows there is a 10 percent probability that the water level would decline to 1082 feet msl by 2016 and to 1002 feet msl by 2076. It should also be noted that the Lake Mead elevations depicted in Figure 3.2-6 represent water levels at the end of December which is when lake levels are at a seasonal high. Conversely, the Lake Mead water level generally reaches its annual low in July.

Three distinct traces are added to Figure 3.2-6 to illustrate what was actually simulated under the various traces and respective hydrologic sequences and to highlight that the 90th, 50th and 10th percentile lines do not represent actual traces, but rather the ranking of the data from the 85 traces for the conditions modeled. The three traces illustrate the variability among the different traces and that the reservoir levels could temporarily decline below the 10th percentile line. The trace identified as Trace 20 represents the hydrologic sequence that begins in year 1925. The trace identified as Trace 47 represents the hydrologic sequence that begins in year 1952. The trace identified as Trace 77 represents the hydrologic sequence that begins in year 1982.

Figure 3.2-6
Lake Mead End-of-December Water Elevations Under No Action Conditions
90th, 50th and 10th Percentile Values and Representative Traces



In Figure 3.2-6, the 90th and 10th percentile lines bracket the range where 80 percent of future Lake Mead water levels simulated for the No Action conditions occur. The highs and lows shown on the three traces would likely be temporary conditions. The reservoir level would tend to fluctuate through multi-year periods of above average and below average inflows. Neither the timing of water level variations between the highs and the lows, 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 3.2-7 presents the 90th, 50th and 10th percentile plots obtained for the No Action conditions and those obtained for the Implementation Agreement. This figure is best used for comparing the relative differences in the general lake level trends between the simulated No Action and Implementation Agreement conditions.

Figure 3.2-8 shows the frequency at which future Lake Mead end of December water surface elevations under No Action conditions would be at or exceed 1200 feet msl. The corresponding frequency with the Implementation Agreement is also plotted. The lines represent the percentage of values of all 85 traces that are equal to or greater than elevation 1200 feet msl. In year 2016, under the No Action conditions, the percentage of values greater than or equal to elevation 1200 feet msl is 19 percent. After 2016 the annual percentages of values equal to or greater than elevation 1200 feet msl vary around 20 percent for a decade and then decrease gradually to 13 percent in 2076 under No Action conditions.

Figure 3.2-9 provides a comparison of the frequency that future Lake Mead end of December water levels would be at or above elevation 1083 feet msl under No Action and Implementation Agreement conditions. In year 2016, under the No Action conditions, the percentage of values greater than or equal to elevation 1083 feet msl is 89 percent. After 2016 the annual percentages of values equal to or greater than elevation 1083 feet msl decline to 56 percent in 2076 under No Action conditions.

Figure 3.2-7
Lake Mead End-of-December Water Elevations
Comparison of Implementation Agreement and No Action Conditions
90th, 50th and 10th Percentile Values

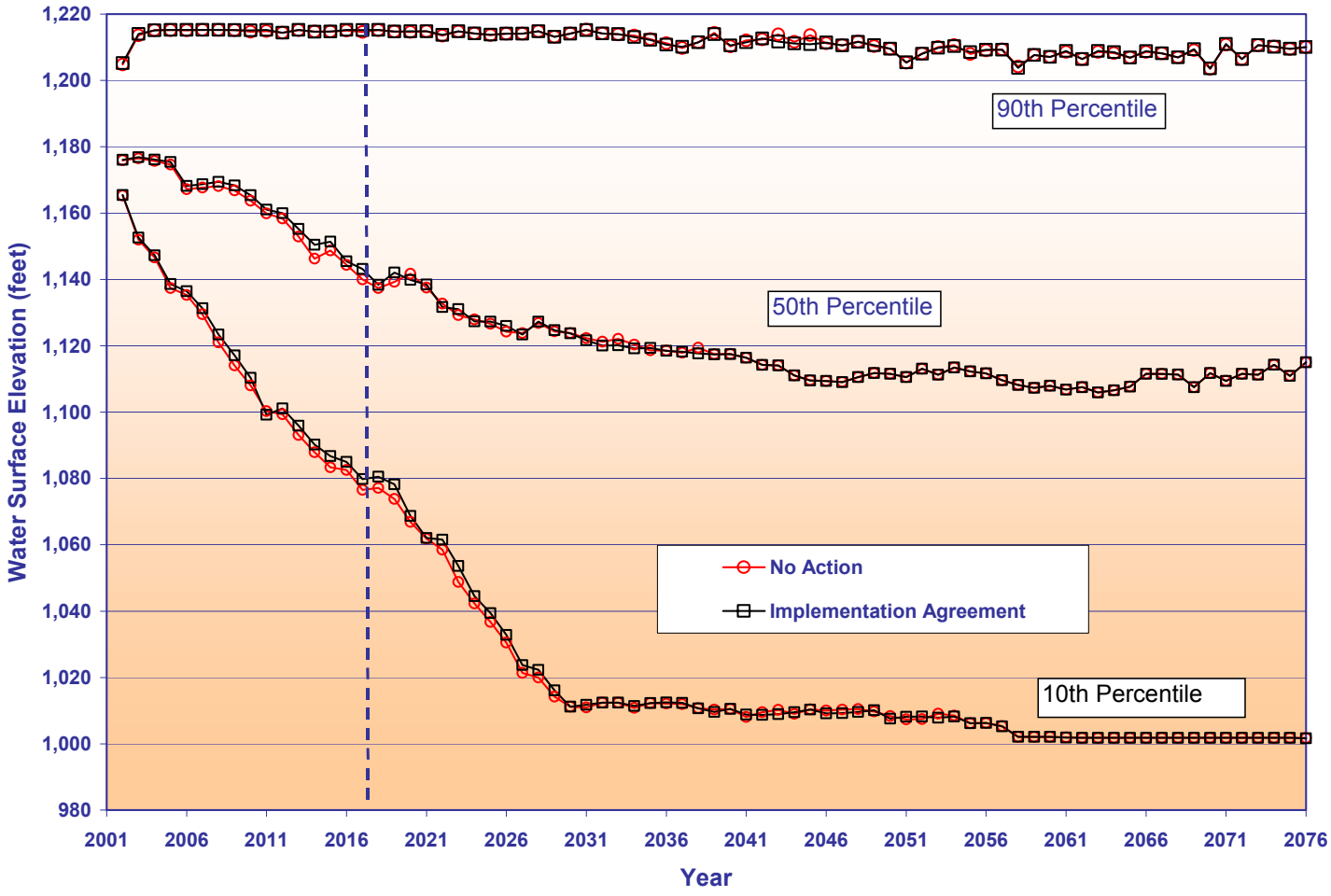


Figure 3.2.8
Lake Mead End-of-December Water Elevations
Comparison of Implementation Agreement and No Action Conditions
Percentage of Values Greater than or Equal to Elevation 1200 Feet

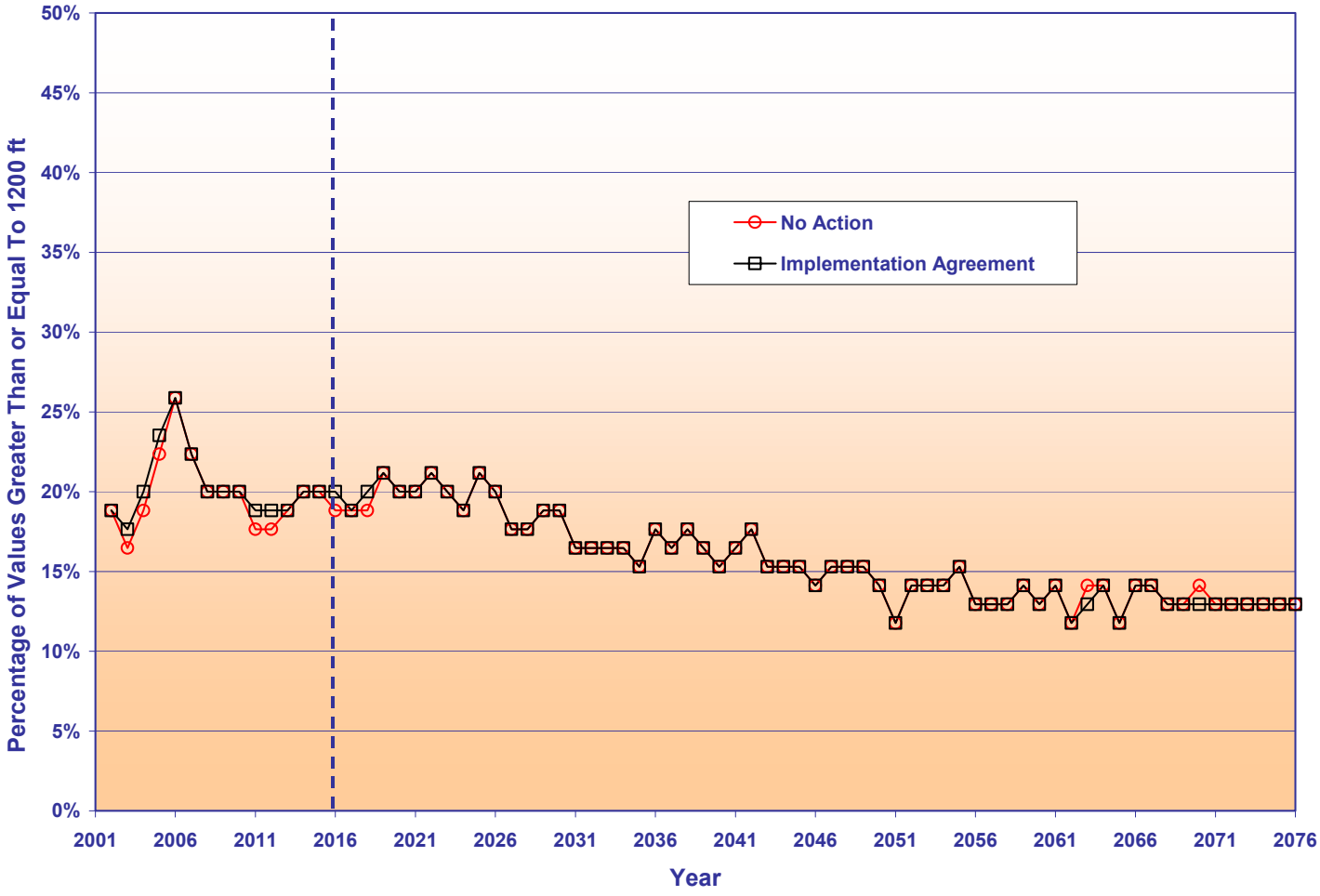


Figure 3.2-9
Lake Mead End-of-December Water Elevations
Comparison of Implementation Agreement to No Action Conditions
Percentage of Values Greater than or Equal to Elevation 1083 Feet

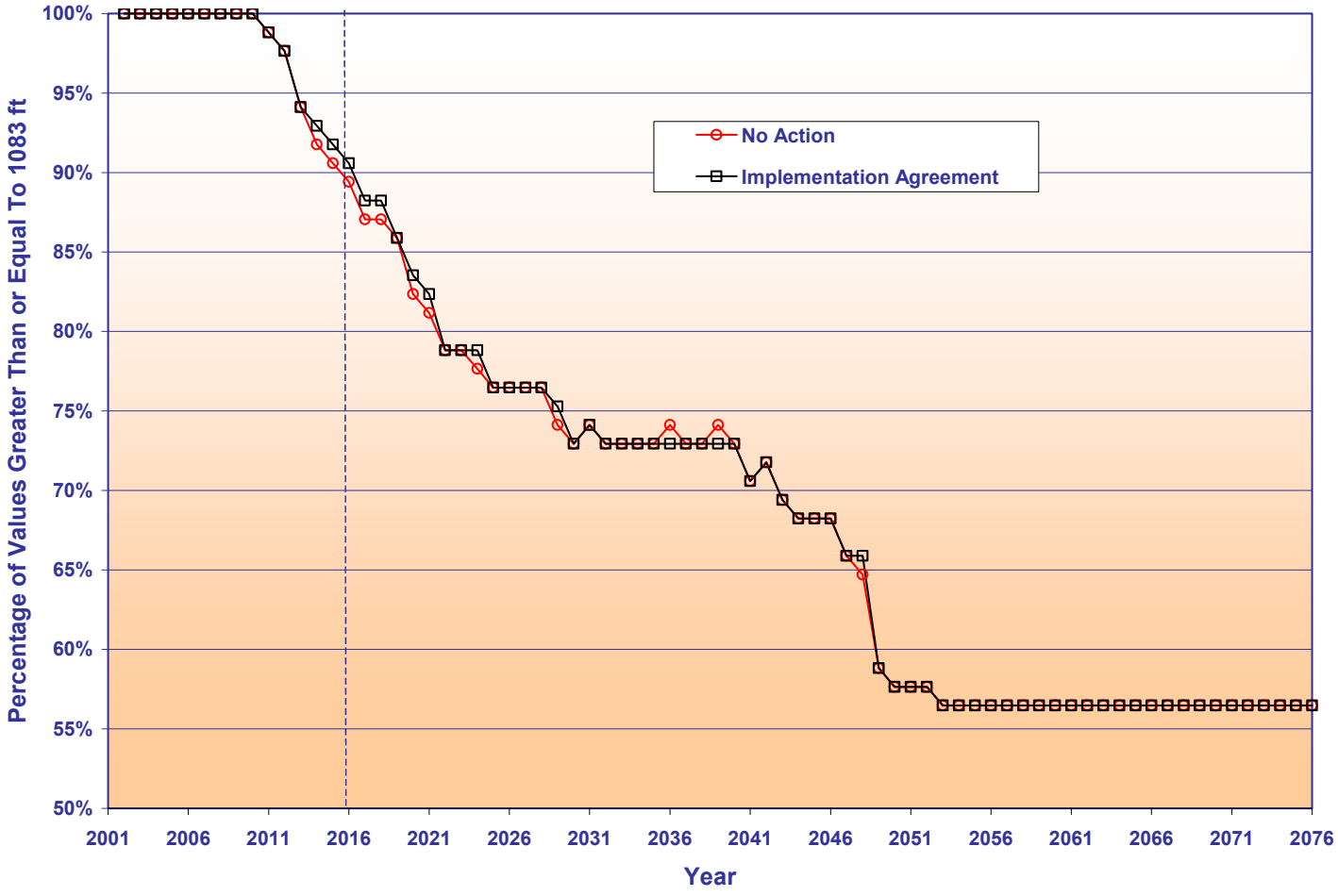


Figure 3.2-10 provides a comparison of the frequency that future Lake Mead end of December water levels would be at or above elevation 1050 feet msl under No Action and Implementation Agreement conditions. Between 2002 and 2016, under No Action conditions, the percentage of values greater than or equal to elevation 1050 feet msl is 100 percent. After 2016 the annual percentages of values equal to or greater than elevation 1050 feet msl decline to 60 percent in 2071 under No Action conditions.

Figure 3.2-11 provides a comparison of the frequency that future Lake Mead end of December water elevations under No Action conditions and the Implementation Agreement would be at or exceed a lake water elevation of 1000 feet msl. Between 2002 and 2016, under the No Action conditions, the percentage of values greater than or equal to elevation 1000 feet msl is 100 percent. After 2016 the annual percentages of values equal to or greater than elevation 1000 feet msl remain at 100 percent for several decades before declining to 94 percent in 2076 under No Action conditions.

3.2.3.2 COMPARISON OF IMPLEMENTATION AGREEMENT TO NO ACTION

Figure 3.2-7 compared the 90th, 50th and 10th percentile water levels of the Implementation Agreement to those of the No Action conditions. As discussed above, under No Action conditions, future Lake Mead water levels at the upper and lower 10th percentiles would likely be temporary and the water levels are expected to fluctuate between them in response to multi-year variations in basin runoff conditions. The same would apply to the Implementation Agreement.

The 90th percentile, median (50th percentile) and 10th percentile values of the Implementation Agreement are compared to those of the No Action conditions in Table 3.2-4. The values presented in this table are for years 2016, 2026, 2036, 2046, and 2076. There are no significant differences between the values under Implementation Agreement and No Action Conditions.

Table 3.2-4
Lake Mead End-of-December Water Elevations
Comparison of Implementation Agreement to No Action Conditions
90th, 50th and 10th Percentile Values

Year	No Action			Implementation Agreement		
	90th Percentile	50th Percentile	10th Percentile	90th Percentile	50th Percentile	10th Percentile
2016	1215	1144	1083	1215	1146	1085
2026	1214	1124	1031	1214	1126	1033
2036	1213	1119	1012	1211	1119	1013
2046	1211	1109	1010	1211	1109	1009
2076	1210	1115	1002	1210	1115	1002

Figure 3.2-10
Lake Mead End-of-December Water Elevations
Comparison of Implementation Agreement to No Action Conditions
Percentage of Values Greater than or Equal to Elevation 1050 Feet

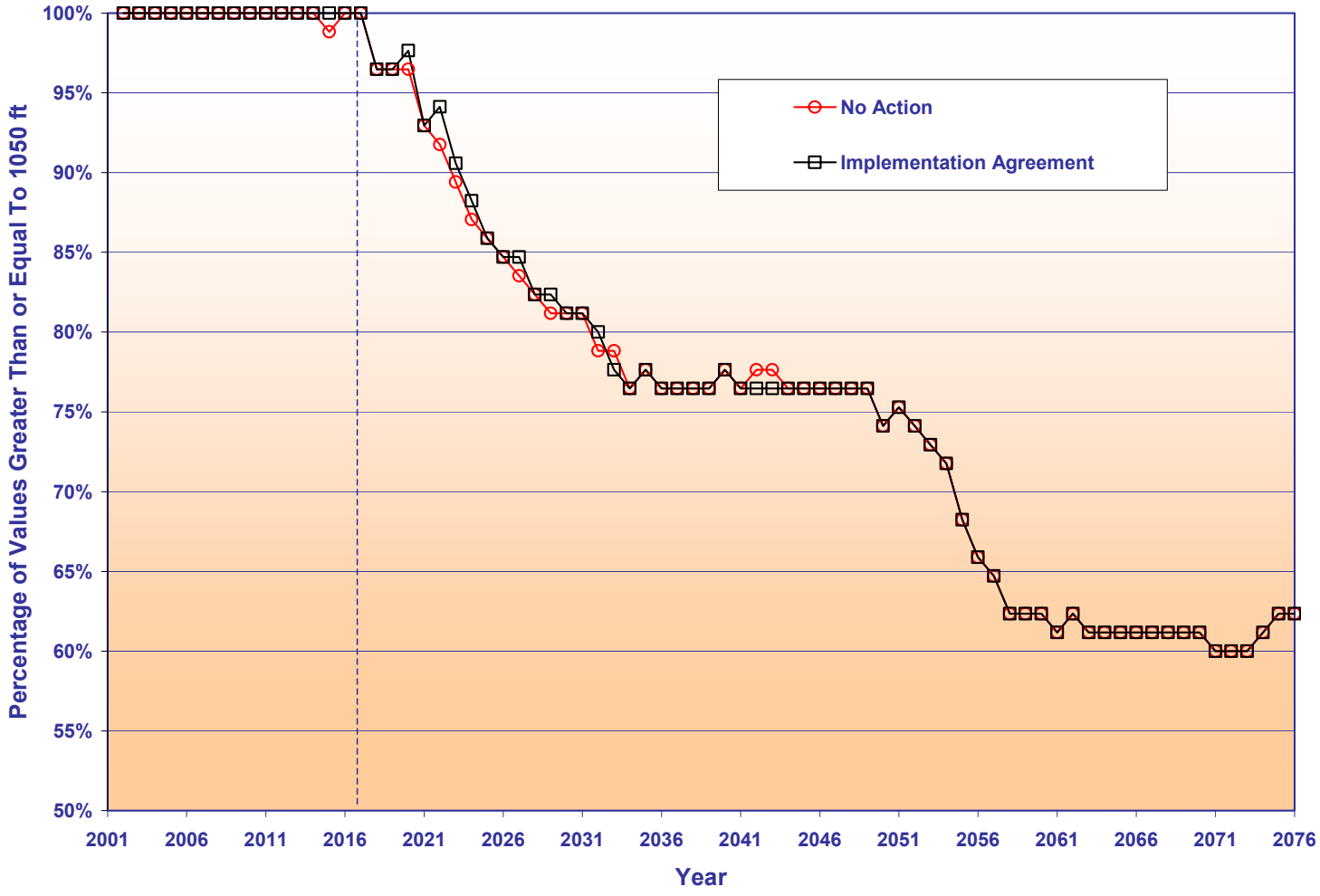


Figure 3.2-11
Lake Mead End-of-December Water Elevations
Comparison of Implementation Agreement to No Action Conditions
Percentage of Values Greater than or Equal to Elevation 1000 Feet

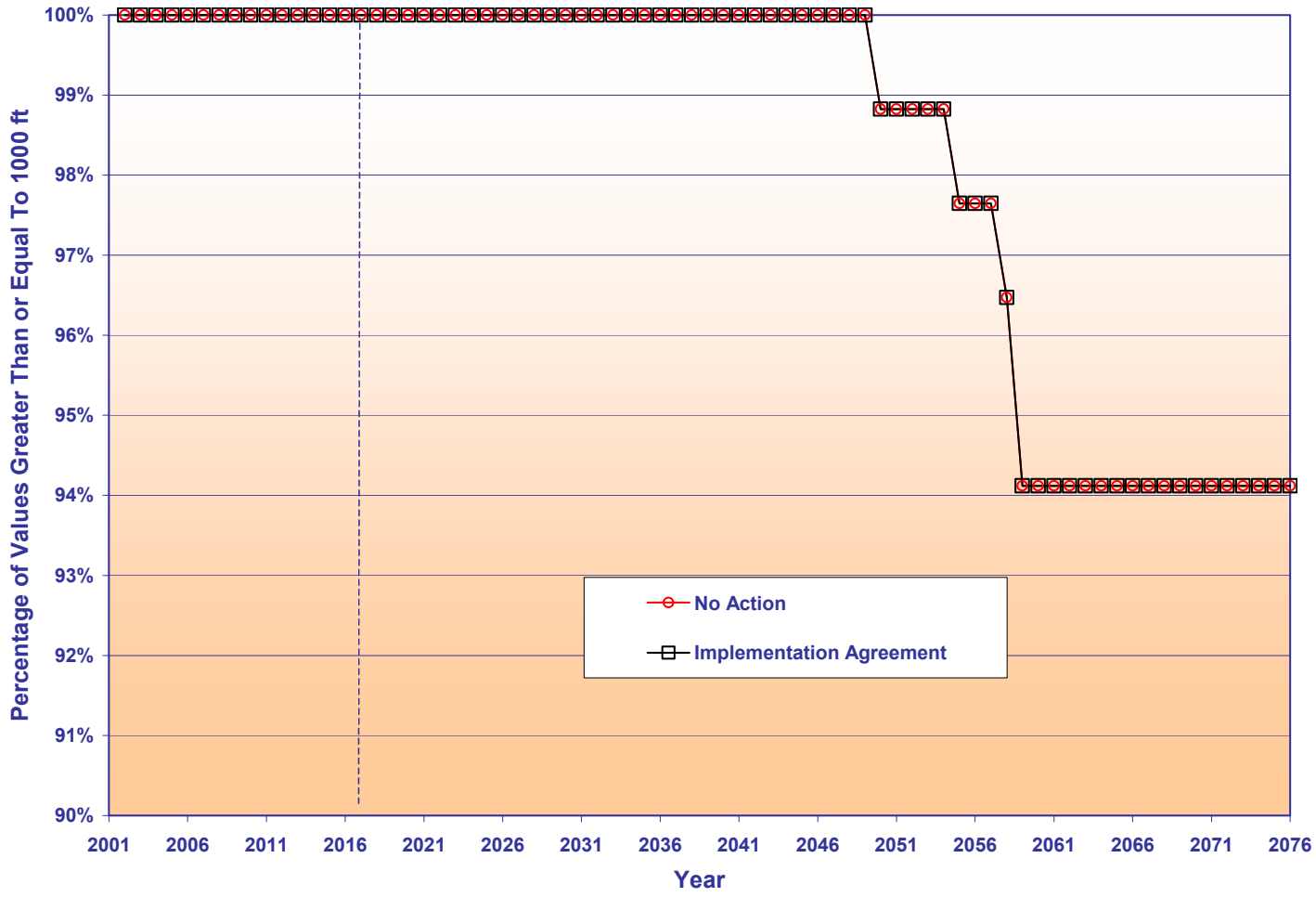


Figure 3.2-8 compared the percentage of Lake Mead elevations that were at or above 1200 feet msl for the Implementation Agreement and No Action conditions. Table 3.2-5 provides a summary of that comparison for years 2016, 2026, 2036, 2046, and 2076.

Table 3.2-5
Lake Mead End-of-December Water Elevations
Comparison of Implementation Agreement to No Action Conditions
Percentage of Values Greater than or Equal to Elevation 1200 Feet

Year	No Action	Implementation Agreement
2016	19%	20%
2026	20%	20%
2036	18%	18%
2046	14%	14%
2076	13%	13%

Figure 3.2-9 compared the percentage of Lake Mead elevations that were at or above 1083 feet msl for the Implementation Agreement and No Action conditions. Table 3.2-6 provides a summary of that comparison for years 2016, 2026, 2036, 2046, and 2076.

Table 3.2-6
Lake Mead End-of-December Water Elevations
Comparison of Implementation Agreement to No Action Conditions
Percentage of Values Greater than or Equal to Elevation 1083 Feet

Year	No Action	Implementation Agreement
2016	89%	91%
2026	76%	76%
2036	74%	73%
2046	68%	68%
2076	56%	56%

Figure 3.2-10 compared the percentage of Lake Mead elevations that were at or above 1050 feet msl for the Implementation Agreement and No Action conditions. Table 3.2-7 provides a summary of that comparison for years 2016, 2026, 2036, 2046, and 2076.

Table 3.2-7
Lake Mead End-of-December Water Elevations
Comparison of Implementation Agreement to No Action Conditions
Percentage of Values Greater than or Equal to Elevation 1050 Feet

Year	No Action	Implementation Agreement
2016	100%	100%
2026	85%	85%
2036	76%	76%
2046	76%	76%
2076	62%	62%

Figure 3.2-11 compared the percentage of Lake Mead elevations that were at or above 1000 feet msl for the Implementation Agreement and No Action conditions. Table 3.2-8 provides a summary of that comparison for years 2016, 2026, 2036, 2046, and 2076.

Table 3.2-8
Lake Mead End-of-December Water Elevations
Comparison of Implementation Agreement to No Action Conditions
Percentage of Values Greater than or Equal to Elevation 1000 Feet

Year	No Action	Implementation Agreement
2016	100%	100%
2026	100%	100%
2036	100%	100%
2046	100%	100%
2076	94%	94%

3.2.3.3 SENSITIVITY ANALYSIS

The water surface elevations of Lake Mead presented above are based on model operations in which the Lake Mead water surface elevation of 1083 feet msl was assumed to be the shortage protection level. In order to test the sensitivity of that assumption on the results of the model operation, model runs were also conducted with an assumed Lake Mead protection level of 1050 feet msl. With the 1050-foot protection level, the resulting water levels on Lake Mead range up to approximately 13 feet lower than those based on the 1083-foot protection level under Implementation Agreement Conditions, after 2010 for the 50th and 10th percentiles. Lake Mead water level plots based on the use of the 1050-foot protection level are included in Attachment D.

3.2.4 RIVER FLOWS BELOW HOOVER DAM

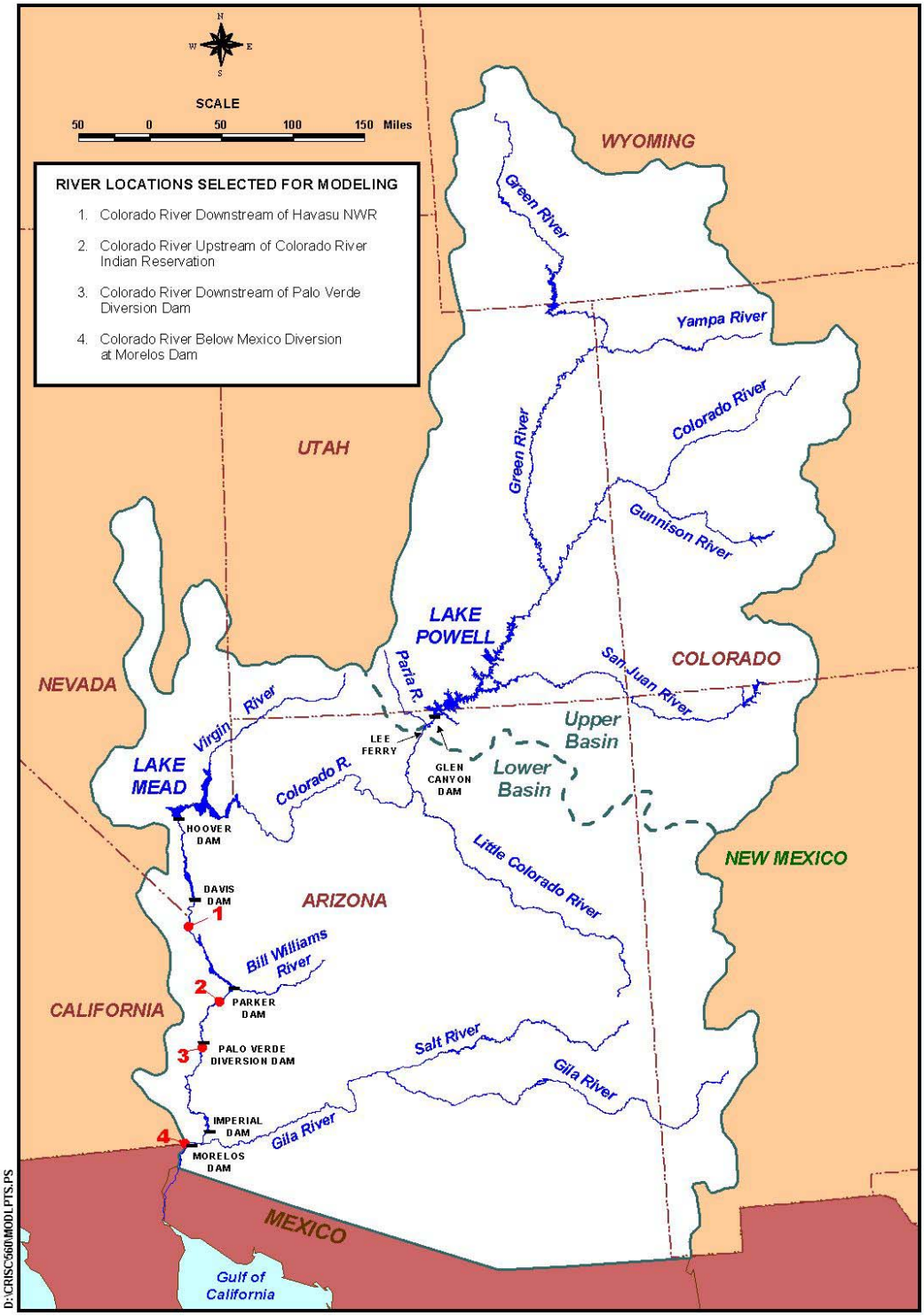
This section describes results of the analysis of the simulated Colorado River flows below Hoover Dam. The model of the Colorado River system was used to simulate future mean monthly flows under No Action and Implementation Agreement conditions. Four specific river locations were selected to represent flows within selected river reaches below Hoover Dam. The river reaches and corresponding flow locations are listed in Table 3.2-9 and shown on Map 3.2-1.

Table 3.2-9
Colorado River Flow Locations Identified for Evaluation

Colorado River Reach	Selected River Flow Locations	
	Description	Approximate River Mile [1]
Between Hoover Dam and Parker Dam	Havasu National Wildlife Refuge (NWR)	242.3
Between Parker Dam and Palo Verde Diversion Dam	Upstream of Colorado River Indian Reservation	180.8
Between Palo Verde Diversion and Imperial Dam	Downstream of the Palo Verde Diversion Dam	133.8
Between Imperial Dam and SIB	Below the Mexico Diversion at Morelos Dam	23.1

[1] River miles as measured from the southerly international boundary with Mexico

Map 3.2-1
Colorado River Locations Selected for Modeling



Two types of analysis of the potential of Implementation Agreement to affect river flows were conducted. In the first analysis, the potential effects on the total annual volume of flow in each reach were evaluated. In this analysis, the mean monthly flows were first summed over each calendar year. The 90th, 50th, and 10th percentiles of the annual volumes were then computed for each year. Plots of these percentiles for No Action and Implementation Agreement conditions are included in this section for each of the four river points. Cumulative distributions of the annual flow volumes are also presented for 2016 to aid in the understanding of the effects.

The second analysis investigated the potential effects on seasonal flows. Cumulative distributions of mean monthly flows (in cfs) were produced for specific years and selected months representative of each season. The mean monthly flows for January were used to represent the winter season flows and likewise for April, July, and October to represent spring, summer, and fall, respectively. The specific years analyzed included 2006, 2016, 2026, and 2050. The data and graphs for 2016 are presented in this section to illustrate the process.

It should be noted that the monthly demand schedules used in the model are based on a distribution of the total annual demand (a percentage for each month). Although each diversion point may use a different distribution, those percentages do not change from year to year, and cannot reflect potential future changes in the system that might affect the monthly distributions. Therefore, the seasonal differences are primarily governed by the overall changes in annual flow volumes, coupled with the effect of each diversion's distribution upstream of the point of interest.

Daily and hourly releases from Hoover Dam reflect the short-term demands of Colorado River water users with diversions located downstream, storage management in Lakes Mohave and Havasu, and power production at Hoover, Davis and Parker Dams. The close proximity of Lake Mohave to Hoover Dam effectively dampens the short-term fluctuations below Hoover Dam. The scheduling and subsequent release of water through Davis and Parker Dams create short-term fluctuations in river flows, depths, and water surface elevations downstream of these structures. These fluctuations of water surface elevations in the river are most noticeable in the river reaches located immediately downstream of the dams and lessen as the downstream distance increases. The Implementation Agreement, however, will have no effect on the short-term operations of Hoover, Davis and Parker Dam, and therefore, short-term fluctuations in river reaches downstream of Hoover Dam were not evaluated.

3.2.4.1 RIVER FLOWS BETWEEN HOOVER DAM AND PARKER DAM

The river flows between Hoover Dam and Parker Dam are composed mainly of flow releases from Hoover Dam and Davis Dam. Inflows from the Bill Williams River and other intermittent tributaries are infrequent and are usually concentrated into short time periods due to their dependence on localized precipitation. Tributary inflows comprise less than one percent of the total annual flow in this reach of the river.

A point on the Colorado River downstream of Davis Dam was used to evaluate the river flows for this reach, located immediately downstream of the Havasu National Wildlife Refuge (NWR). The 90th, 50th, and 10th percentile annual flow volumes for this reach are shown in Figure 3.2-12. As shown by the 50th percentile values, annual flow volumes in this reach would be more uniform under the Implementation Agreement conditions than under the No Action conditions during the 15-year interim surplus guidelines period. The plot indicates that the Implementation Agreement would reduce the No Action highs during this period by up to approximately 10 percent. This is attributable to the reduction in California's mainstem depletions by MWD resulting from the conservation measures and water transfers implemented in California. Beyond the 15-year interim period, the annual flow volumes under the Implementation Agreement are essentially the same (within one percent) as those under the No Action conditions.

At the 90th and 10th percentile levels the flows under Implementation Agreement conditions are essentially the same as those under the No Action conditions. Figure 3.2-13 shows the distribution of annual flow volumes for year 2016.

Figures 3.2-14(a-d) present comparisons of the representative seasonal flows under No Action conditions and the Implementation Agreement for 2016. As expected, the largest flows occur in the spring and summer seasons for No Action conditions and all alternatives due to downstream irrigation demands. For flows that are due primarily to flood control releases from Lake Mead (flows in the 80th - 100th percentile range), the range of mean monthly flows is generally unchanged by the Implementation Agreement, except during the winter season where the Implementation Agreement would cause higher flows in the 80th to 85th percentile range. In the lower percentiles, the seasonal flows with the Implementation Agreement vary slightly higher or lower than the flows under No Action conditions. The approximate departure of Implementation Agreement from No Action varied from 15 percent higher (January) to 3 percent lower (April) in 2016.

A numerical comparison of the 70th percentile seasonal flow values is shown on Table 3.2-10. The values representing the seasons are the mean monthly flows in January, April, July and October.

Table 3.2-10
Comparison of Mean Monthly Flow (cfs) – Implementation Agreement to No Action Conditions
Colorado River Downstream of Havasu NWR (River Mile = 242.3)
70th Percentile Values for Year 2016

Season (Representative Month)	Mean Monthly Flows (cfs) for Year 2016 at the 70th Percentile	
	No Action	Implementation Agreement
Winter (January)	8,171	8,314
Spring (April)	16,198	16,041
Summer (July)	15,921	15,887
Fall (October)	11,781	11,170

Figure 3.2-12
Colorado River Downstream of Havasu NWR Annual Flow Volume (af)
Comparison of Implementation Agreement to No Action Conditions
90th, 50th and 10th Percentile Values

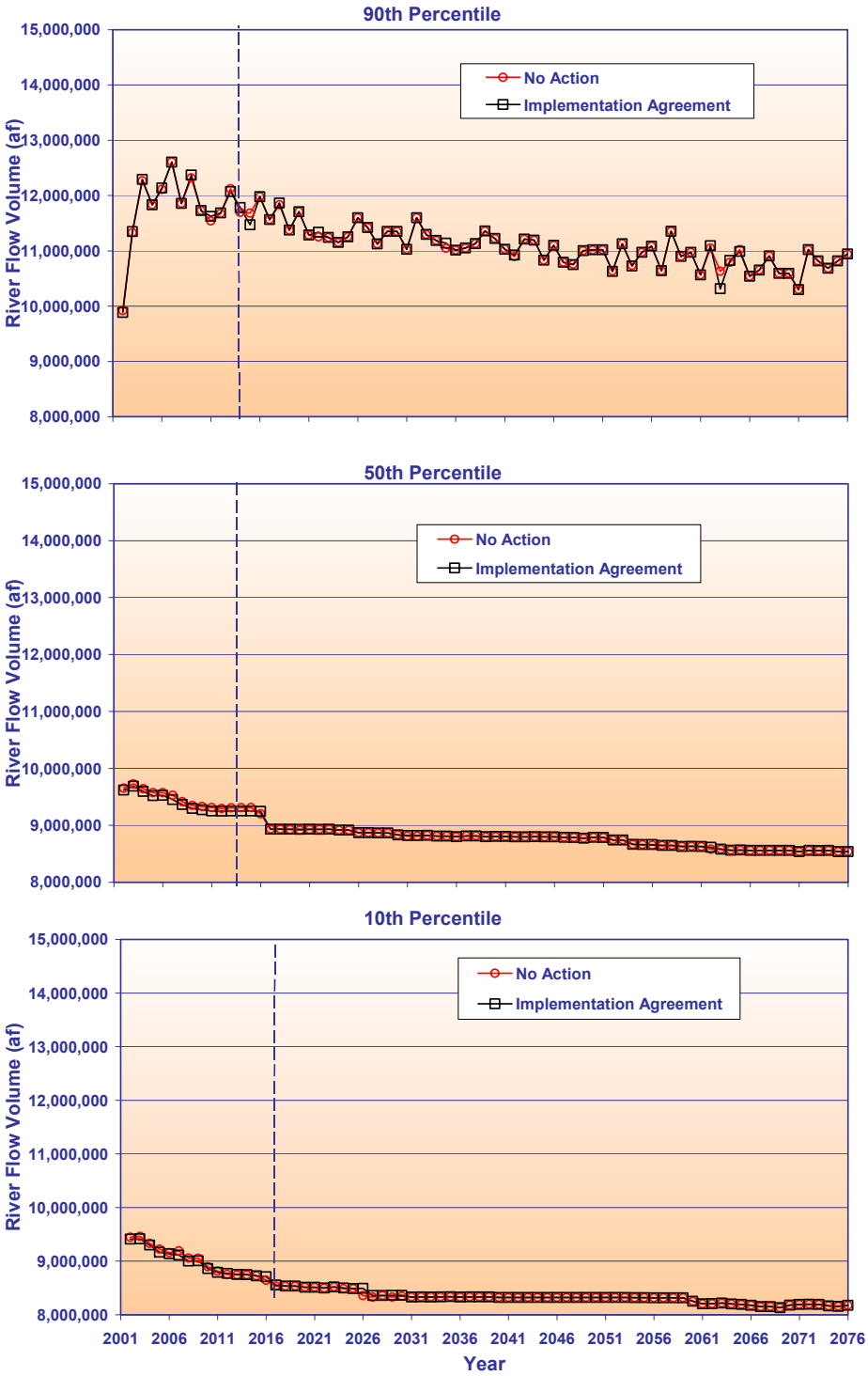


Figure 3.2-13
Colorado River Annual Flow Volume Downstream of Havasu NWR
Comparison of Implementation Agreement to No Action Conditions for Modeled Year 2016

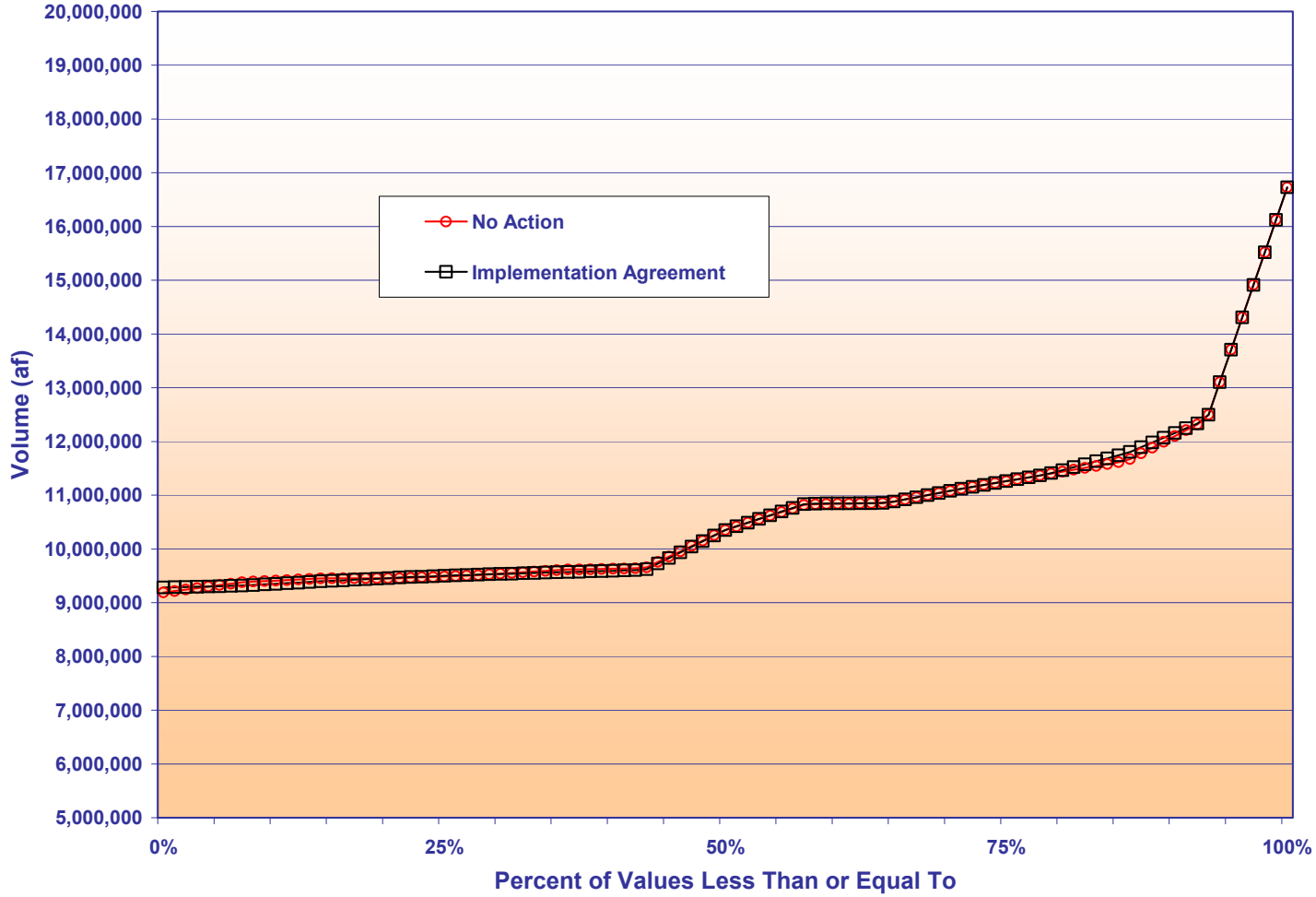


Figure 3.2-14a
Colorado River Seasonal Flows Downstream of Havasu NWR
Comparison of Implementation Agreement to No Action Conditions for Modeled Year 2016

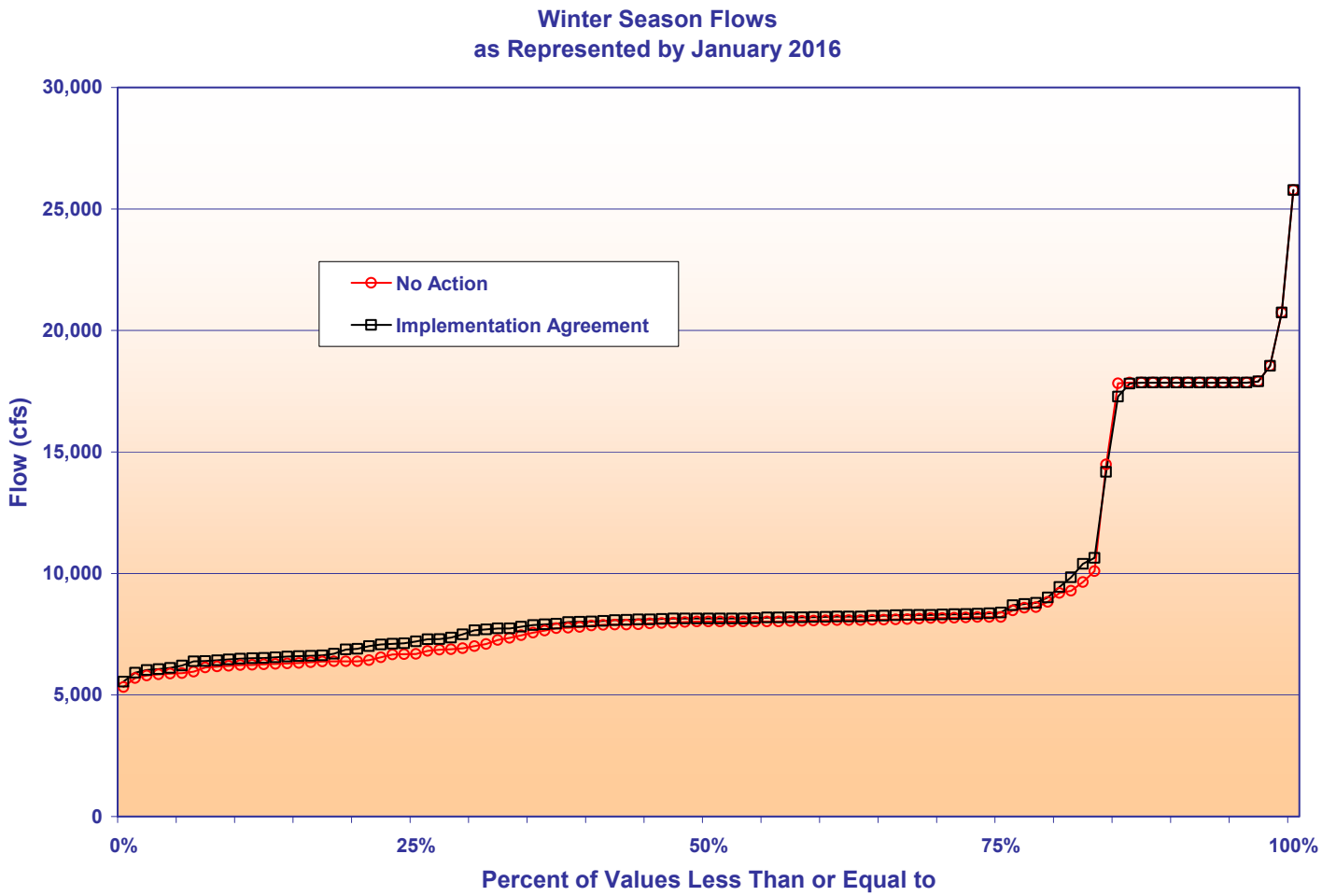


Figure 3.2-14b
Colorado River Seasonal Flows Downstream of Havasu NWR
Comparison of Implementation Agreement to No Action Conditions for Modeled Year 2016

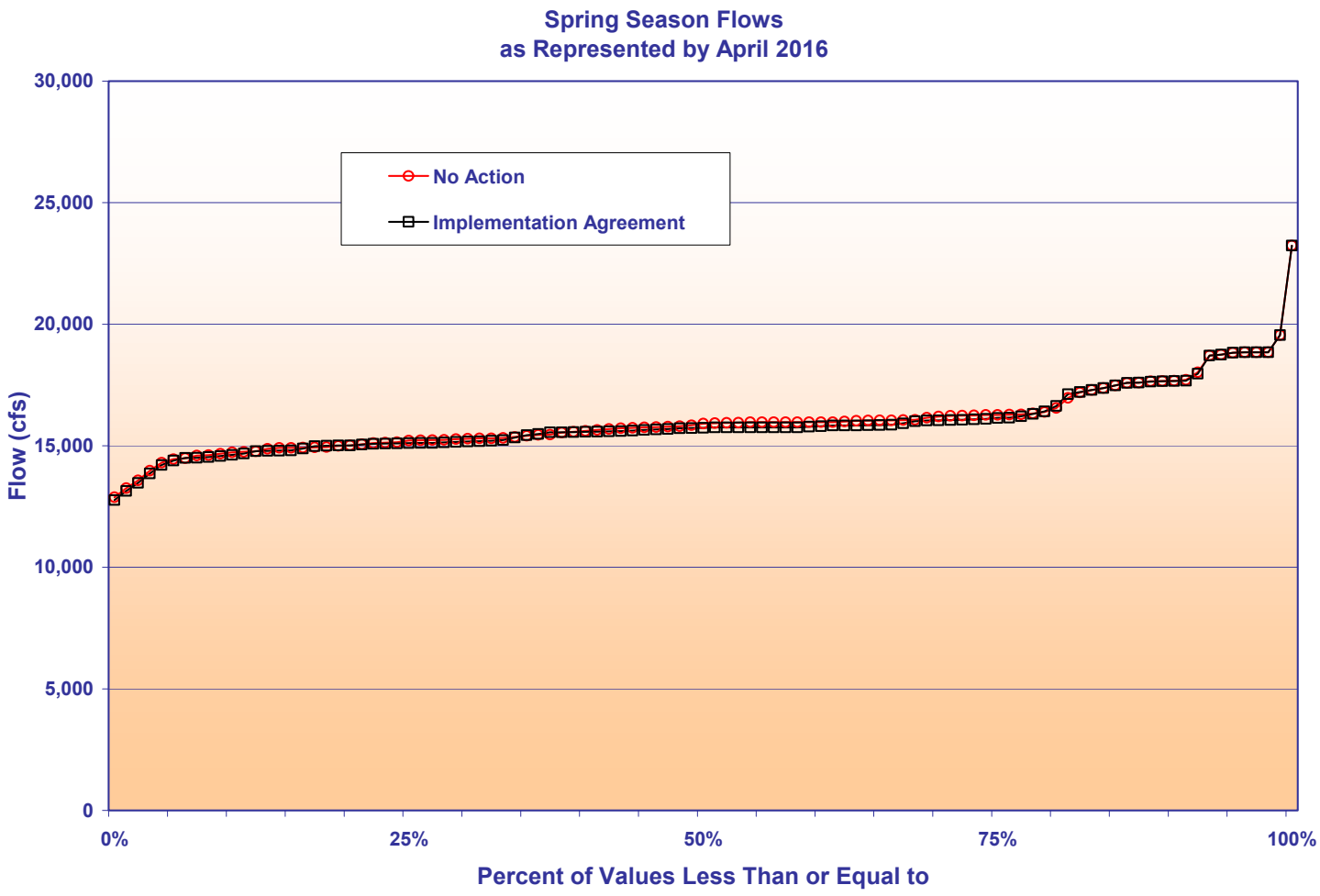


Figure 3.2-14c
Colorado River Seasonal Flows Downstream of Havasu NWR
Comparison of Implementation Agreement to No Action Conditions for Modeled Year 2016

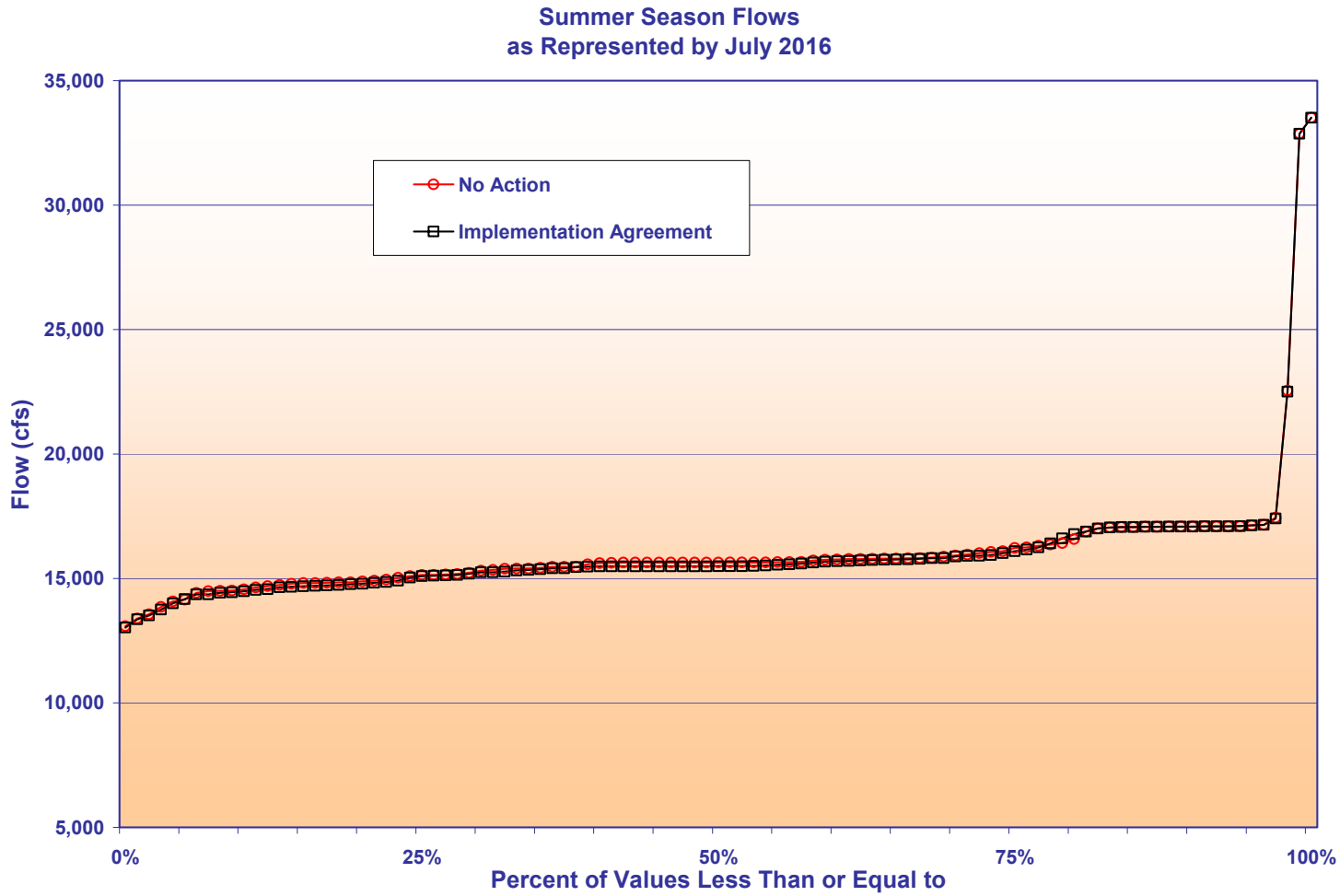
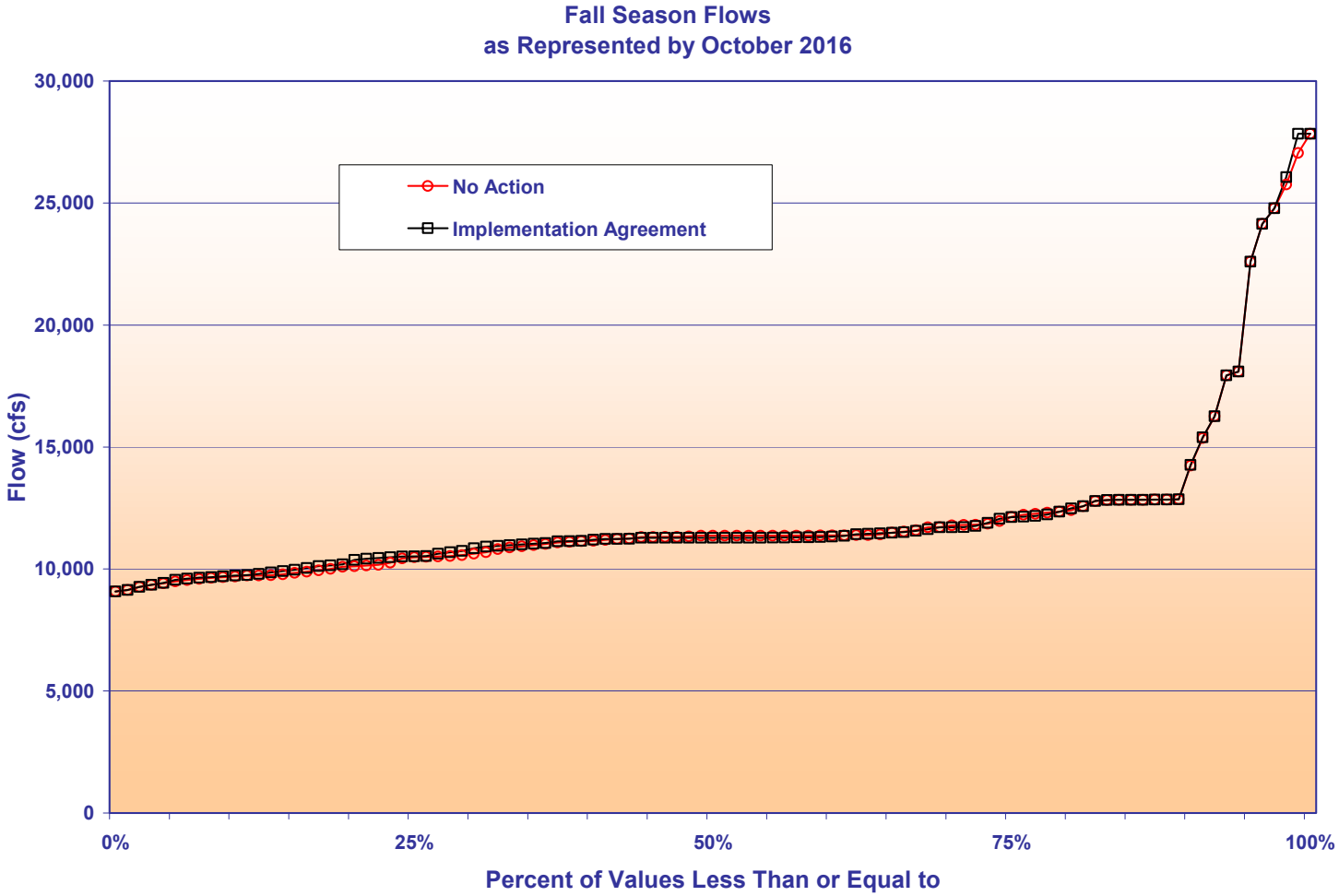


Figure 3.2-14d
Colorado River Seasonal Flows Downstream of Havasu NWR
Comparison of Implementation Agreement to No Action Conditions for Modeled Year 2016



3.2.4.2 RIVER FLOWS BETWEEN PARKER DAM AND PALO VERDE DIVERSION DAM

The point on the Colorado used to evaluate the river flows in the reach of the river located between Parker Dam and the Palo Verde Diversion Dam is located immediately upstream of the Colorado River Indian Reservation (CRIR) diversion. The CRIR diversion is located at Headgate Rock Dam, approximately 14 miles below Parker Dam. Flows in this reach of the river result from primarily from releases from Parker Dam (Lake Havasu).

Future flows in this reach would be affected by the Implementation Agreement because the proposed water transfers and exchanges between the California agricultural water agencies and MWD would change the point of diversion from the river. For example, under a potential transfer between IID and MWD (or SDCWA), the water that would normally be diverted at Imperial Dam would now be diverted above Parker Dam.

The 90th, 50th, and 10th percentile annual flow volumes for this reach are shown in Figure 3.2-15. As shown by the 50th percentile values, the modeled annual flow volumes in this reach under the Implementation Agreement decline gradually between 2002 and 2016, as the water transfers take effect and certain amounts of California's water are diverted from Lake Havasu rather than at Imperial Dam. After 2016 the annual flow reduction continues. At the 10th percentile level, the same comparative annual flow patterns occur. Flows at the 90th percentile level are dominated by surplus water deliveries and flood flows, and do not exhibit a significant difference between the Implementation Agreement and No Action conditions.

Figure 3.2-16, shows the cumulative distribution of annual flow volumes is for year 2016.

A numerical comparison of the 70th percentile seasonal flow values is shown on Table 3.2-11. The values representing the seasons are the mean monthly flows in January, April, July and October.

Table 3.2-11
Comparison of Mean Monthly Flow (cfs) – No Action Conditions and Implementation Agreement
Colorado River Upstream of CRIR Diversion (River Mile = 180.8)
70th Percentile Values for Year 2016

Season (Representative Month)	Mean Monthly Flows (cfs) for Year 2016 at the 70th Percentile	
	No Action	Implementation Agreement
Winter (January)	4,087	3,819
Spring (April)	12,009	11,315
Summer (July)	13,282	12,604
Fall (October)	8,120	7,838

Figures 3.2-17 (a-d) present comparisons of the representative seasonal flows under No Action conditions and the Implementation Agreement for 2016. As expected, the largest flows occur in the spring and summer seasons under the No Action and

Implementation Agreement conditions due to downstream irrigation demands. As on the 90th, 50th, and 10th percentile plots, the seasonal flows under the Implementation Agreement are slightly lower than those under No Action conditions. For flows that are due primarily to flood control releases from Lake Mead (flows in the 90th - 100th percentile range), the range of mean monthly flows is not affected by the Implementation Agreement, since these magnitudes are dictated by the flood control regulations.

Figure 3.2-15
Colorado River Upstream of CRIR Diversion Annual Flow Volume (af)
Comparison of Implementation Agreement to No Action Conditions
90th, 50th and 10th Percentile Values

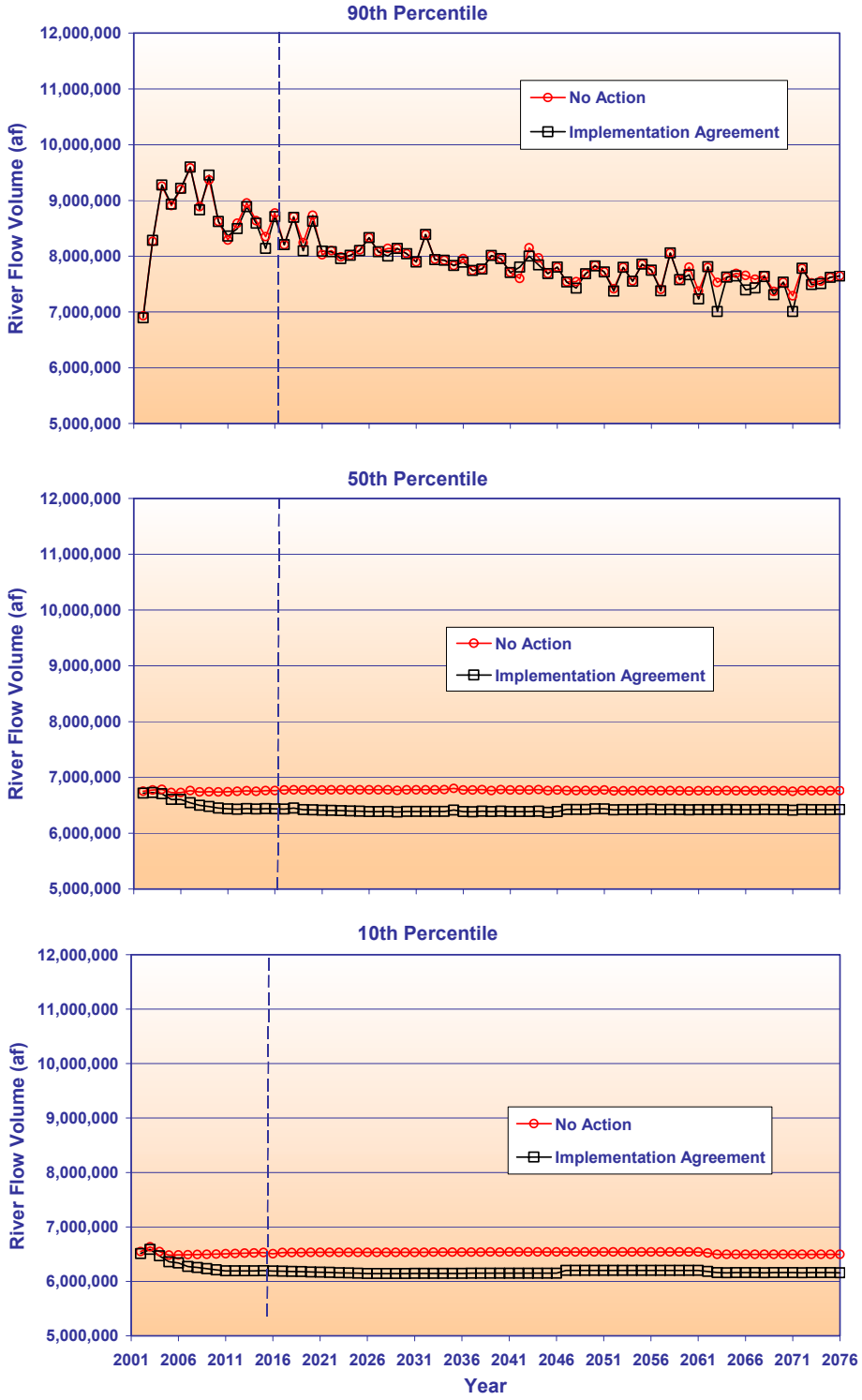


Figure 3.2-16
Colorado River Annual Flow Volumes Upstream of Colorado River Indian Reservation
Comparison of Implementation Agreement to No Action Conditions for Modeled Year 2016

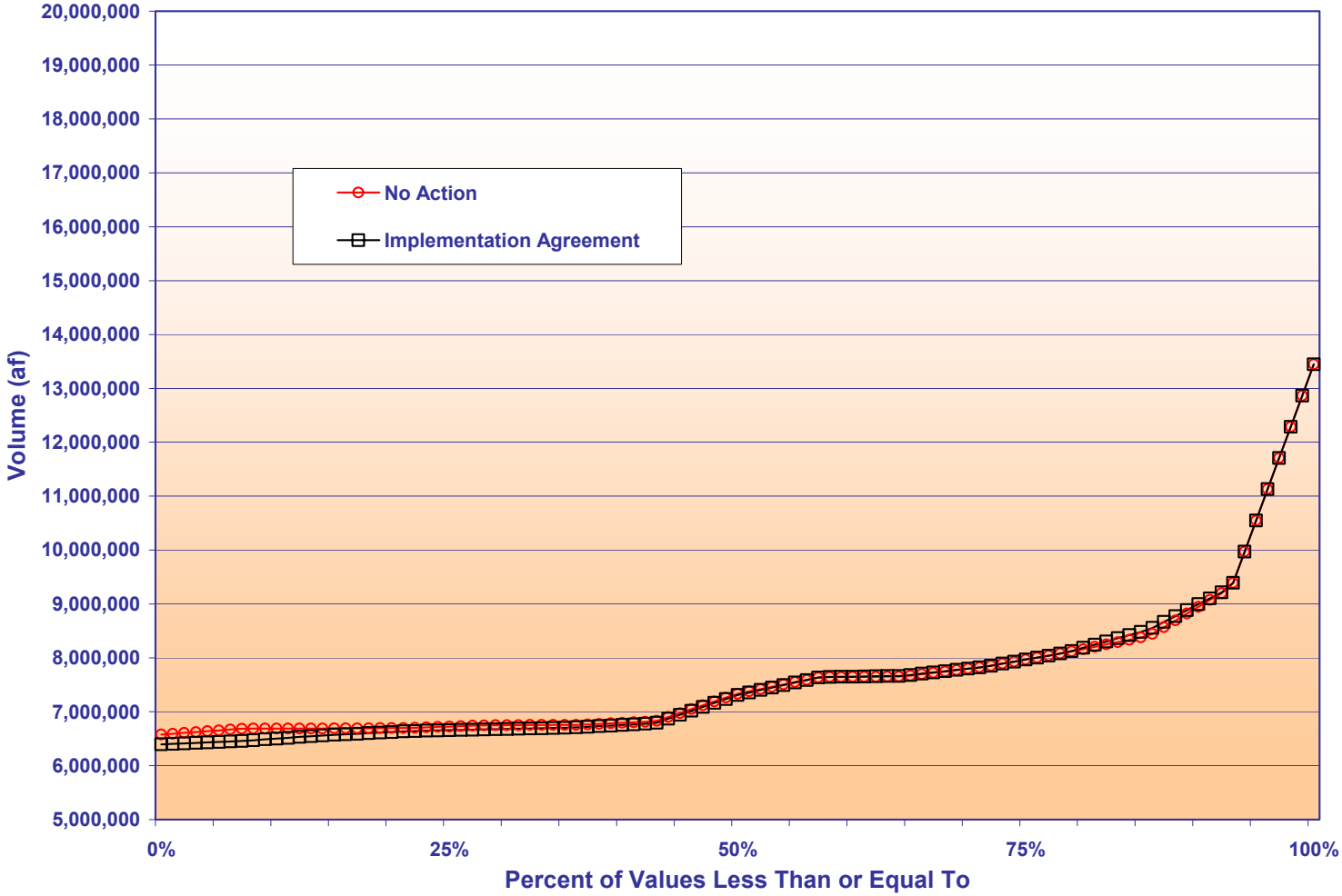


Figure 3.2-17a
Colorado River Seasonal Flows Upstream of Colorado River Indian Reservation
Comparison of Implementation Agreement to No Action Conditions for Modeled Year 2016

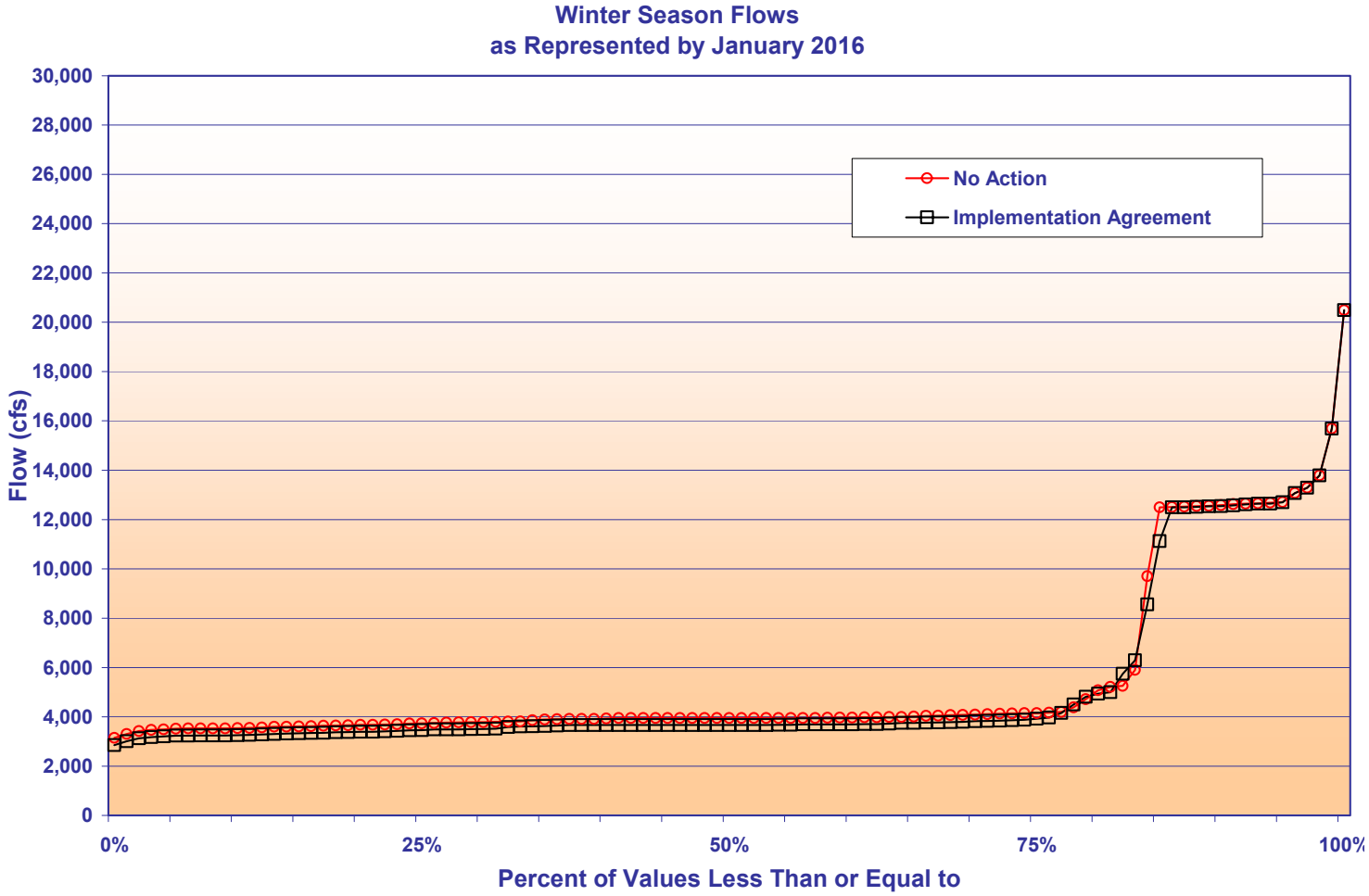


Figure 3.2-17b
Colorado River Seasonal Flows Upstream of Colorado River Indian Reservation
Comparison of Implementation Agreement to No Action Conditions for Modeled Year 2016

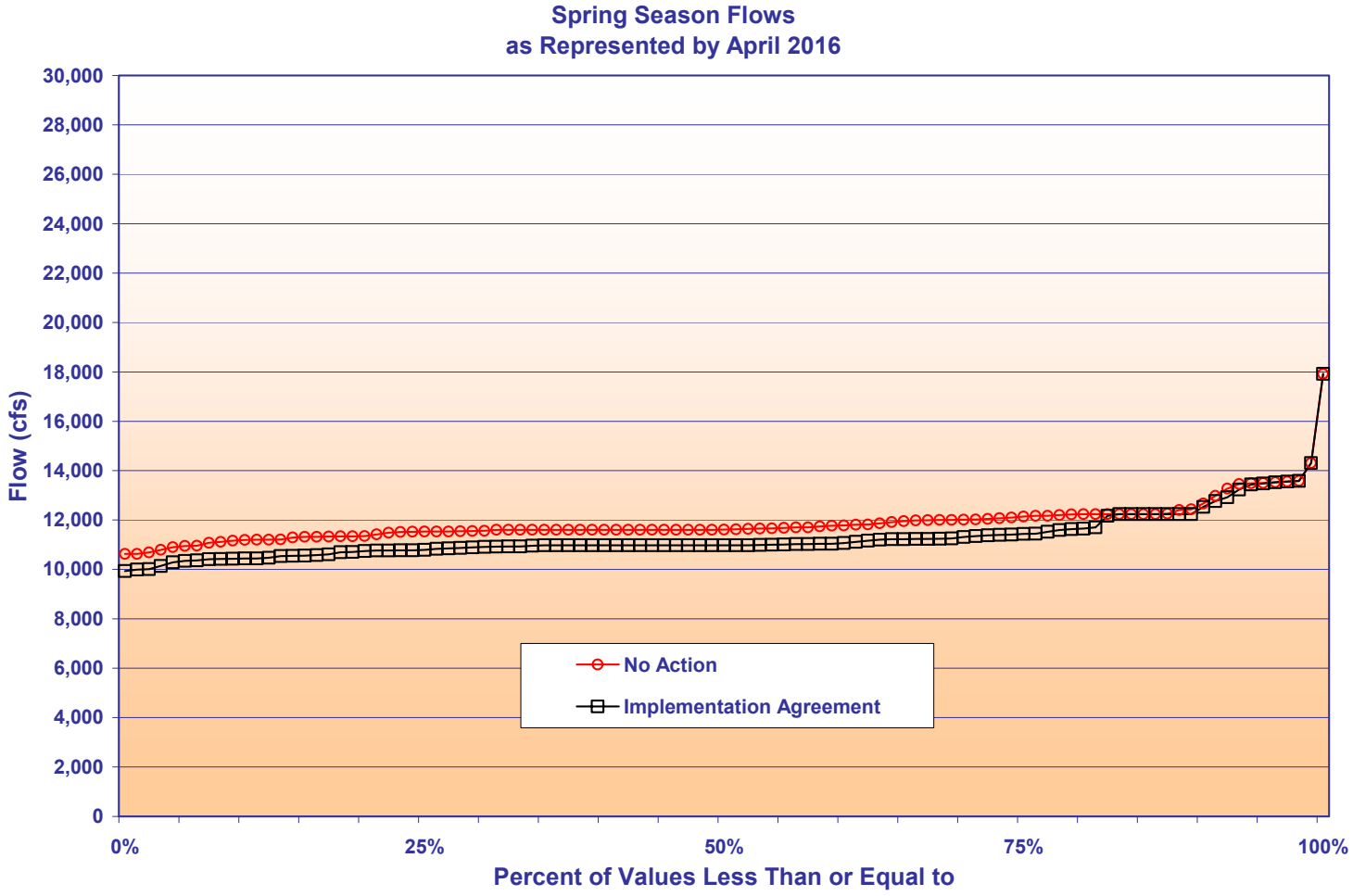


Figure 3.2-17c
Colorado River Seasonal Flows Upstream of Colorado River Indian Reservation
Comparison of Implementation Agreement to No Action Conditions for Modeled Year 2016

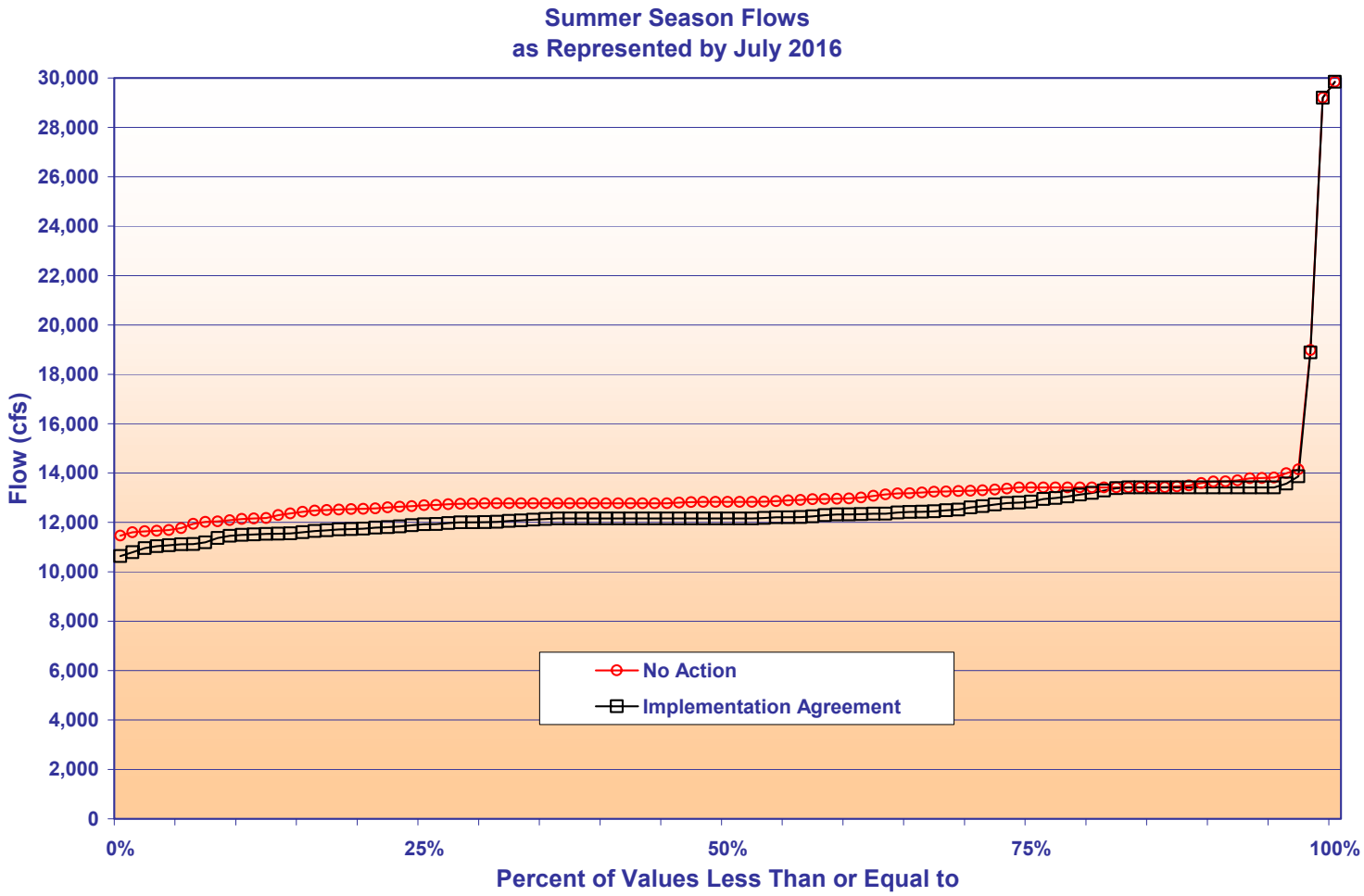
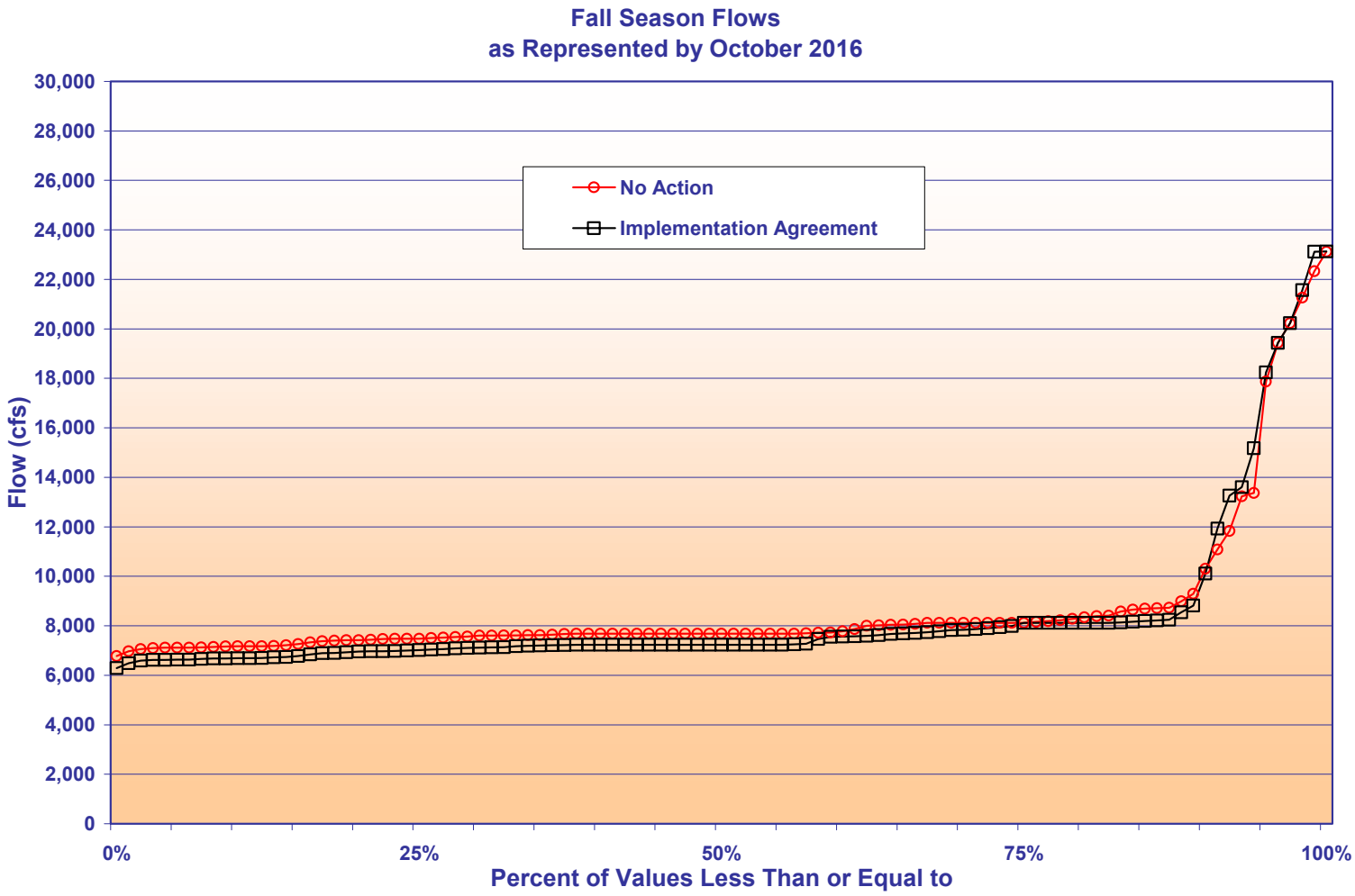


Figure 3.2-17d
Colorado River Seasonal Flows Upstream of Colorado River Indian Reservation
Comparison of Implementation Agreement to No Action Conditions for Modeled Year 2016



3.2.4.3 RIVER FLOWS BETWEEN PALO VERDE DIVERSION DAM AND IMPERIAL DAM

The flow of the Colorado River between Palo Verde Diversion Dam and Imperial Dam is normally set at the amount needed to meet the United States diversion requirements downstream of the Palo Verde Diversion plus deliveries to Mexico. The river location that was modeled for this reach of the river is located immediately downstream of the Palo Verde Diversion Dam.

Future flows in this reach would be affected by the Implementation Agreement because the proposed water transfers and exchanges between the California agricultural water agencies and MWD would change the point of diversion from the river. For example, under a potential transfer between IID and MWD (or SDCWA), the water that would normally be diverted at Imperial Dam would now be diverted above Parker Dam.

The 90th, 50th, and 10th percentile annual flow volumes for this reach are shown in Figure 3.2-18. As shown by the 50th percentile values, the modeled annual flow volumes in this reach under the Implementation Agreement decline gradually between 2002 and 2016, as the water transfers take effect and certain amounts of California's water are diverted from Lake Havasu rather than at Imperial Dam. After 2016 the annual flow reduction continues. At the 10th percentile level, the same comparative annual flow patterns occur. Flows at the 90th percentile level are dominated by surplus water deliveries and flood flows, and do not exhibit a significant difference between the Implementation Agreement and No Action conditions.

Figure 3.2-19, shows the cumulative distribution of annual flow volumes for year 2016.

Figures 3.2-20 (a-d) present comparisons of the representative seasonal flows under No Action conditions and the Implementation Agreement for 2016. As expected, the largest flows occur in the spring and summer seasons under the No Action and Implementation Agreement conditions due to downstream irrigation demands. As on the 90th, 50th, and 10th percentile plots, the seasonal flows under the Implementation Agreement are slightly lower than those under No Action conditions. For flows that are due primarily to flood control releases from Lake Mead (flows in the 85th - 100th percentile range), the range of mean monthly flows is not affected by the Implementation Agreement, since these magnitudes are dictated by the flood control regulations. In the lower percentiles, the seasonal flows with the Implementation Agreement are slightly lower than the flows under No Action conditions (from six to 11 percent lower in various seasons in 2016).

A numerical comparison of the 70th percentile seasonal flow values is shown on Table 3.2-12. The values representing the seasons are the mean monthly flows in January, April, July and October.

Table 3.2-12
Comparison of Mean Monthly Flow (cfs) – No Action Conditions and Implementation Agreement
Colorado River Downstream of Palo Verde Diversion Dam (River Mile = 133.8)
70th Percentile Values for Year 2016

Season (Representative Month)	Mean Monthly Flows (cfs) for Year 2016 at the 70th Percentile	
	No Action	Implementation Agreement
Winter (January)	3,695	3,420
Spring (April)	10,202	9,633
Summer (July)	11,008	10,458
Fall (October)	7,444	7,003

Figure 3.2-18
Colorado River Downstream Palo Verde Diversion Dam Annual Flow Volume (af)
Comparison of Implementation Agreement to No Action Conditions
90th, 50th and 10th Percentile Values

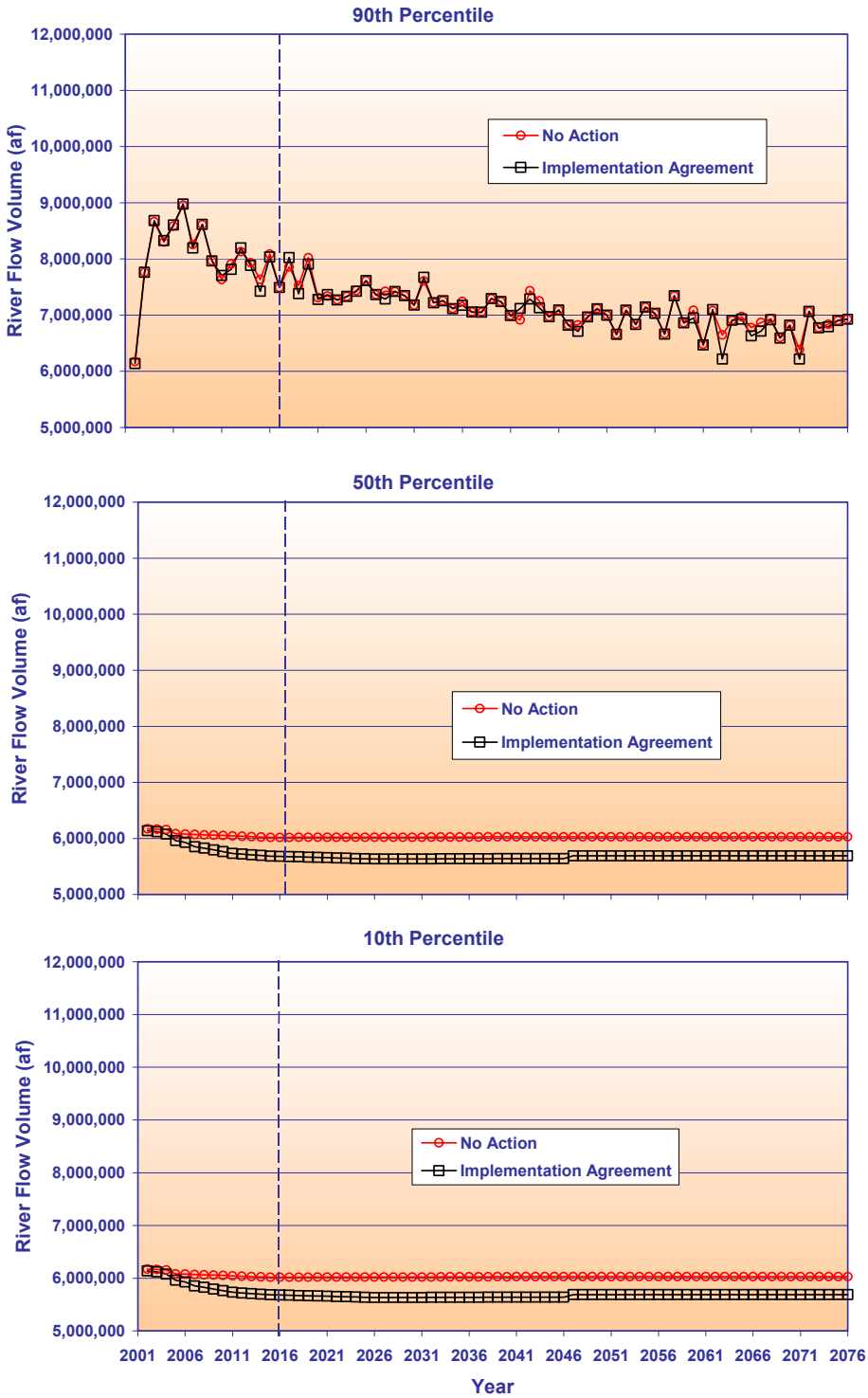


Figure 3.2-19
Colorado River Annual Flow Volumes Downstream of Palo Verde Irrigation Diversion
Comparison of Implementation Agreement to No Action Conditions for Modeled Year 2016

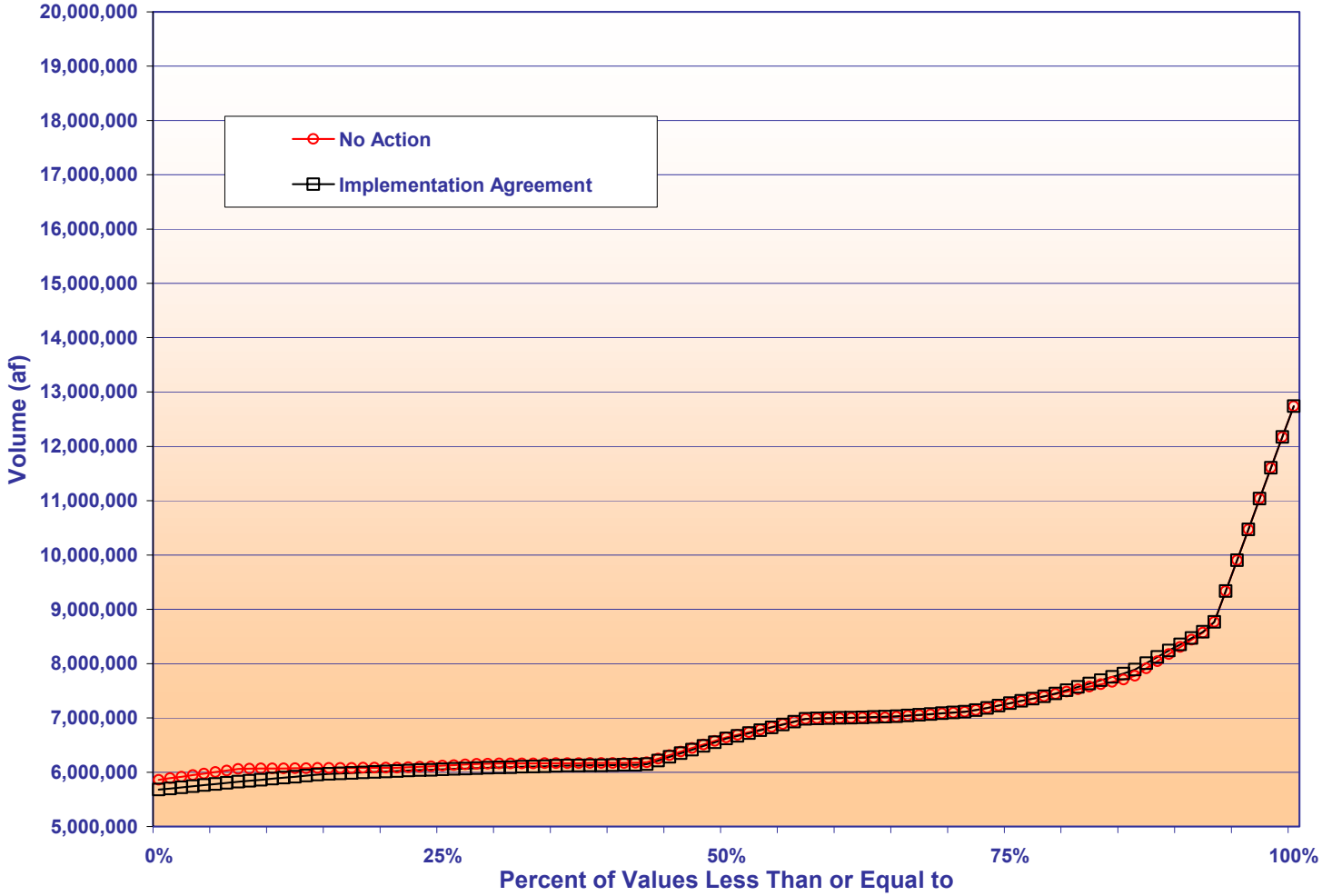


Figure 3.2-20a
Colorado River Seasonal Flows Downstream of Palo Verde Diversion Division
Comparison of Implementation Agreement to No Action Conditions for Modeled Year 2016

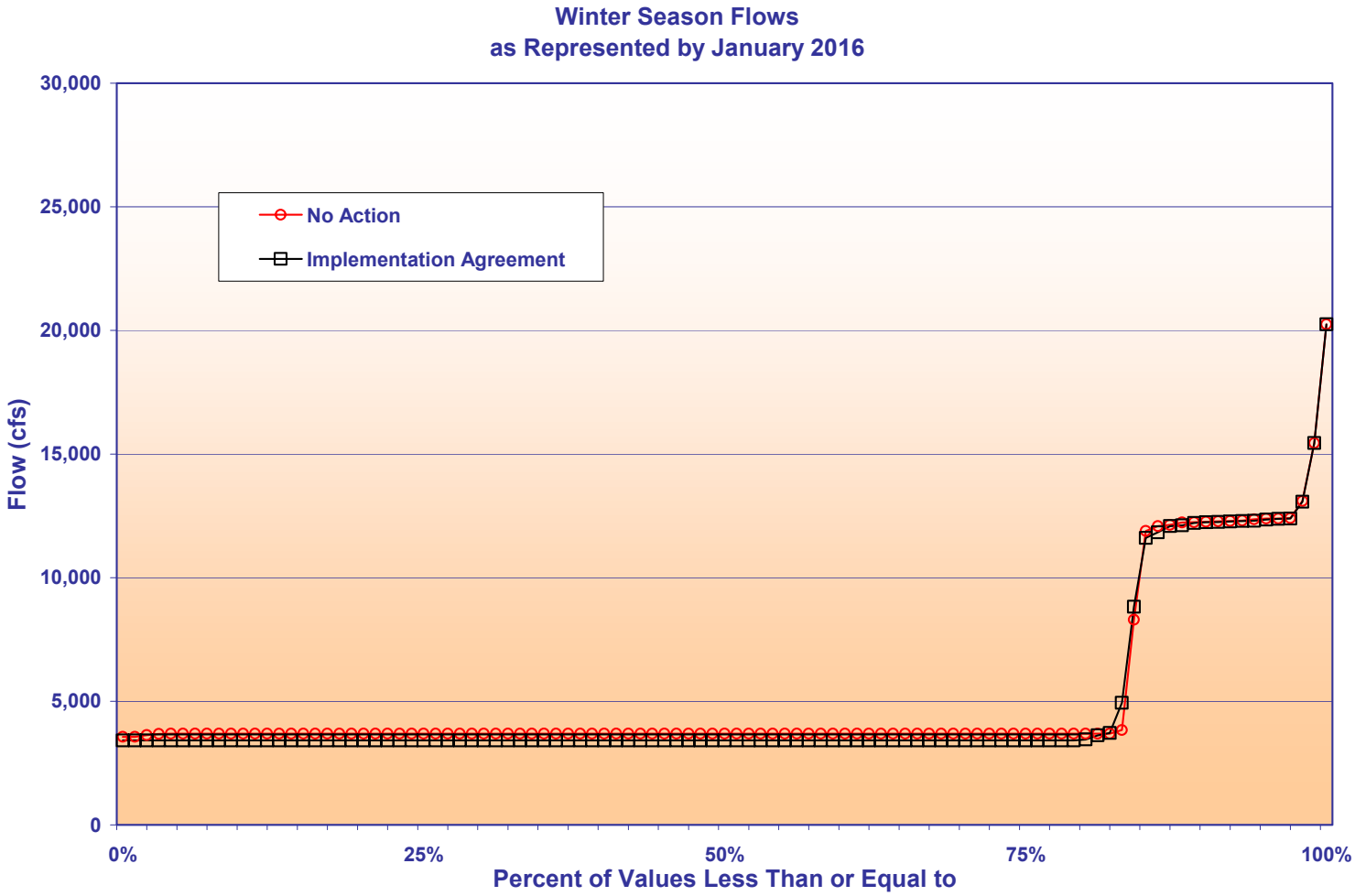


Figure 3.2-20b
Colorado River Seasonal Flows Downstream of Palo Verde Diversion Division
Comparison of Implementation Agreement to No Action Conditions for Modeled Year 2016

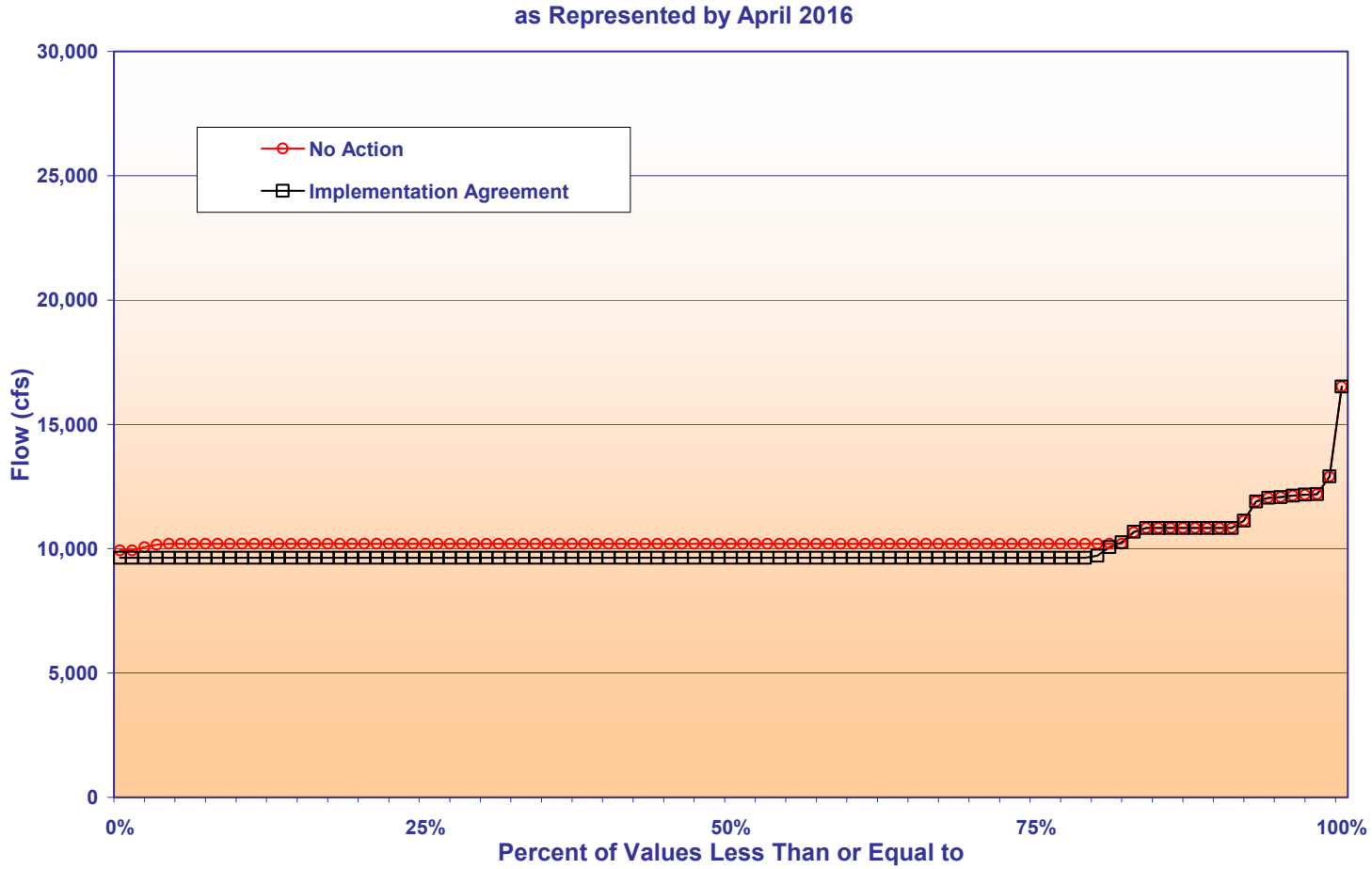


Figure 3.2-20c
Colorado River Seasonal Flows Downstream of Palo Verde Diversion Division
Comparison of Implementation Agreement to No Action Conditions for Modeled Year 2016

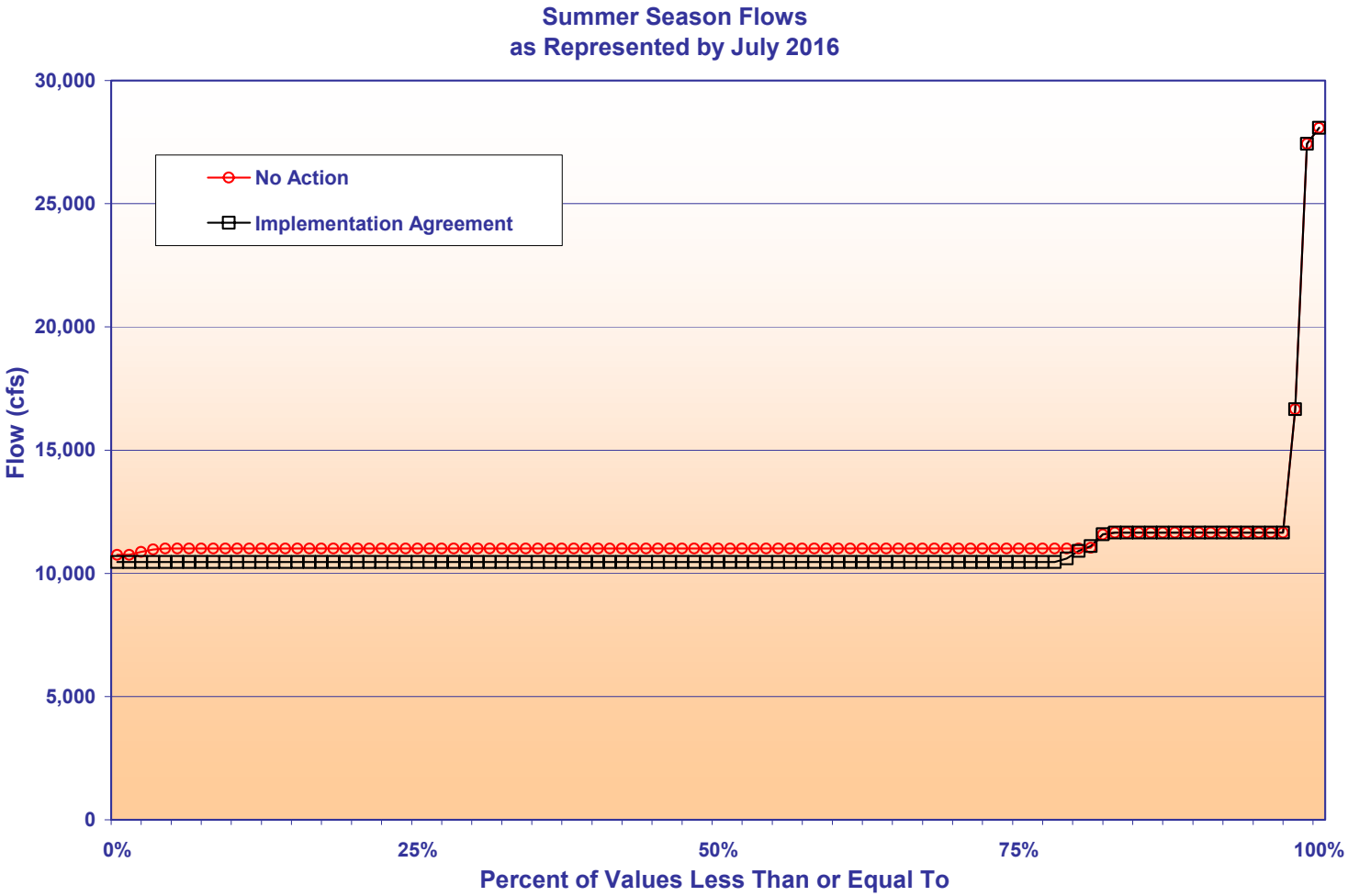
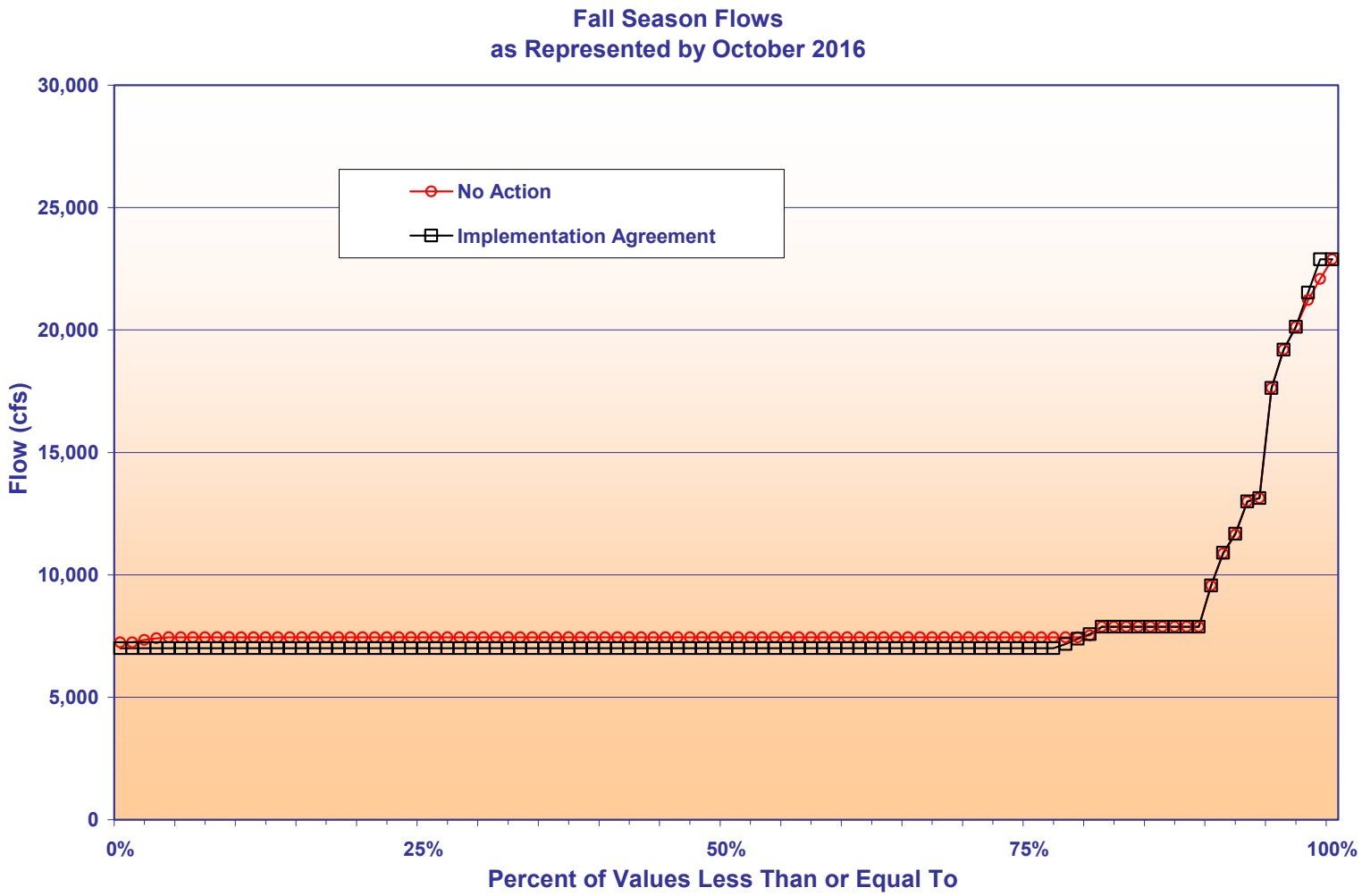


Figure 3.2-20d
Colorado River Seasonal Flows Downstream of Palo Verde Diversion Division
Comparison of Implementation Agreement to No Action Conditions for Modeled Year 2016



3.2.4.4 RIVER FLOWS BETWEEN IMPERIAL DAM AND MORELOS DAM

The flows in the Colorado River below Imperial Dam are primarily comprised of the water delivered to Mexico in accordance with the US-Mexico Water Treaty of 1944. Mexico's principal diversion is at Morelos Dam, which is located, approximately nine miles southwest of Yuma, Arizona. Mexico owns, operates, and maintains Morelos Dam.

The reach of river between Morelos Dam and the SIB is commonly referred to by Reclamation as the Limitrophe Division. Reclamation's authority in this division is limited to maintaining the bankline road, the levee, various drains to the river, and the U.S. Bypass drain that carries agricultural drainage water to the Cienega de Santa Clara in Mexico. Under International Treaty the United States Section of the IBWC is obligated to maintain the river channel within this division. Reclamation provides assistance to the IBWC, when requested, for maintenance needs in this reach of the river.

Minute 242 of the Mexican Water Treaty of 1944 provide requirements for deliveries at the NIB and SIB near Yuma and San Luis, Arizona, respectively (Note: Minutes are defined as decisions of IBWC and signed by the Mexican and United States commissioners of IBWC). Up to 140,000 af annually of agricultural drainage water can be delivered to Mexico at the SIB. The remaining 1,360,000 af of water is to be delivered to Mexico at the NIB annually and diverted at Morelos Dam for use in Mexico. For several years after the United States Bypass Drain was completed in 1978, the Colorado River Channel downstream of Morelos Dam was normally dry. Flows below Morelos Dam now occur only when water in excess of Mexico's requirement arrives at the NIB.

Much of the NIB water is diverted at Imperial Dam into the All-American Canal (AAC) where it is returned to the bed of the Colorado River through Siphon Drop and Pilot Knob Powerplants. A portion of the NIB deliveries remains in the river, passing through Imperial and Laguna Dams to Morelos Dam.

Water in excess of Mexico's water order at the NIB is normally passed through Morelos Dam, through the Limitrophe Division, and into the original Colorado River channel downstream. Water in excess of Mexico's water order occurs primarily when flood releases are made from Lake Mead. Excess water arriving at the NIB may also result from flooding on the Gila River, and from operational activities upstream (i.e., cancelled water orders in the United States, maintenance activities, etc.).

In December of each year, Mexico provides to the United States an advance monthly water order for the following calendar year. Normally, this water order can only be changed by providing the United States with written notice, 30 days in advance and each monthly water order can be increased or decreased by no more than 20 percent of the original monthly water order. The Treaty further stipulates that Mexico's total water

order must be no less than 900 cfs and no more than 5500 cfs during the months of January, February, October, November and December. During the remainder of the year, Mexico's water order must be no less than 1500 cfs and no more than 5500 cfs. Daily water orders are usually not allowed to increase or decrease by more than 500 cfs.

As discussed in Section 2.3, the model accounts for all the deliveries to Mexico through diversions at the NIB (Morelos Dam). Flows that are modeled downstream of Morelos Dam represent mean monthly flows that are excess flows in the Colorado River due to Lake Mead flood control releases. These excess flows may reach the Colorado River Delta, although Mexico has the authority to divert them for other uses. Such decisions by Mexico are not modeled, as they are not known. The excess flows are over and above Mexico's normal 1.5 mafy water entitlement, plus the 200,000 afy for surplus deliveries.

The 90th, 50th, and 10th percentile annual flow volumes for this reach are shown in Figure 3.2-21. These flows are dependent solely upon infrequent flood control releases, hence no flows are observed at either the 10th or 50th percentiles. At the 90th percentile level, the Implementation Agreement scenario produces annual flow volumes slightly above and below the No Action values to 2016, and annual flow volumes equal to or slightly above No Action flows after 2016.

Figure 3.2-22 shows the cumulative distribution of annual flow volumes for year 2016.

Figures 3.2-23 (a-d) present comparisons of the representative seasonal flows under No Action conditions and the Implementation Agreement for 2016. As expected, the only differences seen for flows are due to flood control releases from Lake Mead (flows in the 80th – 100th percentile range). As seen in the figures, where the Implementation Agreement flows differ from the No Action flows, the Implementation Agreement flows are higher (up to approximately 40 percent higher between the 85th and 90th percentiles for January 2016).

A numerical comparison of the 90th percentile seasonal flow values is shown on Table 3.2-13. The values representing the seasons are the mean monthly flows in January, April, July and October.

Table 3.2-13
Comparison of Mean Monthly Flow Data – No Action Conditions and Implementation Agreement
Colorado River Downstream of Morelos Dam (River Mile = 23.1)
90th Percentile Values (cfs) for Year 2016

Season (Representative Month)	Mean Monthly Flows (cfs) for Year 2016 at the 90th Percentile	
	No Action	Implementation Agreement
Winter (January)	8,361	8,346
Spring (April)	0	0
Summer (July)	0	0
Fall (October)	1,679	1,679

Figure 3.2-21
Colorado River Below Mexico Diversion at Morelos Dam Annual Flow Volume (af)
Comparison of Implementation Agreement to No Action Conditions
90th, 50th and 10th Percentile Values

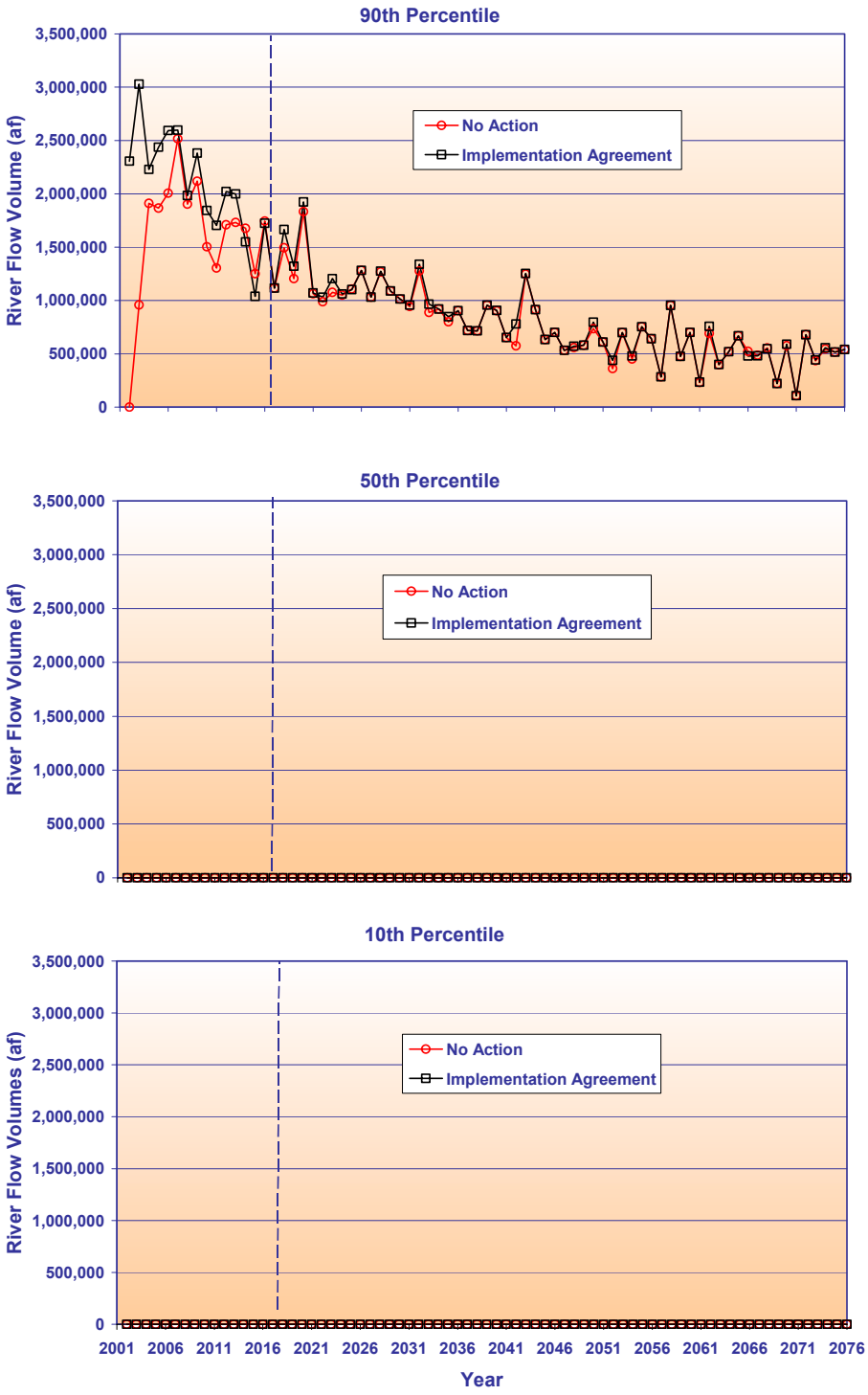


Figure 3.2-22
Colorado River Annual Flow Volumes Below Mexico Diversion at Morelos Dam
Comparison of Implementation Agreement to No Action Conditions for Modeled Year 2016

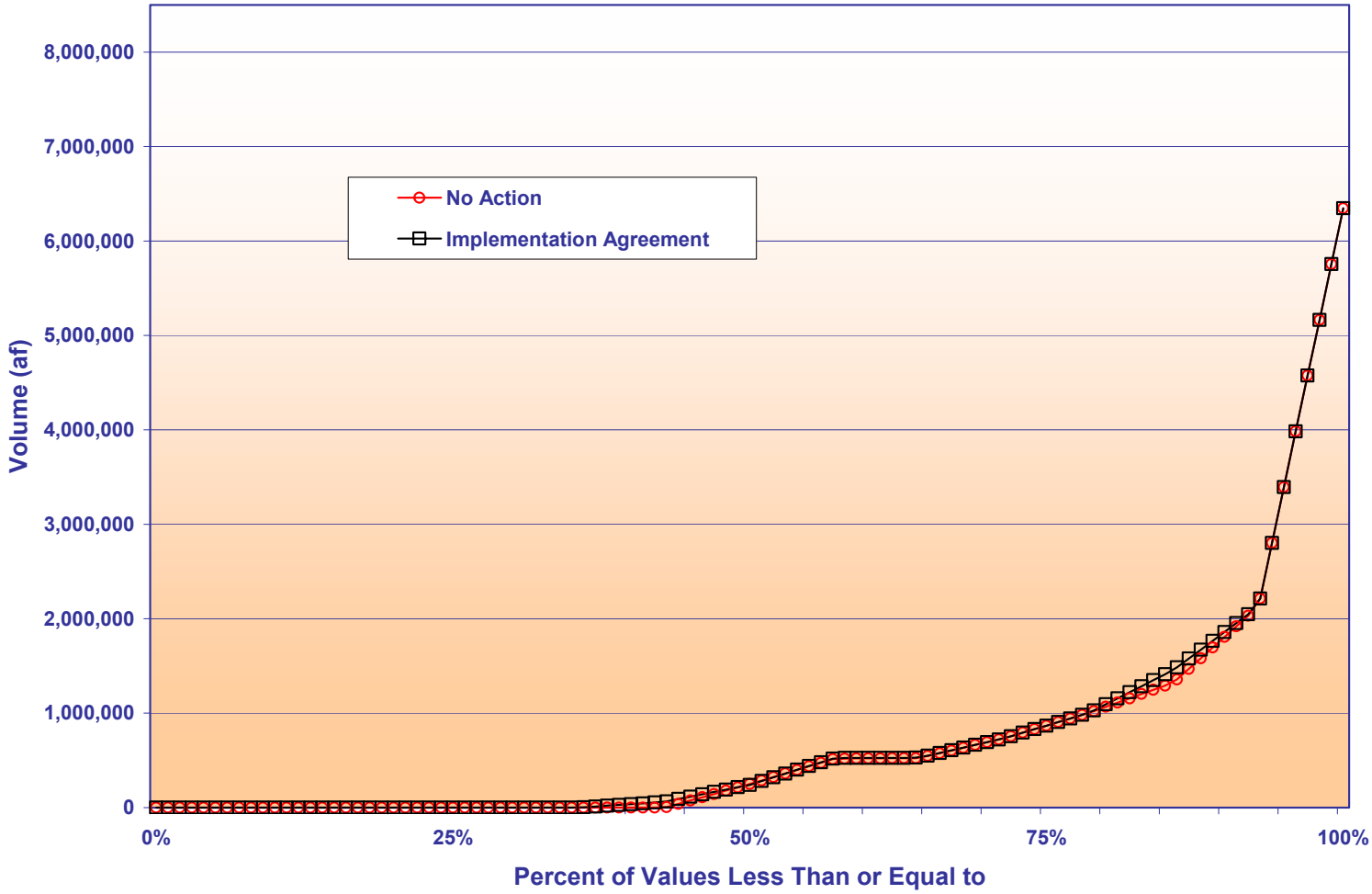


Figure 3.2-23a
Colorado River Seasonal Flows Below Mexico Diversion at Morelos Dam
Comparison of Implementation Agreement to No Action Conditions for Modeled Year 2016

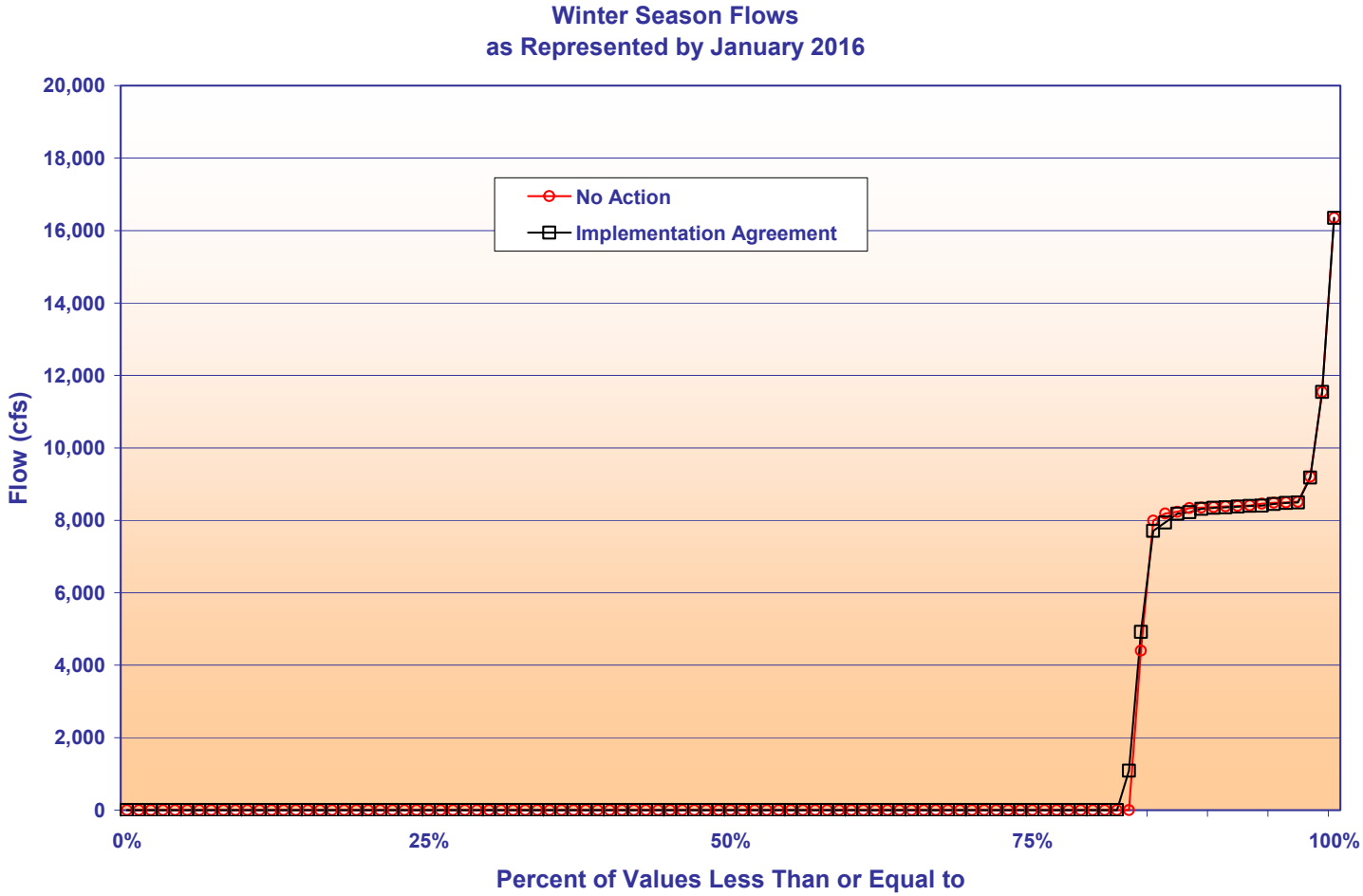


Figure 3.2-23b
Colorado River Seasonal Flows Below Mexico Diversion at Morelos Dam
Comparison of Implementation Agreement to No Action Conditions for Modeled Year 2016

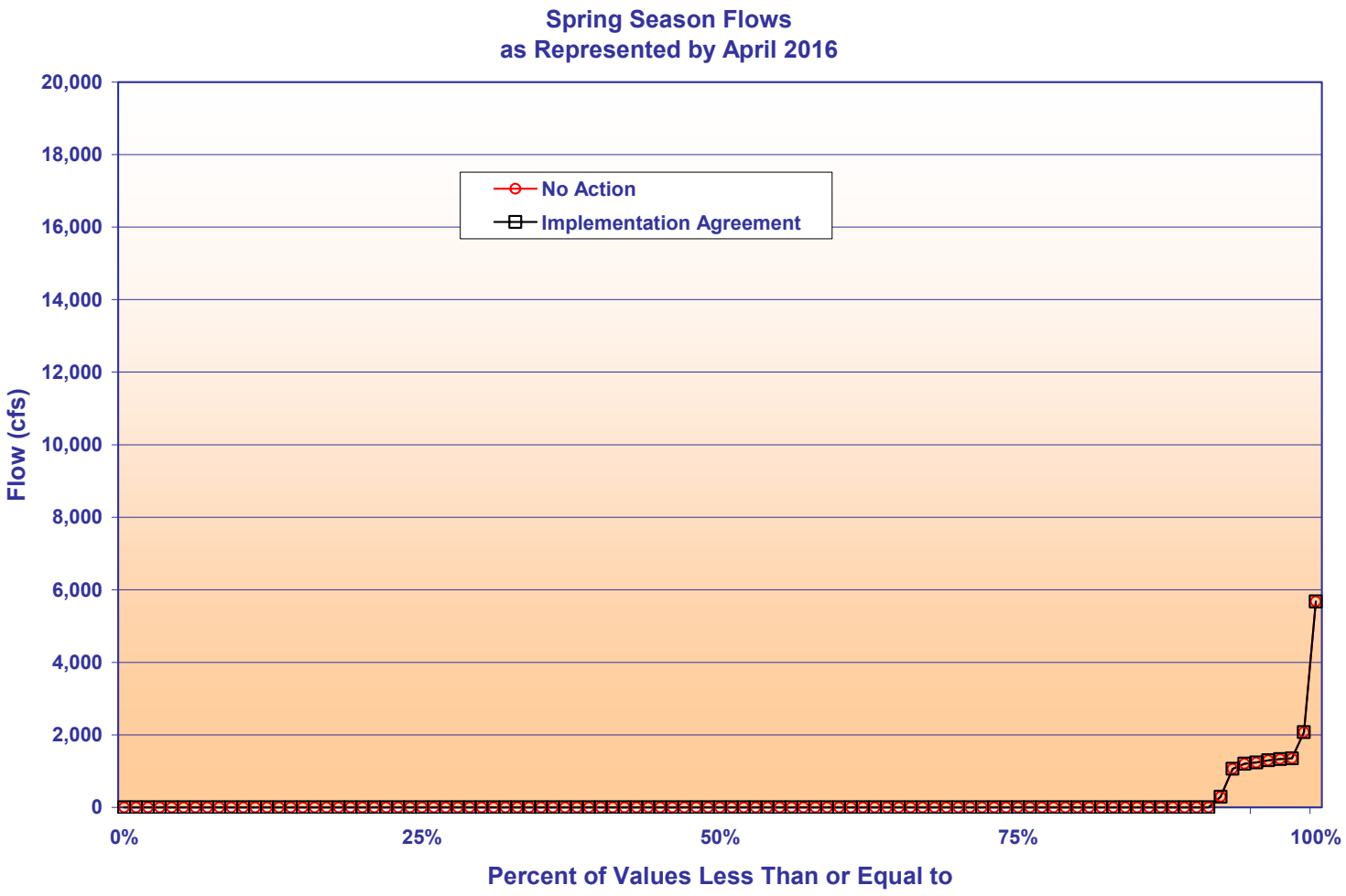


Figure 3.2-23c
Colorado River Seasonal Flows Below Mexico Diversion at Morelos Dam
Comparison of Implementation Agreement to No Action Conditions for Modeled Year 2016

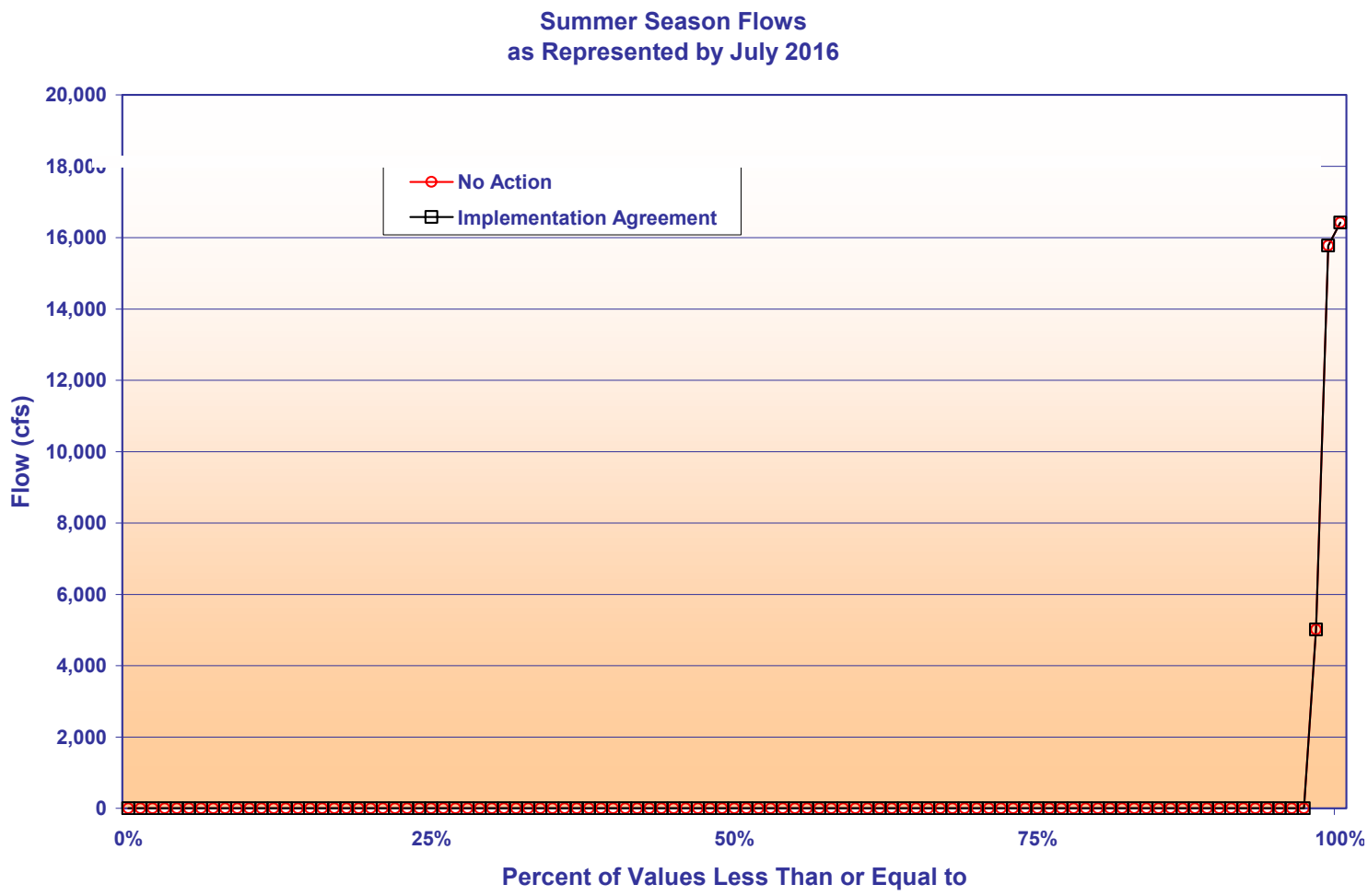
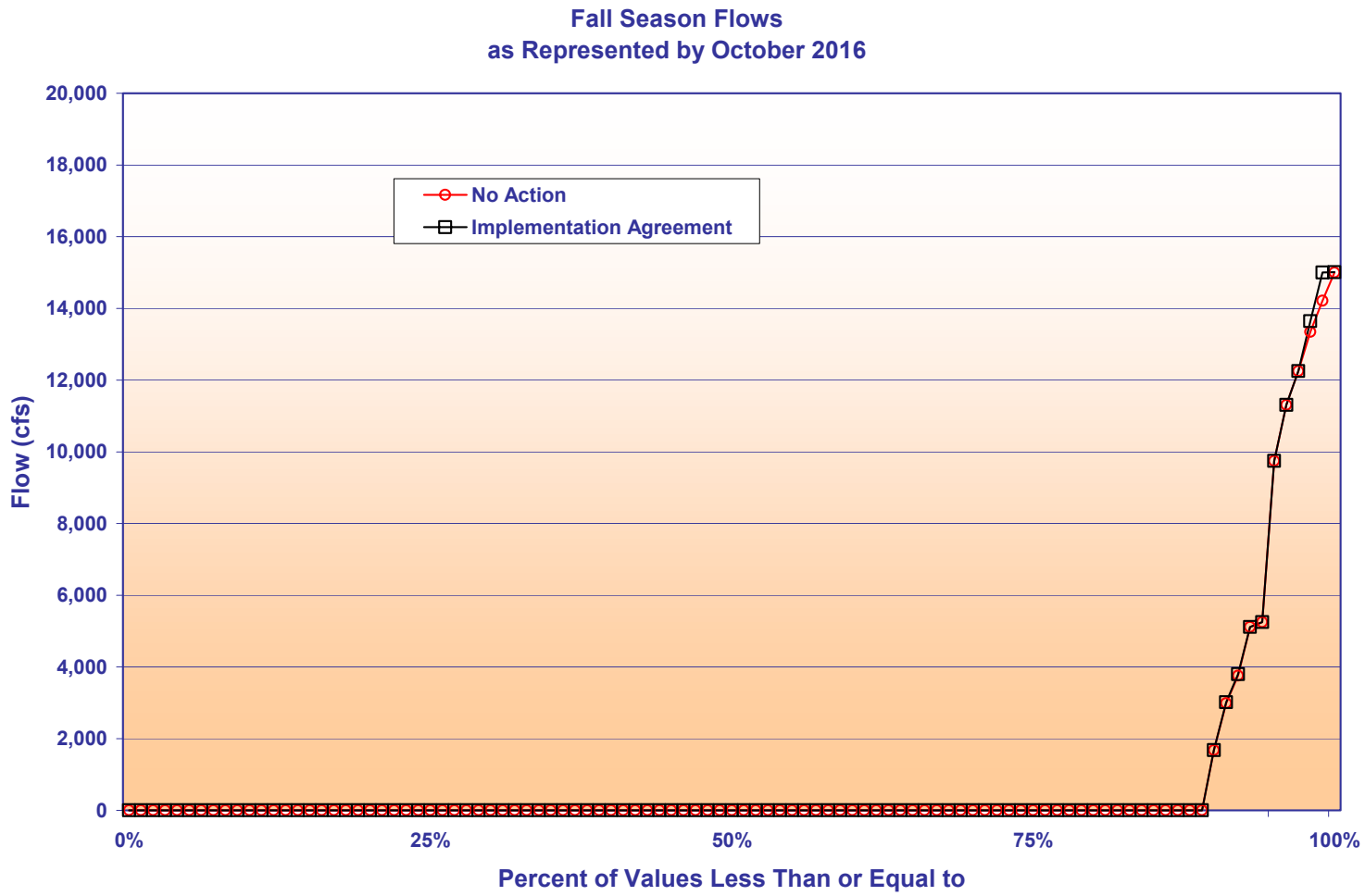


Figure 3.2-23d
Colorado River Seasonal Flows Below Mexico Diversion at Morelos Dam
Comparison of Implementation Agreement to No Action Conditions for Modeled Year 2016



3.3 ANALYSIS OF CUMULATIVE EFFECTS

This section describes the results of the analysis that evaluates the potential cumulative impacts to the levels of Lakes Powell and Mead and riverflows resulting from the proposed implementation of all the water management programs contemplated under this Technical Memorandum**.** The modeled operational scenarios that are used to evaluate the cumulative effects of the various water management programs in this section consist of the Baseline for the Cumulative Analysis (Baseline Conditions) and the Cumulative Analysis Conditions, which are defined in Section 2.2. The period of analysis is 75 years.

3.3.1 LAKE POWELL WATER LEVELS

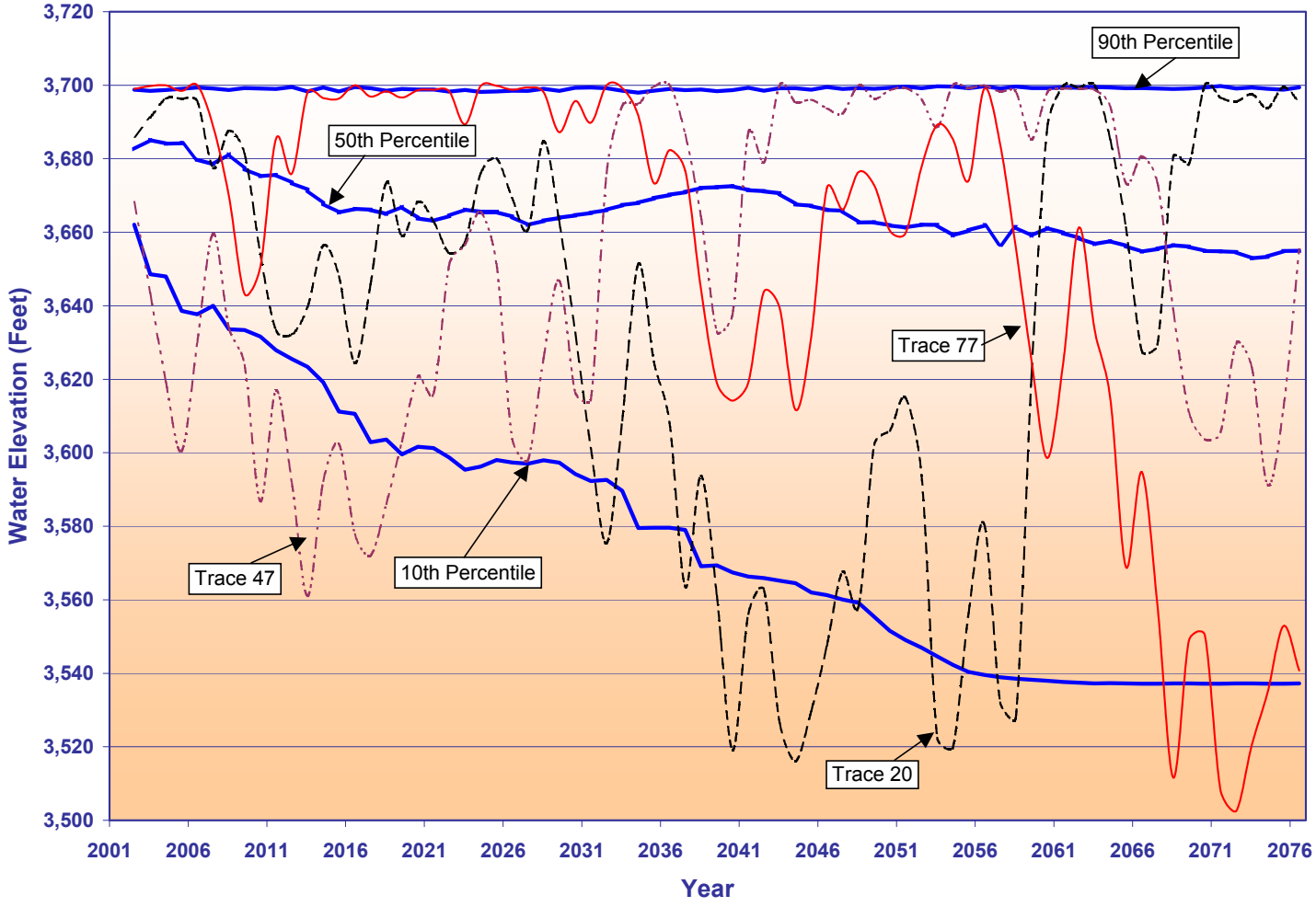
3.3.1.1 MODELING RESULTS OF BASELINE FOR CUMULATIVE ANALYSIS

Under the Baseline for Cumulative Analysis conditions, the water surface elevation of Lake Powell is projected to fluctuate between full level and decreasingly lower levels during the period of analysis (2002 to 2076). Figure 3.3-1 illustrates the range of water levels by three lines, labeled 90th Percentile, 50th Percentile and 10th Percentile. The 50th percentile line shows the median water level for each future year. The median water level under Baseline for Cumulative Analysis conditions is shown to decline to approximately 3666 feet msl by 2016 and remaining at this or slightly higher levels through 2076. The 10th percentile line shows there is a 10 percent probability that the water level would drop to 3611 feet msl by 2016 and to 3537 feet msl by 2076.

Generally, there is about a 20-foot difference between the annual high and low water levels at Lake Powell. It should also be noted that the Lake Powell elevations depicted in Figure 3.3-1 are for modeled lake water levels at the end of July, which influence recreation at the reservoir. The Lake Powell water level generally reaches its seasonal high in July whereas the seasonal low occurs at the end of the year.

Three distinct traces were added to Figure 3.3-1 to illustrate what was actually simulated under the various traces and respective hydrologic sequences and to highlight that the 90th, 50th and 10th percentile lines do not represent actual traces, but rather the ranking of the data from the 85 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 10th percentile line. The trace identified as Trace 20 represents the hydrologic sequence that begins in year 1926. The trace identified as Trace 47 represents the hydrologic sequence that begins in year 1953. The trace identified as Trace 77 represents the hydrologic sequence that begins in year 1983.

Figure 3.3-1
Lake Powell End-of-July Water Elevations Under Baseline for Cumulative Analysis
90th, 50th and 10th Percentile Values and Representative Traces



In Figure 3.3-1, the 90th and 10th percentile lines bracket the range where 80 percent of the water levels simulated for the Baseline for Cumulative Analysis conditions occur. 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 between the highs and the lows, 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 3.3-2 presents a comparison of the 90th, 50th and 10th percentile plots under Baseline for Cumulative Analysis conditions and those under the Cumulative Analysis Conditions. This figure is best used for comparing the relative differences in the general lake level trends that result from the simulation of Baseline for Cumulative Analysis and Cumulative Analysis Conditions.

Figure 3.3-3 shows the frequency that future Lake Powell end-of-July water elevations would exceed elevation 3695 feet msl under the Baseline for Cumulative Analysis and Cumulative Analysis conditions. When the Lake Powell water level is at or exceeds 3695 feet msl, the reservoir is considered to be essentially full. In year 2016, under Baseline for Cumulative Analysis conditions, the percentage of values greater than or equal to elevation 3695 feet msl is 21 percent. After 2016 the annual percentages of values equal to or greater than elevation 3695 feet msl increase gradually to 29 percent and then decrease to 24 percent in 2076 under Baseline for Cumulative Analysis conditions.

Figure 3.3-4 shows the frequency that future Lake Powell end-of-July water elevations under Baseline for Cumulative Analysis conditions and the Cumulative Analysis would be at or exceed a lake water elevation of 3612 feet msl. Lake Powell water surface elevation 3612 feet msl is used in this analysis as the low threshold elevation for marina and boat ramps at Lake Powell. This threshold elevation of 3612 feet msl is used to evaluate the Baseline for Cumulative Analysis conditions and the effects of the Cumulative Analysis on shoreline facilities at Lake Powell. The lines represent the percentage of values greater than or equal to the lake water elevation of 3612 feet msl under the Baseline for Cumulative Analysis conditions and the Cumulative Analysis. In year 2016, under the Baseline for Cumulative Analysis conditions, the percentage of values greater than or equal to elevation 3612 feet msl is 89 percent. Between 2016 and 2076, the annual percentages of values greater than or equal to elevation 3612 feet msl decrease gradually to 68 percent.

Figure 3.3-2
Lake Powell End-of-July Water Elevations
Comparison of Cumulative Analysis to Baseline for Cumulative Analysis Conditions
90th, 50th and 10th Percentile Values

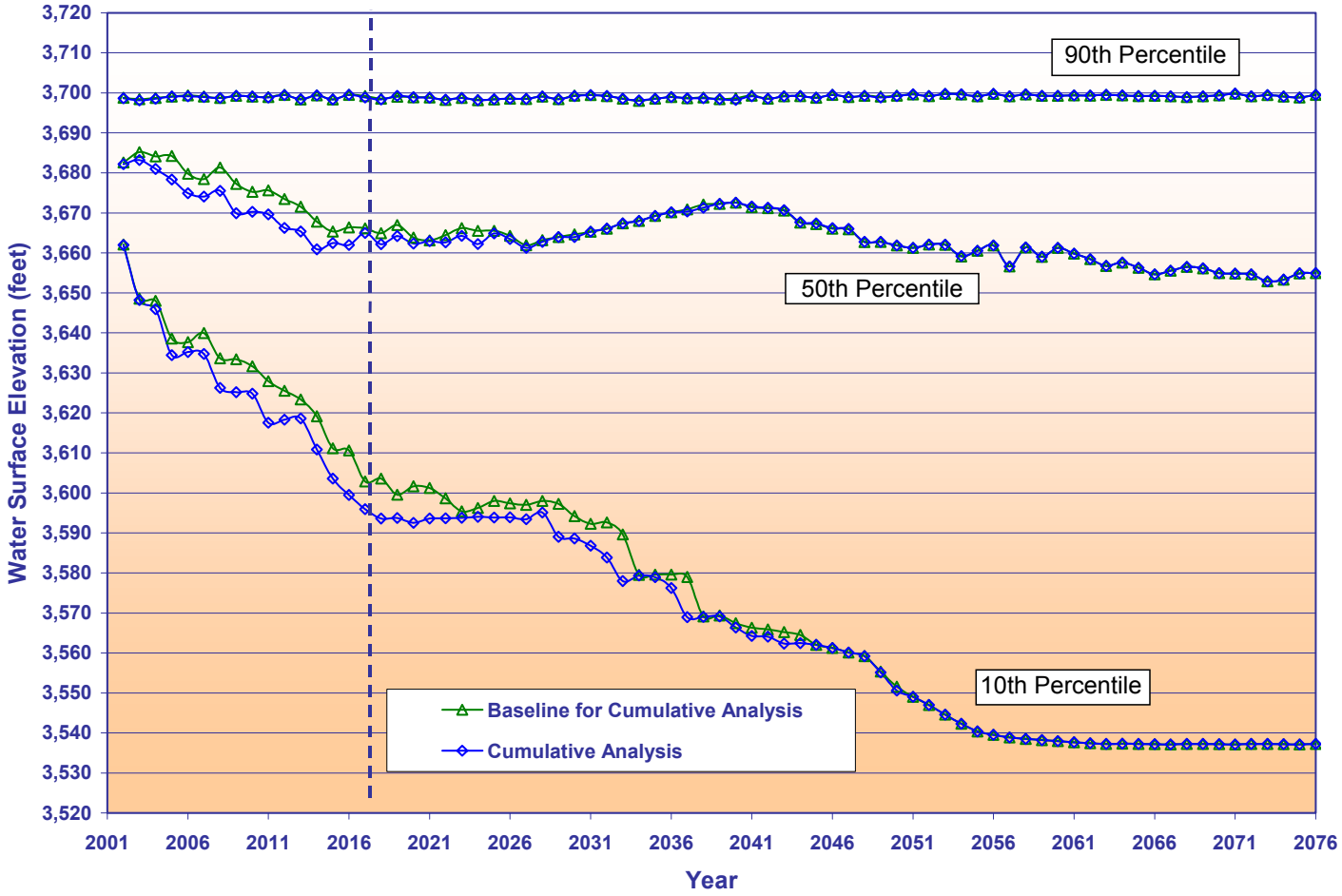
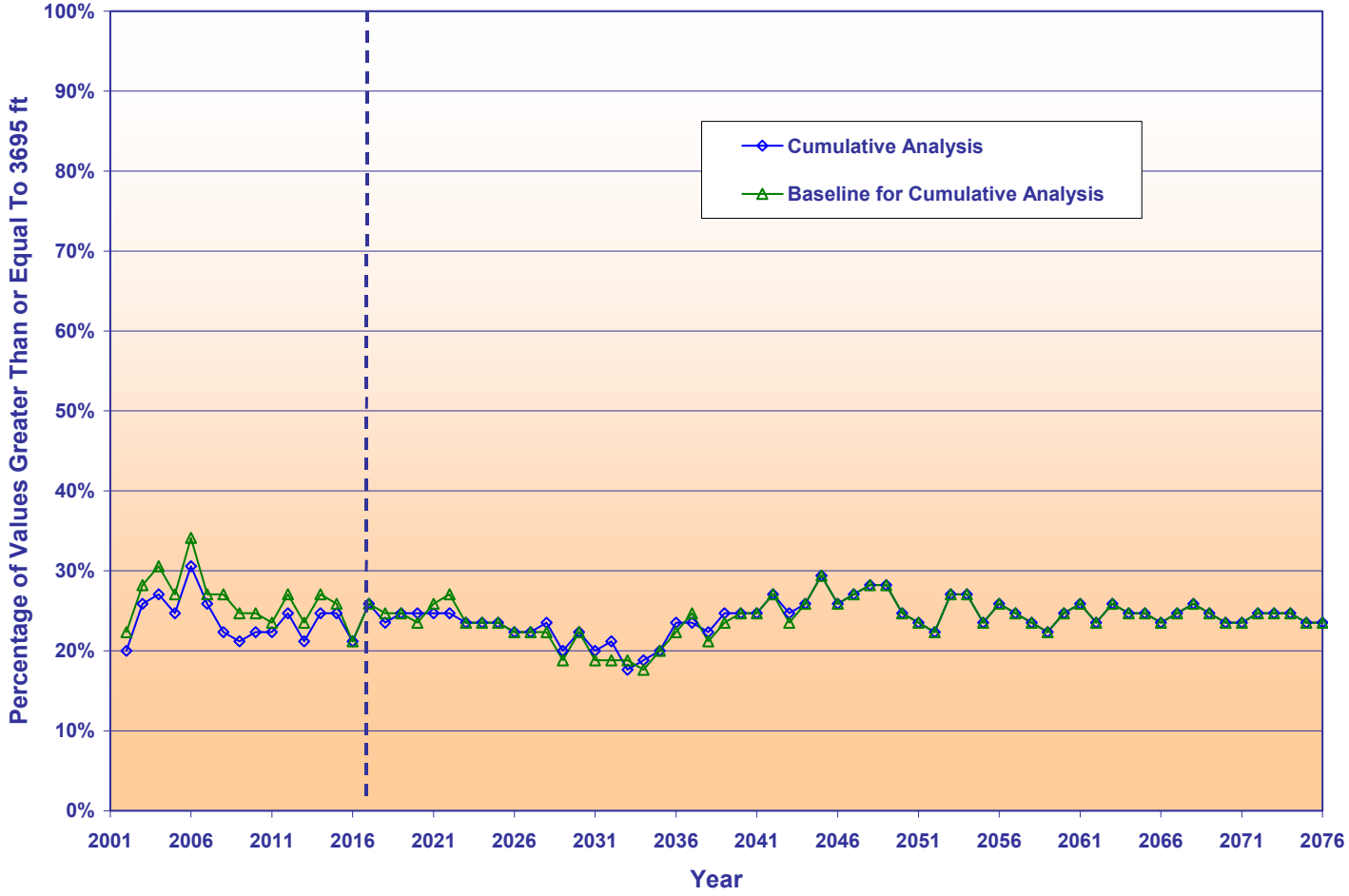


Figure 3.3-3
Lake Powell End-of-July Water Elevations
Comparison of Cumulative Analysis to Baseline for Cumulative Analysis Conditions
Percentage of Values Greater than or Equal to Elevation 3695 Feet



3.3.1.2 COMPARISON OF CUMULATIVE ANALYSIS TO BASELINE FOR CUMULATIVE ANALYSIS CONDITIONS

Figure 3.3-2 compared the 90th, 50th and 10th percentile water levels under the Cumulative Analysis to those under Baseline for Cumulative Analysis conditions. The median (50th percentile) water level of Lake Powell would be lower during and immediately after the interim surplus period but after several decades water levels would be the same as those under baseline conditions. These changes are primarily the result of the interim surplus guidelines on the river system [Ref. ISC FEIS, Page 3.3-23], offset to a minor degree by the effect of the changes anticipated under the Implementation Agreement (see Section 3.2.1).

As discussed above, under Baseline for Cumulative Analysis conditions, future Lake Powell water levels at the upper and lower 10th percentiles would likely be temporary and the water level would fluctuate between them in response to multi-year variations in basin runoff conditions. The same would apply to Cumulative Analysis conditions.

Table 3.3-1 presents a comparison of the 90th percentile, median (50th percentile) and 10th percentile values of the Cumulative Analysis to those of the Baseline for Cumulative Analysis conditions. The values presented in this table are for years 2016, 2026, 2036, 2046 and 2076.

Table 3.3-1
Lake Powell End-of-July Water Elevations
Comparison of Cumulative Effects to Cumulative Analysis Baseline
90th, 50th and 10th Percentile Values

Year	Baseline for Cumulative Analysis			Cumulative Analysis		
	90th Percentile	50th Percentile	10th Percentile	90th Percentile	50th Percentile	10th Percentile
2016	3699	3666	3611	3699	3662	3599
2026	3699	3664	3597	3699	3663	3594
2036	3699	3670	3580	3699	3670	3576
2046	3699	3666	3561	3699	3666	3561
2076	3699	3655	3537	3699	3655	3537

Figure 3.3-3 compared the percentage of Lake Powell elevations that exceeded 3695 feet msl for the Cumulative Analysis and Baseline for Cumulative Analysis conditions. Table 3.3-2 provides a summary of that comparison for years 2016, 2026, 2036, 2046 and 2076.

Figure 3.3-4
Lake Powell End-of-July Water Elevations
Comparison of Cumulative Analysis to Baseline for Cumulative Analysis Conditions
Percentage of Values Greater than or Equal to Elevation 3612 Feet

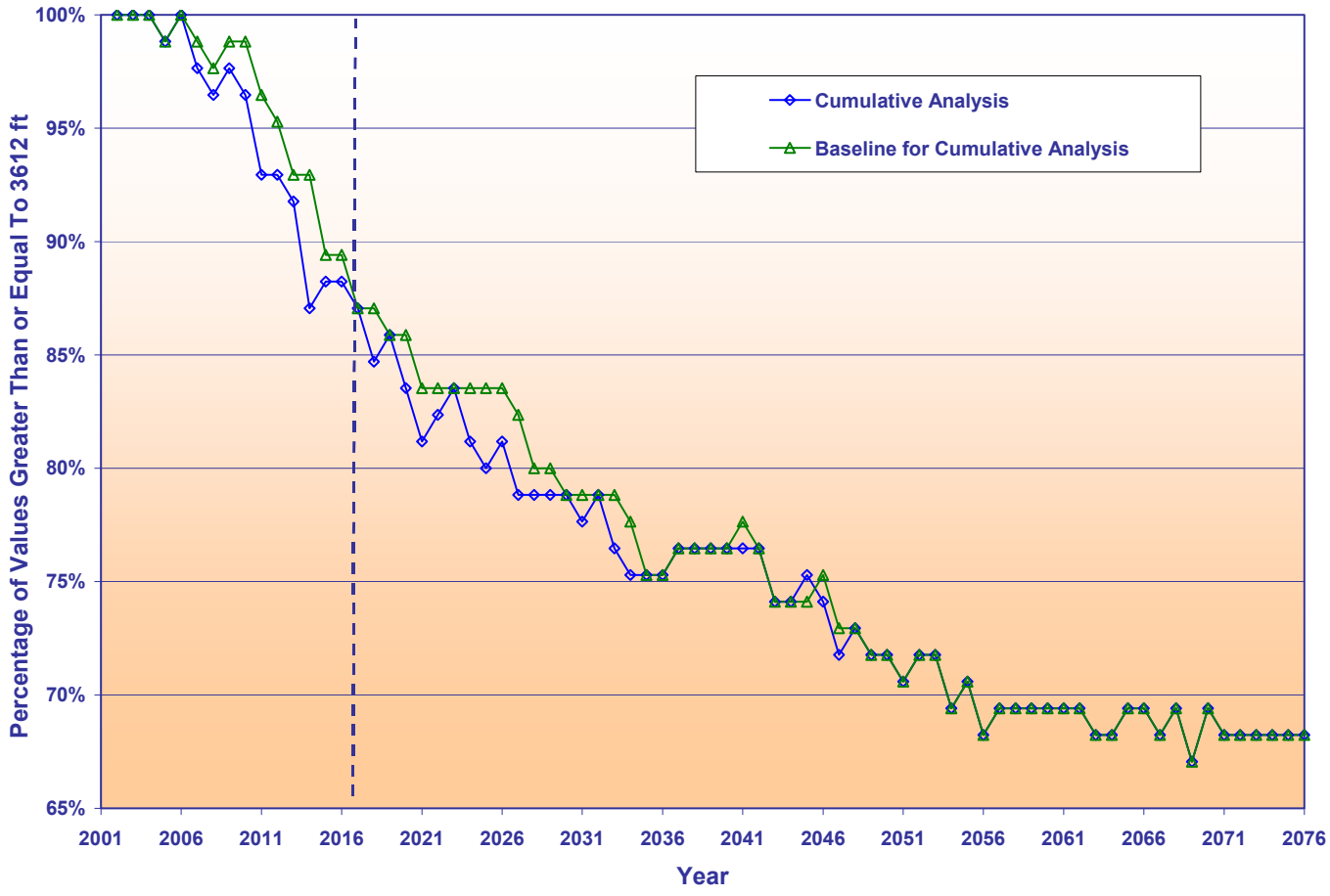


Table 3.3-2
Lake Powell End-of-July Water Elevations
Comparison of Cumulative Analysis to Baseline for Cumulative Analysis
Percentage of Values Greater than or Equal to Elevation 3695 Feet

Year	Baseline For Cumulative Analysis	Cumulative Analysis
2016	21%	21%
2026	22%	22%
2036	22%	24%
2046	26%	26%
2076	24%	24%

Figure 3.3-4 compared the percentage of Lake Powell elevations that exceeded 3612 feet msl under the Cumulative Analysis and Baseline for Cumulative Analysis conditions. Table 3.3-3 provides a summary of that comparison for years 2016, 2026, 2036, 2046 and 2076.

Table 3.3-3
Lake Powell End-of-July Water Elevations
Comparison of Cumulative Analysis to Baseline for Cumulative Analysis
Percentage of Values Greater than or Equal to Elevation 3612 Feet

Year	Baseline For Cumulative Analysis	Cumulative Analysis
2016	89%	88%
2026	84%	81%
2036	75%	75%
2046	75%	74%
2076	68%	68%

3.3.1.3 SENSITIVITY ANALYSIS

The water surface elevations of Lake Powell presented above are based on model operations in which the Lake Mead water surface elevation of 1083 feet msl was assumed to be the shortage protection level. In order to test the sensitivity of that assumption on the results of the model operation, model runs were also conducted with an assumed Lake Mead protection level of 1050 feet msl. With the 1050-foot protection level on Lake Mead, the water levels on Lake Powell were essentially the same as those based on the 1083-foot protection level under Cumulative Analysis Conditions. Lake Mead water level plots based on the use of the 1050-foot protection level are included in Attachment D.

3.3.2 RIVER FLOWS BETWEEN LAKE POWELL AND LAKE MEAD

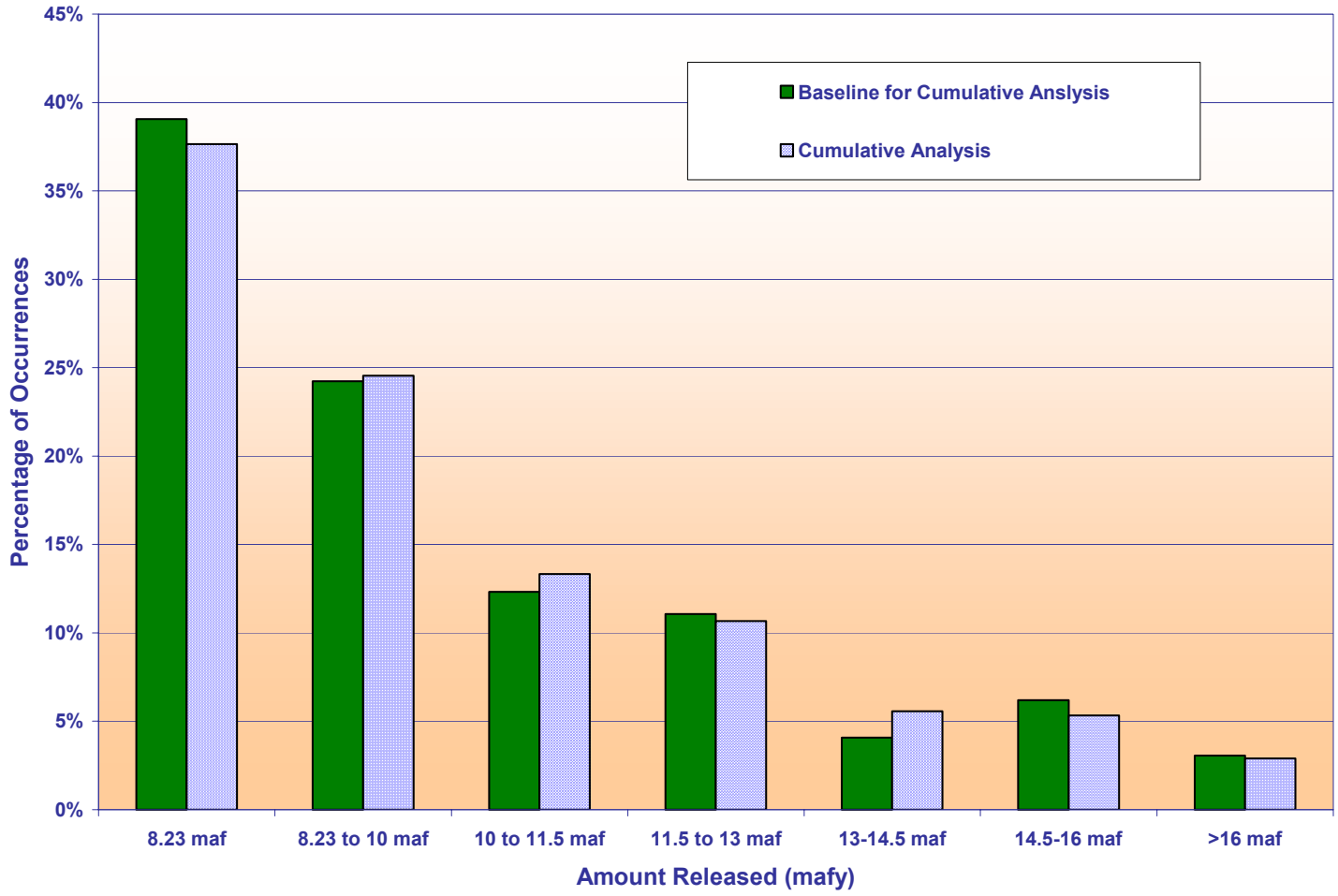
The river flows between Glen Canyon Dam and Lake Mead result from controlled releases from Glen Canyon Dam (Lake Powell) and include gains from tributaries in this reach of the river. Releases from Glen Canyon Dam are managed as previously discussed in Section 1.2 The most significant gains from perennial streams include inflow from the Little Colorado River and Paria River. However, inflow from these

streams is concentrated over very short periods of time, and on average, make up approximately two percent of the total annual flow in this reach of the river.

Figure 3.3-5 provides a comparison of the relative frequency of occurrence of annual releases from Lake Powell under the Baseline for Cumulative Analysis and Cumulative Analysis conditions, during the interim surplus guidelines period (through 2016). The probability of minimum releases from Lake Powell (8.23 maf) during the interim surplus period would be lower under Cumulative Analysis conditions than under Baseline for Cumulative Analysis. This change is primarily the result of the interim surplus guidelines on the river system, offset to a minor degree by the effect of the changes anticipated under the Implementation Agreement (See Section 3.2.2).

Releases between 8.23 and 11.5 maf generally correspond to years where equalization releases are being made from Lake Powell. The relative frequency of equalization during that period tends to decrease the probability of low releases under Cumulative Analysis conditions, compared to the Baseline for Cumulative Analysis. The decrease is associated with surplus water delivery from Lake Mead under the interim surplus guidelines, partially offset by the reduction in Lake Mead releases associated with the Implementation Agreement.

Figure 3.3-5
Histogram of Modeled Lake Powell Annual Releases (Water Years)
2002 to 2016 (85 Traces)



3.3.3 LAKE MEAD WATER LEVELS

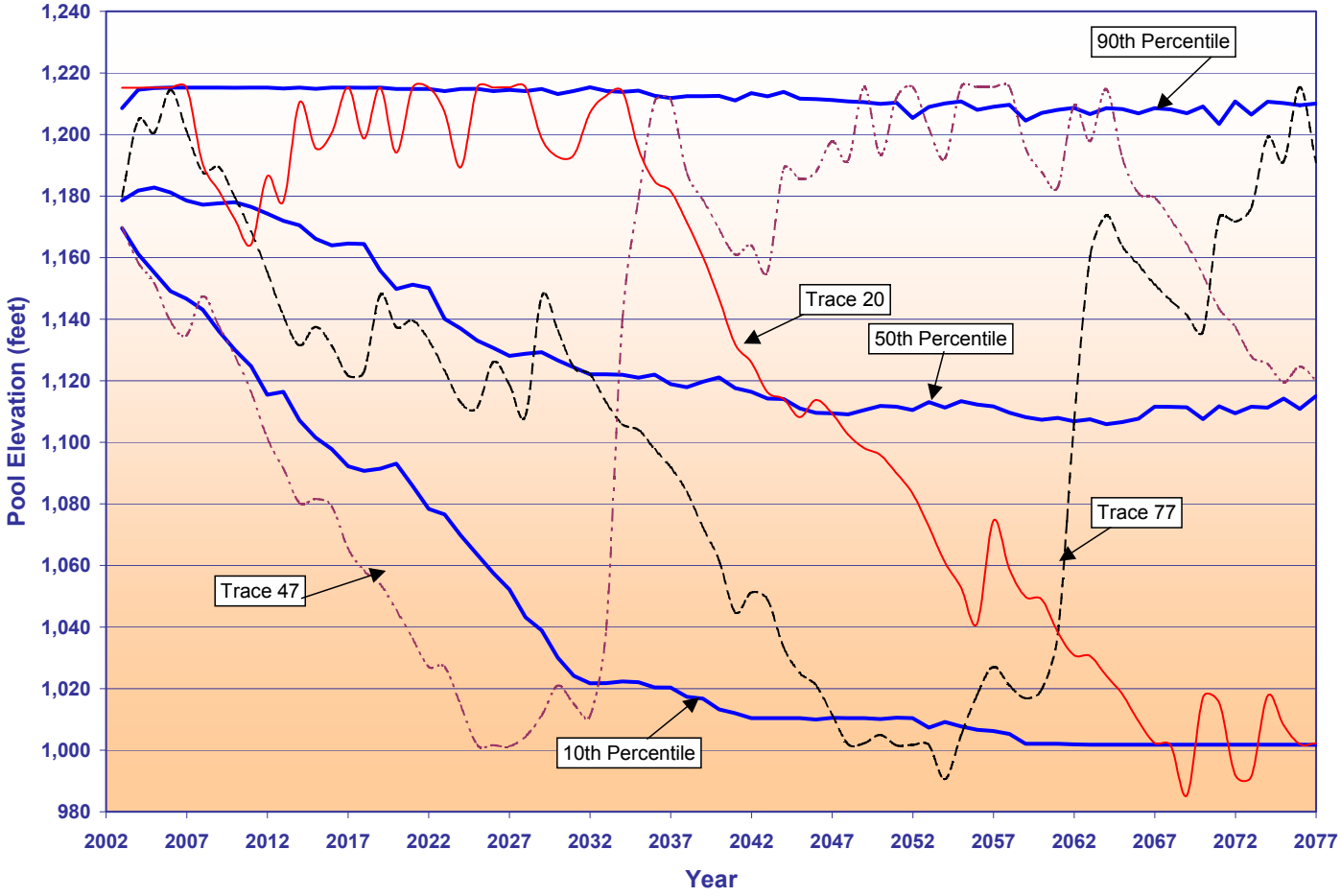
This section summarizes the results of the future Lake Mead water level simulations under Baseline for Cumulative Analysis conditions and Cumulative Analysis conditions.

3.3.3.1 MODELING RESULTS OF BASELINE FOR CUMULATIVE ANALYSIS

Under the Baseline for Cumulative Analysis conditions, the water surface elevation of Lake Mead is projected to fluctuate between full level and decreasingly lower levels during the period of analysis (2002 to 2076). Figure 3.3-6 illustrates the range of water levels (end of December) by three lines, labeled 90th Percentile, 50th Percentile and 10th Percentile. The 50th percentile line shows the median water level for each future year. The median water level under Baseline for Cumulative Analysis conditions is shown to decline to 1165 feet msl by 2016 and to 1115 feet msl by 2076. The 10th percentile line shows there is a 10 percent probability that the water level would decline to 1092 feet msl by 2016 and to 1002 feet msl by 2076. It should also be noted that the Lake Mead elevations depicted in Figure 3.3-6 represent water levels at the end of December which is when lake levels are at a seasonal high. Conversely, the Lake Mead water level generally reaches its annual low in July.

Three distinct traces are added to Figure 3.3-6 to illustrate what was actually simulated under the various traces and respective hydrologic sequences and to highlight that the 90th, 50th and 10th percentile lines do not represent actual traces, but rather the ranking of the data from the 85 traces for the conditions modeled. The three traces illustrate the variability among the different traces and that the reservoir levels could temporarily decline below the 10th percentile line. The trace identified as Trace 20 represents the hydrologic sequence that begins in year 1926. The trace identified as Trace 47 represents the hydrologic sequence that begins in year 1953. The trace identified as Trace 77 represents the hydrologic sequence that begins in year 1983.

Figure 3.3-6
Lake Mead End-of-December Water Elevations Under Baseline for Cumulative Analysis Conditions
90th, 50th and 10th Percentile Values and Representative Traces



In Figure 3.3-6, the 90th and 10th percentile lines bracket the range where 80 percent of future Lake Mead water levels simulated for the Baseline for Cumulative Analysis conditions occur. The highs and lows shown on the three traces would likely be temporary conditions. The reservoir level would tend to fluctuate through multi-year periods of above average and below average inflows. Neither the timing of water level variations between the highs and the lows, 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 3.3-7 presents the 90th, 50th and 10th percentile plots obtained for the Baseline for Cumulative Analysis conditions and those obtained for the Cumulative Analysis. This figure is best used for comparing the relative differences in the general lake level trends between the simulated Baseline for Cumulative Analysis and Cumulative Analysis conditions.

Figure 3.3-8 shows the frequency at which future Lake Mead end of December water surface elevations under Baseline for Cumulative Analysis conditions would be at or exceed 1200 feet msl. The corresponding frequency with the Cumulative Analysis is also plotted. The lines represent the percentage of values of all 85 traces that are equal to or greater than elevation 1200 feet msl. In year 2016, under the Baseline for Cumulative Analysis conditions, the percentage of values greater than or equal to elevation 1200 feet msl is 21 percent. After 2016 the annual percentages of values equal to or greater than elevation 1200 feet msl increase slightly to 22 percent and then decrease gradually to 13 percent in 2076 under Baseline for Cumulative Analysis conditions.

Figure 3.3-9 provides a comparison of the frequency that future Lake Mead end of December water levels would be at or above elevation 1083 feet msl under Baseline for Cumulative Analysis and Cumulative Analysis conditions. In year 2016, under the Baseline for Cumulative Analysis conditions, the percentage of values greater than or equal to elevation 1083 feet msl is 95 percent. After 2016 the annual percentages of values equal to or greater than elevation 1083 feet msl decline gradually to 56 percent in 2076 under Baseline for Cumulative Analysis conditions.

Figure 3.3-7
Lake Mead End-of-December Water Elevations
Comparison of Cumulative Analysis and Baseline for Cumulative Analysis Conditions 90th, 50th and 10th Percentile Values

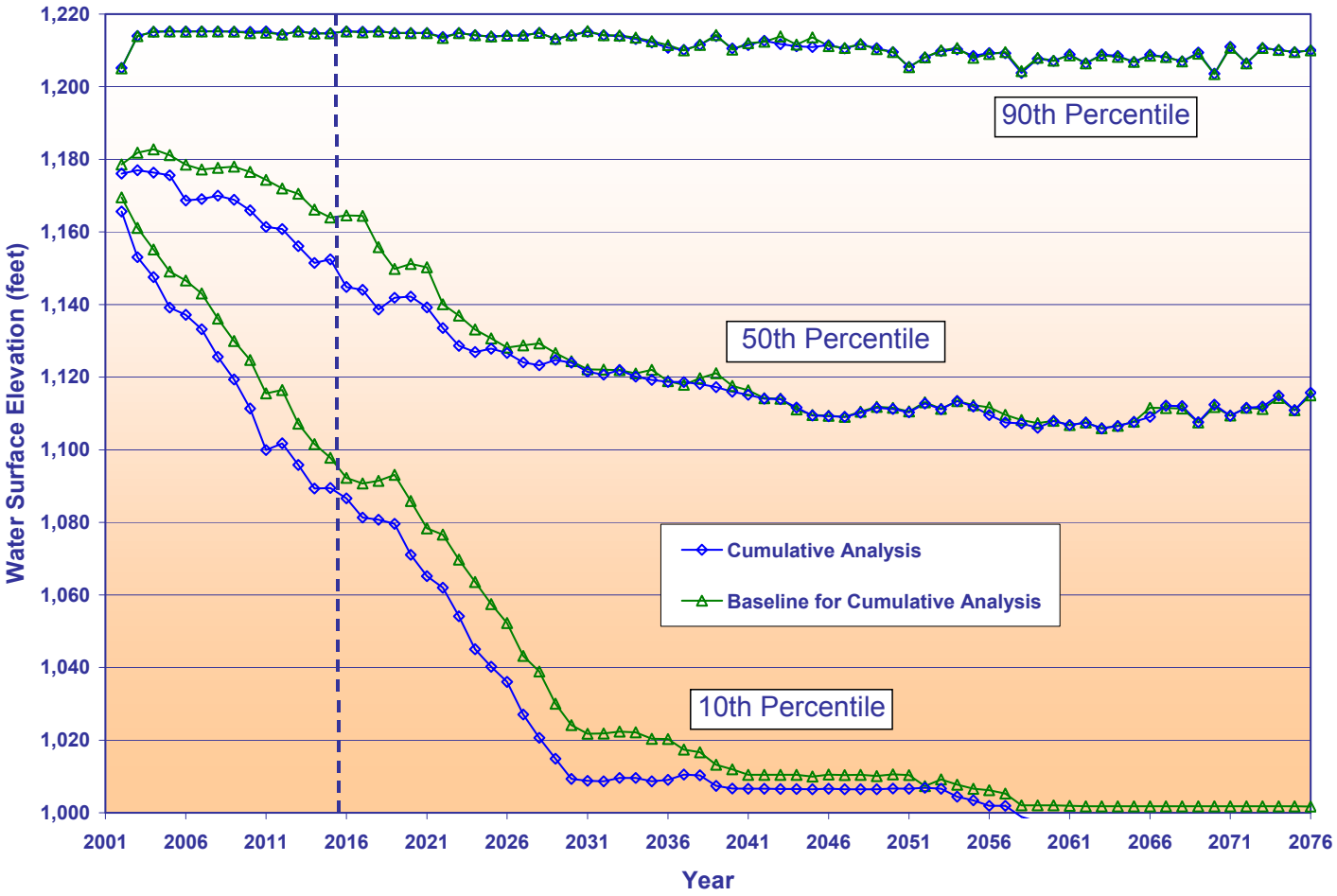


Figure 3.3.8
Lake Mead End-of-December Water Elevations
Comparison of Cumulative Analysis and Baseline for Cumulative Analysis Conditions
Percentage of Values Greater than or Equal to Elevation 1200 Feet

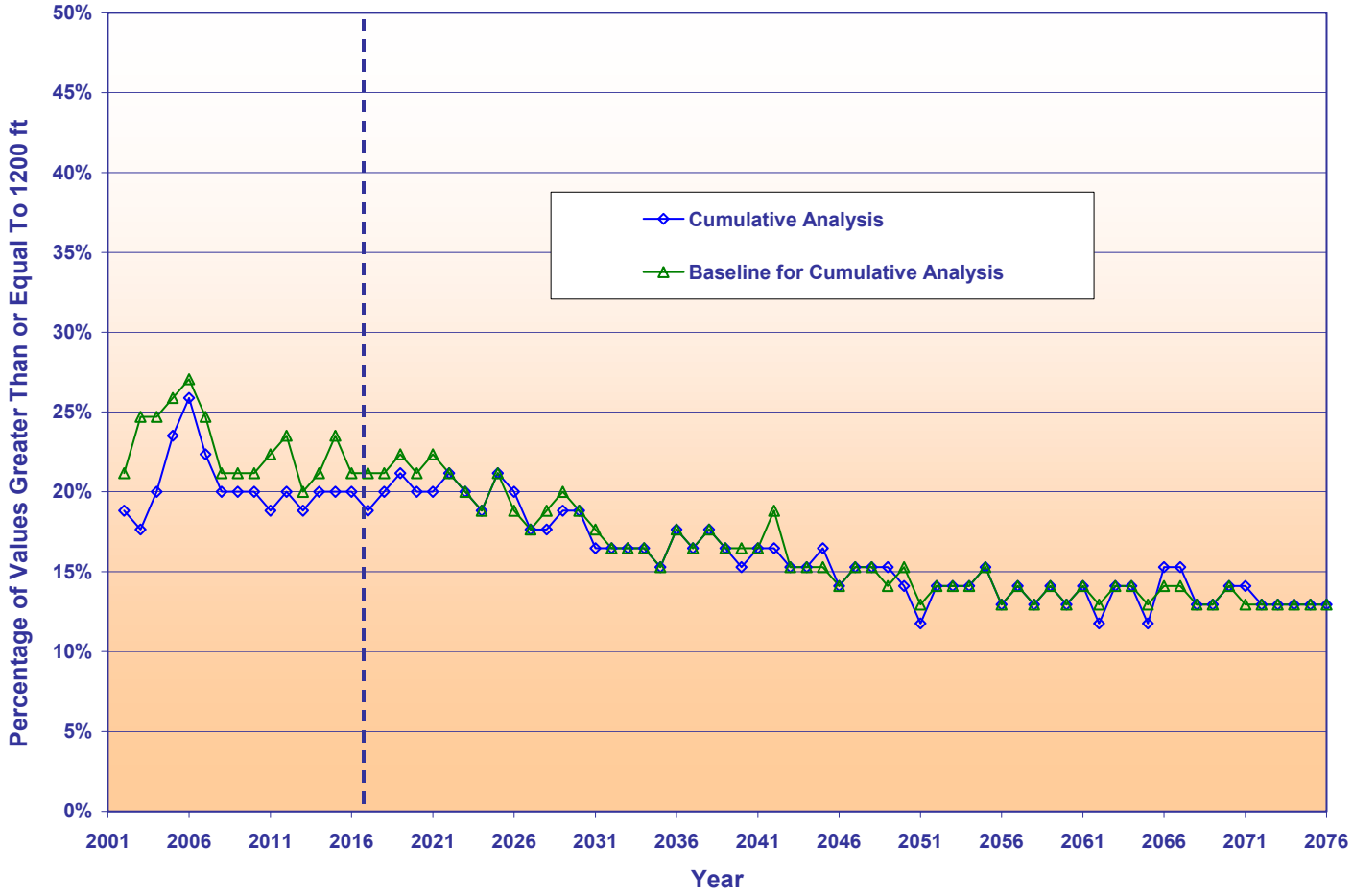


Figure 3.3-10 provides a comparison of the frequency that future Lake Mead end of December water levels would be at or above elevation 1050 feet msl under Baseline for Cumulative Analysis and Cumulative Analysis conditions. In year 2016, under the Baseline for Cumulative Analysis conditions, the percentage of values greater than or equal to elevation 1050 feet msl is 100 percent. After 2016 the annual percentages of values equal to or greater than elevation 1200 feet msl decline gradually to 62 percent in 2076 under Baseline for Cumulative Analysis conditions.

Figure 3.3-11 provides a comparison of the frequency that future Lake Mead end of December water elevations under Baseline for Cumulative Analysis conditions and the Cumulative Analysis would be at or exceed a lake water elevation of 1000 feet msl. In year 2016, under the Baseline for Cumulative Analysis conditions, the percentage of values greater than or equal to elevation 1000 feet msl is 100 percent. After 2016 the annual percentages of values equal to or greater than elevation 1200 feet msl remain at 100 percent for over three decades before declining gradually to 94 percent in 2076 under Baseline for Cumulative Analysis conditions.

3.3.3.2 COMPARISON OF CUMULATIVE ANALYSIS TO BASELINE FOR CUMULATIVE ANALYSIS

Figure 3.3-7 compared the 90th, 50th and 10th percentile water levels of the Cumulative Analysis to those of the Baseline for Cumulative Analysis conditions. The median (50th percentile) water level of Lake Mead would be lower during and immediately after the interim surplus period but after several decades water levels would be the same as those under baseline conditions. These changes are primarily the result of the Interim surplus guidelines on the river system [Ref. ISC FEIS, Page 3.3-35], offset to a minor degree by the effect of the changes anticipated under the Implementation Agreement (see Section 3.2.3).

As discussed previously, under Baseline for Cumulative Analysis conditions, future Lake Mead water levels at the upper and lower 10th percentiles would likely be temporary and the water levels are expected to fluctuate between them in response to multi-year variations in basin runoff conditions. The same would apply to the water levels under Cumulative Analysis conditions.

The 90th percentile, median (50th percentile) and 10th percentile values of the Cumulative Analysis are compared to those of the Baseline for Cumulative Analysis conditions in Table 3.3-4. The values presented in this table are for years 2016, 2026, 2036, 2046, and 2076.

Table 3.3-4
Lake Mead End-of-December Water Elevations
Comparison of Cumulative Effects to Cumulative Analysis Baseline
90th, 50th and 10th Percentile Values

Year	Baseline for Cumulative Analysis			Cumulative Analysis		
	90th Percentile	50th Percentile	10th Percentile	90th Percentile	50th Percentile	10th Percentile
2016	1215	1165	1092	1215	1145	1087
2026	1215	1128	1052	1214	1127	1036
2036	1212	1119	1020	1211	1119	1009
2046	1211	1109	1011	1211	1109	1007
2076	1210	1115	1002	1210	1116	997

Figure 3.3-9
Lake Mead End-of-December Water Elevations
Comparison of Cumulative Analysis to Baseline for Cumulative Analysis Conditions
Percentage of Values Greater than or Equal to Elevation 1083 Feet

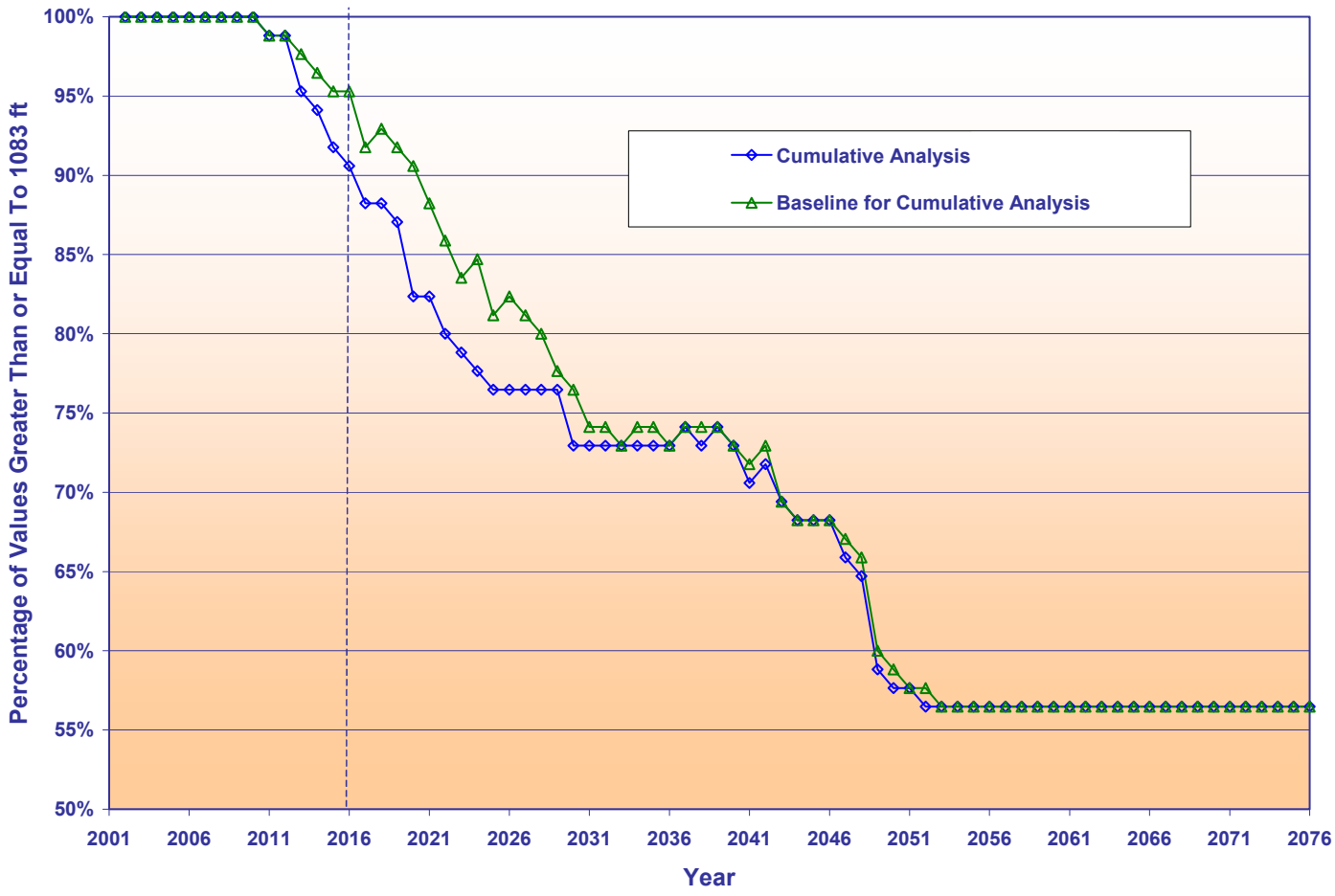


Figure 3.3-10
Lake Mead End-of-December Water Elevations
Comparison of Cumulative Analysis to Baseline for Cumulative Analysis Conditions
Percentage of Values Greater than or Equal to Elevation 1050 Feet

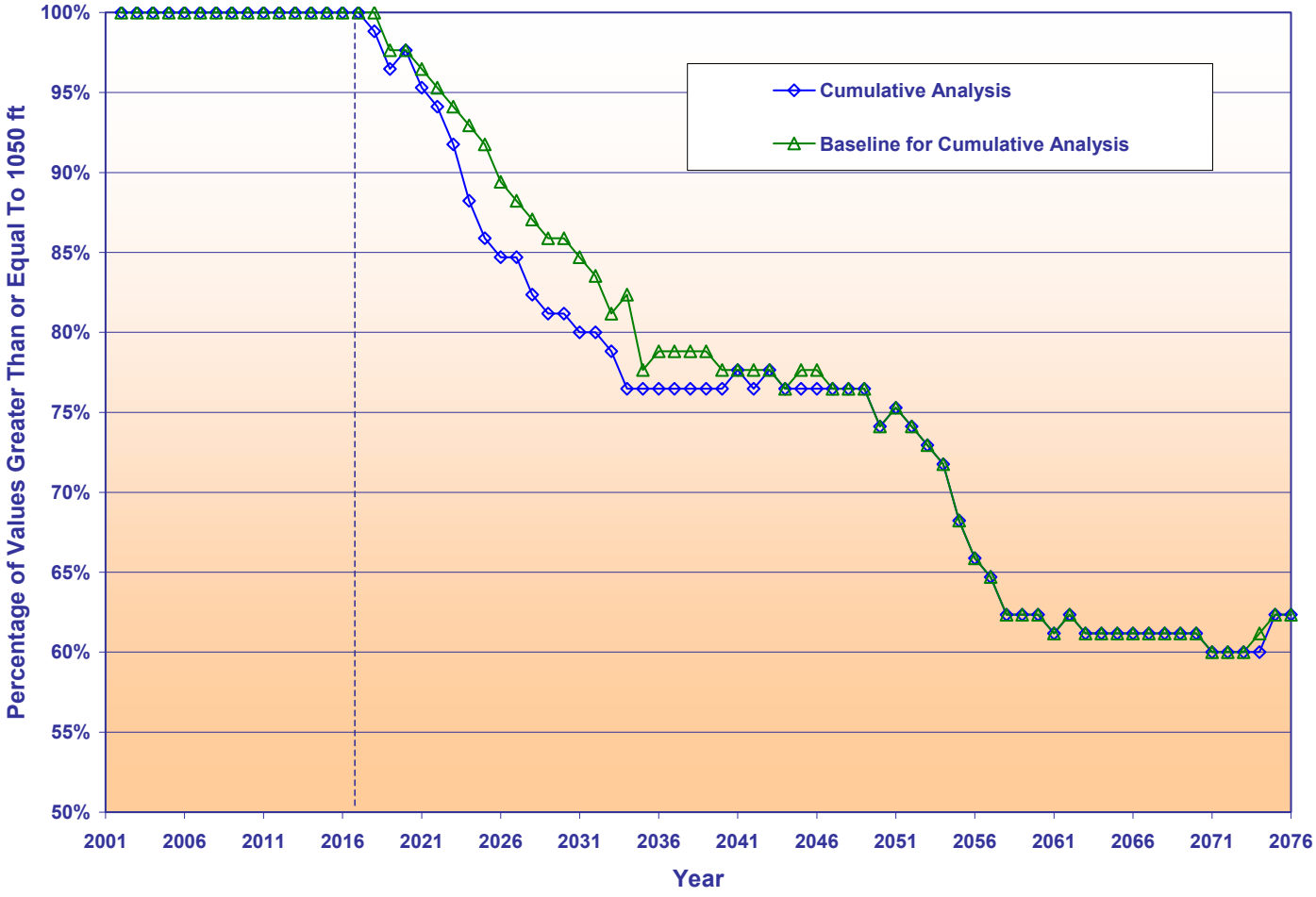


Figure 3.3-11
Lake Mead End-of-December Water Elevations
Comparison of Cumulative Analysis to Baseline for Cumulative Analysis Conditions
Percentage of Values Greater than or Equal to Elevation 1000 Feet

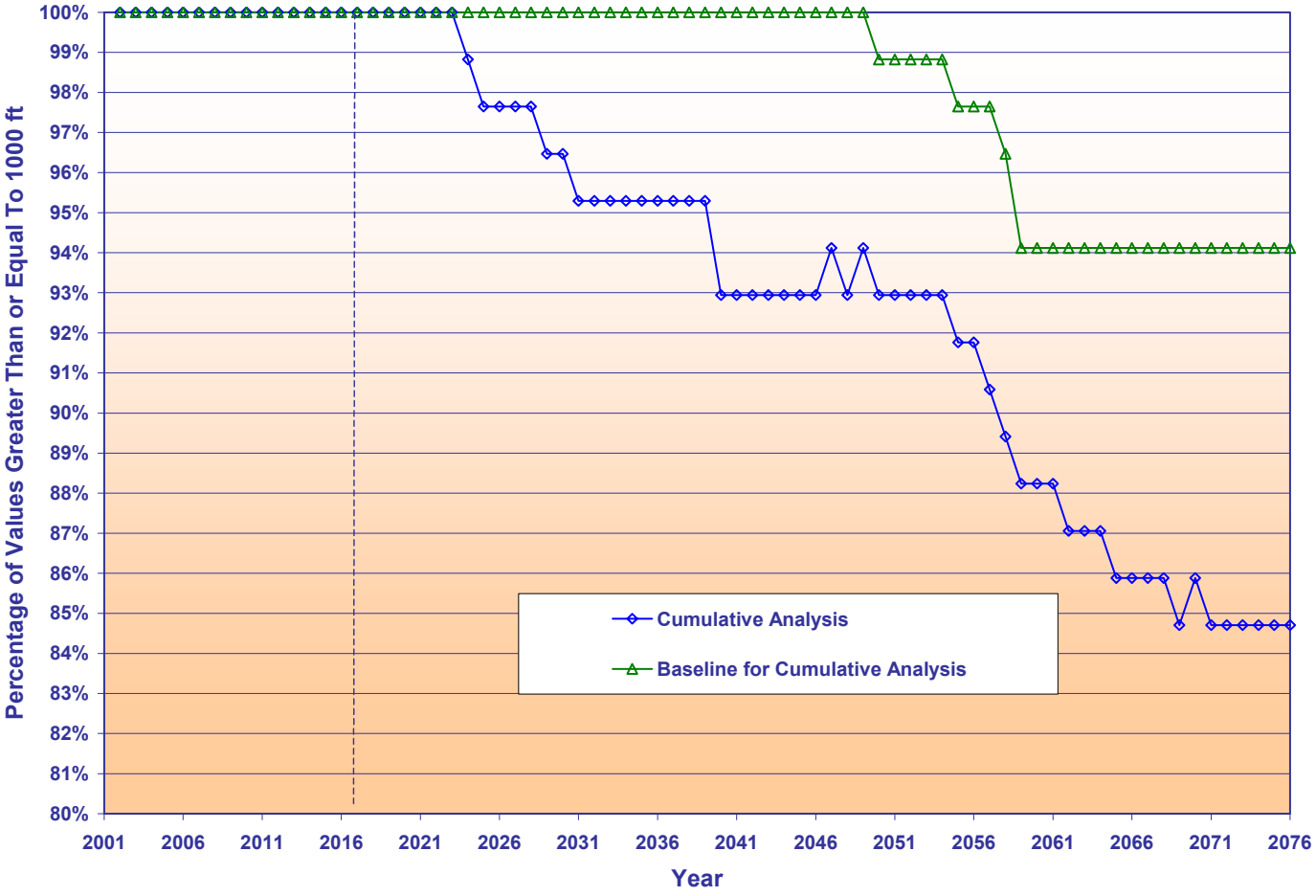


Figure 3.3-8 compared the percentage of Lake Mead elevations that were at or above 1200 feet msl for the Cumulative Analysis and Baseline for Cumulative Analysis conditions. Table 3.3-5 provides a summary of that comparison for years 2016, 2026, 2036, 2046, and 2076.

Table 3.3-5
Lake Mead End-of-December Water Elevations
Comparison of Cumulative Analysis to Baseline for Cumulative Analysis
Percentage of Values Greater than or Equal to Elevation 1200 Feet

Year	Baseline for Cumulative Analysis	Cumulative Analysis
2016	21%	20%
2026	19%	20%
2036	18%	18%
2046	14%	14%
2076	13%	13%

Figure 3.3-9 compared the percentage of Lake Mead elevations that were at or above 1083 feet msl for the Cumulative Analysis and Baseline for Cumulative Analysis conditions. Table 3.3-6 provides a summary of that comparison for years 2016, 2026, 2036, 2046, and 2076.

Table 3.3-6
Lake Mead End-of-December Water Elevations
Comparison of Cumulative Analysis to Baseline for Cumulative Analysis
Percentage of Values Greater than or Equal to Elevation 1083 Feet

Year	Baseline for Cumulative Analysis	Cumulative Analysis
2016	95%	91%
2026	82%	76%
2036	73%	73%
2046	68%	68%
2076	56%	56%

Figure 3.3-10 compared the percentage of Lake Mead elevations that were at or above 1050 feet msl for the Cumulative Analysis and Baseline for Cumulative Analysis conditions. Table 3.3-7 provides a summary of that comparison for years 2016, 2026, 2036, 2046, and 2076.

Table 3.3-7
Lake Mead End-of-December Water Elevations
Comparison of Cumulative Analysis to Baseline for Cumulative Analysis
Percentage of Values Greater than or Equal to Elevation 1050 Feet

Year	Baseline for Cumulative Analysis	Cumulative Analysis
2016	100%	100%
2026	89%	85%
2036	78%	76%
2046	78%	76%
2076	62%	62%

Figure 3.3-11 compared the percentage of Lake Mead elevations that were at or above 1000 feet msl for the Cumulative Analysis and Baseline for Cumulative Analysis conditions. Table 3.3-8 provides a summary of that comparison for years 2016, 2026, 2036, 2046, and 2076.

Table 3.3-8
Lake Mead End-of-December Water Elevations
Comparison of Cumulative Analysis to Baseline for Cumulative Analysis
Percentage of Values Greater than or Equal to Elevation 1000 Feet

Year	Baseline for Cumulative Analysis	Cumulative Analysis
2016	100%	100%
2026	100%	98%
2036	100%	95%
2046	100%	93%
2076	94%	85%

3.3.3.3 SENSITIVITY ANALYSIS

The water surface elevations of Lake Mead presented above are based on model operations in which the Lake Mead water surface elevation of 1083 feet msl was assumed to be the shortage protection level. In order to test the sensitivity of that assumption on the results of the model operation, model runs were also conducted with an assumed Lake Mead protection level of 1050 feet msl. With the 1050-foot protection level, the resulting water levels on Lake Mead range up to 15 feet lower than those based on the 1083-foot protection level under Cumulative Impact Conditions, at the 50th percentile, after 2016. Lake Mead water level plots based on the use of the 1050-foot protection level are included in Attachment D.

3.3.4 RIVER FLOWS BELOW HOOVER DAM

This section describes results of the analysis of the simulated Colorado River flows below Hoover Dam. The model of the Colorado River system was used to simulate

future mean monthly flows under Baseline for Cumulative Analysis and Cumulative Analysis conditions. Four specific river locations were selected to represent flows within selected river reaches below Hoover Dam. The river reaches and corresponding flow locations are listed in Table 3.3-9 and their locations were shown on Map 3.2-1 in Section 3.2.

Table 3.3-9
Colorado River Flow Locations Identified for Evaluation

Colorado River Reach	Selected River Flow Locations	
	Description	Approximate River Mile [1]
Between Hoover Dam and Parker Dam	Havasu National Wildlife Refuge (NWR)	242.3
Between Parker Dam and Palo Verde Diversion Dam	Upstream of Colorado River Indian Reservation	180.8
Between Palo Verde Diversion and Imperial Dam	Downstream of the Palo Verde Diversion Dam	133.8
Between Imperial Dam and SIB	Below the Mexico Diversion at Morelos Dam	23.1

[1] River miles as measured from the southerly international boundary with Mexico

Two types of model data analysis were used to portray cumulative impacts on river flows. In the first analysis, the potential effects on the total annual volume of flow in each reach were evaluated. In this analysis, the mean monthly flows were first summed over each calendar year. The 90th, 50th, and 10th percentiles of the annual volumes were then computed for each year. Plots of these percentiles for the Baseline for the Cumulative Analysis and the Cumulative Analysis conditions are included in this section for each of the four river points listed above.

The second analysis investigated the potential effects on seasonal flows. The mean monthly flows for January were used to represent the winter season flows and likewise for April, July, and October to represent spring, summer, and fall, respectively. The specific years analyzed for seasonal flows included 2006, 2016, 2026, and 2050. Only the data and graphs for 2016 are presented in this section.

It should be noted that the monthly demand schedules used in the model are based on a distribution of the total annual demand (a specific percentage for each month). Although each diversion point may use a different distribution, those percentages do not change from year to year in the model, and thus can not reflect potential future changes in the system that might affect the monthly distributions. Therefore, the seasonal differences are primarily governed by the overall changes in annual flow volumes, coupled with the effect of each diversion's distribution upstream of the point of interest.

Daily and hourly releases from Hoover Dam reflect the short-term demands of Colorado River water users with diversions located downstream, storage management in Lakes Mohave and Havasu, and power production at Hoover, Davis and Parker Dams. The close proximity of Lake Mohave to Hoover Dam effectively dampens the short-term fluctuations below Hoover Dam. The scheduling and subsequent release of water through Davis and Parker Dams create short-term fluctuations in river flows, depths,

and water surface elevations downstream of these structures. These fluctuations of water surface elevations in the river are most noticeable in the river reaches located immediately downstream of the dams and lessen as the downstream distance increases.

3.3.4.1 RIVER FLOWS BETWEEN HOOVER DAM AND PARKER DAM

The river flows between Hoover Dam and Parker Dam are comprised mainly of flow releases from Hoover Dam and Davis Dam. Inflows from the Bill Williams River and other intermittent tributaries are infrequent and are usually concentrated into short time periods due to their dependence on localized precipitation. Tributary inflows comprise less than one percent of the total annual flow in this reach of the river.

A point on the Colorado River downstream of Davis Dam was used to evaluate the river flows for this reach, located immediately downstream of the Havasu National Wildlife Refuge (NWR).

The 90th, 50th, and 10th percentile annual flow volumes for this reach are shown in Figure 3.3-12. As shown by the 50th percentile values, annual flow volumes in this reach would be greater under the Cumulative Analysis conditions than under the Baseline for Cumulative Analysis conditions during the 15-year interim surplus guidelines period through 2016. The plot indicates that the Cumulative Analysis conditions would increase flows above the Baseline during this period by up to approximately six percent. The difference is primarily the result of the interim surplus guidelines on the river system [Ref. ISC FEIS, Page 3.3-46], offset to a minor degree by the effect of the changes anticipated under the Implementation Agreement (See Section 3.2.4.1). Beyond the 15-year interim period, the annual flow volumes under the Cumulative Analysis are essentially the same (within one percent) as those under the Baseline for Cumulative Analysis conditions.

At the 90th percentile level the annual flow pattern under Cumulative Analysis is generally similar that of the Baseline for the Cumulative Analysis, with the Cumulative Analysis flows tending to exceed Baseline flows intermittently. The 10th percentile level exhibits a relationship similar to that described for the 50th percentile level until 2016. Beyond 2016 the 10th percentile flows under Cumulative Analysis conditions are essentially the same as those under the Baseline for Cumulative Analysis conditions.

Figure 3.3-13 shows the cumulative distribution of annual flow volumes for year 2016.

Figures 3.2-14(a-d) present comparisons of the representative seasonal flows under Baseline for Cumulative Analysis conditions and the Cumulative Analysis for 2016. As expected, the largest flows occur in the spring and summer seasons for Baseline for Cumulative Analysis conditions and Cumulative Analysis conditions due to downstream irrigation demands. For flows that are due primarily to flood control releases from Lake Mead (flows in the 80th - 100th percentile range), the seasonal

flows under the Cumulative Analysis conditions vary higher or lower than the flows under the Baseline for Cumulative Analysis during the fall and winter seasons. In the lower percentiles, the seasonal flows under the Cumulative Analysis conditions varied from being approximately the same as Baseline flows (within one percent) to being approximately eight percent higher (January).

A numerical comparison of the 70th percentile seasonal flow values is shown on Table 3.3-10. The values tabulated are the mean monthly flows in January, April, July and October.

Table 3.3-10
Comparison of Mean Monthly Flow Data – Baseline for Cumulative Analysis and Cumulative Analysis
Colorado River Downstream of Havasu NWR (River Mile = 242.3)
70th Percentile Values for Year 2016

Season (Representative Month)	Mean Monthly Flows (cfs) for Year 2016 at the 70th Percentile	
	Baseline for Cumulative Analysis	Cumulative Analysis
January (January)	8,035	8,399
Spring (April)	16,038	15,979
Summer (July)	15,855	15,704
Fall (October)	12,091	11,880

Figure 3.3-12
Colorado River Downstream of Havasu NWR Annual Flow Volume (af)
Comparison of Cumulative Analysis to Baseline for Cumulative Analysis Conditions
90th, 50th and 10th Percentile Values

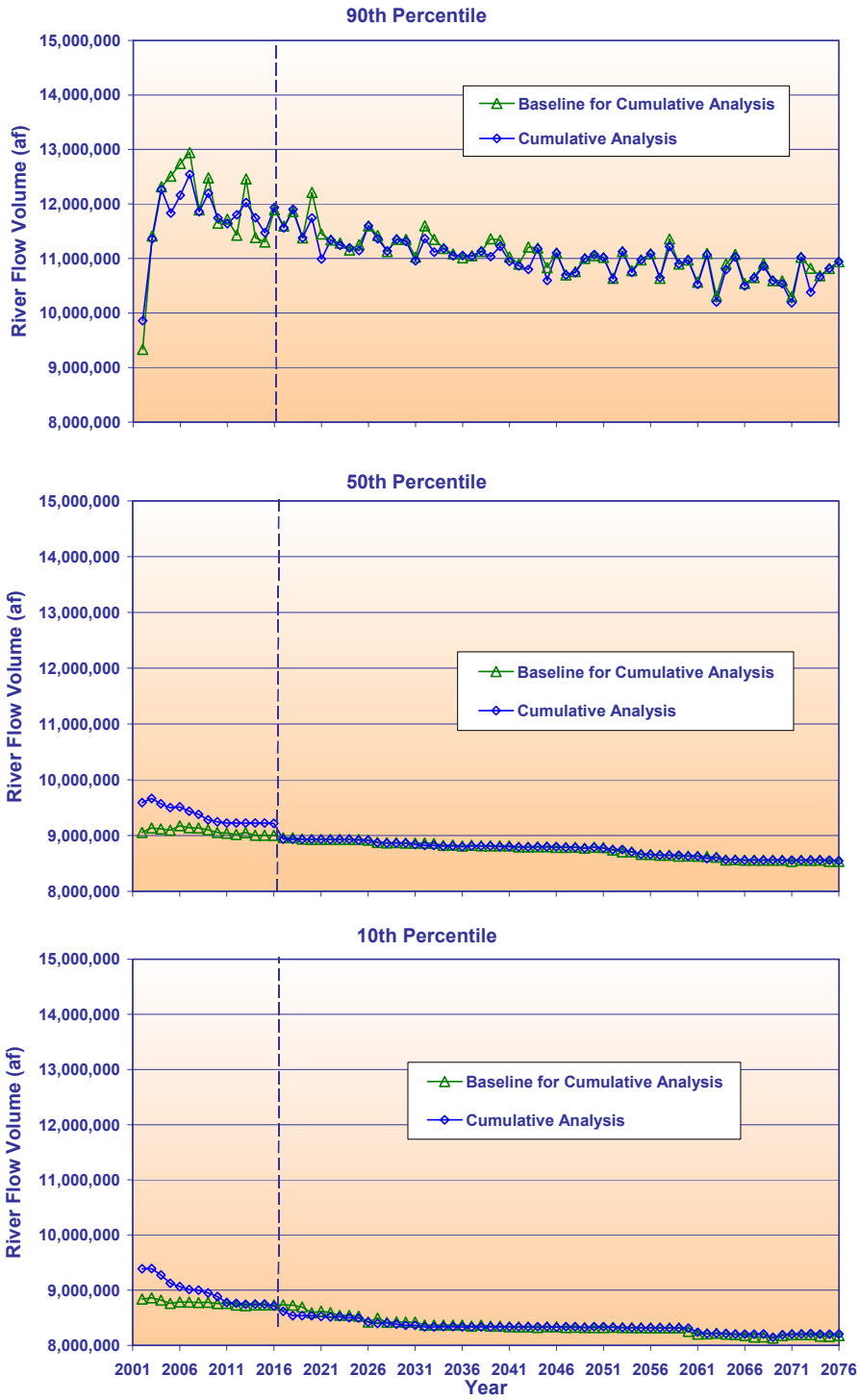


Figure 3.3-13
Colorado River Annual Flow Volume Downstream of Havasu NWR
Comparison of Cumulative Analysis to Baseline for Cumulative Analysis Conditions for Modeled Year 2016

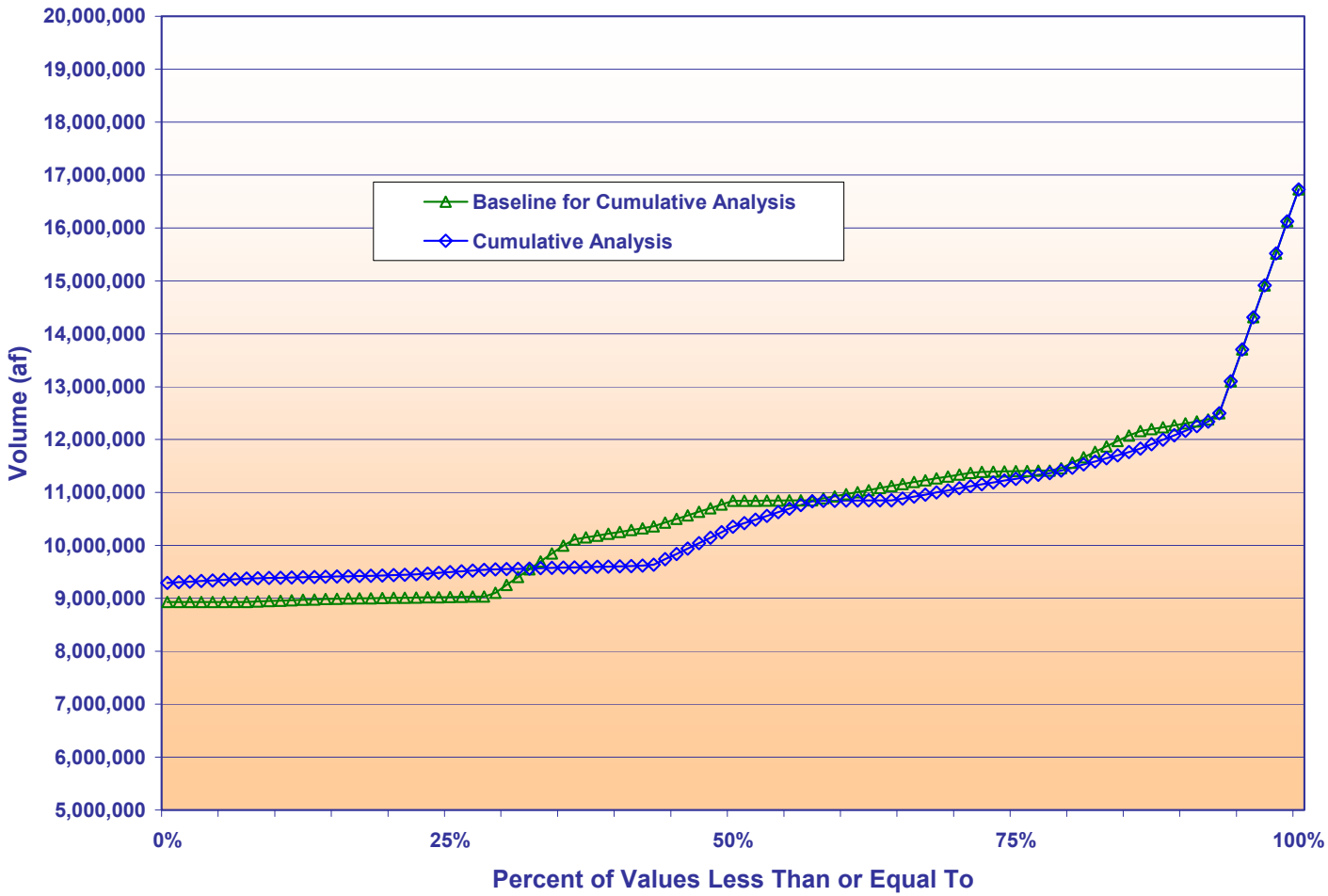


Figure 3.3-14a
Colorado River Seasonal Flows Downstream of Havasu NWR
Comparison of Cumulative Analysis to Baseline for Cumulative Analysis Conditions for Modeled Year 2016

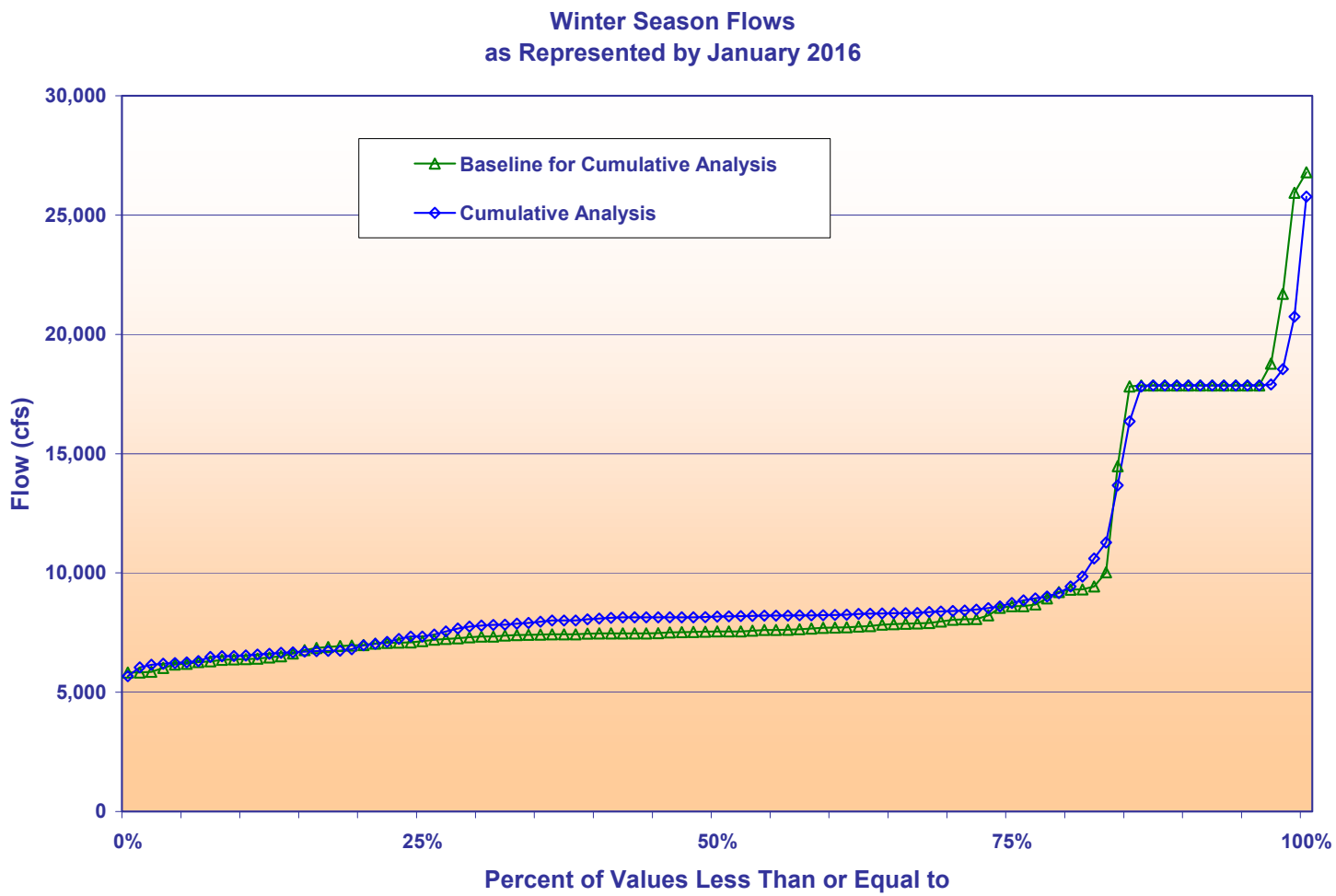


Figure 3.3-14b
Colorado River Seasonal Flows Downstream of Havasu NWR
Comparison of Cumulative Analysis to Baseline for Cumulative Analysis Conditions for Modeled Year 2016

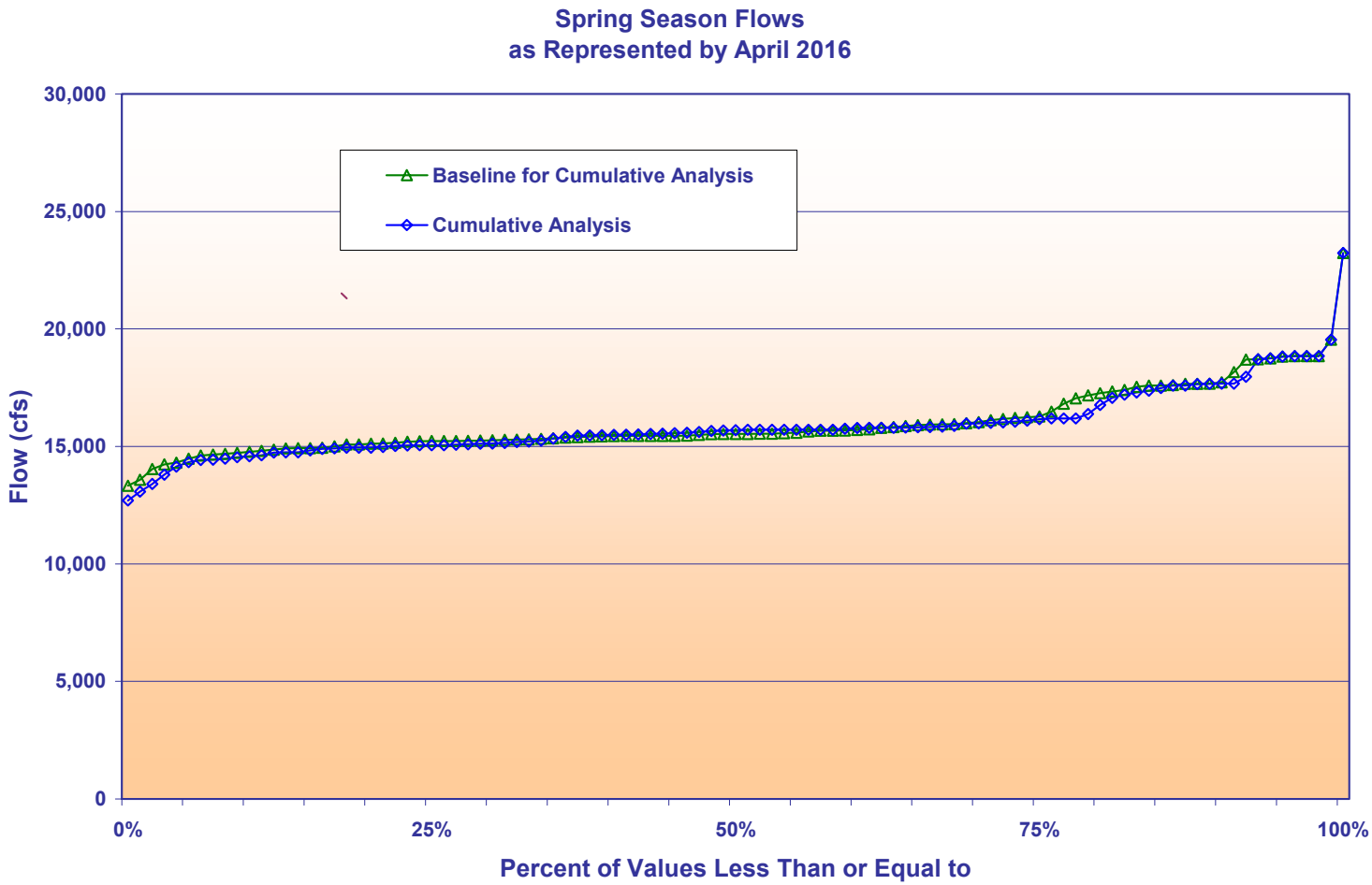


Figure 3.3-14c
Colorado River Seasonal Flows Downstream of Havasu NWR
Comparison of Cumulative Analysis to Baseline for Cumulative Analysis Conditions for Modeled Year 2016

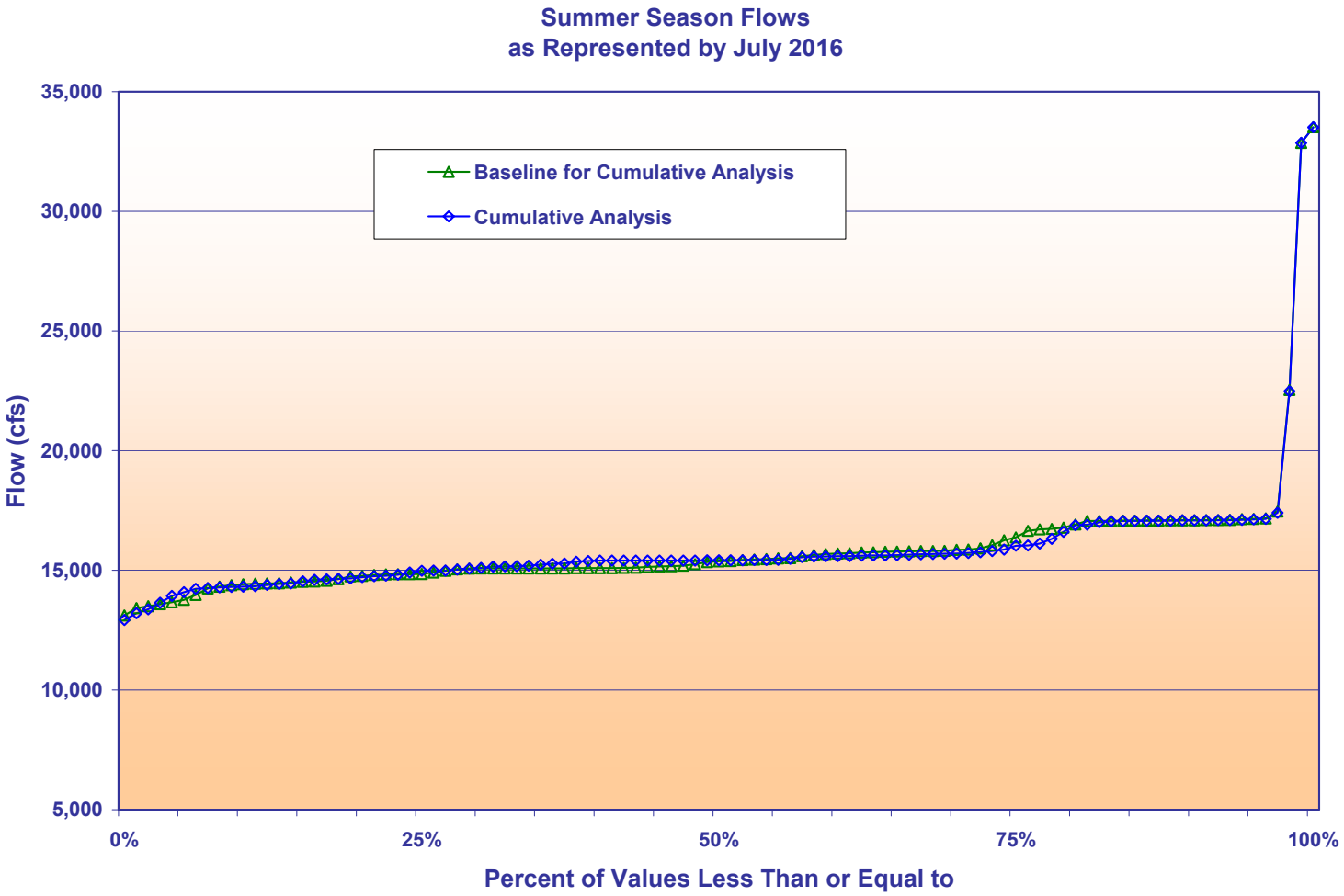
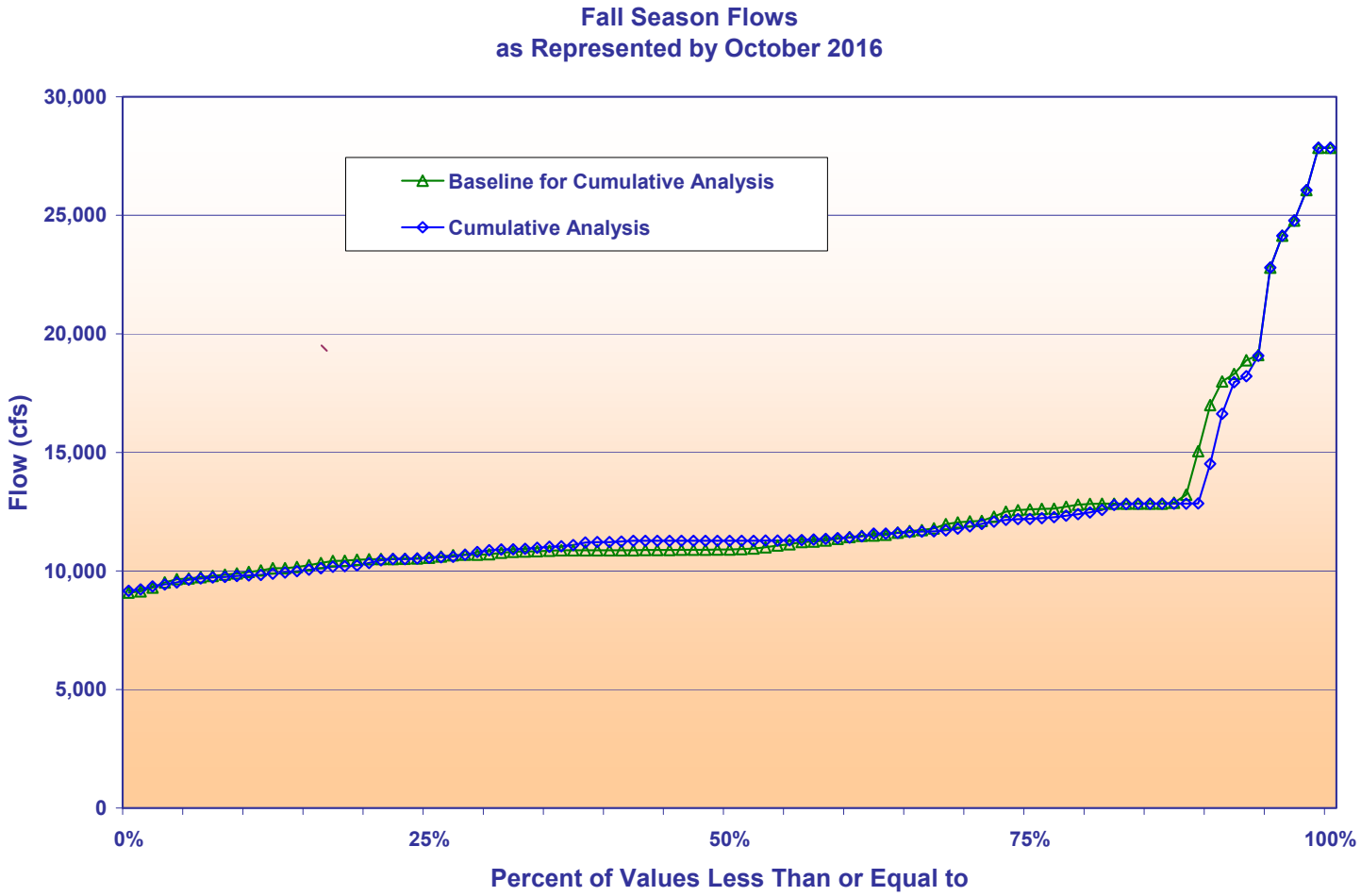


Figure 3.3-14d
Colorado River Seasonal Flows Downstream of Havasu NWR
Comparison of Cumulative Analysis to Baseline for Cumulative Analysis Conditions for Modeled Year 2016



3.3.4.2 RIVER FLOWS BETWEEN PARKER DAM AND PALO VERDE DIVERSION DAM

The point on the Colorado used to evaluate the river flows in the reach of the river located between Parker Dam and the Palo Verde Diversion Dam is located immediately upstream of the Colorado River Indian Reservation (CRIR) diversion. 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 from Parker Dam (Lake Havasu).

Future flows in this reach would be affected by the Cumulative Analysis because the proposed water transfers and exchanges between the California agricultural water agencies and MWD would change the point of diversion from the river. For example, under a potential transfer between PVID and MWD, the water that would normally be diverted at Palo Verde Dam would now be diverted above Parker Dam.

The 90th, 50th, and 10th percentile annual flow volumes for this reach are shown in Figure 3.3-15. As shown by the 50th percentile values, the modeled annual flow volumes in this reach under the Cumulative Analysis decline gradually between 2002 and 2016, as the water transfers take effect and certain amounts of California's water are diverted from Lake Havasu rather than at Imperial Dam. The difference results primarily from the proposed Implementation Agreement (See Section 3.2.4.2), augmented to a minor degree by the effect of the additional proposed water transfer in the cumulative analysis. The interim surplus guidelines do not affect this section of river significantly [Ref. ISC FEIS, Page 3.3-55]. After 2016 the volumes under Cumulative Analysis conditions continue to be less than for the Baseline.

At the 10th percentile level, the same comparative annual flow patterns occur. The 90th percentile flows under the Cumulative Analysis conditions vary higher or lower than the flows under the Baseline for Cumulative Analysis during the fall and winter seasons. However, the plots do not exhibit a significant difference between the Cumulative Analysis conditions and the Baseline for Cumulative Analysis conditions. At the 90th percentile level flows are dominated by surplus water deliveries and flood flows.

Figure 3.3-16, shows the cumulative distribution of annual flow volumes for year 2016.

Figures 3.3-17 (a-d) present comparisons of the representative seasonal flows under Baseline for Cumulative Analysis conditions and the Cumulative Analysis for 2016. As expected, the largest flows occur in the spring and summer seasons under the Baseline for Cumulative Analysis and Cumulative Analysis conditions due to downstream irrigation demands. The seasonal flows of the Cumulative Analysis conditions are slightly lower than those of the Baseline for Cumulative Analysis conditions. For flows that are due primarily to flood control releases from Lake Mead (flows in the 80th - 100th percentile range), the seasonal flows under the Cumulative Analysis conditions vary higher or lower than the flows under the Baseline for Cumulative Analysis during

the fall and winter seasons. However, the range of the seasonal flows is not affected by the Cumulative Analysis.

A numerical comparison of the 70th percentile seasonal flow values is shown on Table 3.3-11. The values tabulated are the mean monthly flows in January, April, July and October.

Table 3.3-11
Comparison of Mean Monthly Flow Data – Baseline for Cumulative Analysis and Cumulative Analysis
Colorado River Upstream of CRIR Diversion (River Mile = 180.8)
70th Percentile Values for Year 2016

Season (Representative Month)	Mean Monthly Flows (cfs) for Year 2016 at the 70th Percentile	
	Baseline for Cumulative Analysis	Cumulative Analysis
Winter (January)	4,090	3,835
Spring (April)	12,009	11,455
Summer (July)	13,307	12,841
Fall (October)	8,119	7,825

Figure 3.3-15
Colorado River Upstream of CRIR Diversion Annual Flow Volume (af)
Comparison of Implementation Agreement to Baseline for Cumulative Analysis Conditions
90th, 50th and 10th Percentile Values

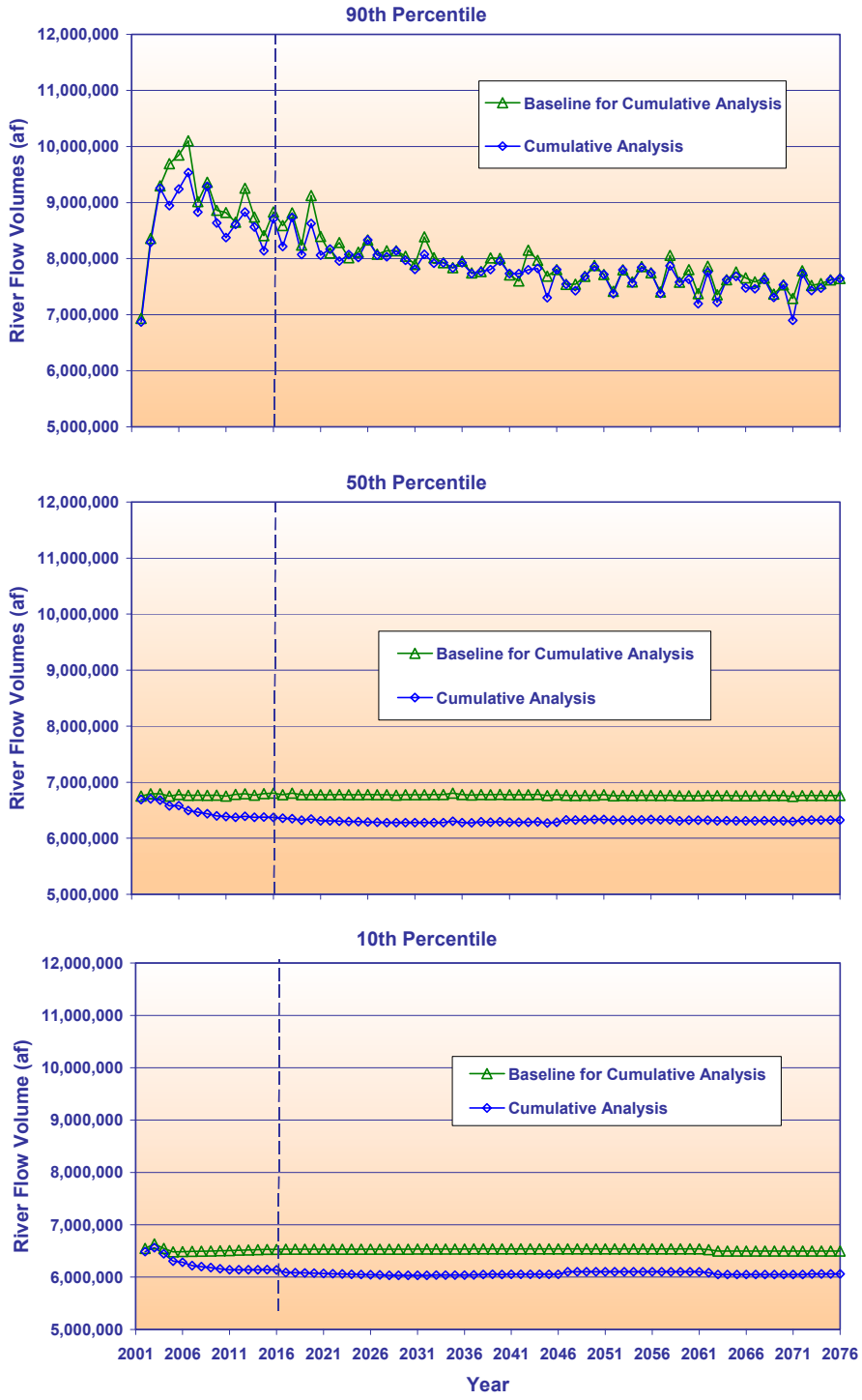


Figure 3.3-16
Colorado River Annual Flow Volumes Upstream of Colorado River Indian Reservation
Comparison of Cumulative Analysis to Baseline for Cumulative Analysis Conditions for Modeled Year 2016

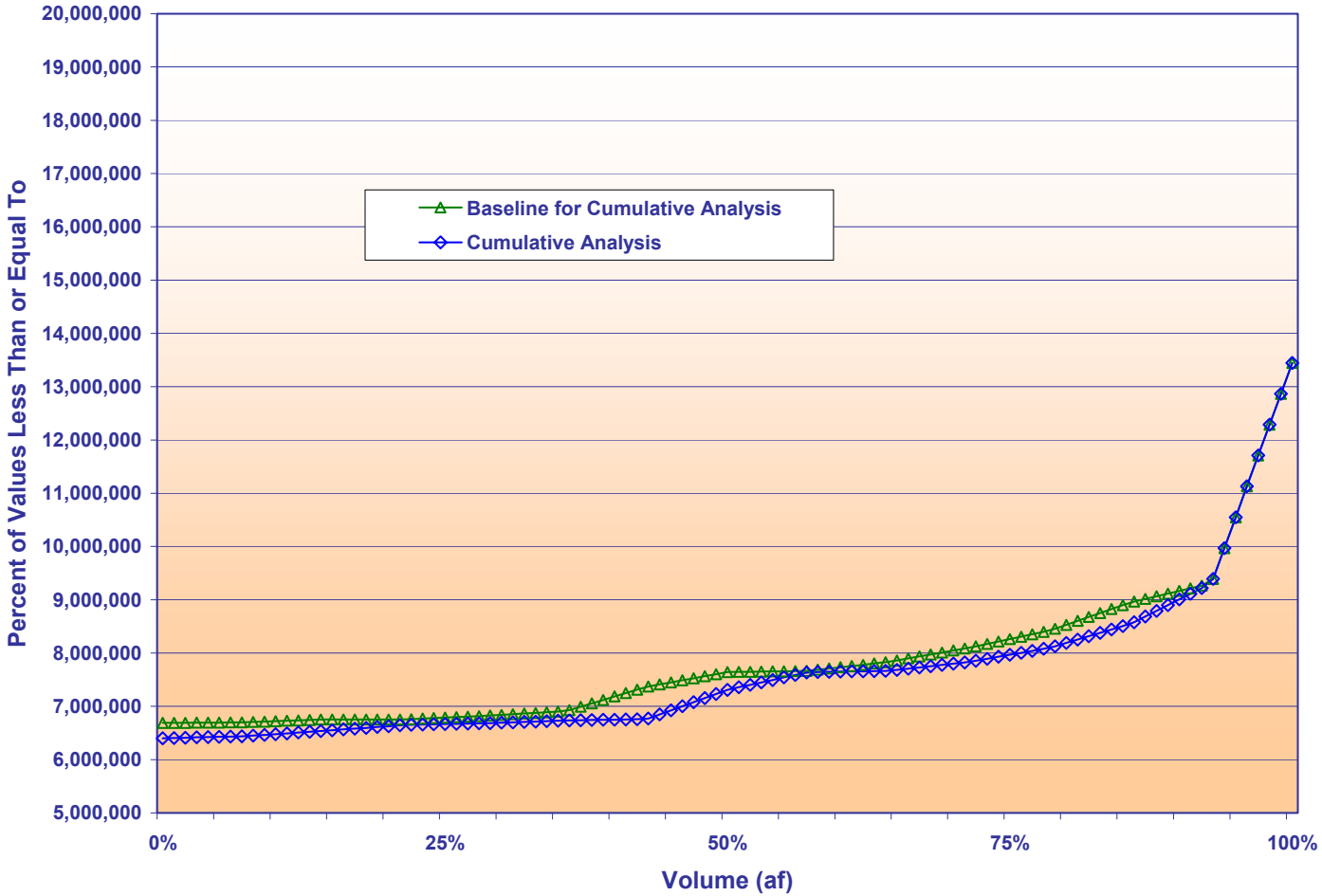


Figure 3.3-17a
Colorado River Seasonal Flows Upstream of Colorado River Indian Reservation
Comparison of Cumulative Analysis to Baseline for Cumulative Analysis Conditions for Modeled Year 2016

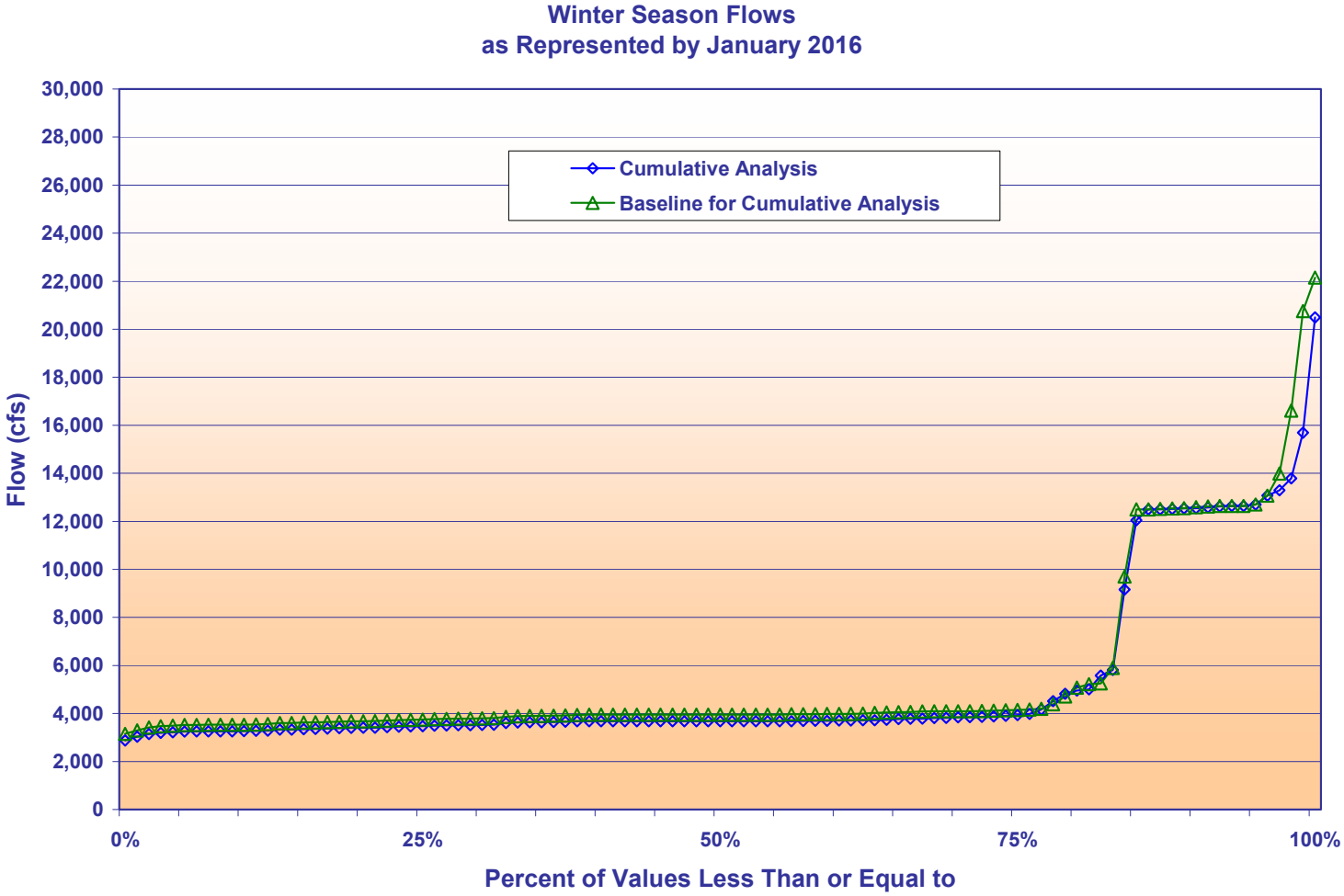


Figure 3.3-17b
Colorado River Seasonal Flows Upstream of Colorado River Indian Reservation
Comparison of Cumulative Analysis to Baseline for Cumulative Analysis Conditions for Modeled Year 2016

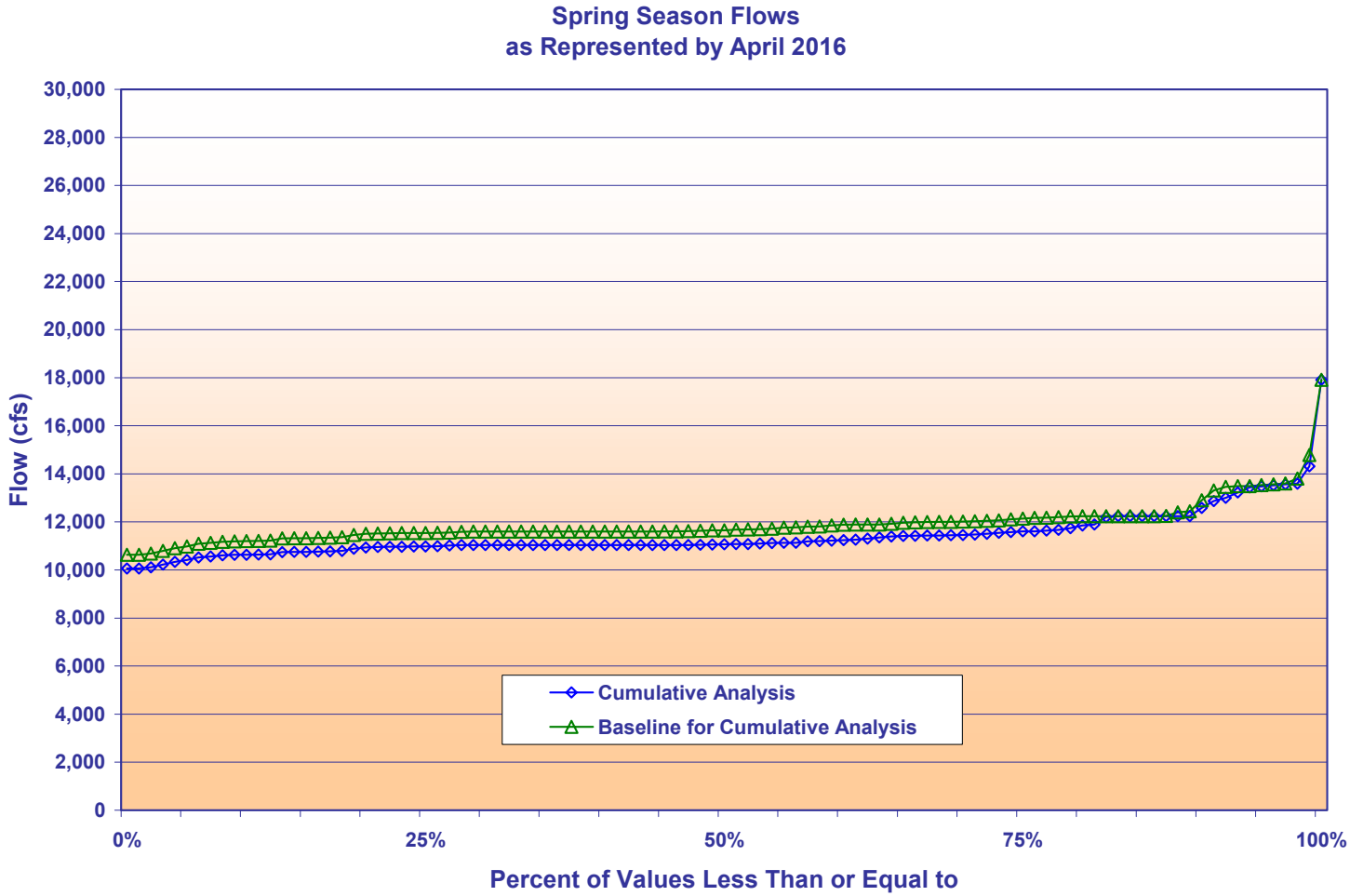


Figure 3.3-17c
Colorado River Seasonal Flows Upstream of Colorado River Indian Reservation
Comparison of Cumulative Analysis to Baseline for Cumulative Analysis Conditions for Modeled Year 2016

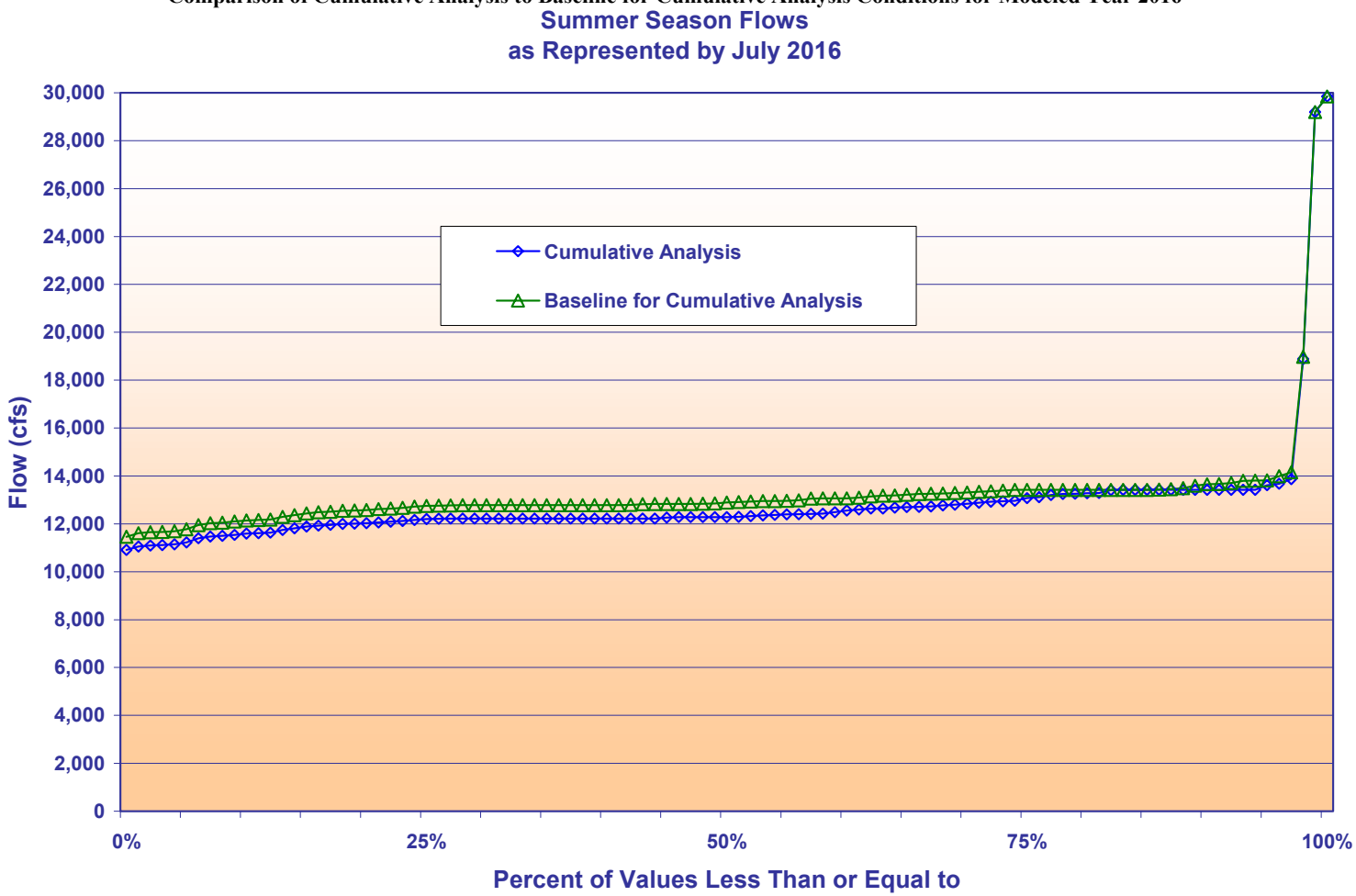
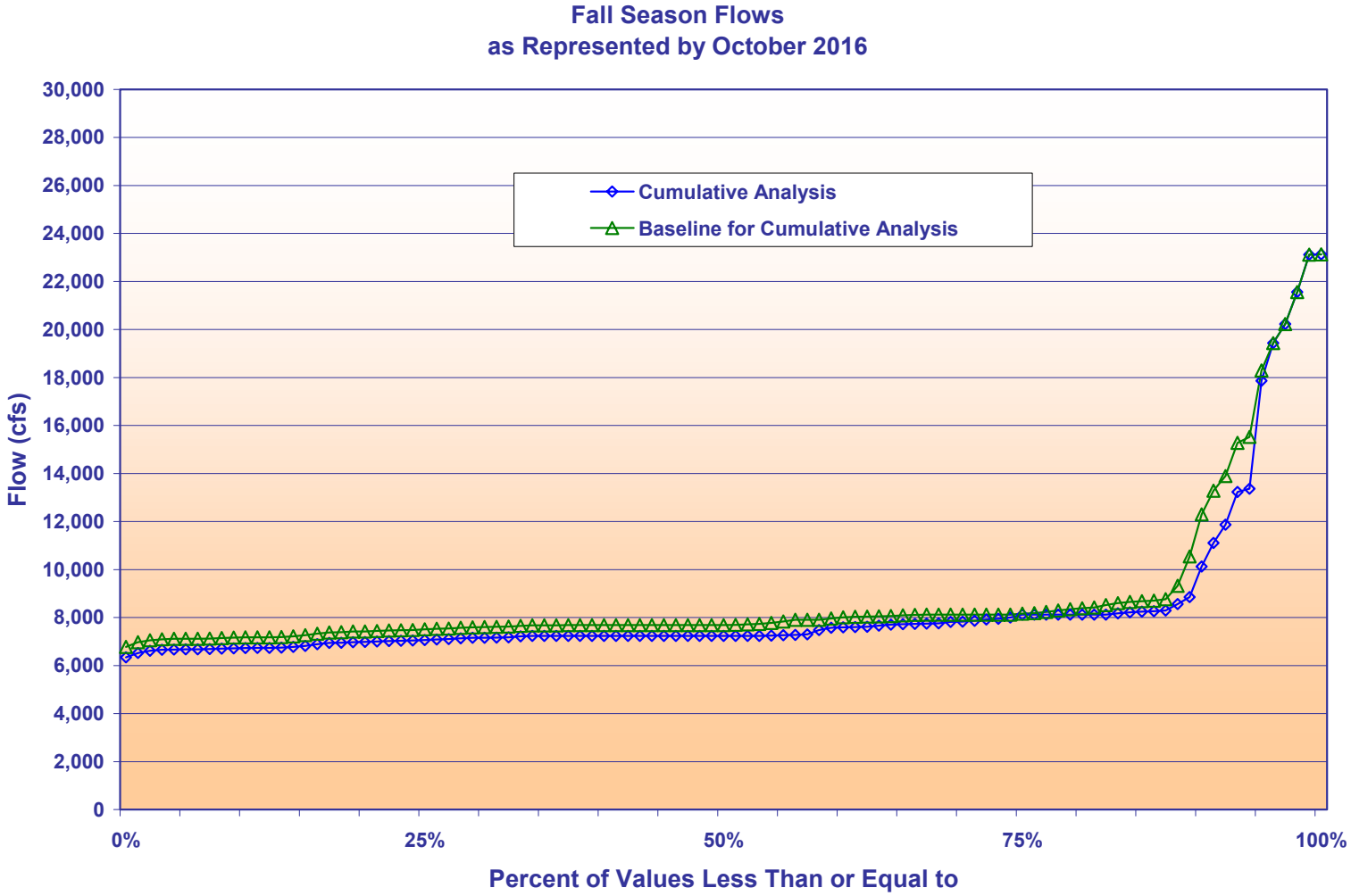


Figure 3.3-17d
Colorado River Seasonal Flows Upstream of Colorado River Indian Reservation
Comparison of Implementation Agreement to Baseline for Cumulative Analysis Conditions for Modeled Year 2016



3.3.4.3 RIVER FLOWS BETWEEN PALO VERDE DIVERSION DAM AND IMPERIAL DAM

The flow of the Colorado River between Palo Verde Diversion Dam and Imperial Dam is normally set at the amount needed to meet the United States diversion requirements downstream of the Palo Verde Diversion plus deliveries to Mexico. The river location that was modeled for this reach of the river is located immediately downstream of the Palo Verde Diversion Dam.

Future flows in this reach would be affected by the Cumulative Analysis because the proposed water transfers and exchanges between the California agricultural water agencies and MWD would change the point of diversion from the river. For example, under a potential transfer between IID and MWD (or SDCWA), the water that would normally be diverted at Imperial Dam would now be diverted above Parker Dam.

The 90th, 50th, and 10th percentile annual flow volumes for this reach are shown in Figure 3.3-18. As shown by the 50th percentile values, the modeled annual flow volumes in this reach under the Cumulative Analysis decline gradually between 2002 and 2016, as the water transfers take effect and certain amounts of California's water are diverted from Lake Havasu rather than at Imperial Dam. After 2016 the annual flow conditions would remain lower than under the baseline. The difference results primarily from the proposed Implementation Agreement (See Section 3.2.4.3), augmented to a minor degree by the effect of the additional proposed water transfer in the cumulative analysis. The interim surplus guidelines do not affect this section of river significantly

At the 10th percentile level, the same comparative annual flow patterns occur. The 90th percentile flows under the Cumulative Analysis conditions vary higher or lower than the flows under the Baseline for Cumulative Analysis during the fall and winter seasons. However, the plots do not exhibit a significant difference between the Cumulative Analysis conditions and the Baseline for Cumulative Analysis conditions. At the 90th percentile level, flows are dominated by surplus water deliveries and flood flows.

Figure 3.3-19, shows the cumulative distribution of annual flow volumes for year 2016.

Figures 3.3-20 (a-d) present comparisons of the representative seasonal flows under Baseline for Cumulative Analysis conditions and the Cumulative Analysis for 2016. As expected, the largest flows occur in the spring and summer seasons under the Baseline for Cumulative Analysis and Cumulative Analysis conditions due to downstream irrigation demands. The seasonal flows under the Cumulative Analysis are slightly lower than those under Baseline for Cumulative Analysis conditions. For flows that are due primarily to flood control releases from Lake Mead (flows in the 80th - 100th percentile range), the range of mean monthly flows is not affected by the Cumulative Analysis, since these magnitudes are dictated by the flood control regulations. In the lower percentiles, the seasonal flows with the Cumulative Analysis are slightly lower

than the flows under Baseline for Cumulative Analysis conditions (from six to 11 percent lower in various seasons in 2016).

A numerical comparison of the 70th percentile seasonal flow values is shown on Table 3.3-12. The values tabulated are the mean monthly flows in January, April, July and October.

Table 3.3-12
Comparison of Mean Monthly Flow Data – Baseline for Cumulative Analysis and Cumulative Analysis
Colorado River Downstream of Palo Verde Diversion Dam (River Mile = 133.8)
70th Percentile Values for Year 2016

Season (Representative Month)	Mean Monthly Flows (cfs) for Year 2016 at the 70th Percentile	
	Baseline for Cumulative Analysis	Cumulative Analysis
Winter (January)	3,695	3,420
Spring (April)	10,202	9,633
Summer (July)	11,008	10,458
Fall (October)	7,444	7,003

Figure 3.3-18
Colorado River Downstream of Palo Verde Diversion Dam Annual Flow Volume (af)
Comparison of Cumulative Analysis to Baseline for Cumulative Analysis Conditions
90th, 50th and 10th Percentile Values

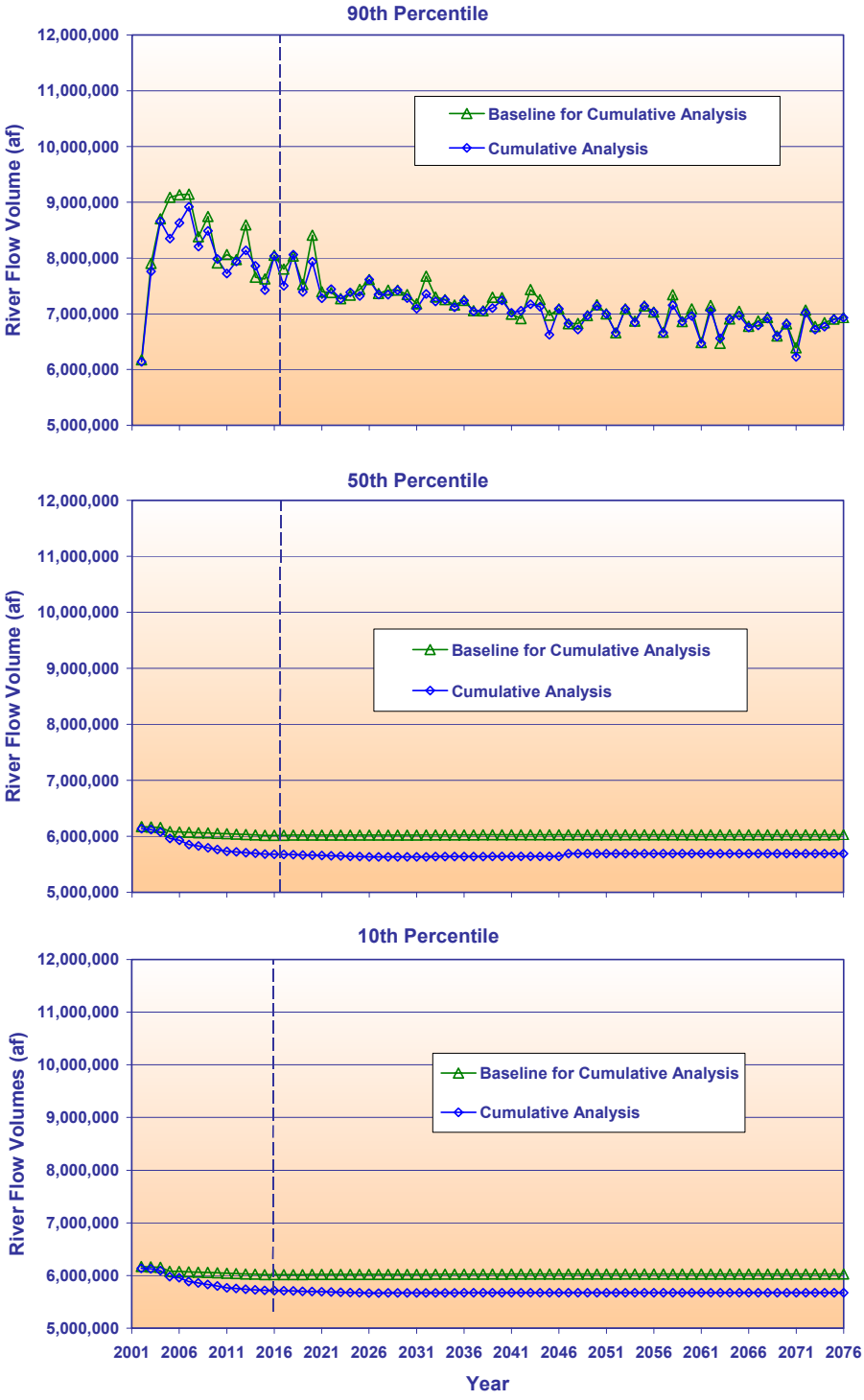


Figure 3.3-19
Colorado River Annual Flow Volumes Downstream of Palo Verde Irrigation Diversion
Comparison of Cumulative Analysis to Baseline for Cumulative Analysis Conditions for Modeled Year 2016

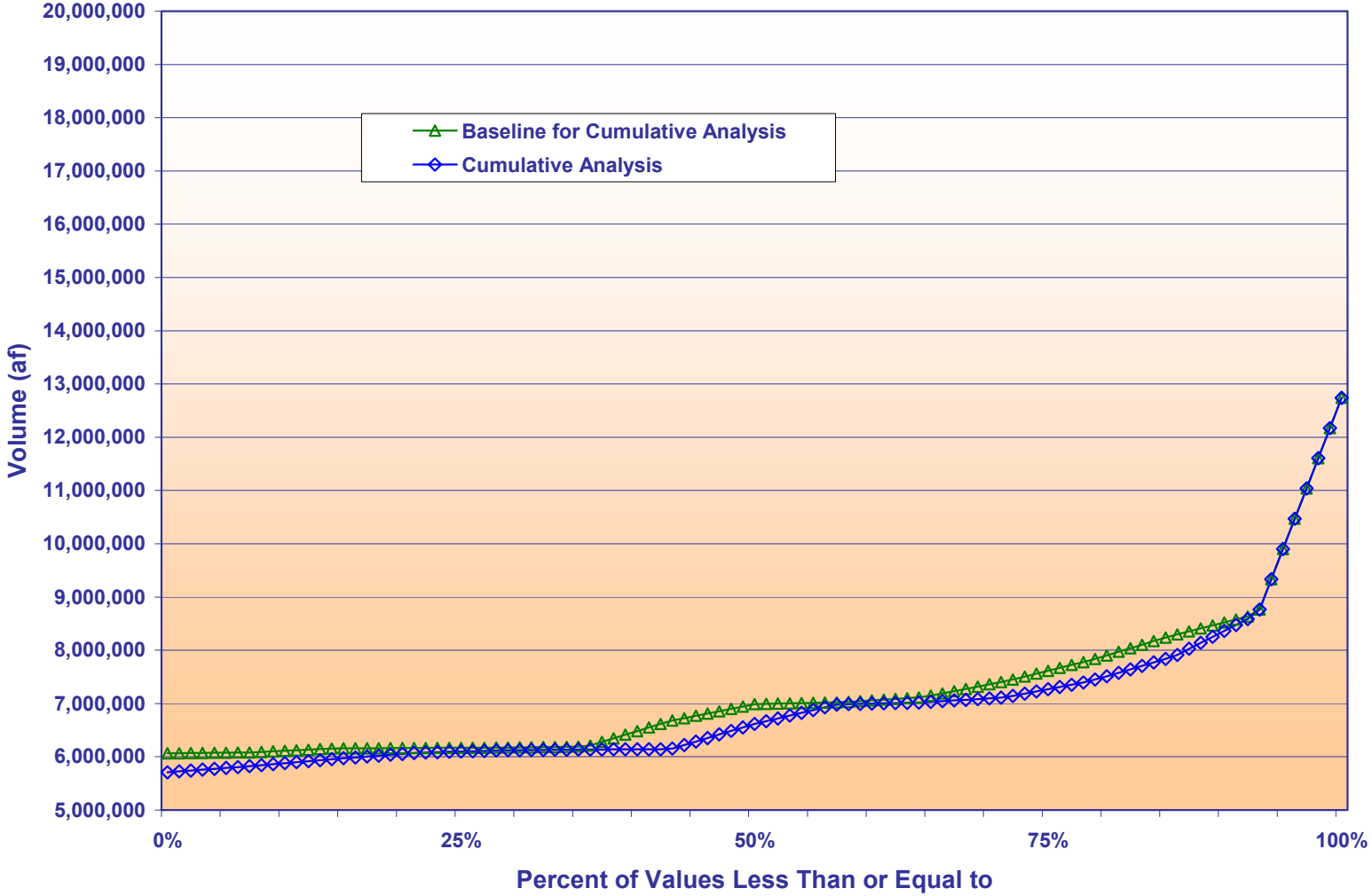


Figure 3.3-20a
Colorado River Seasonal Flows Downstream of Palo Verde Diversion Division
Comparison of Cumulative Analysis to Baseline for Cumulative Analysis Conditions for Modeled Year 2016

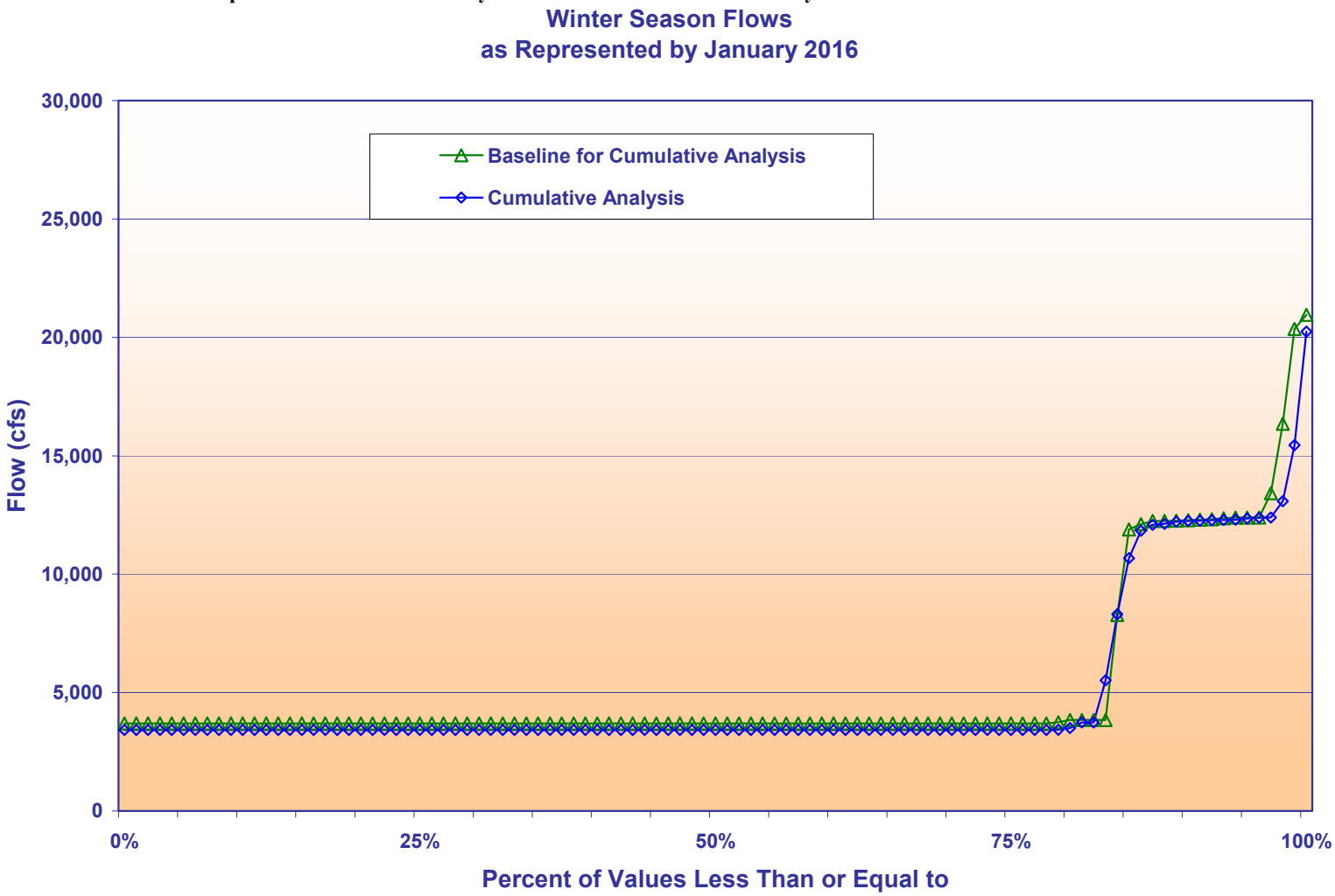


Figure 3.3-20b
Colorado River Seasonal Flows Downstream of Palo Verde Diversion Division
Comparison of Cumulative Analysis to Baseline for Cumulative Analysis Conditions for Modeled Year 2016

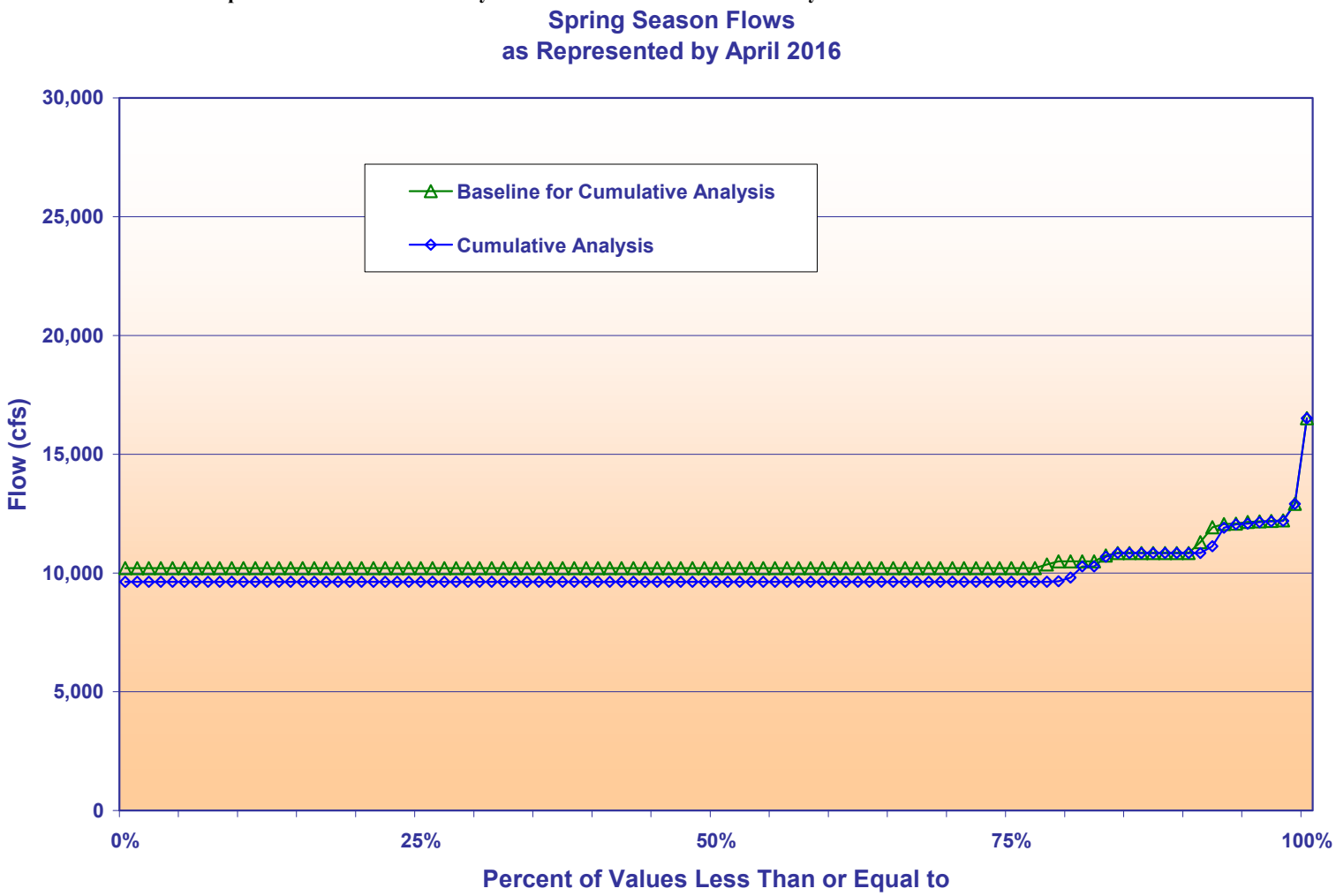


Figure 3.3-20c
Colorado River Seasonal Flows Downstream of Palo Verde Diversion Division
Comparison of Cumulative Analysis to Baseline for Cumulative Analysis Conditions for Modeled Year 2016

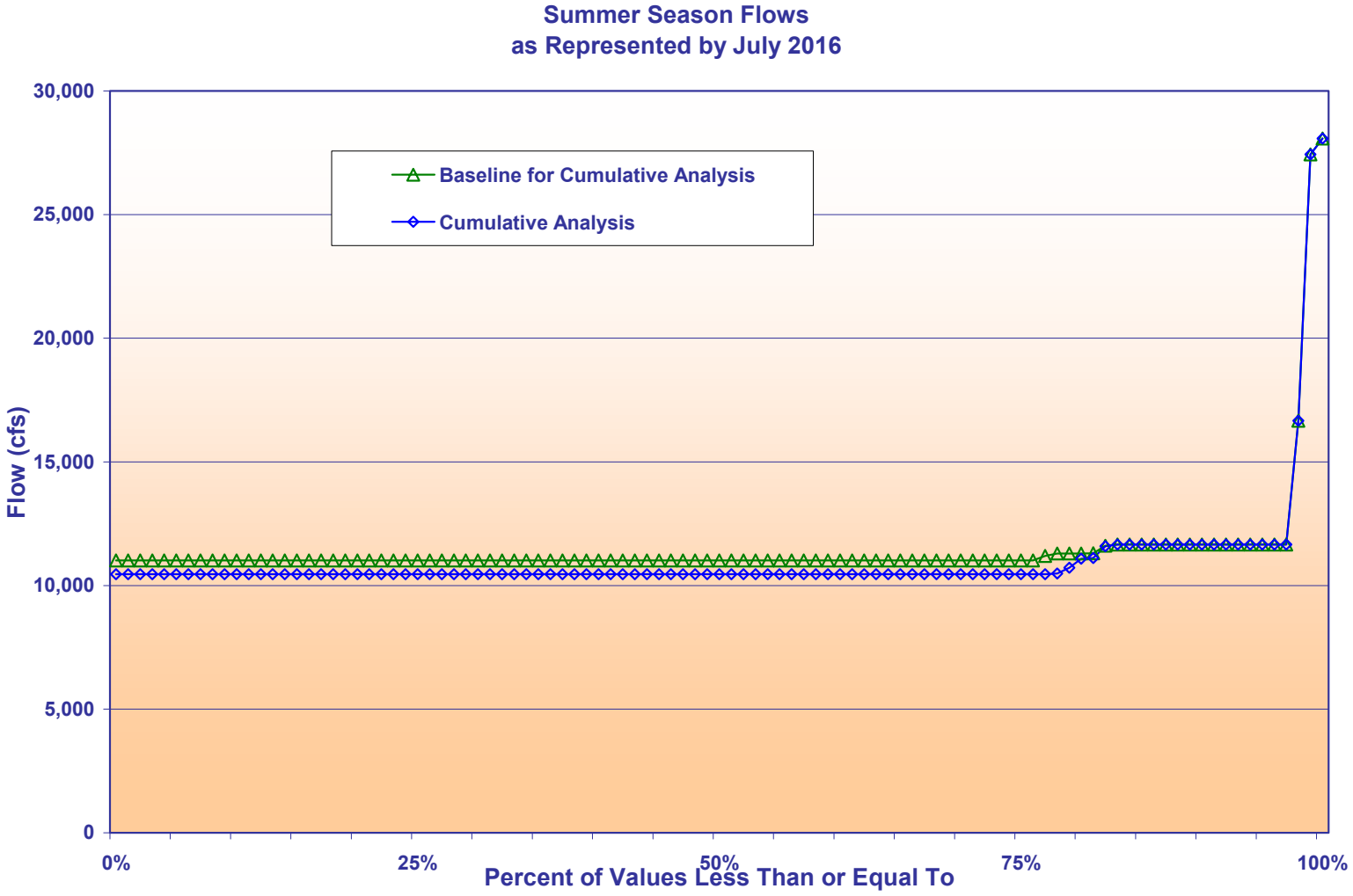
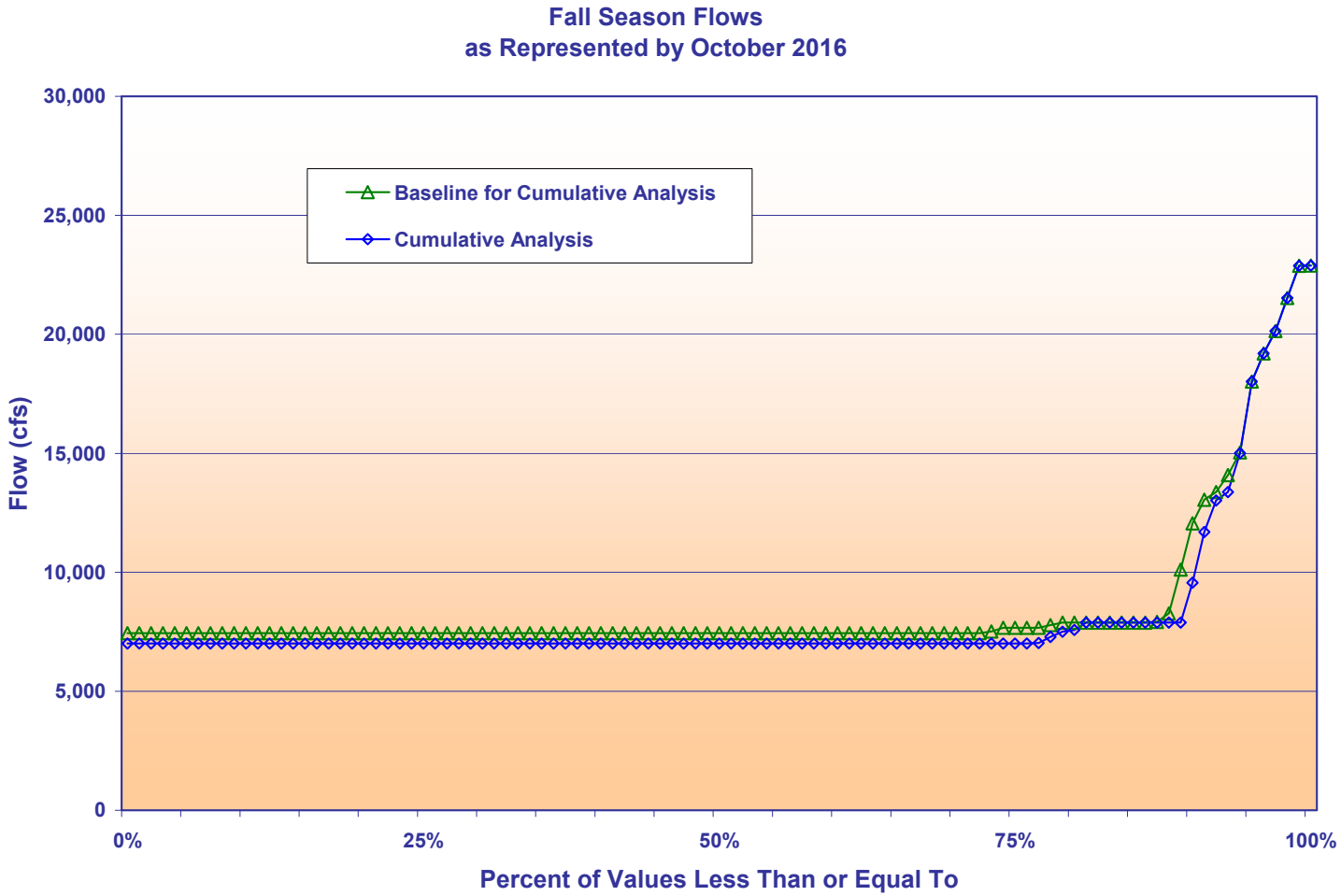


Figure 3.3-20d
Colorado River Seasonal Flows Downstream of Palo Verde Diversion Division
Comparison of Cumulative Analysis to Baseline for Cumulative Analysis Conditions for Modeled Year 2016



3.3.4.4 RIVER FLOWS BETWEEN IMPERIAL DAM AND MORELOS DAM

As explained in Section 3.2.4.4, the flows in the Colorado River below Imperial Dam consist primarily of the water delivered to Mexico in accordance with the provisions of the US-Mexican Water Treaty of 1944. Mexico's principal diversion is at Morelos Dam, which is located approximately nine miles southwest of Yuma, Arizona.

As discussed in Section 2.3, the model accounts for all deliveries to Mexico as diversions at the NIB (Morelos Dam). Flows that are modeled downstream of Morelos Dam represent mean monthly flows that are excess flows in the Colorado River due to Lake Mead flood control releases. These excess flows may reach the Colorado River Delta, although Mexico has the authority to divert them for other uses. Such decisions by Mexico are not modeled as they are not known. The excess flows are over and above Mexico's normal 1.5 mafy water entitlement plus the 200,000 afy of surplus delivery when available.

The 90th, 50th, and 10th percentile annual flow volumes for this reach are shown in Figure 3.3-21. Since these flows are dependent solely upon infrequent flood control releases, no flows are observed at either the 10th or 50th percentiles. At the 90th percentile level, the Implementation Agreement produces a pattern of annual flow volumes similar to that produced by No Action conditions, with the Implementation Agreement values occasionally being slightly higher or slightly lower than the No Action values.

Figure 3.3-22 shows the cumulative distribution of annual flow volumes for year 2016.

Figures 3.3-23 (a-d) present comparisons of the representative seasonal flows under Baseline for Cumulative Analysis conditions and the Cumulative Analysis for 2016. As expected, the only differences seen for flows are due to flood control releases from Lake Mead (flows in the 80th – 100th percentile range). As seen in the figures, where the Cumulative Analysis flows differ significantly from the Baseline for Cumulative Analysis flows, the Cumulative Analysis flows are lower than Baseline flows. This is primarily caused by the interim surplus guidelines in effect from 2002 to 2016.

A numerical comparison of the 90th percentile seasonal flow values is shown on Table 3.3-13. The values tabulated are the mean monthly flows in January, April, July and October.

Table 3.3-13
Comparison of Mean Monthly Flow Data – Baseline for Cumulative Analysis and Cumulative Analysis
Colorado River Downstream of Morelos Dam (River Mile = 23.1)
90th Percentile Values (cfs) for Year 2016

Season (Representative Month)	Mean Monthly Flows (cfs) for Year 2016 at the 90th Percentile	
	Baseline for Cumulative Analysis	Cumulative Analysis
Winter (January)	8,384	8,346
Spring (April)	0	0
Summer (July)	0	0
Fall (October)	4,176	1,679

Figure 3.3-21
Colorado River Below Mexico Diversion at Morelos Dam Annual Flow Volume (af)
Comparison of Cumulative Analysis to Baseline for Cumulative Analysis Conditions
90th, 50th and 10th Percentile Values

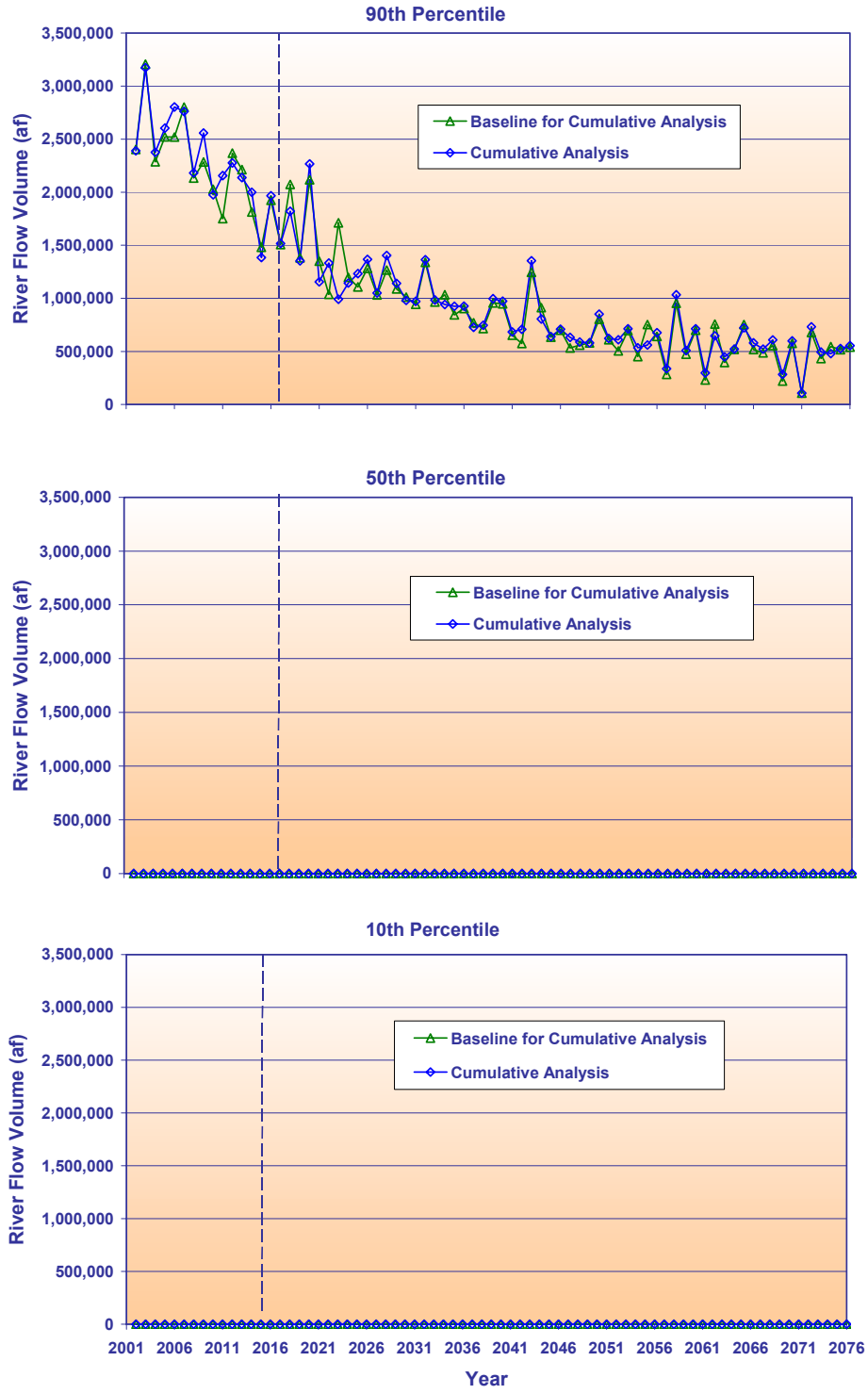


Figure 3.3-22
Colorado River Annual Flow Volumes Below Mexico Diversion at Morelos Dam
Comparison of Cumulative Analysis to Baseline for Cumulative Analysis Conditions for Modeled Year 2016

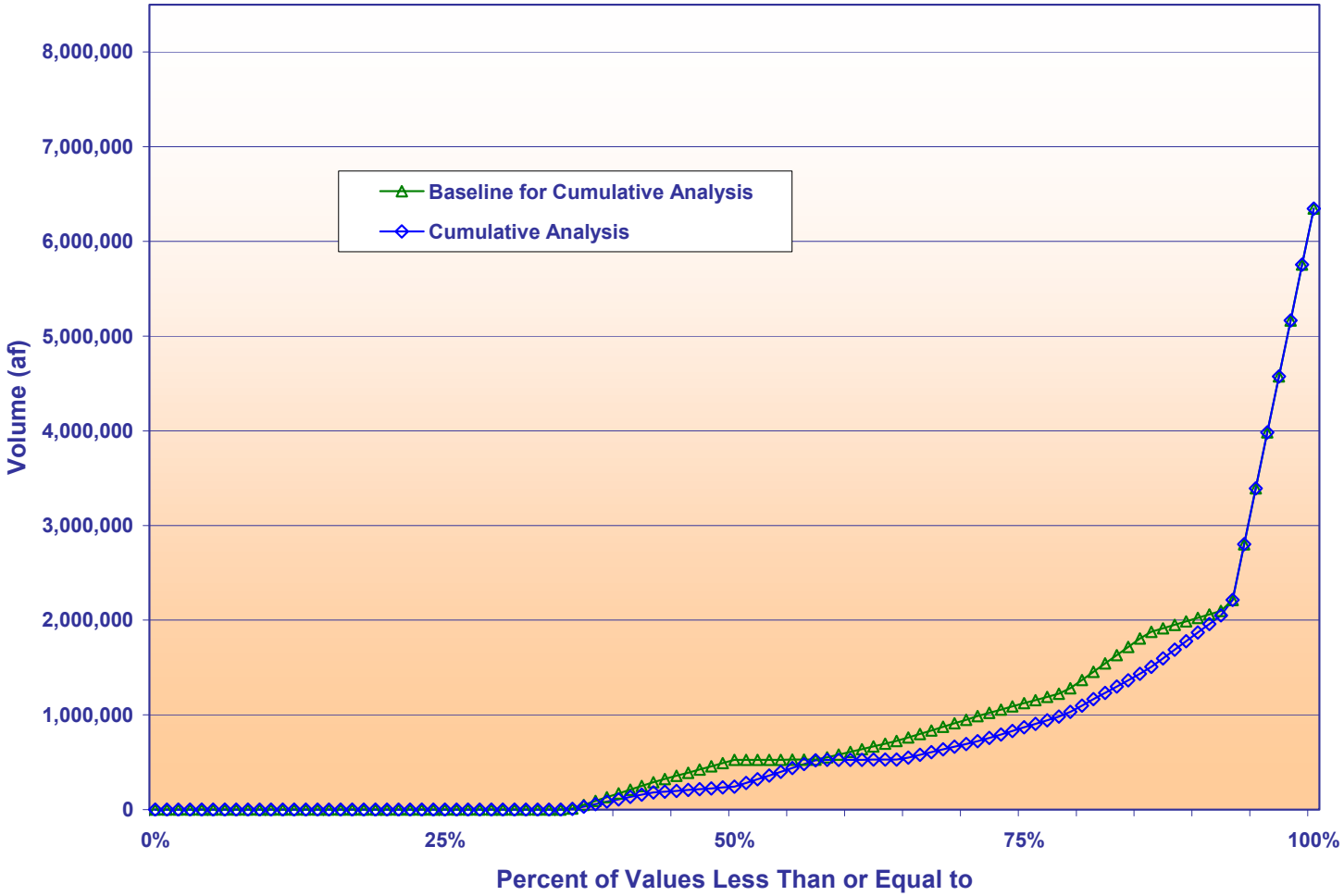


Figure 3.3-23a
Colorado River Seasonal Flows Below Mexico Diversion at Morelos Dam
Comparison of Cumulative Analysis to Baseline for Cumulative Analysis Conditions for Modeled Year 2016

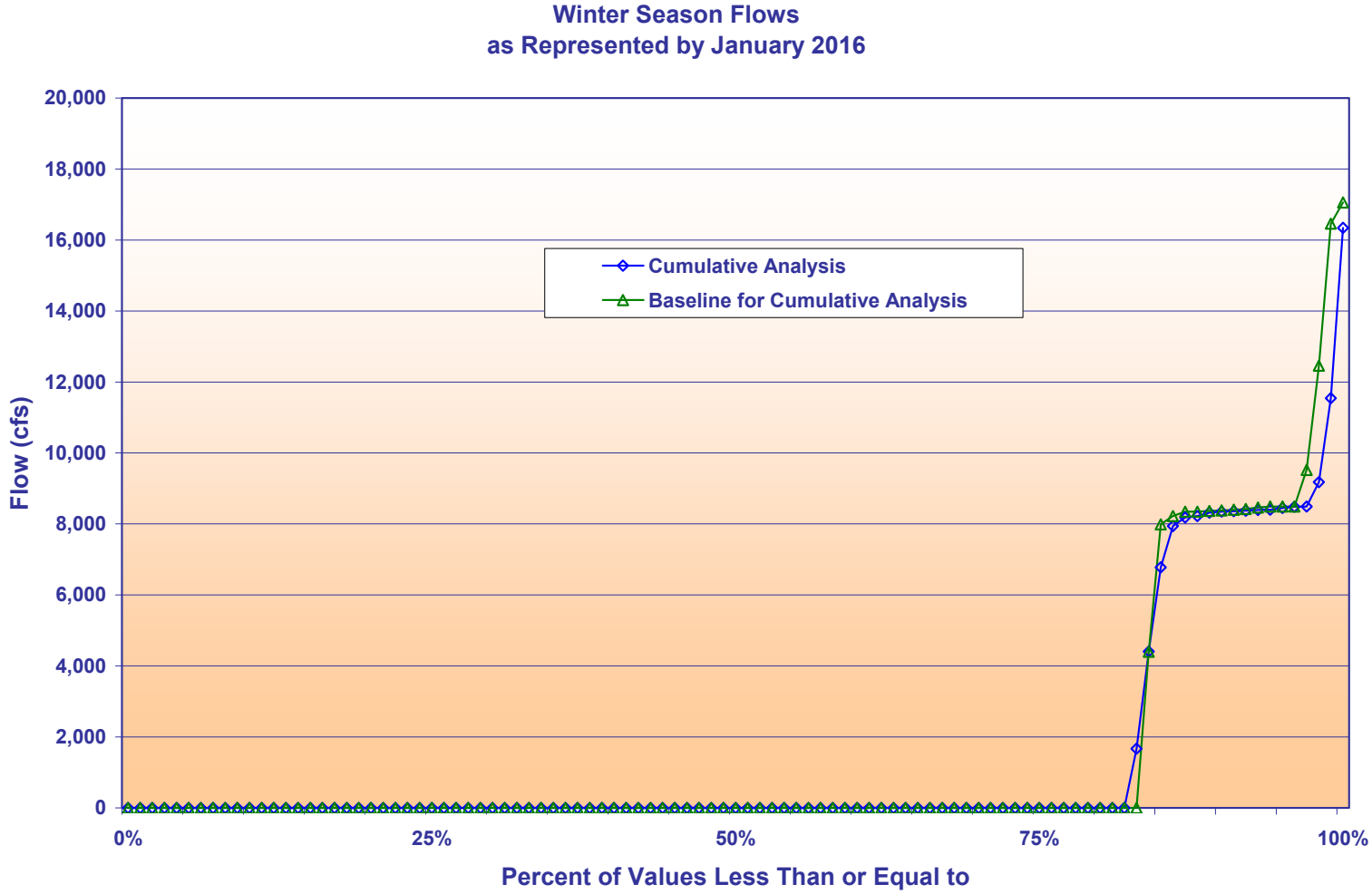


Figure 3.3-23b
Colorado River Seasonal Flows Below Mexico Diversion at Morelos Dam
Comparison of Cumulative Analysis to Baseline for Cumulative Analysis Conditions for Modeled Year 2016

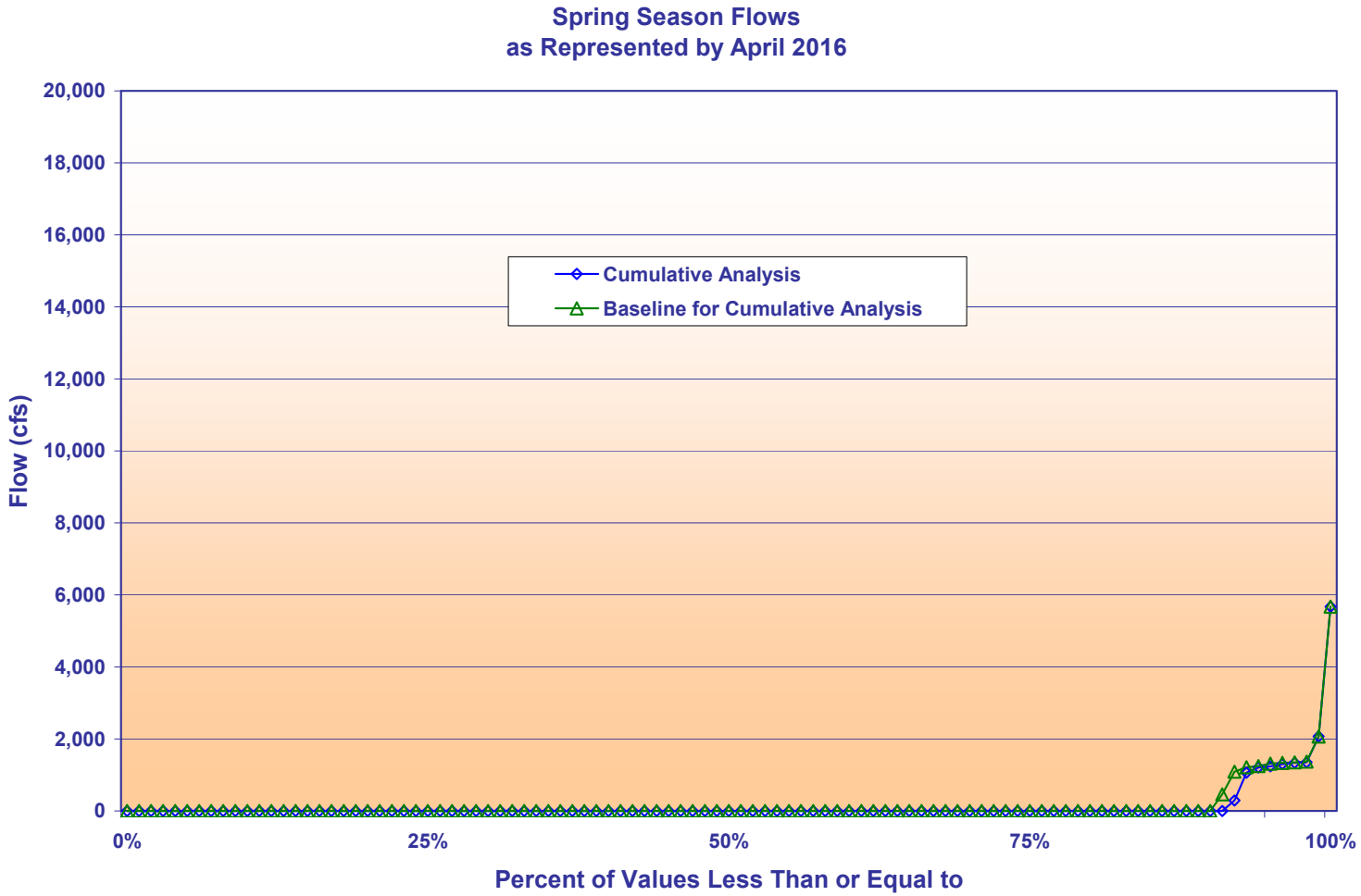


Figure 3.3-23c
Colorado River Seasonal Flows Below Mexico Diversion at Morelos Dam
Comparison of Cumulative Analysis to Baseline for Cumulative Analysis Conditions for Modeled Year 2016

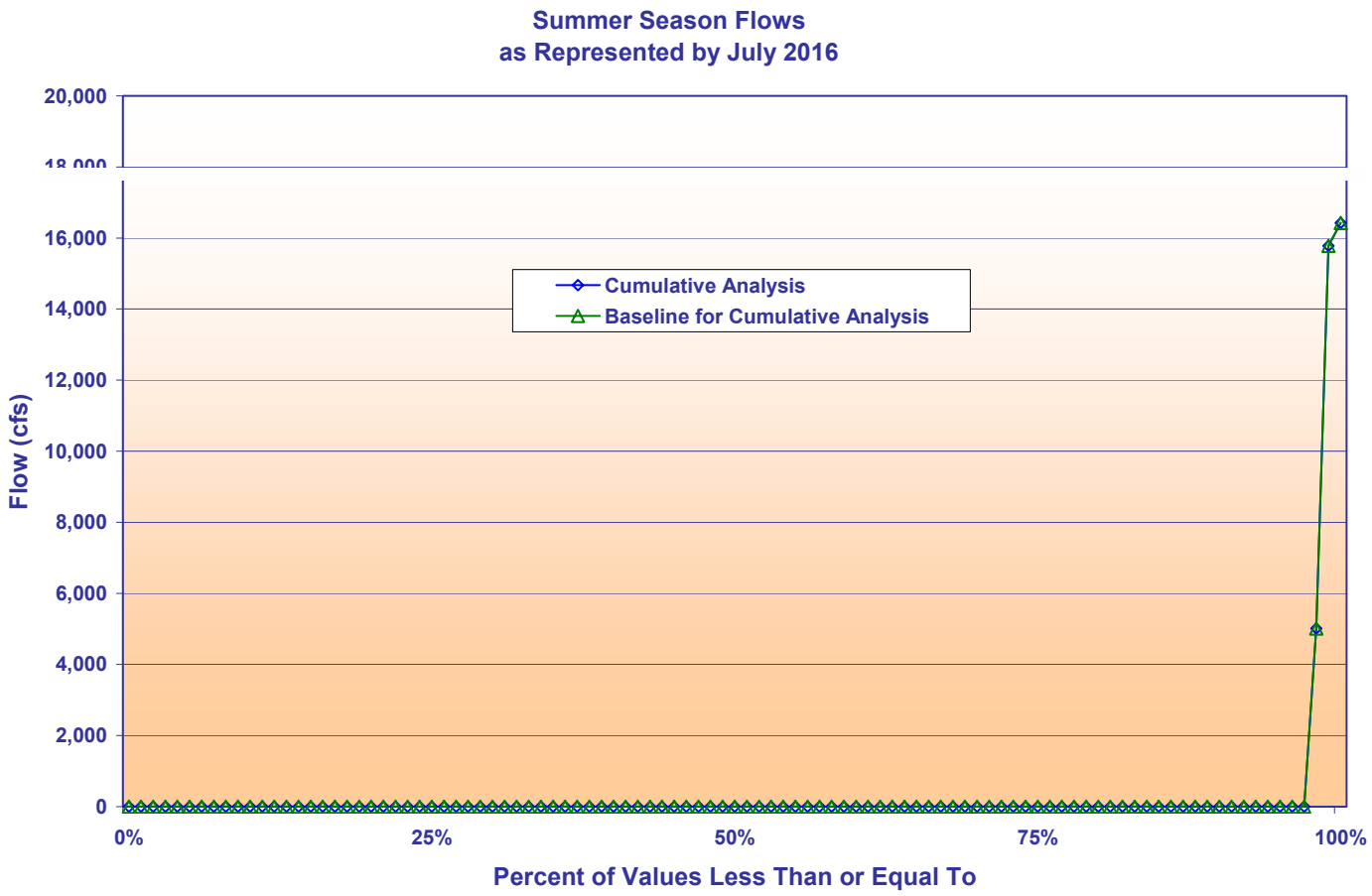
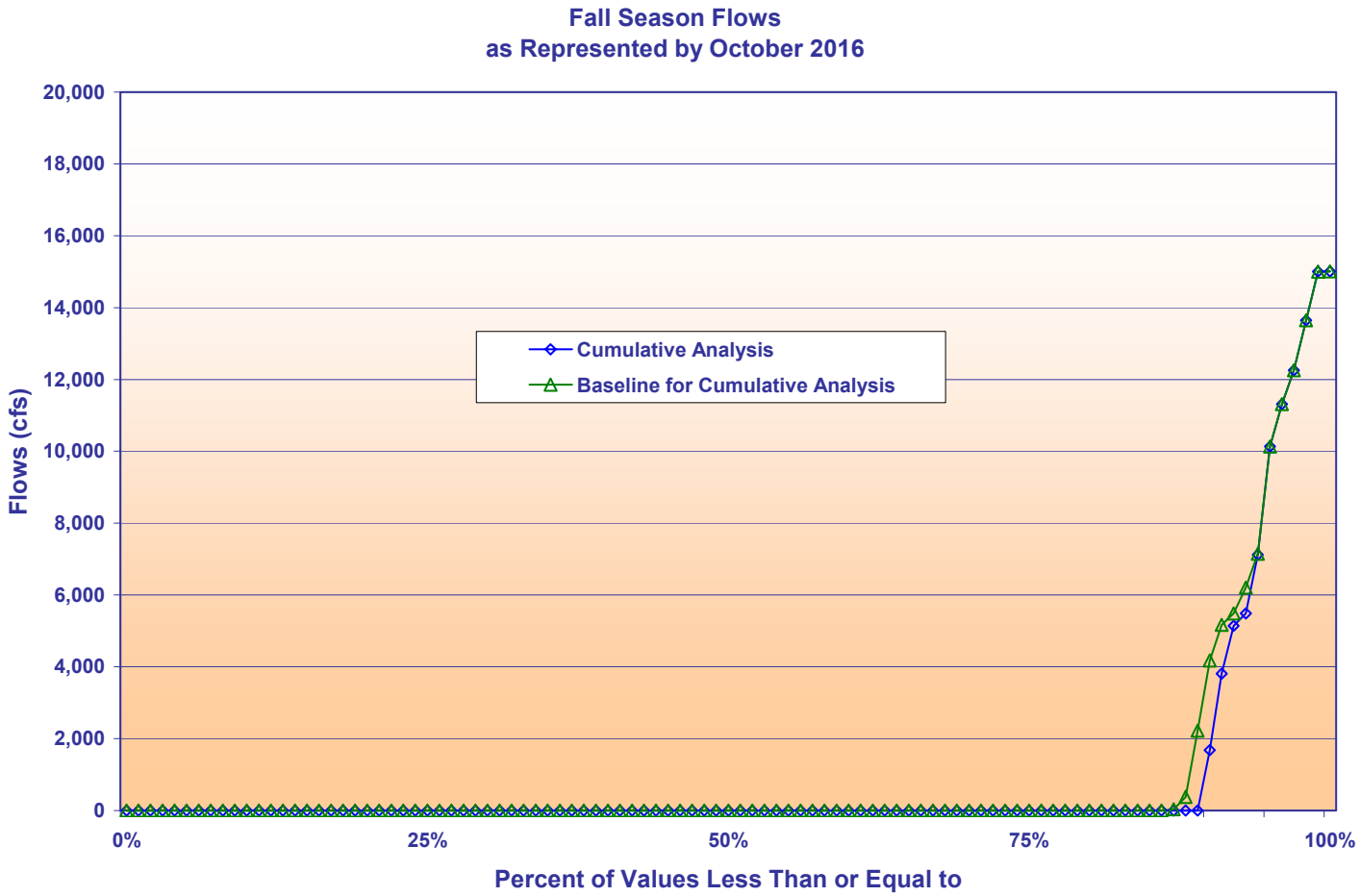


Figure 3.3-23d
Colorado River Seasonal Flows Below Mexico Diversion at Morelos Dam
Comparison of Cumulative Analysis to Baseline for Cumulative Analysis Conditions for Modeled Year 2016



4.0 WATER SUPPLY

4.1 INTRODUCTION

This section discusses the water supply available to the Lower Division states and Mexico under the four operational scenarios modeled. It provides an evaluation of the effectiveness of meeting the water delivery objectives previously articulated by the Lower Division states and notes the states' contingency plans in the event of shortages. Water supply deliveries are the deliveries of Colorado River water by Reclamation to entities in the seven Basin States and Mexico, consistent with the *Law of the River*, as discussed in Section 1.1.

As with the previous river operations analysis, the water supply is also presented in the form of two different analyses. Section 4.5 provides a summary of the analysis that evaluates the potential effects of water transfers on water supply. Section 4.6 provides a summary of the cumulative analysis that evaluates the potential effects of the various proposed water management programs on water supply.

4.2 METHODOLOGY

The model was used to produce estimates of future water supply deliveries for the Lower Division states and Mexico under the four modeled operational scenarios. The modeled water demands of the Lower Division states reflect demand projections provided by the water users. The demand schedules used to model the Lower Division States' normal depletions are included in Attachment A of this Technical Memorandum. The demand schedule used to model the Upper Division states' depletions is included in Attachment B of this Technical Memorandum.

The output from each model run included monthly and annual diversions, return flows and depletions for the Colorado River water users in acre-feet (af). The water supply data was analyzed using statistical methods as discussed in Section 2.6. The analysis of water transfers (Section 4.5) focused upon the comparison of the model results of the No Action to those of the Implementation Agreement conditions. The analysis of cumulative effects (Section 4.6) focused upon the comparison of the model results of the Baseline for Cumulative Analysis to those of the Cumulative Analsysis conditions. See Section 2.0 for a further explanation of the modeling process and assumptions.

The data evaluated consisted principally of data relating to the amount of water available for consumptive use in the Lower Division states under the four modeled scenarios during the 75-year period of analysis. Because differences between the modeled scenarios are at times small in relation to the quantities and time periods, it was necessary to compare the data in precise terms. However, it should be noted results described below represent approximations of probable future conditions that become increasingly uncertain over time.

The time period for the analysis is 2002 through 2076. The analysis is based on depletion schedules for those years provided by the states and Tribes.

Protection was provided for the water level of Lake Mead at elevation 1083 feet msl and elevation 1000 feet msl by imposing shortages. As discussed earlier in Section 2.4, the elevation of 1083 feet msl is assumed to be the lowest elevation at which the Hoover Powerplant can produce power efficiently and the elevation of 1000 feet msl is assumed to be the lowest that the secondary SNWA intake can operate.

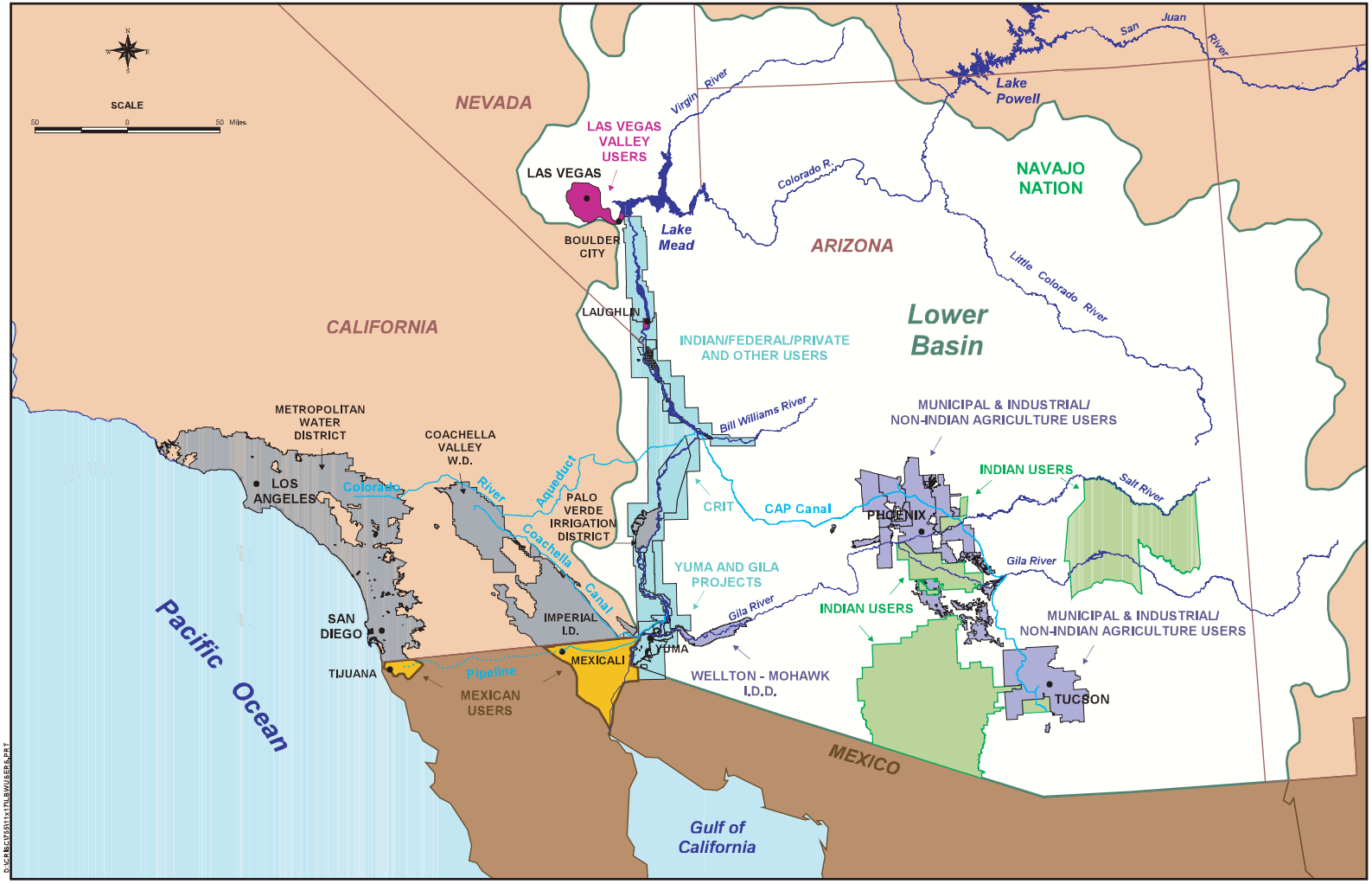
The results are portrayed graphically in two ways. As discussed in section 2.5, the modeling process involved making 85 separate runs (traces) which were then examined for the range of water supply available in a given year under each of the four modeled scenarios. One way that these results can be portrayed graphically is to plot the 90th percentile values (meaning that 90 percent of the values produced by the model were less than that value), the 50th percentile values (the median value) and the 10th percentile values (meaning that 10 percent of the values produced by the model were less than that value). Plots of the maximum and minimum depletion values produced by the model for any given year were added to this "90-50-10" array. Plots for the Lower Division states and Mexico under the four modeled scenarios are presented in this section.

A second way that the results are portrayed is derived by first ranking all the annual values for a desired period, e.g., the 15-year interim surplus guidelines period (2002 through 2016), the subsequent 60-year period (2017 through 2076) and the entire 75-year period of analysis (2002 through 2076). The annual depletion values can then be plotted versus the percent of values that are greater than or equal to. This type of plot provides a distribution of the respective state's depletion and allows for a generalized comparison of the water supply available under each respective modeled scenario, for each period of time.

4.3 WATER SERVICE AREAS

Colorado River water diverted at or below Lake Mead is used in the states of Arizona, California, and Nevada, and in Mexico. Map 4.3-1 presents the water service areas in the Lower Basin.

Map 4.3-1
Colorado River Water Service Areas in the Lower Basin



4.4 WATER USE PROJECTION PROCESS

For the Upper Division States, estimates of future projected use to 2050 were taken from the ISC FEIS (USBR, 2000). Beyond 2050, the same value used for 2050 was used for years 2051 through 2076 (i.e., the Upper Division Water use was at "full development" by 2050). The schedules are presented in Attachment B.

For the Lower Division States, estimates of future projected use under normal conditions were also taken from the ISC FEIS. For the operational scenarios that include the QSA, these schedules were modified to reflect the assumed water transfers and extended appropriately. These schedules are detailed in Attachment A and reflect each state's annual water apportionment from the Colorado River.

Similarly, Lower Division States' surplus schedules for the Interim Surplus Guidelines (referred to as the "Basin States Plan" in the ISC FEIS) and the 70R strategy were taken from the ISC FEIS. These schedules are shown in Attachment C.

Finally, Lower Division Entities' Shortage amounts are computed within the model as described in Section 2.4.

The states' water delivery requests are distributed among the major diversion points along the river system (approximately 120 such points are modeled for all seven Basin States).

4.4.1 STATE OF ARIZONA

The portions of Arizona in the Lower Basin that depend on Colorado River mainstream water consist of the following areas:

- The lower Colorado River from Lake Mead to the SIB;
- The Gila River Valley upstream from Yuma, Arizona; and
- A large area in the central part of the state served by facilities of the CAP.

Under the Boulder Canyon Project Act of 1928 (BCPA) and the Supreme Court Decree, Arizona v. California, 1964 (Decree), Arizona receives on annual apportionment of 2.8 maf from the Lower Division states' total of 7.5 maf.

In addition, Arizona can also use up to 50,000 afy of water pumped from Lake Powell under the State's Upper Basin apportionment. Numerous districts and other entities that divert and distribute the water administer the contractual arrangements for the use of Colorado River water in Arizona. The Central Arizona Water Conservation District (CAWCD) administers the CAP water diversions. The Director of the Arizona Department of Water Resources has state statutory authority to represent the state in Colorado River water supply matters.

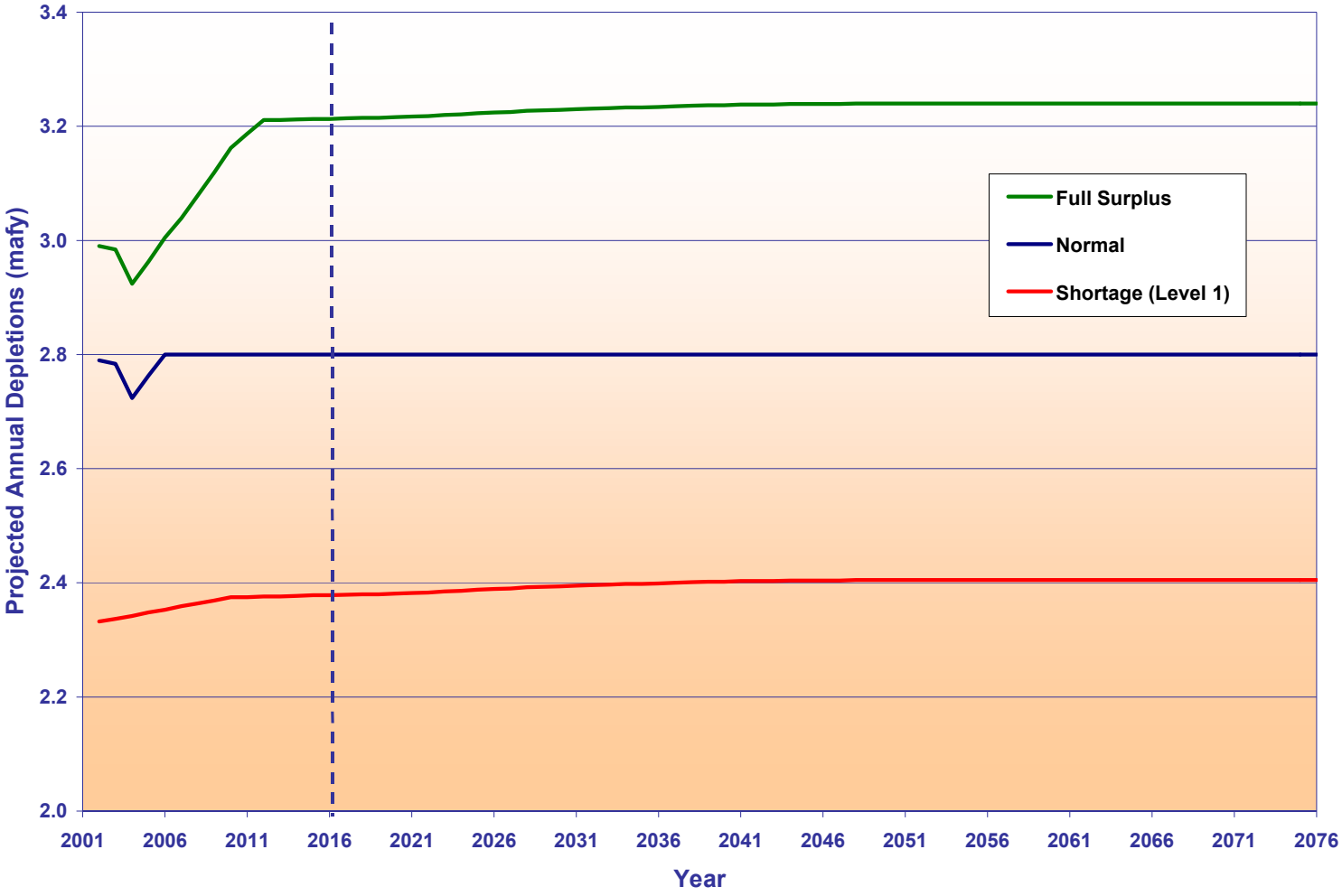
Arizona established the Arizona Water Banking Authority (AWBA) in 1996. The state legislation that authorized the AWBA states that it was created: 1) to increase Arizona's use of Colorado River water by delivering through the CAP system and storing water that otherwise would be unused by Arizona; 2) to ensure an adequate water supply to CAP municipal and industrial (M&I) users in times of shortages or disruptions of the CAP system; 3) to meet water management plan objectives of the Arizona state groundwater code; 4) to assist in settling Indian water rights claims; and 5) to provide an opportunity for authorized agencies in California and Nevada to store unused Colorado River water in Arizona for future use.

Arizona has numerous users of Colorado River water. The largest diversion of water is the CAP that delivers water to contractors in the central part of the state. CAP's diversion is located at Lake Havasu. The next three largest diversions are those of the Colorado River Indian Reservation at Headgate Rock Dam and the Gila and Yuma Projects, whose diversions are located at Imperial Dam. The remaining diversions serve irrigated areas and community development along the river corridor, including lands of the Fort Mojave Indian Reservation, water used by federal agencies in Arizona, the cities of Bullhead, Lake Havasu and Parker, Mojave Valley Irrigation District and Cibola Irrigation District. A portion of the water from the river corridor is also diverted by wells located along the river.

The CAP and other fourth priority Arizona users that contracted for Colorado River water after September 30, 1968, have the lowest priority. The exceptions are lower priority contractors that contracted for unused normal year entitlement and surplus year supplies when available. Included in the CAP category are Bullhead City, Lake Havasu City, Mojave Valley Irrigation District and others. For the most part, the non-CAP contracts total 164,652 afy. The non-CAP users include present perfected rights or other rights that predate the BCPA and users that contracted before September 30, 1968.

Under shortage conditions, initial shortages in the United States would be shared between Nevada and Arizona on a four and 96 percent basis, respectively. Within Arizona, if any use of water was occurring under contracts for unused entitlement, that use would be the first eliminated under shortage conditions. Any remaining reduction in Arizona would be shared pro rata between the CAP and the non-CAP holders of fourth priority entitlements. More severe shortages would result in holders of higher priority entitlements having to incur reduction in their water use. For this report, all Arizona shortages are assigned to the CAP. Furthermore, the analysis of Arizona's water supply has been limited to an analysis of the effects of water availability on total Arizona diversions. Figure 4.4-1 presents a graphical illustration of Arizona's normal, full surplus and first level shortage condition depletion schedules that were used as input for the model. These data are presented in tabular format in Attachment A.

Figure 4.4-1
Arizona Projected Colorado River Water Demand Schedules
(Full Surplus, Normal and Shortage Water Supply Conditions)



Arizona's consumptive use of Colorado River water, including that used for groundwater banking, reached its normal year entitlement of 2.8 maf in 1997. However, its consumptive use since then has been somewhat less than this amount.

As shown on Figure 4.4-1, Arizona's normal year depletion schedule is projected to reach 2.8 maf in 2006, and remains at that level thereafter. For modeling purposes, Arizona's unused apportionment in 2002 through 2005 was distributed to MWD (73 percent) and SNWA (27 percent). The CAP's projected normal year depletions are approximately 1.458 maf in 2002 and gradually decrease to 1.395 maf by 2048, which represent approximately one-half of the state's total normal demand. The demands of Arizona's non-CAP users meanwhile increase towards their full apportionment amount as time progresses, making up the balance of Arizona's normal 2.8 maf apportionment.

The state's projected full surplus depletions increase from 2.99 maf in 2002 to approximately 3.24 maf in 2037. The projected CAP surplus condition demand rises steadily from 1.658 maf in 2002 to approximately 1.835 maf in 2012. Thereafter, the CAP surplus condition depletion schedule remains flat at approximately 1.835 maf. First level shortage condition depletions for Arizona increases from 2.332 maf in 2002 to 2.405 maf by 2048 and remain at that level thereafter, reflecting the modeling assumption discussed in Section 2.4 of limiting CAP to 1.0 maf.

The modeled Colorado River water deliveries under the four modeled operational scenarios assumed that all Arizona shortages would be assigned to the CAP, as discussed in Section 2.4. Although it is recognized that under the current Arizona priority framework there would be some sharing of Arizona shortages between the CAP and users at the same priority, modeling at this level of detail was not necessary to analyze deliveries on a statewide basis.

Arizona's basic strategy for meeting short-term shortages in CAP M&I supply centers on reduced uses for recharge, reduced agricultural deliveries and an increased use of groundwater. In addition to naturally occurring groundwater, Arizona has established a groundwater bank and is currently actively storing CAP water that is in excess of its current needs for future withdrawal. As discussed above, the AWBA administers the groundwater bank. Groundwater banking is occurring with the intent of providing a source for withdrawal during periods when the amount of Colorado River water available for diversion under the CAP priority is curtailed by shortage conditions. Additionally, CAWCD has stored a substantial amount of CAP water in central Arizona.

It is projected that CAP water will be used for groundwater recharge until about 2040 under normal and surplus conditions. This use will be terminated first in case of shortage. For other interim and long term contract users, agriculture has the lowest priority. Therefore, irrigation users will be reduced before CAP M&I or Indian users in case of shortage conditions. Most irrigation users have rights to pump groundwater as a replacement supply. The increased use of the groundwater supplies and the management

of the groundwater basins are expected to be consistent with the state's groundwater management goals.

When CAP diversions are limited to 1.0 maf during first-level shortage conditions, the impact before year 2020 would be to both groundwater recharge and agricultural users. After 2020, CAP M&I users would also be impacted by shortage conditions.

4.4.2 STATE OF CALIFORNIA

The Colorado River supplies about 14 percent of the water used in California by agriculture, industry, commercial businesses and residential customers. All of the Colorado River water used by California is used in the southern California region. Colorado River water is by far the most important source of water for southern California, accounting for over 60 percent of its water supply. During the last several years, the Colorado River has supplied up to 5.2 maf of the 8.4 maf of water used annually in southern California.

Under the BCPA and the Decree, 7.5 maf of Colorado River water is apportioned for consumptive use in the Lower Division states (California, Nevada and Arizona). In 1964, the Decree established California's normal apportionment of 4.4 maf from within the Lower Division states' 7.5 maf apportionment. The 1979 and 1984 Supplemental Decrees also awarded present perfected water rights to Indian reservations along the Colorado River. The 1964 Decree granted California, Arizona and Nevada respectively 50 percent, 46 percent, and four percent shares of any surplus water the Secretary determines to be available for use by the Lower Division states.

In California, a priority system for the principal parties that claimed rights to Colorado River water was established by the California Seven-Party Agreement of August 31, 1931, the provisions of which are included in water delivery contracts between the Secretary and California Parties. The priority system allows water apportioned but unused by a senior priority holder to cascade down to the next lower priority. The Seven-Party Agreement limits a priority holder's use of this water to beneficial use exclusively on lands within the priority holder's service area. Water transfers that are proposed in California's Draft Colorado River Water Use Plan (CRBC, 2000) will work within the framework of the Seven-Party Agreement and within the framework of the agreements that are executed to carry out those transfers.

Agriculture and present perfected rights have highest priority to about 90 percent of California's entitlement. The balance goes to the MWD, which provides wholesale water service to most of the communities within the southern California coastal plain. California's largest agricultural water agencies that rely on Colorado River water include the IID, Palo Verde Irrigation District (PVID) and the Coachella Valley Water District (CVWD).

Three major structures divert water from the Colorado River to California. Parker Dam forms Lake Havasu, which supplies water for MWD's Colorado River Aqueduct on the

California side of the state line and for the Central Arizona Project on the Arizona side of the state line. Palo Verde Diversion Dam supplies water to PVID's canal system. Imperial Dam diverts water to the All American Canal on the California side of the state line and to the Gila Gravity Main Canal on the Arizona side of the state line. The AAC is used to deliver water to the Yuma Project, IID and the CVWD.

California has relied on the Secretary's release of unused Nevada and Arizona Colorado River apportionments in accordance with Article II(B)(6) of the Decree for more than three decades. In recent years, Nevada and Arizona depletions have approached their apportionment amounts as a result of the completion of the CAP and rapid population growth in these states. Additionally, Arizona has started to bank its water (such as by groundwater storage) to protect against future shortages. As a result, there is currently not enough Nevada and Arizona unused apportionment to meet California's demand. Since 1996, California has received as much as 800,000 af above its annual 4.4 maf normal apportionment due to determinations by the Secretary of surplus conditions on the Colorado River through the AOP process.

The California Department of Water Resources (Department) projects that over the next several decades, California's overall demand for water will continue to increase. Urban demand is expected to outweigh projected declines in agricultural demand. For example, the Department's 1993 California Water Plan projected that urban water demand will increase by 60 percent from 1990 to 2020. However, California's ability to access Colorado River water beyond its normal apportionment may be limited for the following two reasons:

- Since Arizona and Nevada will be using their normal apportionments, California's access to any substantial amount of water above its normal apportionment will depend on surplus determinations by the Secretary on a year-by-year basis. Under pre-Interim Surplus Guidelines conditions Colorado River system management practices, such determinations were not certain, as they depended on conditions which change each year, namely snowpack runoff and reservoir storage.

- Even with a surplus determination, California's access is limited by the capacity of its delivery systems. Currently, the existing delivery system to urban users, the Colorado River Aqueduct, is operating at near capacity (approximately 1.3 maf per year).

If the amount of Colorado River water available for use in California was limited to the 4.4 maf normal apportionment, the immediate impact would fall mainly on the MWD because much of the allocation to California above normal apportionment now is used by urban users serviced by MWD. MWD (or its customers) would have to look to: 1) other California users of Colorado River water, namely the agriculture agencies, or 2) other sources, such as northern California water supplies, for about 700,000 af of the

approximately 2 maf of MWD's normal annual water deliveries, which ranged between 1.5 maf and 2.6 maf during the 1990s.

California faces other issues that may impact the quantity or quality of the supply of Colorado River water to certain users. In particular, listing of additional endangered bird and fish species could reduce the amount of water available for non-environmental purposes. Also, Colorado River salinity control projects could impact the quantity and quality of future Colorado River water. Both the type of crops produced (high market value crops generally require water that is low in salinity) and the quality of southern California drinking water could change.

The Colorado River Board of California (Board) developed a plan for California to live within its normal apportionment of 4.4 maf. The Board's draft plan was previously referred to as the California 4.4 Plan (dated August 11, 1997) and addressed various water supply management issues that are focused on changes in the use, supply or transfer of Colorado River water. The draft plan was updated, renamed and re-released in May 2000 as the *California Colorado River Water Use Plan* (CA Plan). The CA Plan relies first on a variety of intrastate measures that either conserve water or increase water supplies. The plan also relies on measures that would make extra water available to California. (CRBC, 2000)

California's use of Colorado River water reached a high of 5.4 maf in 1974 and has varied from 4.5 to 5.2 maf per year over the past 10 years. Limiting California to 4.4 maf per year would reduce California's annual water supply by approximately 800,000 afy. All or most of this reduction would be borne by MWD unless arrangements with agricultural agencies are implemented. While the water supply analysis for this report is focused on the total California depletions, the assumption is made that the surplus deliveries that may become available would be managed and distributed by and between the California users in accordance with the proposed provisions of the CA Plan, the corresponding Quantification Settlement Agreement (QSA) and associated cooperative programs. Most of these cooperative programs are between MWD or one of its member agencies and the agricultural water agencies. Under these programs, MWD will be able to use its basic Colorado River water apportionment plus water made available from water conservation by other California agencies and from groundwater storage programs. These programs include the following:

- **Coachella Groundwater Storage Program** - Cooperative program with the Desert Water Agency and the CVWD that exchanges their State Water Project (SWP) entitlements for MWD's Colorado River water and provides storage of Colorado River water for future extraction by these two agencies.

- **Water Conservation Program with Imperial Irrigation District** - MWD and the IID entered into a water conservation agreement in December 1988. The agreement called for IID to implement various projects to conserve water

including improving its water distribution system and on-farm management of water.

- **Demonstration Project on Underground Storage of Colorado River Water in Central Arizona** - Under a cooperative program with the CAP, MWD has placed 89,000 af and the SNWA has placed 50,000 af of unused Colorado River water in underground storage (groundwater banking) in central Arizona.

- **Agricultural-to-Urban Intrastate Water Transfers –** The SDCWA and IID have negotiated an agreement by which IID will transfer agricultural water conserved through various conservation and efficiency programs to SDCWA for urban use – where demand is growing. The agreement contemplates transfer of up to 200,000 afy. A number of bills have been introduced in the California Senate that attempt to address this and other similar intrastate water transfers, including SB 1011 (Costa), SB 1082 (Kelley), SB 1335 (Polanco) and AB 554 (Papan). To date, the legislature has enacted only SB 1082 which would facilitate a transfer of water between the IID and the SDCWA.

- **Palo Verde Irrigation District Land Management, Crop Rotation and Water Supply Program –** MWD and Palo Verde Irrigation District are developing a land management, crop rotation and water supply program in the Palo Verde Valley. The program's objective is to develop a flexible and reliable water supply for MWD of approximately 100,000 AFY for 35 years to assist in stabilizing the farm economy within the Palo Verde Valley through sign-up payments and annual payments for participating farmers and through implementation of specific community improvement programs. Participation in the program would be voluntary. Participating farmers would, at MWD's request and with specific notice periods, not irrigate a portion of their farmland. The same land would not be irrigated for a minimum one-year term and a maximum three-year term, at the farmer's option. A base load area of 6,000 acres would not be irrigated each year of the program's 35-year period. MWD would have the option to increase the non-irrigated area from 6,000 acres up to a maximum of 26,500 acres. However, a maximum of 24,000 acres in any 25-year period or 26,500 acres in any 10-year period during the 35-year program would be dedicated to the program. MWD would provide financial compensation to the participating farmers. Not irrigating a portion of the Palo Verde Valley's farmland would result in less Colorado River water being used by PVID. The amount of water conserved by the program would be determined on an annual basis by a verification committee composed of MWD, PVID and Reclamation and would be made available for diversion by MWD at Lake Havasu through its CRA facilities.

Table 4.4-1
Cooperative Water Conservation/Transfer and Exchange Projects

Cooperative Water Conservation/ Transfer Project	*Annual Yield (AF)*	*Estimated Start Date*
IID/MWD 1988 Agreement	100,000 – 110,000[1]	On-going
IID/SDCWA Water Conservation and Transfer Agreement	130,000 – 200,000[2]	2002
CVWD/MWD SWP Water Transfer/Colorado River Water Exchange	35,000	2002
Coachella Canal Lining – MWD/SLR[3]	26,000[3]	2005[4]
All American Canal Lining – MWD/SLR[3]	67,700[3]	2006[4]
CVWD/IID/MWD Water Conservation and Transfer (First 50 KAFY and Second 50 KAFY)[5]	100,000[5]	2007
TOTAL	**458,700 – 538,700**	**—**

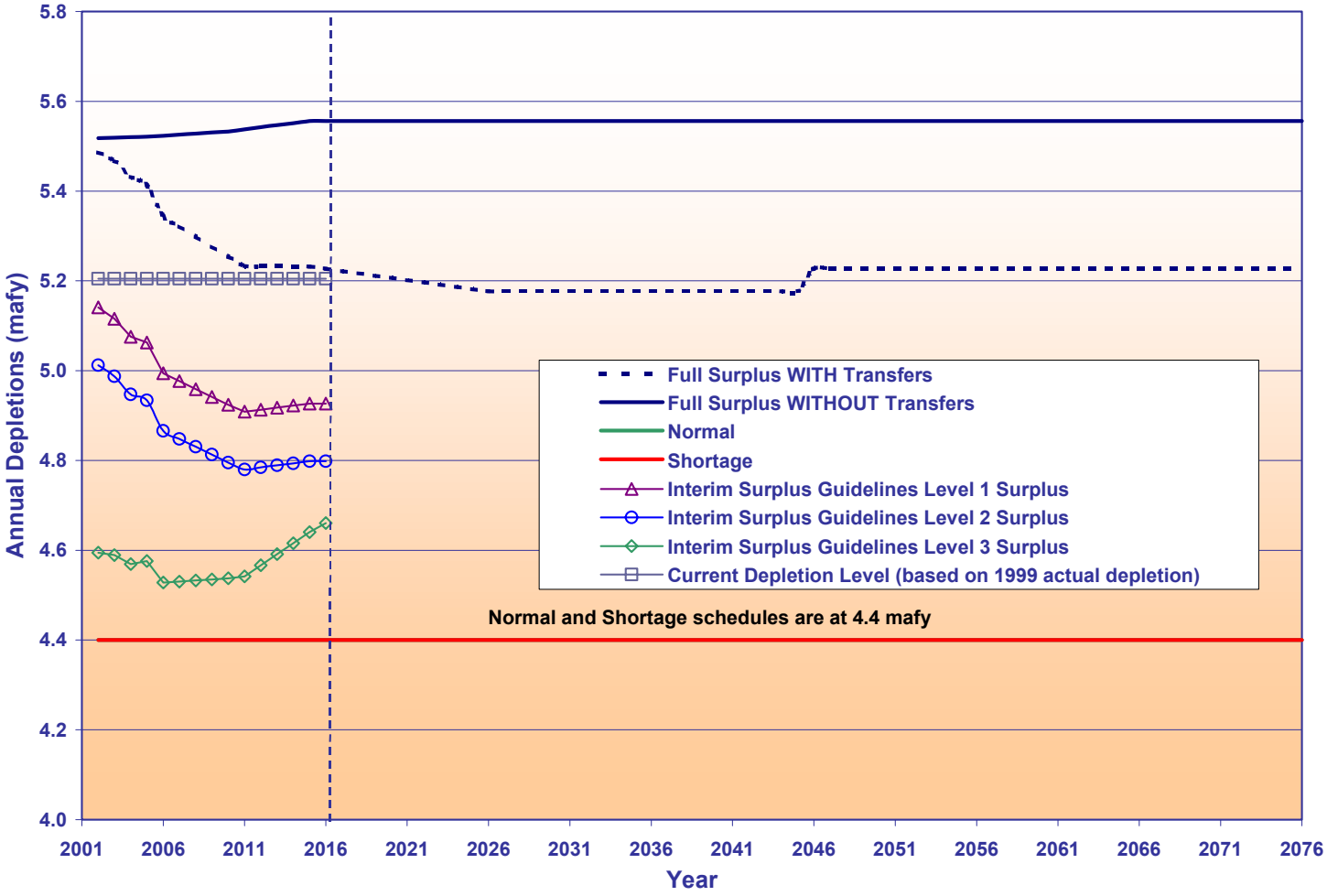
***Notes*:**
(1) Yield to MWD, except for 20 KAFY to be made available to CVWD under the IA and QSA.
(2) Yield to SDCWA; will ramp up at 20 KAFY during project implementation.
(3) Yield to MWD of 21.5 and 56.2 KAFY from Coachella Canal and All American Canal lining projects, respectively; and to the San Luis Rey Indian Water Rights Settlement Parties of 4.5 and 11.5 KAFY from the Coachella Canal and All American Canal lining project, respectively.
(4) Date by which full conservation benefits will be achieved.
(5) Yield to CVWD; will ramp up at 5 KAFY during project implementation. MWD has option to utilize part or all water not utilized by CVWD.

Figure 4.4-2 presents a graphical illustration of California's full surplus, normal and first level shortage demand schedules that were used as input to the model. Two full surplus depletion schedules are shown (with and without transfers). These two surplus schedules consider the fact that California anticipates a continued need for surplus water, when available, in order to implement the conjunctive use programs (e.g., groundwater banking) that will assist California in reducing its projected Colorado River depletion toward its normal apportionment of 4.4 mafy.

However, California's full surplus schedule that considers the proposed intrastate water transfers is substantially less than the full surplus schedule without the transfers over time. This reflects the additional cooperative programs that would increase the amount of water transferred from agricultural agencies to MWD. Therefore, as a result of the Quantification Settlement Agreement (QSA), the cooperative programs, and the proposed increased intrastate transfers, the full surplus depletion schedules for California are reduced while at the same time allowing MWD to continue to meet its users' needs.

As illustrated by the graph, the interim surplus guidelines provide an opportunity to manage the surplus deliveries coincident with the management of Lake Mead water levels while at the same time, providing a structure whereby total deliveries to California are reduced. These reductions are significant when compared to California's current depletion level of 5.2 mafy, also shown on Figure 4.4-2. Both California's normal and Level 1 shortage condition water depletion schedules are at 4.4 maf throughout the period of analysis.

Figure 4.4-2
California Projected Colorado River Water Demand Schedules
(Full Surplus, Normal and Shortage Water Supply Conditions)



4.4.3 STATE OF NEVADA

The portion of Nevada that depends on Colorado River water is limited to southern Nevada, primarily the Las Vegas Valley and the Laughlin area further south. The Colorado River Commission and SNWA manage Nevada's Colorado River water supply. The SNWA coordinates the distribution and use of the water by its member agencies whose systems provide retail distribution.

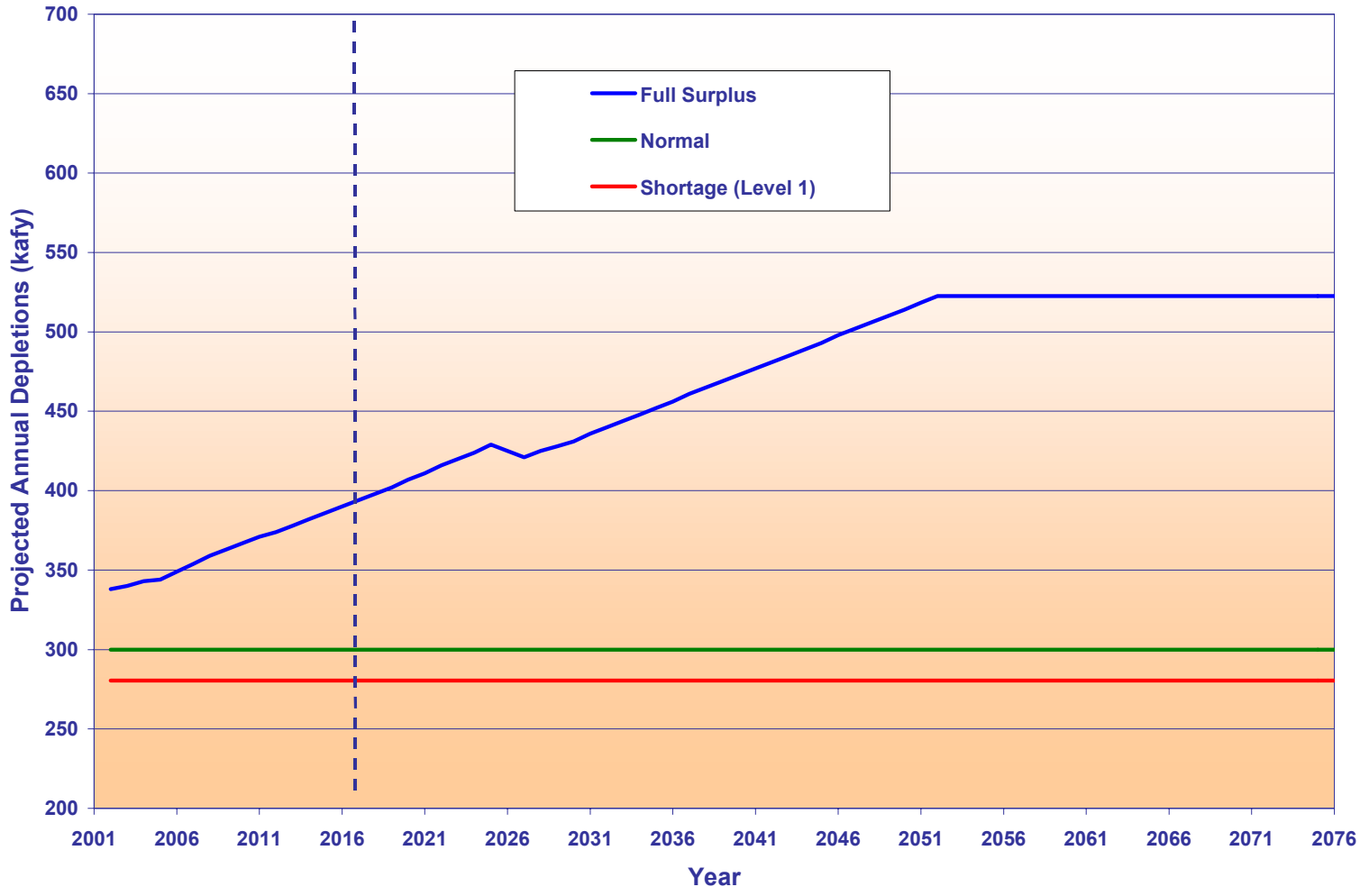
Nevada has five principal points of diversion for Colorado River water. The largest of these is the Las Vegas Valley that pumps water from Lake Mead at Saddle Island (on the west shore of the lake's Boulder Basin) through facilities of SNWA. The water is pumped at two adjacent pumping plants. The Lake Mead minimum water surface elevations for each intake are 1050 feet msl and 1000 feet msl, respectively. The pumped water is treated before being distributed to the Las Vegas Valley and to Boulder City water distribution systems. Three other diversion points are downstream of Davis Dam. They serve the community of Laughlin, Southern California Edison's coal fired Mohave Generating Station and uses on that portion of the Fort Mojave Indian Reservation lying in Nevada. The fifth diversion consists of water used by federal agencies in Nevada, primarily the National Park Service and its concessionaires at various points on lakes Mead and Mohave.

Nevada’s current Colorado River water demand is currently at or slightly above its Colorado River normal water apportionment under the BCPA and the Decree of 300,000 afy. SNWA depletions represent approximately 90 percent of this amount. Figure 4.4-3 presents a graphical illustration of the full surplus, normal and first level shortage demand schedules for Nevada that were used as input to the model.

Nevada's water demand projections for full surplus years rise steadily from a current value of approximately 338,000 af to approximately 514,000 af in approximately 50 years and remains at that level thereafter. Projected depletions under Level 1 Shortage Conditions are approximately 282,000 afy over the period of analysis, reflecting the fact that Nevada’s reduction in consumptive use of Colorado River water is four percent of the total shortage during shortage years.

SNWA's Integrated Resource Plan calls for optimizing both the use of Colorado River water and the use of the Las Vegas Valley shallow aquifer before developing water from additional sources, including the lower Virgin River and Muddy River. The SNWA has been supporting groundwater recharge in the Las Vegas Valley through facilities of member agencies. The artificial recharge of Colorado River water into the Las Vegas Valley groundwater basin is intended to help meet summer peak demands, provide an interim future water supply, and stabilize declining groundwater tables. Water agencies in the valley will be able to withdraw water to meet temporary shortfalls in supply. However, such withdrawals would be coupled with the opportunity for replenishment of the aquifer.

Figure 4.4-3
Nevada Projected Colorado River Water Demand Schedules
(Full Surplus, Normal and Shortage Water Supply Conditions)



Nevada also proposes to bank water in Arizona through arrangements with the AWBA using available groundwater storage capacity as described above in the discussion of alternate supplies for Arizona.

4.4.4 UPPER BASIN STATES

The depletions for the Upper Basin states were developed and submitted by the Upper Colorado River Commission (Commission) to Reclamation in December 1999. These depletions were then modified in coordination with the Commission to include updated Indian Tribe depletions provided by Keller-Bliessner Engineering, acting on behalf of the Indian Tribes with Colorado River water rights, during the preparation of the Interim Surplus Guidelines FEIS. Figure 4.4-4 shows that the Upper Basin depletions are approximately at 4.278 maf in 2002, increase gradually to approximately 5.429 maf by 2060 and for modeling purposes, are assumed to remain at that level thereafter. These depletions do not include the evaporation losses that occur within the Upper Basin and that are estimated to be approximately 574,000 afy. The Upper Division depletion schedule that includes the estimated evaporation losses are presented in tabular form in Attachment B. The modeled depletions as shown on Figure 4.4-4 and presented in Attachment B are consistent with the Upper Division states' apportionment of Colorado River water.

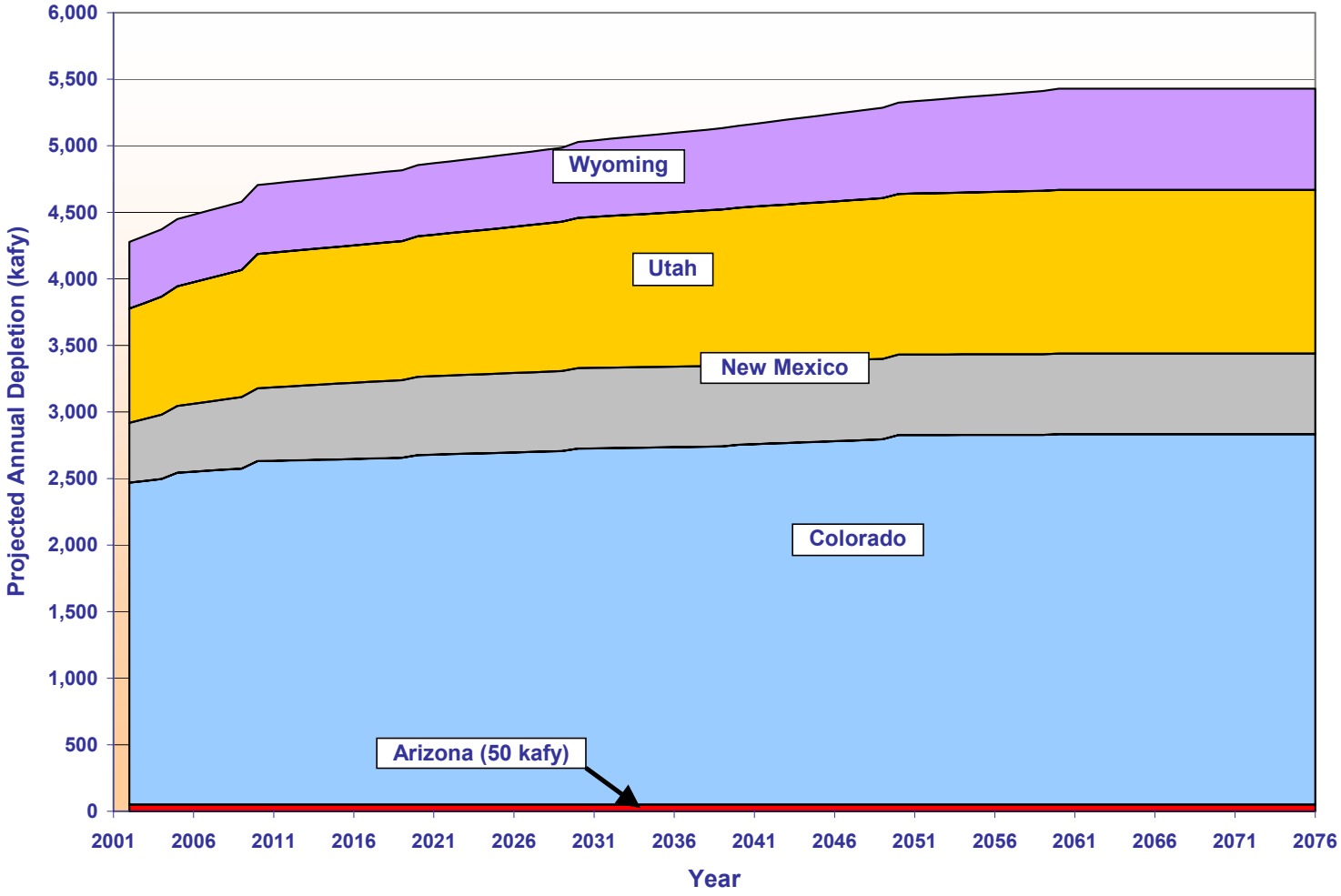
4.4.5 MEXICO

Mexico has a Treaty entitlement to Colorado River water. This entitlement is set forth in Article 10 of the Treaty that states the following:

"Of the waters of the Colorado River, from any and all sources, there are allotted to Mexico:

(a) A guaranteed annual quantity of 1,500,000 af (1,850,234,000 cubic meters) to be delivered in accordance with the provisions of Article 15 of this Treaty.

Figure 4.4-4
Upper Basin Depletion Projections
(Based on 1999 Depletion Schedule)



(b) Any other quantities arriving at the Mexican points of diversion, with the understanding that in any year in which, as determined by the United States Section, there exists a surplus of waters of the Colorado River in excess of the amount necessary to supply uses in the United States and the guaranteed quantity of 1,500,000 af (1,850,234,000 cubic meters) annually to Mexico, the United States undertakes to deliver to Mexico, in the manner set out in Article 15 of this Treaty, additional waters of the Colorado River system to provide a total quantity not to exceed 1,700,000 af (2,096,931,000 cubic meters) a year. Mexico shall acquire no right beyond that provided by this subparagraph by the use of the waters of the Colorado River system, for any purpose whatsoever, in excess of 1,500,000 af (1,850,234,000 cubic meters) annually. In the event of extraordinary drought or serious accident to the irrigation system in the United States, thereby making it difficult for the United States to deliver the guaranteed quantity of 1,500,000 af (1,850,234,000 cubic meters) a year, the water allotted to Mexico under subparagraph (a) of this Article will be reduced in the same proportion as consumptive uses in the United States are reduced."

Additionally, Minute 242 provides, in part, that the United States will deliver to Mexico approximately 1,360,000 acre-feet (1,677,545,000 cubic meters) annually upstream of Morelos Dam and approximately 140,000 acre-feet (172,689,000 cubic meters) annually on the land boundary at San Luis and in the limitrophe section of the Colorado River downstream from Morelos Dam. It should be noted that while a portion of Mexico's 1.5 maf annual apportionment is actually delivered below Morelos Dam, the entire delivery to Mexico was modeled at Morelos Dam. This basic assumption, while different than actual practice, served to simplify and facilitate the analysis of water deliveries to Mexico under the No Action Conditions and Implementation Agreement Conditions.

4.5 ANALYSIS OF WATER TRANSFERS

The following discussion is based on the results of analysis of water supply data generated by the model. This section describes the results of the analysis that evaluated the effect of water transfers on the water deliveries to each of the Lower Basin states. The modeled operational scenarios that are used to evaluate the effects of water transfers in this section include the No Action and the Implementation Agreement conditions.

4.5.1 STATE OF ARIZONA

This section presents the simulated water deliveries to Arizona under the no action and implementation modeled scenarios. The analysis of Arizona's water supply concentrated on total Arizona water depletions.

4.5.1.1 MODELING RESULTS OF NO ACTION

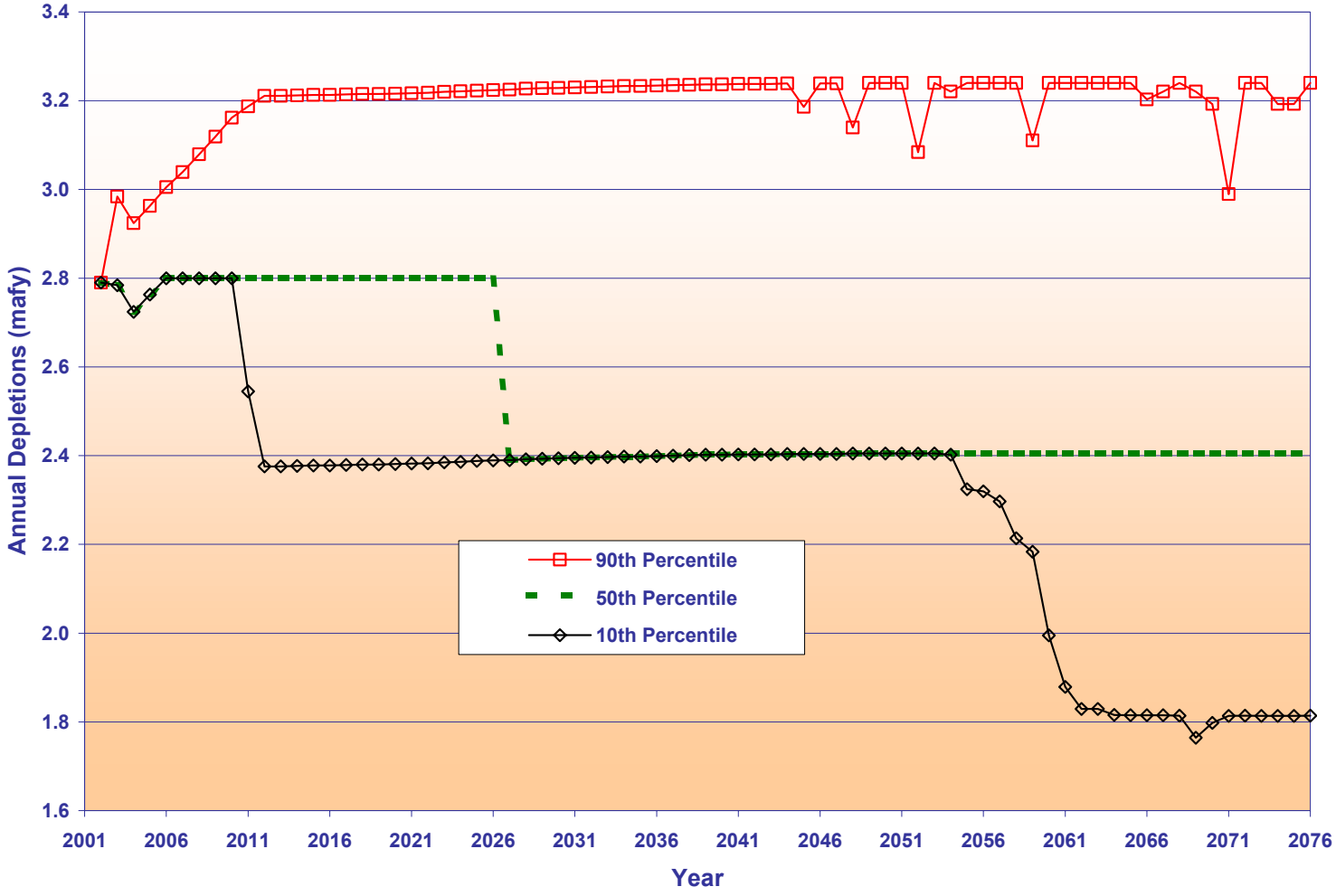
The water deliveries to Arizona are projected to fluctuate throughout the 75-year period of analysis reflecting variations in hydrologic conditions. The 90th, 50th and 10th percentile ranking of modeled water deliveries to Arizona under the no action conditions are presented in Figure 4.5-1.

With the exception of the first year modeled (2002), the 90th percentile line coincides with Arizona's depletion schedule during full surplus water supply conditions through year 2045 (compare Figure 4.5-1 to Figure 4.4-1). As indicated by this 90th percentile line, the probability that the No Action Conditions would provide Arizona's full surplus depletion schedule is at least 10 percent during this period. After year 2045, the 90th percentile line occasionally falls below the full surplus schedule albeit still remains close to Arizona's depletion schedule during full surplus water supply conditions and generally well above 3.0 mafy.

The 50th percentile line represents the median annual depletion values. This 50th percentile line generally coincides with Arizona's projected depletion schedule under normal water supply conditions through year 2025 (see Figure 4.4-1). After 2025, the median values drop to approximately 2.4 maf and remain at approximately that level for the remainder of the 75-year period of analysis.

As noted in Section 4.4.1, under shortage conditions, Arizona would bear 96 percent of the reduction and Nevada would bear four percent. In Arizona, the reduction would be shared prorata among CAP and non-CAP holders of fourth priority entitlements. To simplify the modeling process, the model sets the CAP's shortage water supply condition deliveries at 1.0 maf when the Lake Mead water level is between elevation 1000 feet msl and the assumed shortage protection line as discussed in Section 2.4. This modeling assumption kept Arizona's annual deliveries above 2.4 maf until further cuts to the CAP were necessary to maintain the Lake Mead water level above the 1000 feet msl elevation (a Level 2 shortage condition). Under the No Action modeled scenario, Level 2 shortage condition deliveries to Arizona (below 2.3 mafy) were observed to occur only during years 2054 to 2075 and occurred less than eight percent of the time.

Figure 4.5-1
Arizona Modeled Annual Depletions Under No Action Conditions
90th, 50th and 10th Percentile Values



4.5.1.2 COMPARISON OF IMPLEMENTATION AGREEMENT TO NO ACTION

Figure 4.5-2 provides a comparison of the distribution of Arizona's depletions under the Implementation Agreement to those of the No Action conditions during the 15-year Interim Surplus Guidelines period (years 2002 to 2016). This type of graph is used to represent the frequency that annual deliveries of different magnitudes occur in the respective period. The results presented in Figure 4.5-2 indicate a 70 percent probability that Arizona's depletions would meet or exceed its normal depletion schedule during this period under No Action conditions. The probability that Arizona would receive surplus condition deliveries during this period was approximately 23 percent. The maximum surplus condition depletions under the No Action Conditions were 3.213 maf during this period. The probability that Arizona would receive shortage condition deliveries was 30 percent. The minimum shortage condition depletion was 2.375 maf during this 15-year period.

Figure 4.5-3 provides a comparison of the distribution of the water deliveries to Arizona under the Implementation Agreement to those of the No Action conditions for the 60-year period (years 2017 to 2076) that would follow the Interim Surplus Guidelines period. The results presented in Figure 4.5-3 indicate a 37 percent probability that water deliveries to Arizona would meet its normal depletion schedule during this period under the No Action conditions. The probability that Arizona would receive surplus condition deliveries during this same period under the No Action conditions was approximately 18 percent. The maximum surplus condition depletions under the No Action Conditions were 3.24 maf during this period. The probability that Arizona would receive deliveries less than its normal schedule (Level 1 or Level 2 shortage condition deliveries) was 63 percent. Second level shortage conditions occurred less than 11 percent of the time during this 60-year period. The minimum shortage condition depletion was 1.405 maf.

Figure 4.5-4 provides a comparison of the distribution of the water deliveries to Arizona under the Implementation Agreement conditions to those of the No Action conditions for the entire 75-year period of analysis (years 2002 to 2076). The results presented in Figure 4.5-4 indicate a 44 percent probability that water deliveries to Arizona would meet its normal depletion schedule during this period under the No Action conditions. The probability that Arizona would receive surplus condition deliveries during this same period under the No Action conditions was approximately 19 percent. The maximum surplus condition depletions under the No Action Conditions were 3.24 maf during this period. The probability that Arizona would receive deliveries less than its normal schedule (Level 1 or Level 2 shortage condition deliveries) was 56 percent. Second level shortage conditions occurred less than nine percent of the time during this 75-year period. The minimum shortage condition depletion under the No Action conditions was 1.405 maf.

Figure 4.5-2
Arizona Modeled Depletions
Comparison of Implementation Agreement Conditions to No Action Conditions
Years 2002 to 2016

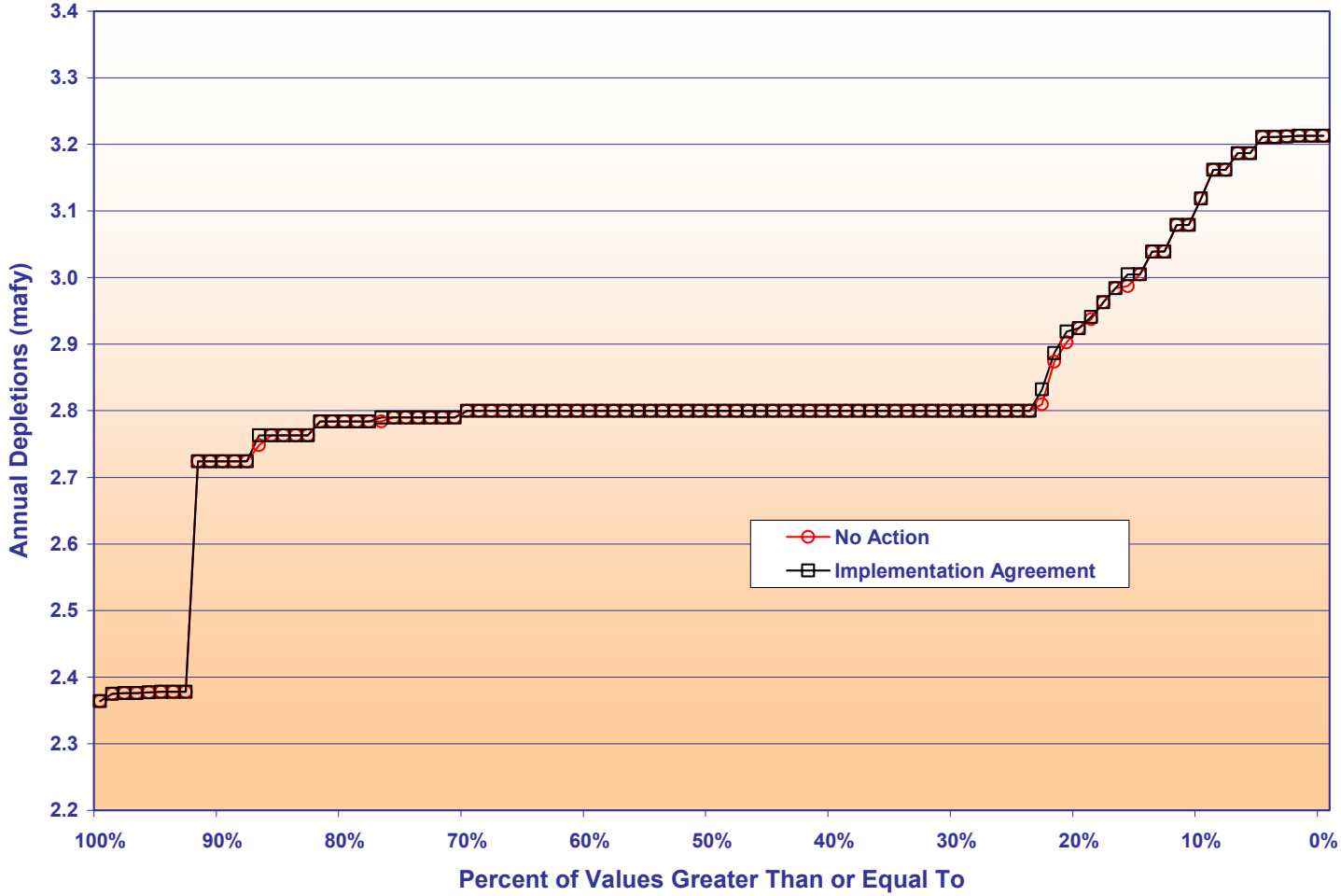


Figure 4.5-3
Arizona Modeled Depletions
Comparison of Implementation Agreement Conditions to No Action Conditions
Years 2017 to 2076

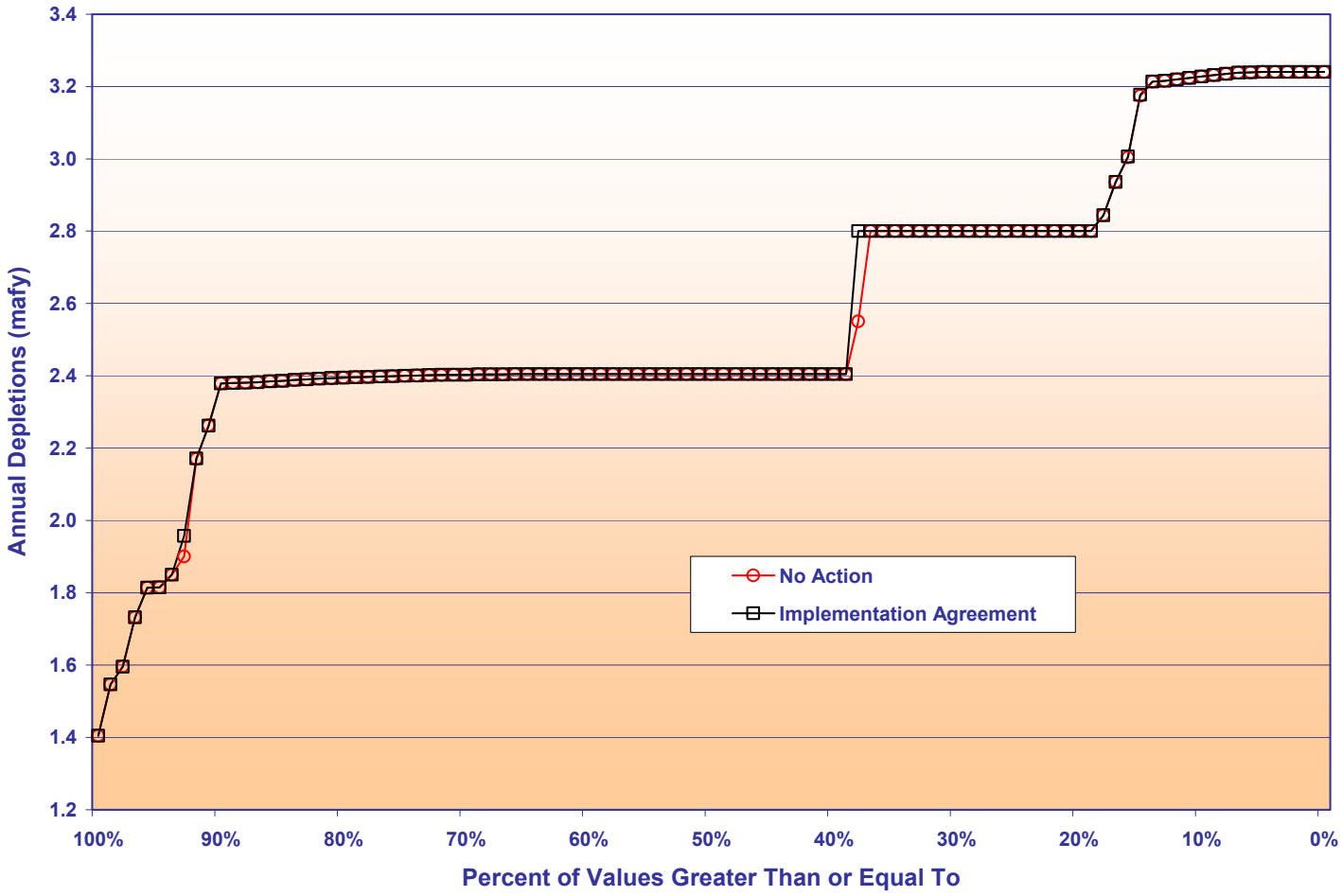


Figure 4.5-4
Arizona Modeled Depletions
Comparison of Implementation Agreement Conditions to No Action Conditions
Years 2002 to 2076

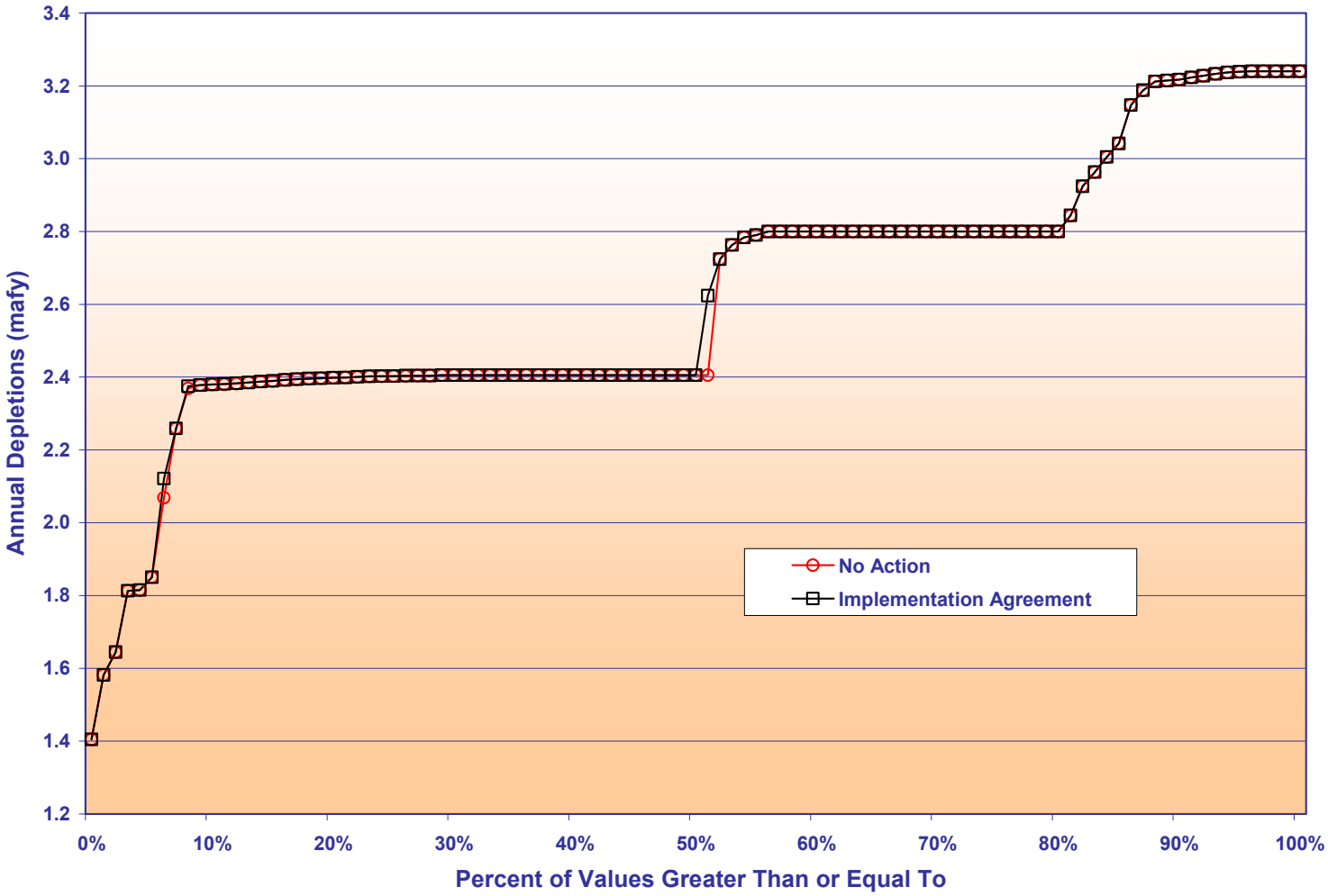


Figure 4.5-5 provides a comparison of the 90th, 50th and 10th percentile values for Arizona's modeled depletions under the No Action conditions to those of the Implementation Agreement conditions. As depicted in Figure 4.5-5, there is little difference in the 90th percentile lines resulting from the Implementation Agreement conditions as compared to those of the No Action conditions. The 90th percentile lines generally coincide with Arizona's full surplus depletion schedule.

The 50th percentile lines for the No Action and Implementation Agreement conditions are identical to each other through year 2024 and coincide with Arizona's surplus depletion schedule during this period. After year 2024, the 50th percentile values for the No Action conditions fall due to increasing probability of the Level 1 shortage condition deliveries. The 50th percentile line for the Implementation Agreement conditions continue to coincide with the normal depletion schedule through year 2026. After 2026, the 50th percentile lines for the Implementation Agreement conditions also falls due to increasing probability of the Level 1 shortages. The 50th percentile values for the No Action and Implementation Agreement conditions remain at approximately 2.4 mafy after year 2027.

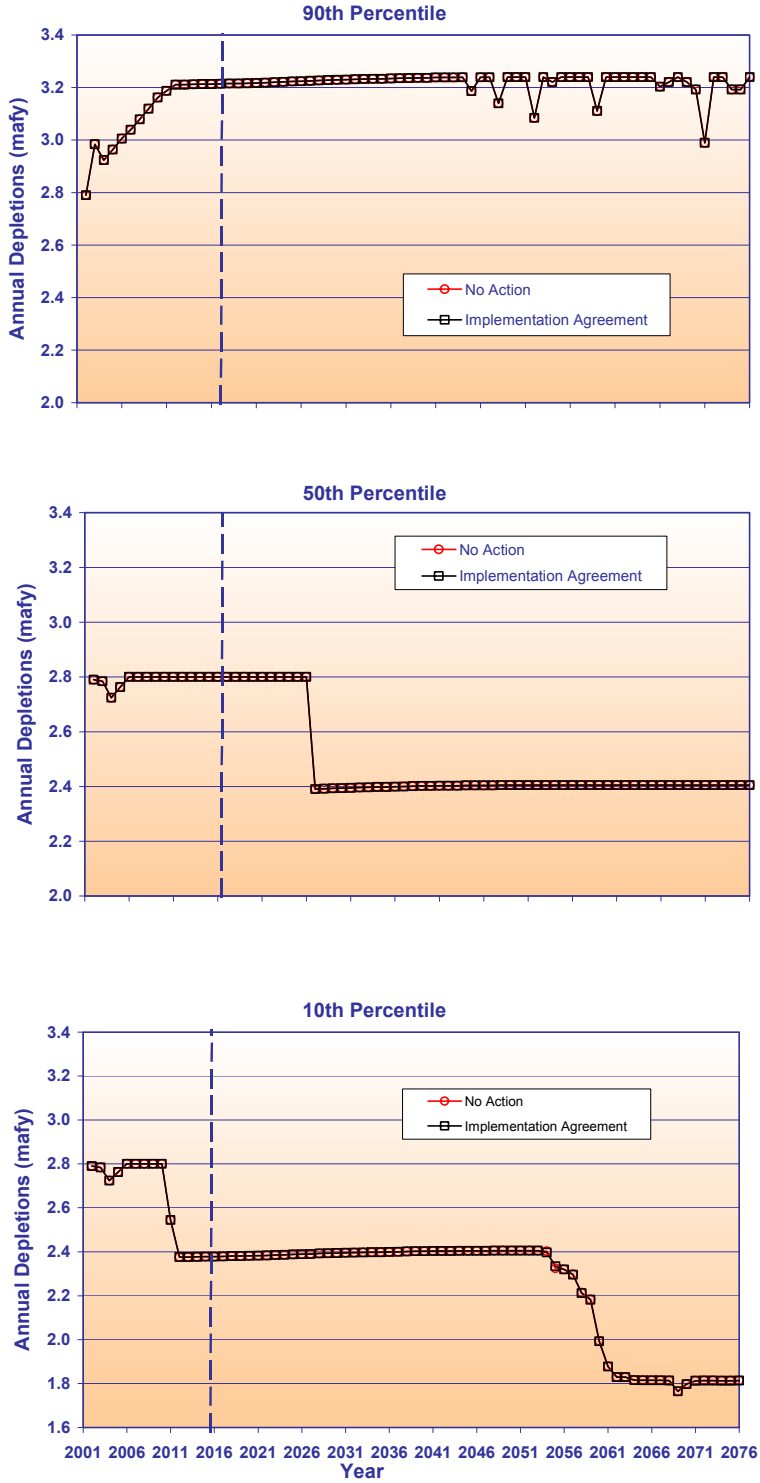
The 10th percentile lines for the No Action and the Implementation Agreement conditions are essentially at or above Arizona's normal depletion schedule through year 2010. After 2010, the 10th percentile values of the No Action and the Implementation Agreement conditions begin to drop down to the Level 1 shortage condition delivery values (approximately 2.4 mafy) and remain at this level through 2053. After 2053, the 50th percentile lines for the No Action and the Implementation Agreement conditions decrease further due to increasing probability of the Level 2 shortage condition deliveries.

Figures 4.5-2, 4.5-3 and 4.5-4 presented comparisons of the distribution of Arizona's depletions under the No Action and the Implementation Agreement conditions during the15-year Interim Surplus Guidelines period (years 2002 to 2016), the 60-year period that follows the Interim Surplus Guidelines (years 2017 to 2076), and the entire period of analysis (years 2002 to 2076), respectively. These graphs best illustrate the frequency that different amounts of annual Arizona water deliveries occur over these time frames. Table 4.5-1 provides a summary of the comparison for these three time periods.

Table 4.5-1
Summary of Arizona Modeled Annual Depletions
Comparison of Implementation Agreement Conditions to No Action Conditions

	Years 2002 to 2016			Years 2017 to 2076			Years 2002 to 2076		
Alternative/Conditions	**Normal***	**Surplus**	**Shortage**	**Normal***	**Surplus**	**Shortage**	**Normal***	**Surplus**	**Shortage**
No Action	70%	23%	30%	37%	18%	63%	44%	19%	56%
Implementation Agreement	70%	23%	30%	38%	18%	62%	44%	19%	56%
*The values under normal represent the total percentage of time that depletions would be at or above the normal depletion conditions.									

Figure 4.5-5
Arizona Modeled Annual Depletions
Comparison of No Action Conditions to Implementation Agreement Conditions
90th, 50th and 10th Percentile Values



The percentage values presented under the column heading labeled “Normal” in Table 4.5-1 represent the total percentage of time that depletions under the noted conditions would be at or above the normal depletion schedule amount. The values presented under the column labeled “Surplus” represent the total percentage of time that depletions under the noted conditions exceed the normal depletion schedule amount. The values presented under the column labeled “Shortage” represent the total percentage of time that depletions under the noted conditions would be below the normal depletion schedule amount.

4.5.2 STATE OF CALIFORNIA

This section presents the simulated water deliveries to California under the No Action and Implementation Agreement conditions. The analysis of California's water supply concentrated on total California water depletions.

4.5.2.1 MODELING RESULTS OF NO ACTION

The water deliveries to California are projected to fluctuate throughout the 75-year period of analysis reflecting variations in hydrologic conditions. The 90th, 50th and 10th percentile rankings of modeled water deliveries to California under the No Action Conditions are presented in Figure 4.5-6. The actual reported (historical) depletions (for years 1990 to 2001) have been added to this graph to provide a benchmark for comparison of the projected future depletion trends.

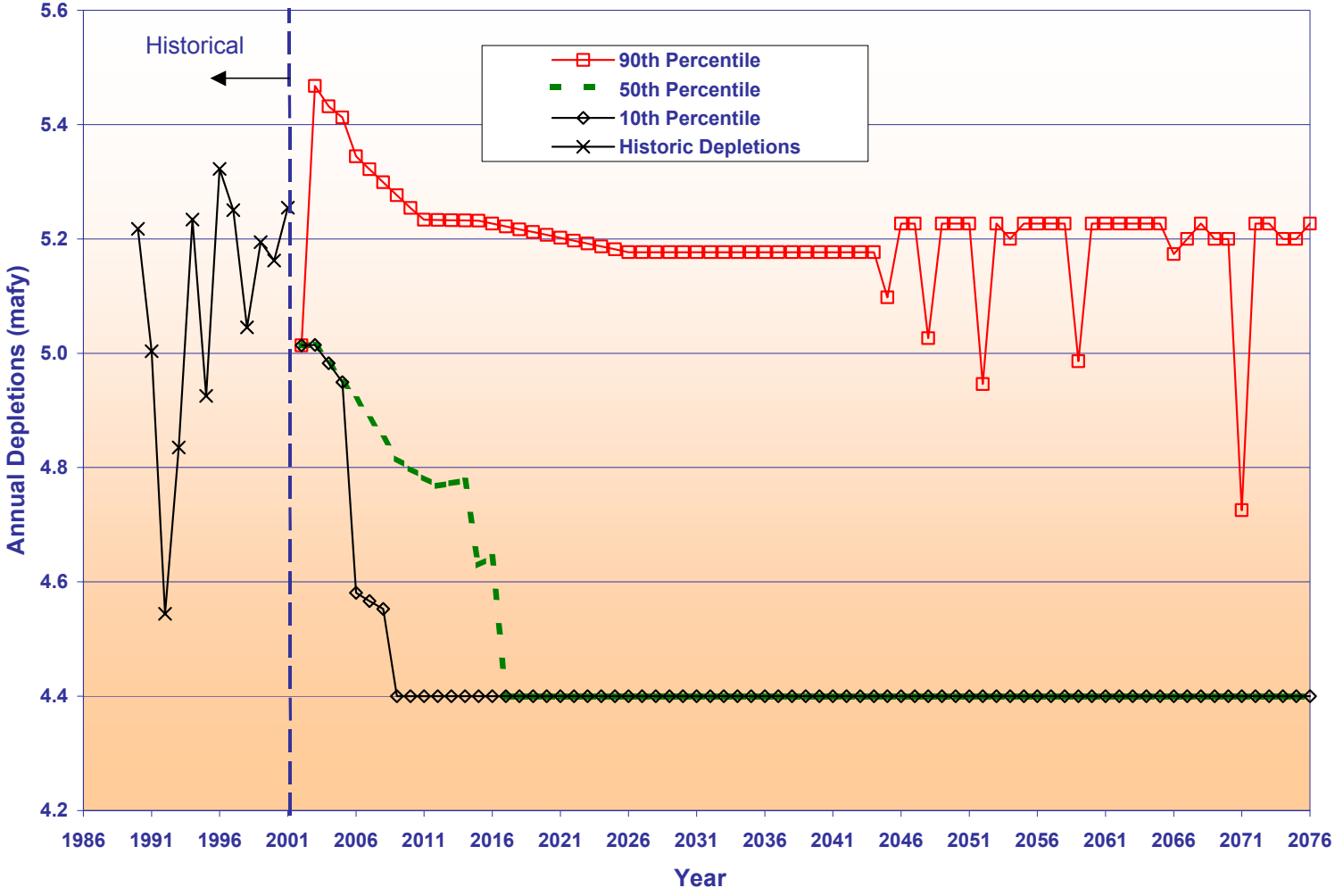
The 90th percentile values generally coincide with California's depletion schedule during full surplus water supply conditions through year 2044. The 90th percentile line represents the magnitude of surplus condition deliveries that would be available at least 10 percent of the time throughout the 75-year period of analysis. After year 2044, the 90th percentile line occasionally falls below the full surplus schedule, an indication of the occurrence of more frequent limited surplus conditions.

From 2002 through 2016, under No Action Conditions, the 50th percentile line for California is above the normal depletion schedule suggesting a better than average probability of surplus condition deliveries. After 2016, the 50th percentile line coincides with California's normal depletion schedule.

From 2002 through 2008, under No Action Conditions, the 10th percentile line for California is also above the normal depletion schedule suggesting at least a 90 percent probability of surplus condition deliveries during this period. After 2008, the 10th percentile line coincides with California's normal depletion schedule.

Annual water deliveries to California were observed to fall below California's normal apportionment of 4.4 maf (a Level 2 shortage condition) less than one percent of the time throughout the 75-year period of analysis. The minimum delivery observed under the No Action conditions was 3.847 maf.

Figure 4.5-6
California Modeled Annual Depletions Under No Action Conditions
90th, 50th and 10th Percentile Values



4.5.2.2 COMPARISON OF IMPLEMENTATION AGREEMENT TO NO ACTION

Figure 4.5-7 provides a comparison of the distribution of the observed California depletions under the Implementation Agreement Conditions to those of the No Action Conditions during the 15-year Interim Surplus Guidelines period (years 2002 to 2016). These graphs are best used to represent the frequency that different magnitude annual water deliveries to California occur in the respective period. The results presented in Figure 4.5-7 indicate a 100 percent probability that California's depletions would meet its normal depletion schedule during this period under the No Action Conditions. The probability that California would receive surplus condition deliveries (any amount greater than 4.4 mafy) during this period under No Action Conditions was approximately 85 percent. The maximum surplus condition depletions observed under the No Action Conditions were 5.468 maf during this 15-year period.

Figure 4.5-8 provides a comparison of the distribution of the water deliveries to California under the Implementation Agreement Conditions to those of the No Action Conditions for the 60-year period (years 2017 to 2076) that follows the Interim Surplus Guidelines period. The results presented in Figure 4.5-8 indicate an approximate 99 percent probability that water deliveries to California would meet its normal depletion schedule during this period under the No Action Conditions. Only one trace was observed to fall below the normal depletion schedule, an indication of a Level 2 shortage condition. The minimum delivery observed under this trace was 3.847 maf. The probability that California would receive surplus condition deliveries during this same period under the No Action Conditions was approximately 18 percent. The maximum surplus condition depletions under the No Action Conditions were 5.227 maf during this 60-year period.

Figure 4.5-9 provides a comparison of the distribution of the water deliveries to California under the Implementation Agreement Conditions to those of the No Action Conditions for the entire period of analysis (years 2002 to 2076). The results presented in Figure 4.5-9 also indicate an approximate 99 percent probability that water deliveries to California would meet its normal depletion schedule under the No Action Conditions. Again, only one trace was observed to fall below the normal depletion schedule, an indication of a Level 2 shortage condition. The minimum delivery observed under this trace was 3.847 maf. The probability that California would receive surplus condition deliveries during this same period under the No Action Conditions was approximately 32 percent. The maximum surplus condition depletions under the No Action Conditions were 5.468 maf during this 75-year period.

Figure 4.5-7
California Modeled Depletions
Comparison of Implementation Agreement Conditions to No Action Conditions
Years 2002 to 2016

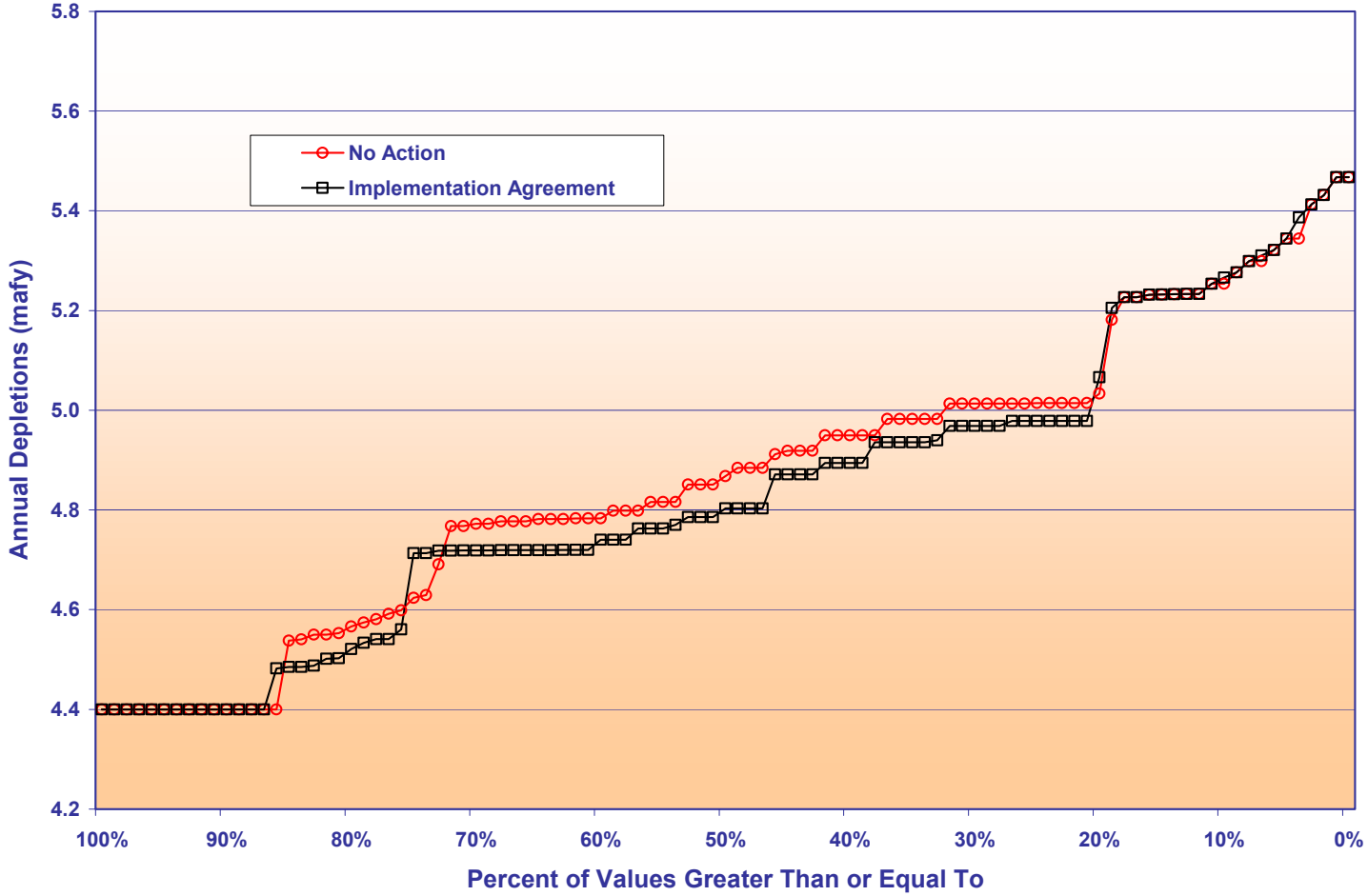


Figure 4.5-8
California Modeled Depletions
Comparison of Implementation Agreement Conditions to No Action Conditions
Years 2017 to 2076

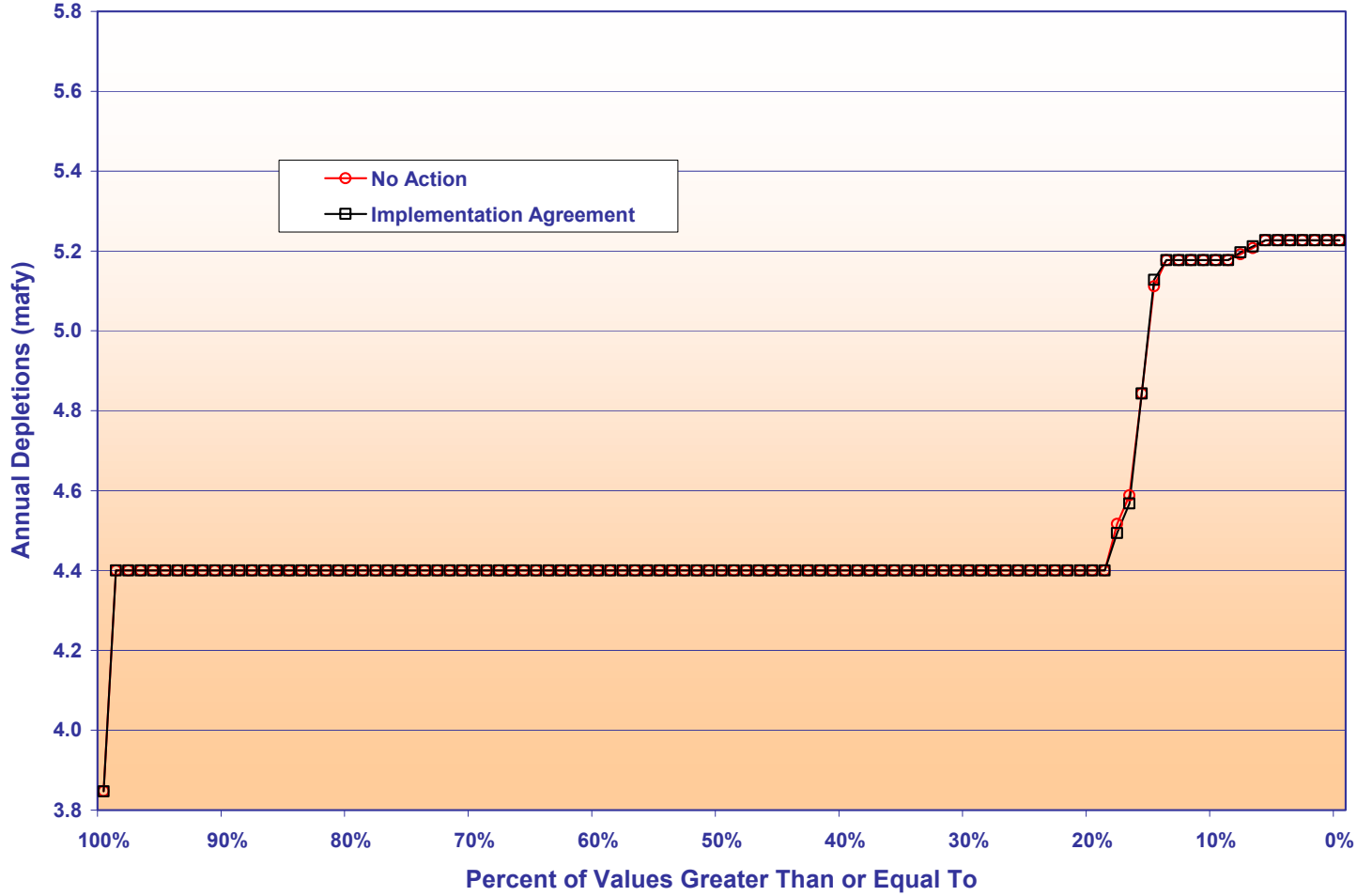


Figure 4.5-9
California Modeled Depletions
Comparison of Implementation Agreement Conditions to No Action Conditions
Years 2002 to 2076

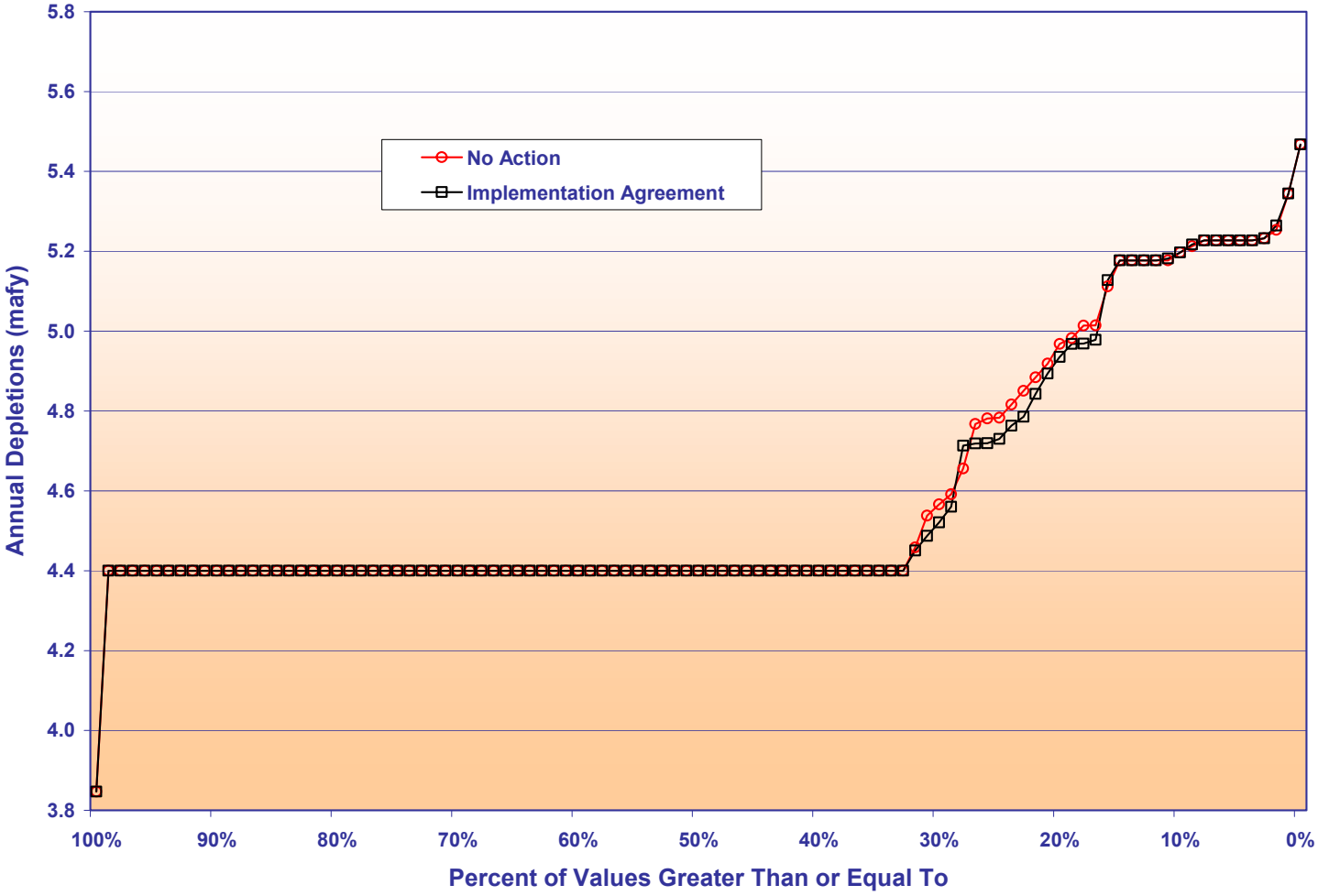
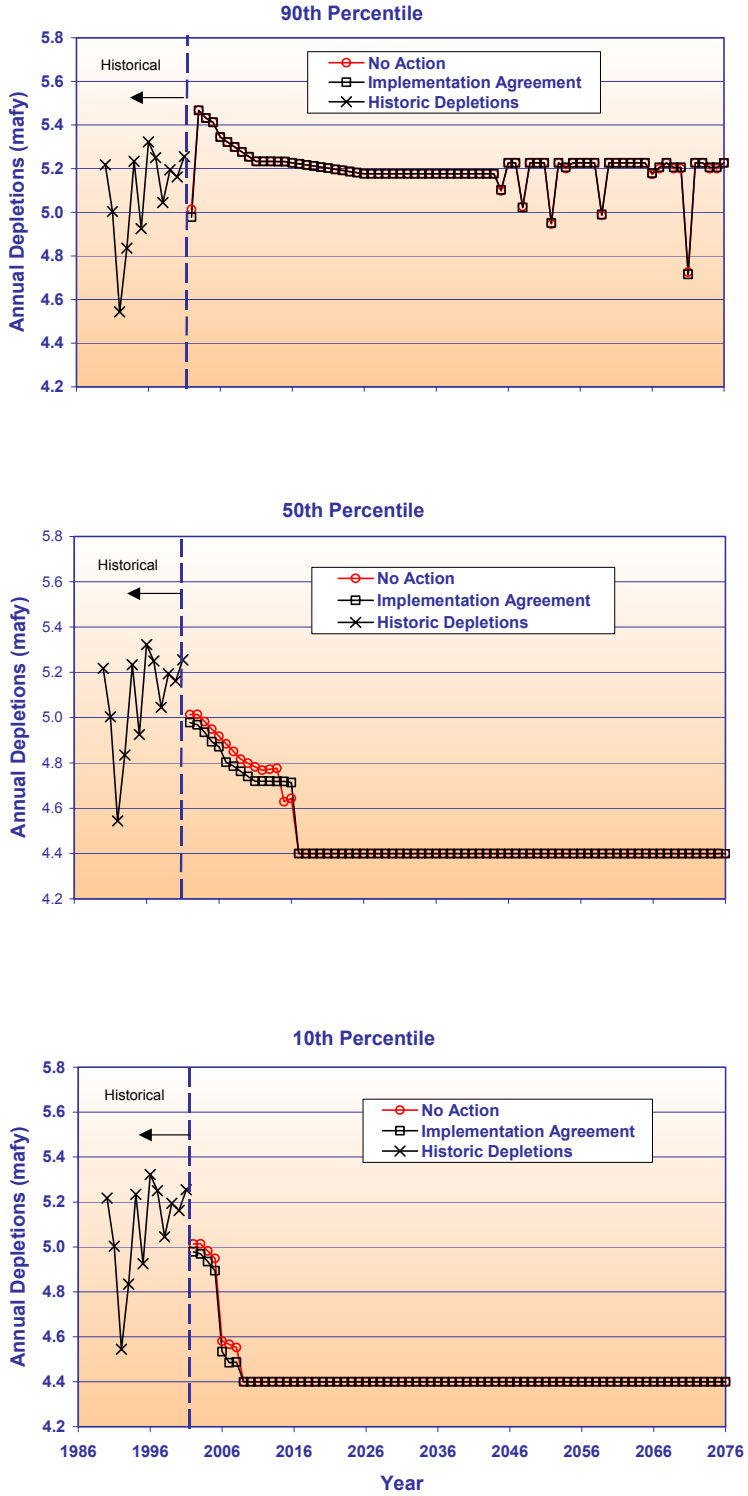


Figure 4.5-10 provides a comparison of the 90th, 50th and 10th percentile values for California's depletions under the Implementation Agreement Conditions to those of the No Action Conditions. The historical depletions (for years 1990 to 2001) have been added to this graph to provide a benchmark for comparison of the projected future depletion trends. As noted in Figure 4.5-10, there is little difference in the 90th percentile values resulting from the Implementation Agreement Conditions to those of the No Action Conditions. Both 90th percentile values generally coincide with California's depletion schedule during full surplus water supply conditions through year 2044. After year 2044, both 90th percentile lines occasionally fall below the full surplus schedule suggesting an increased probability of limited surplus conditions.

From 2002 through 2016, the 50th percentile lines for the Implementation Agreement and No Action conditions are above the normal depletion schedule suggesting a better than average probability of surplus condition deliveries. Comparing the two 50th percentile plots, it can be seen that with the Implementation Agreement California's depletions would reduce steadily during the initial years. In contrast, the depletions would remain higher under No Action conditions. After 2016, the 50th percentile lines for the Implementation Agreement and No Action conditions coincide with California's normal depletion schedule.

From 2002 through 2008, the 10th percentile lines for the Implementation Agreement and No Action conditions are generally above the normal depletion schedule, indicating a better than 90 percent frequency of surplus condition deliveries. The Implementation Agreement would result in a steady reduction in California's depletions in the initial years, in contrast to the No Action conditions. After 2008, the 10th percentile lines for the Implementation Agreement and No Action conditions coincide with California's normal depletion schedule.

Figure 4.5-10
California Modeled Annual Depletions
Comparison of Implementation Agreement Conditions to No Action Conditions
90th, 50th and 10th Percentile Values



Figures 4.5-7, 4.5-8 and 4.5-9 presented comparisons of the distribution of California's depletions under the Implementation Agreement Conditions to those of the No Action Conditions during the 15-year interim surplus guidelines period (years 2002 to 2016), the 60-year period that would follow the interim surplus guidelines (years 2017 to 2076) and the entire 75-year period of analysis (years 2002 to 2076), respectively. Table 4.5-2 provides a tabular summary and comparison for these three periods.

Table 4.5-2
Summary of California Modeled Annual Depletions
Comparison of Implementation Agreement Conditions to No Action Conditions

	Years 2002 to 2016			Years 2017 to 2076			Years 2002 to 2076		
Alternative/Conditions	**Normal***	**Surplus**	**Shortage**	**Normal***	**Surplus**	**Shortage**	**Normal***	**Surplus**	**Shortage**
No Action	100%	85%	0%	99%	18%	1%	99%	32%	<1%
Implementation Agreement	100%	86%	0%	99%	18%	1%	99%	32%	<1%
*The values under normal represent the total percentage of time that depletions would be at or above the normal depletion conditions.									

The percentage values presented under the column heading labeled "Normal" in Table 4.5-2 represent the total percentage of time that depletions under the noted conditions would be at or above the normal depletion schedule amount. The values presented under the column labeled "Surplus" represent the total percentage of time that depletions under the noted conditions exceed the normal depletion schedule amount. The values presented under the column labeled "Shortage" represent the total percentage of time that depletions under the noted conditions would be below the normal depletion schedule amount.

4.5.3 STATE OF NEVADA

This section presents the simulated water deliveries to Nevada under the No Action Conditions and Implementation Agreement Conditions. The analysis of Nevada's water supply concentrated on total Nevada water depletions.

4.5.3.1 MODELING RESULTS OF NO ACTION

The water deliveries to Nevada are projected to fluctuate throughout the 75-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 Conditions is presented in Figure 4.5-11.

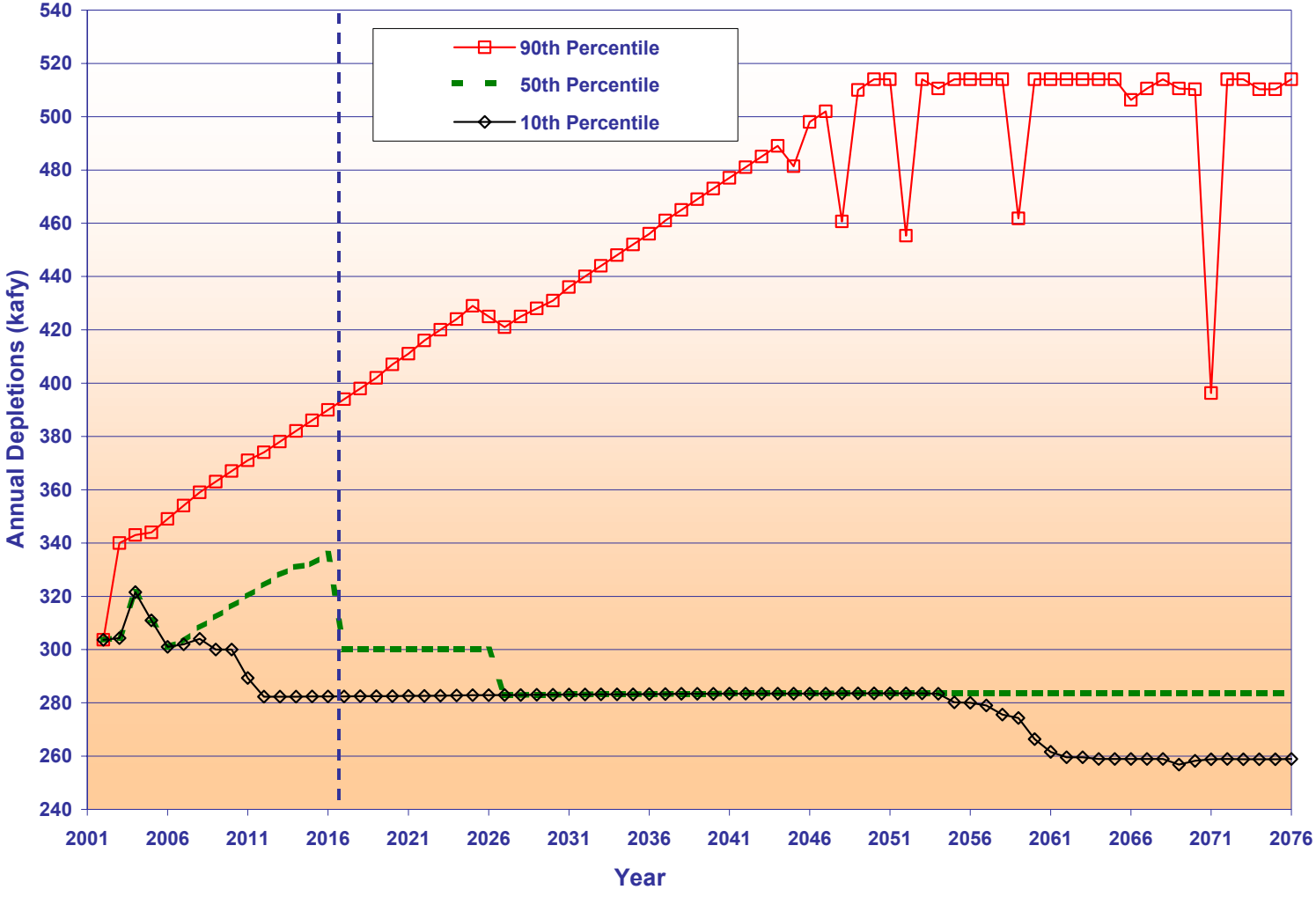
The 90th percentile values generally coincide with Nevada's normal depletion schedule under No Action Conditions through year 2045. After year 2045, the 90th percentile occasionally falls below the full surplus schedule, an indication of limited surplus conditions.

From 2002 through 2016, under No Action Conditions, the 50th percentile line for Nevada is at or above the normal depletion schedule suggesting a better than average probability of surplus condition deliveries. From 2017 through 2024, the 50th percentile line coincides with Nevada's normal depletion schedule. After 2024, the 50th percentile line coincides with Nevada's Level 1 shortage condition depletion schedule.

From 2002 through 2008, under No Action Conditions, the 10th percentile line for Nevada is also at or above the normal depletion schedule suggesting at least a 90 percent probability of surplus condition deliveries during this period. From 2009 through 2054, the 10th percentile line coincides with Nevada's Level 1 shortage condition depletion schedule. After 2054, under No Action Conditions, the 10th percentile begins to fall below 280 maf, an indication of frequent Level 2 shortage conditions.

As noted in Section 4.4.1, the SNWA and CAP essentially take all the reductions in water deliveries during shortage conditions (for modeling purposes). The model sets the SNWA's shortage condition delivery reductions to four percent of the total shortage condition delivery reduction amount when the Lake Mead water level is between elevation 1000 feet msl and the assumed shortage protection line as discussed in Section 2.3. This modeling assumption kept Nevada' annual delivery above 280 kaf until further cuts to the SNWA and CAP were necessary to maintain the Lake Mead water level above the 1000 feet msl elevation, a level 2 shortage condition. Under the No Action Conditions, deliveries to Nevada below 280 kaf occurred less than seven percent of the time during the 75-year period.

Figure 4.5-11
Nevada Modeled Annual Depletions Under No Action Conditions
90th, 50th and 10th Percentile Values



4.5.3.2 COMPARISON OF IMPLEMENTATION AGREEMENT TO NO ACTION

Figure 4.5-12 provides a comparison of the distribution of Nevada's depletions under the Implementation Agreement Conditions to those of the No Action Conditions during the 15-year Interim Surplus Guidelines period (years 2002 to 2016). This graph is best used to represent the frequency that different magnitude water deliveries to Nevada occurred during the 15-year Interim Surplus Guidelines period. The results presented in Figure 4.5-12 indicate an 92 percent probability that water deliveries to Nevada would meet or exceed its normal depletion schedule during this period under the No Action Conditions. The probability that Nevada would receive surplus condition deliveries under the No Action Conditions during this period was approximately 85 percent. The maximum surplus condition depletions under the No Action Conditions were 390 kaf during this 15-year period. The probability that Nevada would receive shortage condition deliveries under No Action Conditions was 8 percent. The minimum shortage condition depletion was 282.3 kaf.

Figure 4.5-13 provides a comparison of the distribution of the water deliveries to Nevada under the Implementation Agreement Conditions to those of the No Action Conditions for the 60-year period (years 2017 to 2076) that would follow the interim surplus guidelines period. The results presented in Figure 4.5-13 indicate a 37 percent probability that water deliveries to Nevada would meet or exceed its normal depletion schedule during this period under the No Action Conditions. The probability that Nevada would receive surplus condition deliveries during this same period under the No Action Conditions was approximately 18 percent. The maximum surplus condition depletions under the No Action Conditions were 514 kaf during this 60-year period. The probability that Nevada would receive shortage condition deliveries was less than 63 percent. The minimum shortage condition depletion during this period was 236.3 kaf.

Figure 4.5-14 provides a comparison of the distribution of the water deliveries to Nevada under the Implementation Agreement Conditions to those of the No Action Conditions for the entire 75-year period of analysis (years 2002 to 2076). The results presented in Figure 4.5-14 indicate a 48 percent probability that water deliveries to Nevada would meet or exceed its normal depletion schedule during this period under the No Action Conditions. The probability that Nevada would receive surplus condition deliveries during this same period under the No Action Conditions was approximately 31 percent. The maximum surplus condition depletions under the No Action Conditions were 514 kaf during this 75-year period. The probability that Nevada would receive shortage condition deliveries was less than 52 percent. The minimum shortage condition depletion during this period was 236.3 kaf.

Figure 4.5-12
Nevada Modeled Depletions
Comparison of Implementation Agreement Conditions to No Action Conditions
Years 2002 to 2016

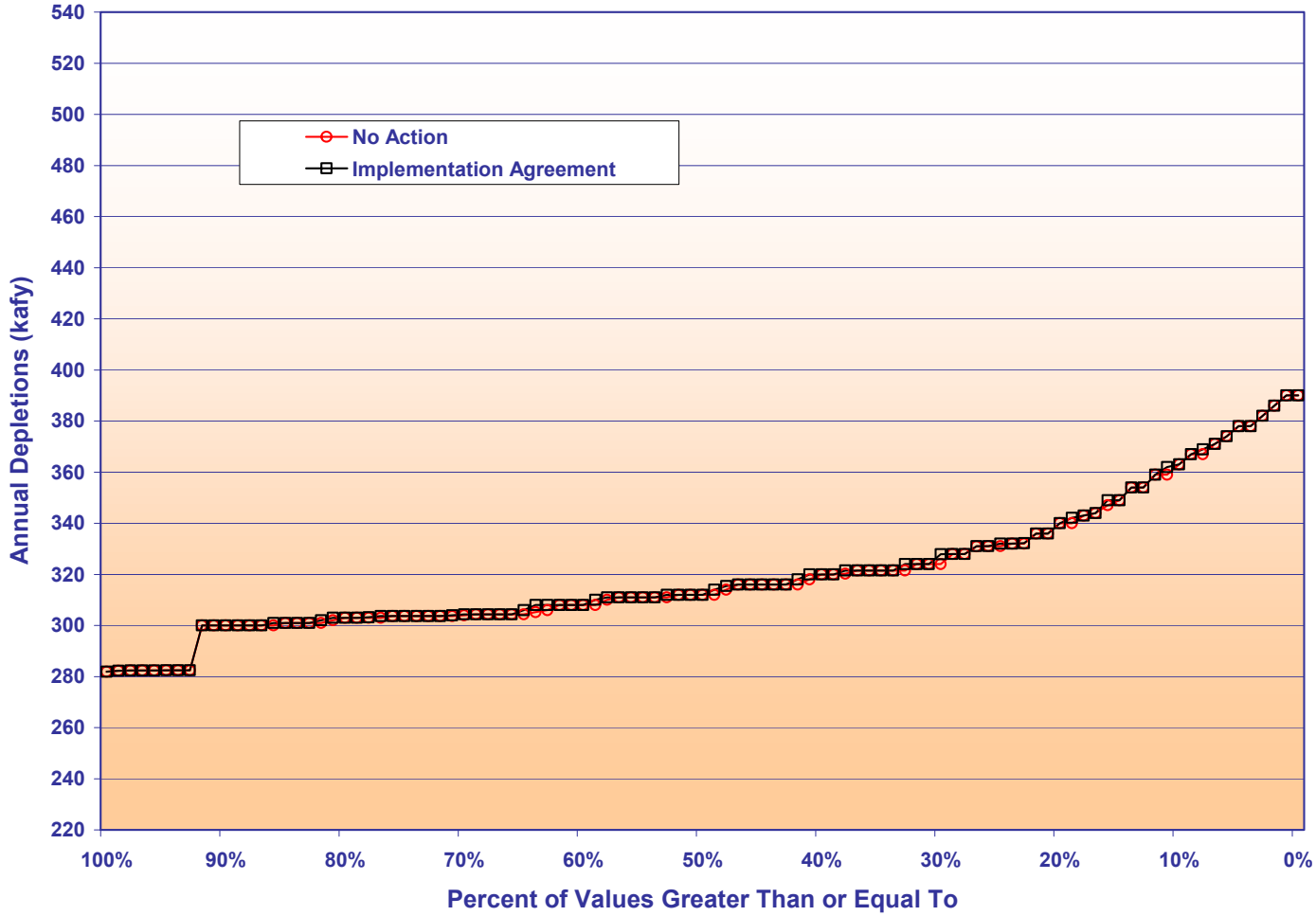


Figure 4.5-13
Nevada Modeled Depletions
Comparison of Implementation Agreement Conditions to No Action Conditions
Years 2017 to 2076

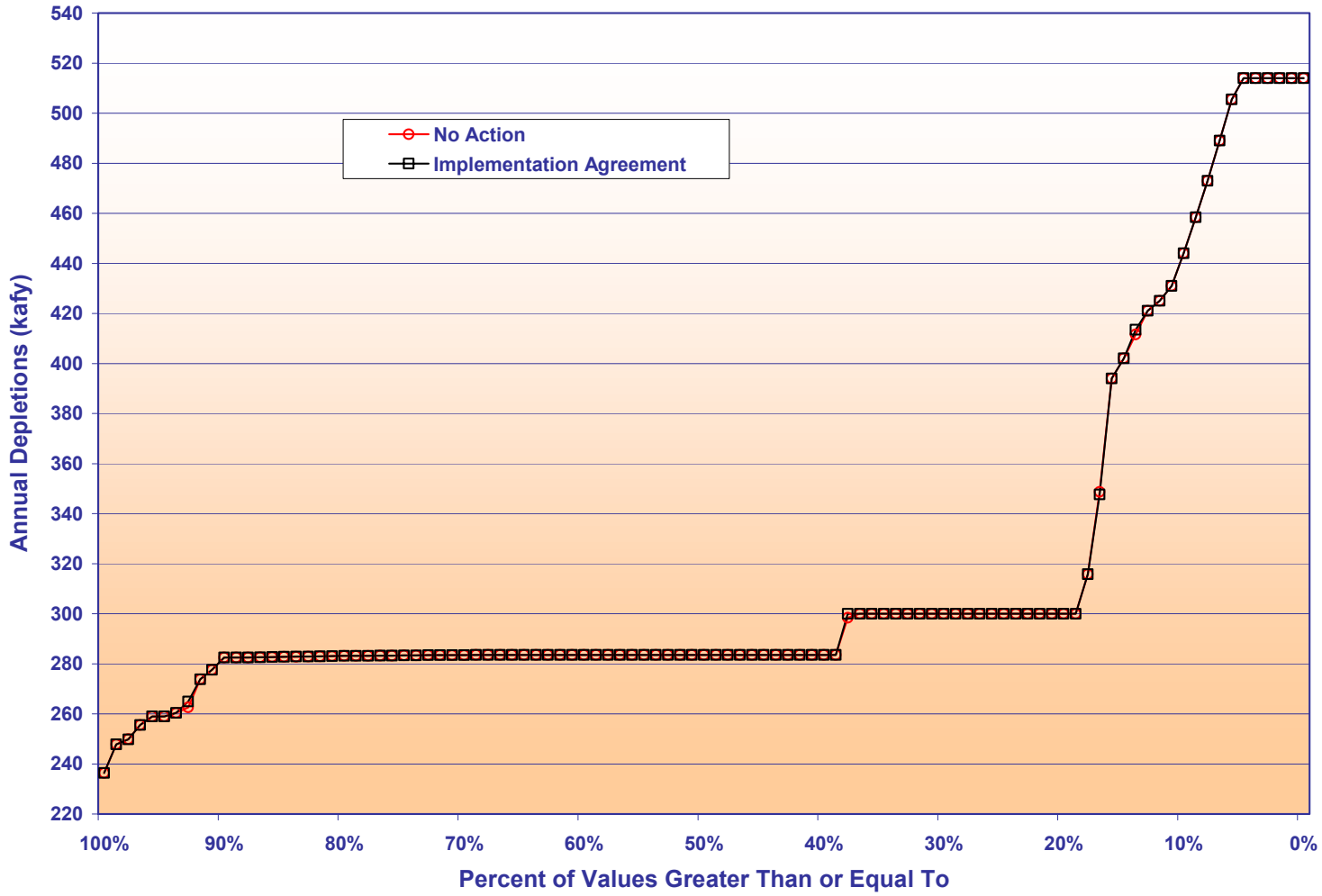


Figure 4.5-14
Nevada Modeled Depletions
Comparison of Implementation Agreement Conditions to No Action Conditions
Years 2002 to 2076

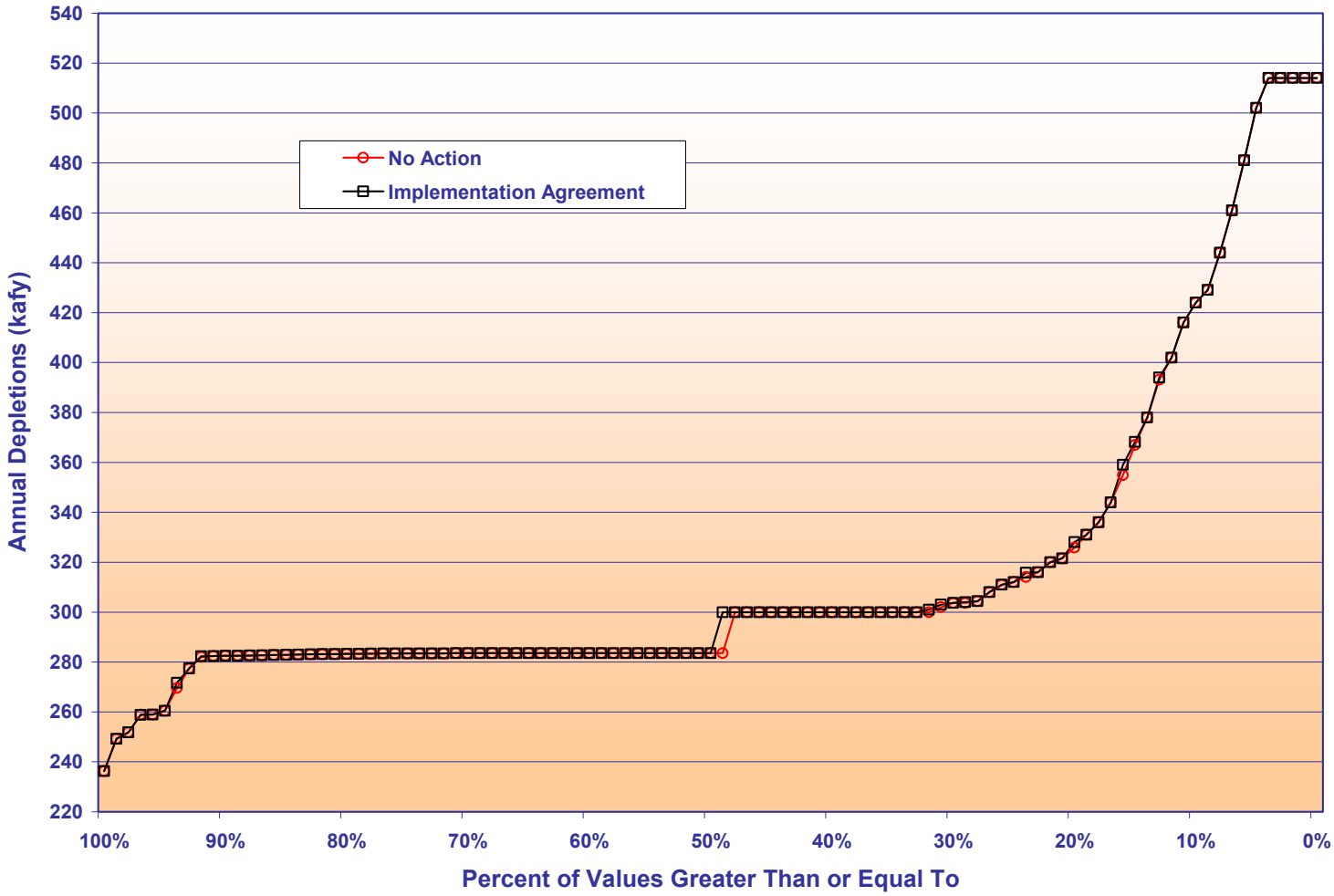
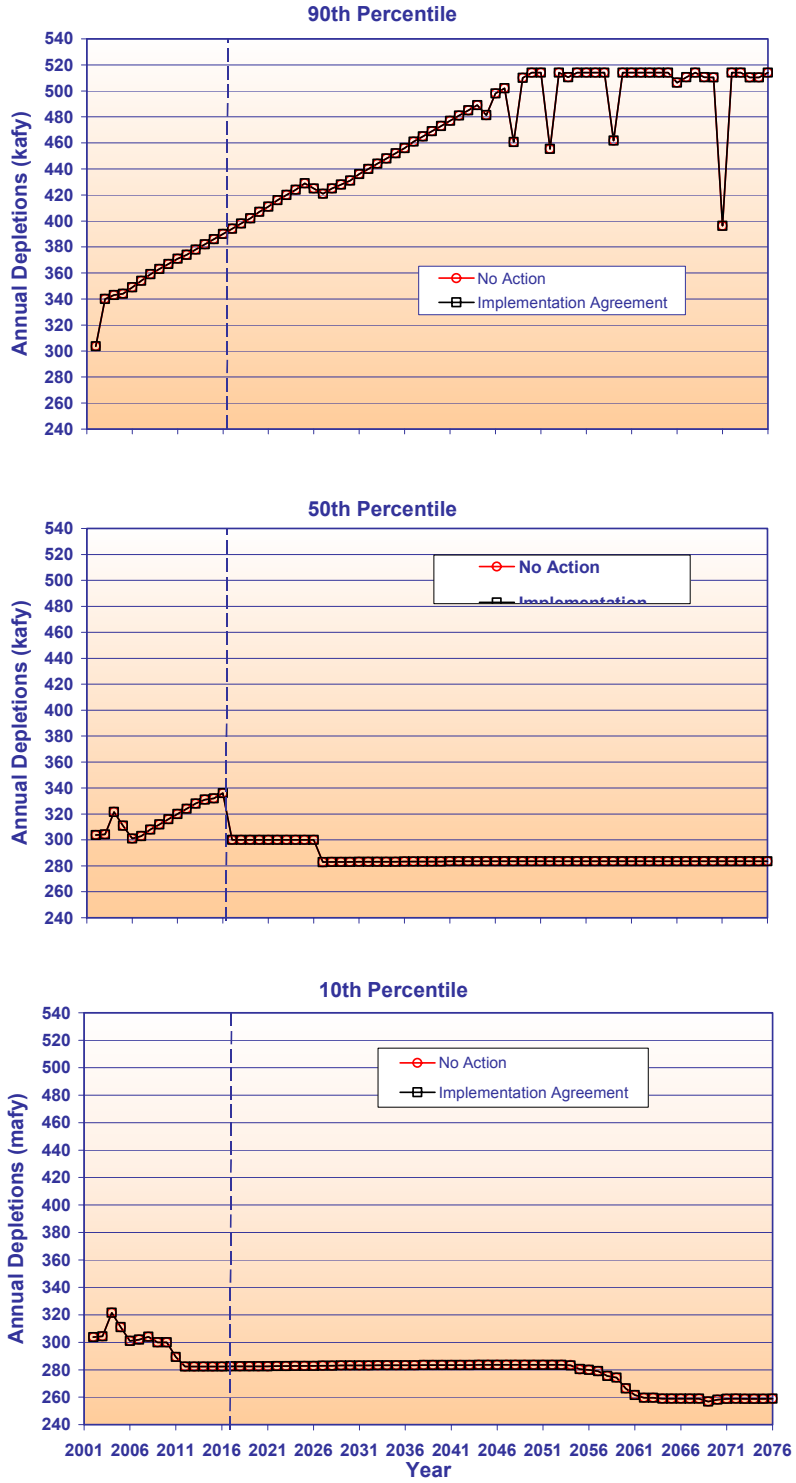


Figure 4.5-15 provides a comparison of the 90th, 50th and 10th percentile values for Nevada's depletions under the No Action Conditions to those of the Implementation Agreement Conditions. As noted in Figure 4.5-15, there is little difference between the 90th percentile values resulting from the Implementation Agreement Conditions and those of the No Action Conditions. Both 90th percentile lines generally coincide with Nevada's normal depletion schedule under No Action Conditions through year 2045. After year 2045, both 90th percentile lines occasionally fall below the full surplus schedule, an indication of limited surplus conditions.

From 2002 through 2016, the 50th percentile lines for both the No Action and Implementation conditions are at or above the normal depletion schedule, an indication of better than average probability of surplus condition deliveries. From 2017 through 2024, both 50th percentile lines coincide with Arizona's normal depletion schedule. After 2024, the 50th percentile line of the No Action Conditions falls to and thereafter coincides with Arizona's Level 1 shortage condition depletion schedule. The 50th percentile line under the Implementation Agreement Conditions continues to coincide with Arizona's normal depletion schedule until year 2026, two years longer than that of the No Action Conditions. After 2026, the 50th percentile line under the Implementation Agreement Conditions also falls to and thereafter coincides with Arizona's Level 1 shortage condition depletion schedule.

As noted in Figure 4.5-15, there is little difference between the 10th percentile values resulting from the Implementation Agreement Conditions and those of the No Action Conditions. Both 10th percentile lines are generally at or above Nevada's normal depletion schedule through year 2010. From 2011 through 2057, both 10th percentile lines generally coincide with Arizona's modeled Level 1 shortage condition depletion schedule. After 2057, the 10th percentile values resulting from the Implementation Agreement Conditions and No Action conditions fall and remain below the Level 1 shortage depletion schedule, an indication of the occurrence of more frequent Level 2 shortage condition deliveries.

Figure 4.5-15
Nevada Modeled Annual Depletions
Comparison of Implementation Agreement Conditions to No Action Conditions
90th, 50th and 10th Percentile Values



Figures 4.5-12, 4.5-13 and 4.5-14 presented comparisons of the distribution of Nevada's depletions under the Implementation Agreement Conditions to those of the No Action Conditions during the 15-year Interim Surplus Guidelines period (years 2002 to 2016), the 60-year period that would follow the Interim Surplus Guidelines (years 2017 to 2076), and the entire 75-year period of analysis (years 2002 to 2076), respectively. These graphs represent the frequency that different magnitude annual deliveries to Nevada occurred under each respective period. Table 4.5-3 provides a tabular summary of the comparison for these three periods.

Table 4.5-3
Summary of Nevada Modeled Annual Depletions
Comparison of Implementation Agreement Conditions to No Action Conditions

	Years 2002 to 2016			Years 2017 to 2076			Years 2002 to 2076		
Alternative/Conditions	**Normal***	**Surplus**	**Shortage**	**Normal***	**Surplus**	**Shortage**	**Normal***	**Surplus**	**Shortage**
No Action	92%	85%	8%	37%	18%	63%	48%	31%	52%
Implementation Agreement	92%	86%	8%	38%	18%	62%	49%	32%	51%
*The values under normal represent the total percentage of time that depletions would be at or above the normal depletion conditions.									

The percentage values presented under the column heading labeled “Normal” in Table 4.5-3 represent the total percentage of time that depletions under the noted conditions would be at or above the normal depletion schedule amount. The values presented under the column labeled “Surplus” represent the total percentage of time that depletions under the noted conditions exceed the normal depletion schedule amount. The values presented under the column labeled “Shortage” represent the total percentage of time that depletions under the noted conditions would be below the normal depletion schedule amount.

4.5.4 UPPER BASIN STATES

There are no specific criteria in the *Law of the River* for surplus or shortage condition water deliveries to users within the Upper Basin states. The normal depletion schedule of the Upper Basin states would be met under both the No Action and Implementation Agreement conditions. The exceptions are potential reductions to certain Upper Basin users whose diversions are located upstream of Lake Powell. For these users, the potential reductions would be attributed to dry hydrologic conditions and inadequate regulating reservoir storage capacity upstream of their diversions.

The proposed water transfers were determined to have no effect on water deliveries to the Upper Basin states, including the Upper Basin Tribes. Therefore, detailed analyses were not necessary for the Upper Basin states' water supply.

4.5.5 MEXICO

This section presents the analyses of the simulated water deliveries to Mexico under the No Action and Implementation Agreement conditions. As discussed previously, Mexico's normal depletion schedule is modeled as 1.5 maf. An additional 15,000 af is included to account for typical scheduling errors and water that is ordered by the Lower Division users but that is not diverted. Therefore, the normal annual depletion schedule deliveries to Mexico were modeled as 1.515 maf. Surplus deliveries to Mexico of up to 200 kaf are delivered under both No Action and the Implementation Agreement conditions only when Lake Mead makes flood control releases. Shortage deliveries to Mexico would only occur if the CAP were cut to zero and further cuts to MWD and Mexico were necessary to keep the Lake Mead water surface elevation above 1000 feet msl, a Level 2 shortage water supply condition.

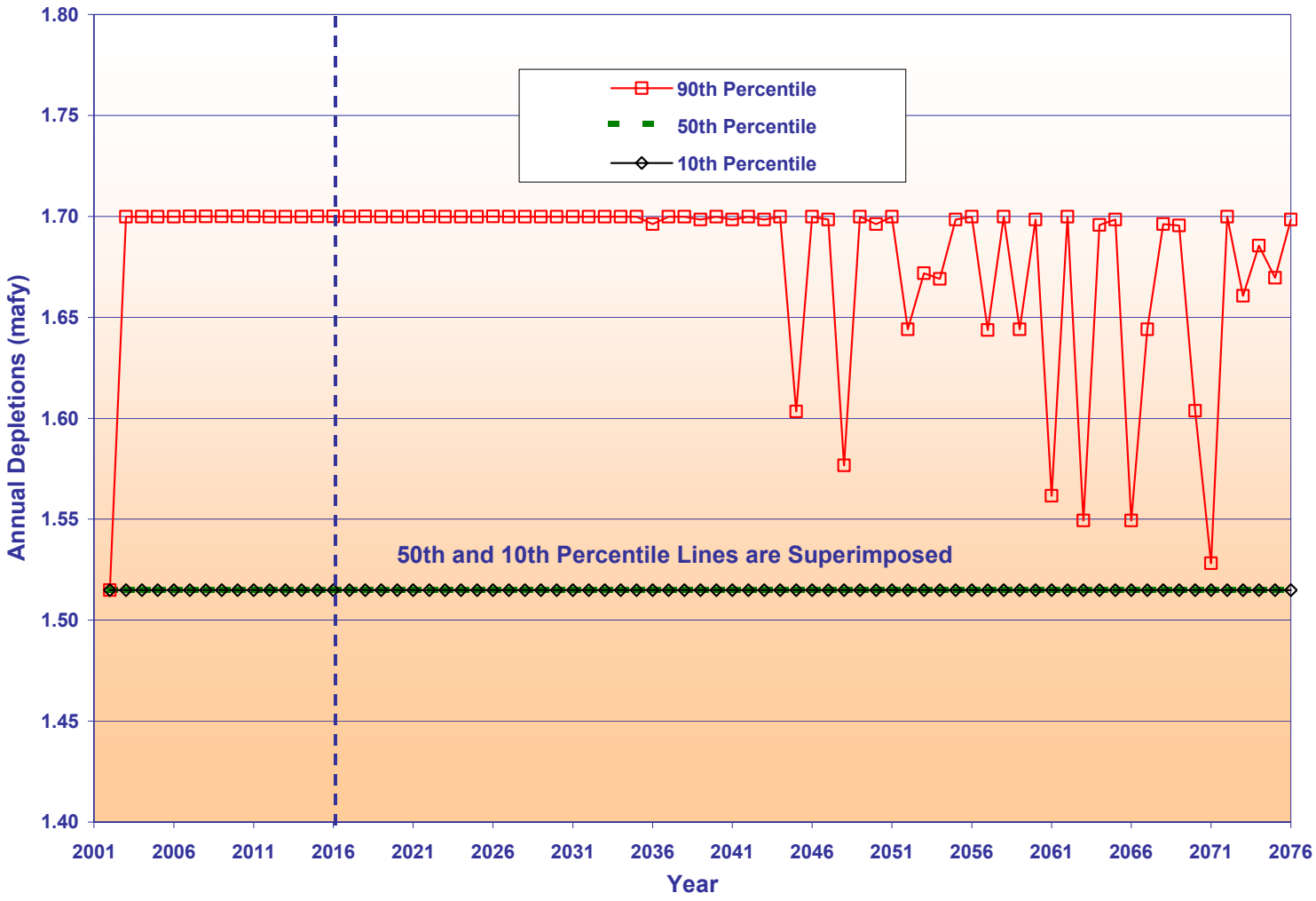
4.5.5.1 MODELING RESULTS OF NO ACTION

The water deliveries to Mexico are projected to be mostly at or above Mexico's normal delivery schedule throughout the 75-year period of analysis. Under the No Action Conditions, annual deliveries to Mexico that were less than its normal depletion schedule were observed to occur in only 19 of the 85-modeled traces, an indication of Level 2 shortage water supply conditions. In these 19 traces, the frequency of occurrence of annual deliveries to Mexico that were less than its normal depletion schedule was only one year of the 75 modeled years, after 2057. The minimum observed delivery to Mexico was 962,019 af.

The 90th, 50th and 10th percentile ranking of modeled water deliveries to Mexico under the No Action Conditions are presented in Figure 4.5-16. The 90th percentile line generally coincides with Mexico's full surplus condition schedule under No Action Conditions through year 2045. After year 2045, the 90th percentile occasionally falls below the full surplus schedule, an indication of limited surplus conditions. As indicated by this 90th percentile line, the probability that the No Action Conditions would provide Mexico some level of surplus condition deliveries is at least 10 percent throughout the 75-year period of analysis.

Under No Action Conditions, the 50th and 10th percentile lines coincide with Mexico's normal depletion schedule. Again, it is noted that the depletion amount depicted by both the 50th and 10th percentile lines is equal to 1.515 maf. The 15,000 af above the 1.5 maf Mexico apportionment was added to the model to account for typical scheduling errors and water that is ordered by the Lower Division users but that is not diverted. Again, it should be noted that the modeled water deliveries to Mexico under No Action Conditions were observed to drop below Mexico's normal depletion schedule in 19 of the 85-modeled traces.

Figure 4.5-16
Mexico Modeled Annual Depletions Under No Action Conditions
90th, 50th and 10th Percentile Values



4.5.5.2 COMPARISON OF IMPLEMENTATION AGREEMENT TO NO ACTION

Figure 4.5-17 provides a comparison of the distribution of Mexico's depletions under the Implementation Agreement Conditions to those of the No Action Conditions during the 15-year Interim Surplus Guidelines period (years 2002 to 2016). Again, this type of graph is used to represent the frequency that annual deliveries of different magnitudes occur in the respective period. The results presented in Figure 4.5-17 indicate a 100 percent probability that Mexico's depletions would meet or exceed its normal depletion schedule during this period under the No Action Conditions. The probability that Mexico would receive surplus condition deliveries during this period was approximately 21 percent under No Action Conditions. The surplus condition depletion under the No Action Conditions was 1.7 maf during this 15-year period.

Figure 4.5-18 provides a comparison of the distribution of the water deliveries to Mexico under the Implementation Agreement Conditions to those of the No Action Conditions for the 60-year period (years 2017 to 2076) that would follow the Interim Surplus Guidelines period. The results presented in Figure 4.5-18 indicate an approximately 99 percent probability that water deliveries to Mexico would meet or exceed its normal depletion schedule during this period under the No Action Conditions. The probability that Mexico would receive surplus condition deliveries during this same period under the No Action Conditions was approximately 16 percent. The maximum surplus condition depletion under the No Action Conditions was also 1.7 maf during this 60-year period.

Figure 4.5-19 provides a comparison of the distribution of the water deliveries to Mexico under the Implementation Agreement Conditions to those of the No Action Conditions for the entire 75-year period of analysis (years 2002 to 2076) that would follow the Interim Surplus Guidelines period. The results presented in Figure 4.5-19 indicate an approximately 99 percent probability that water deliveries to Mexico would meet or exceed its normal depletion schedule during this period under the No Action Conditions. The probability that Mexico would receive surplus condition deliveries during this same period under the No Action Conditions was approximately 17 percent during this 75-year period. The surplus condition depletion under the No Action Conditions was also 1.7 maf during this 75-year period.

Figure 4.5-17
Mexico Modeled Depletions
Comparison of Implementation Agreement Conditions to No Action Conditions
Years 2002 to 2016

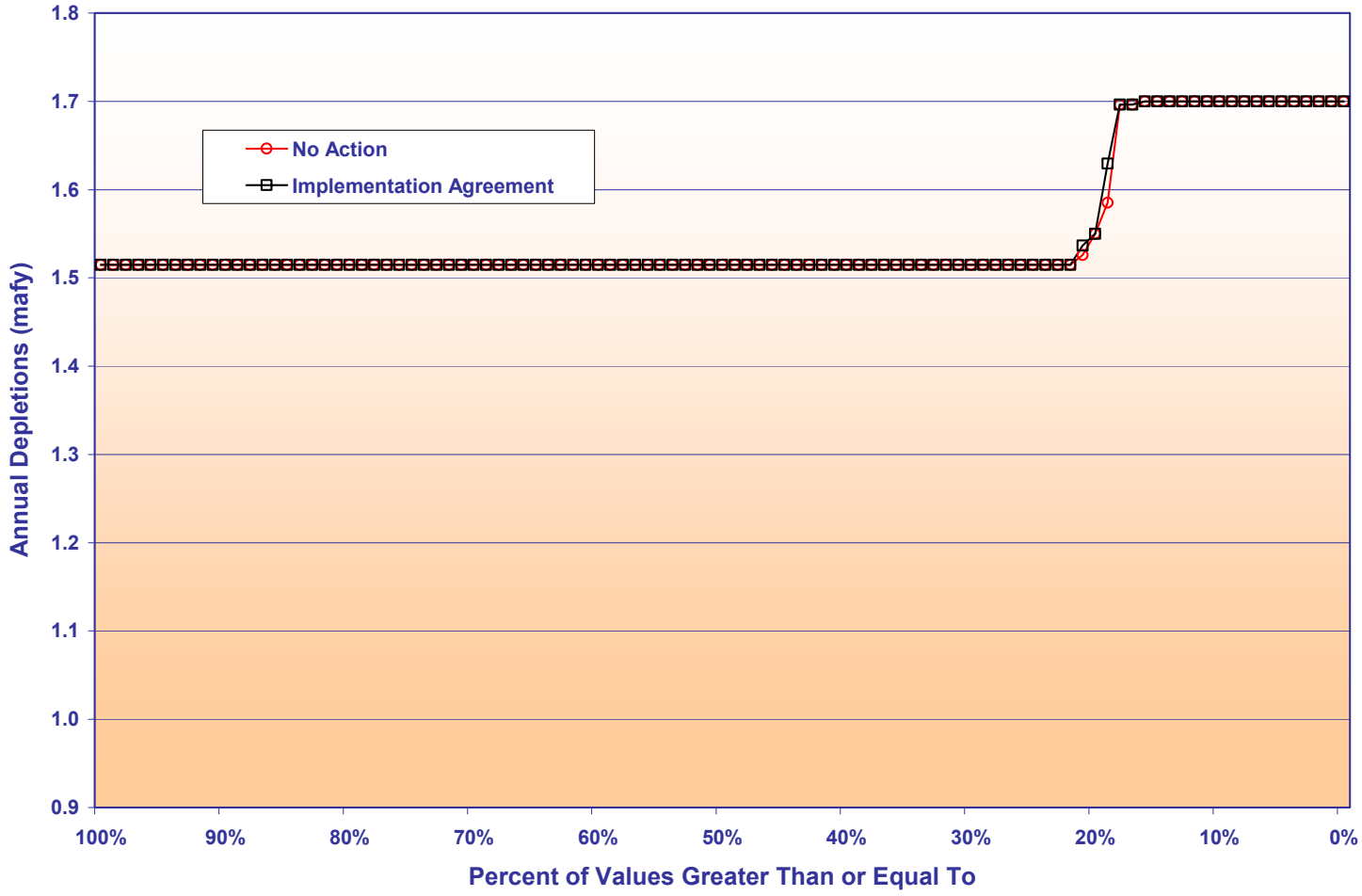


Figure 4.5-18
Mexico Modeled Depletions
Comparison of Implementation Agreement Conditions to No Action Conditions
Years 2017 to 2076

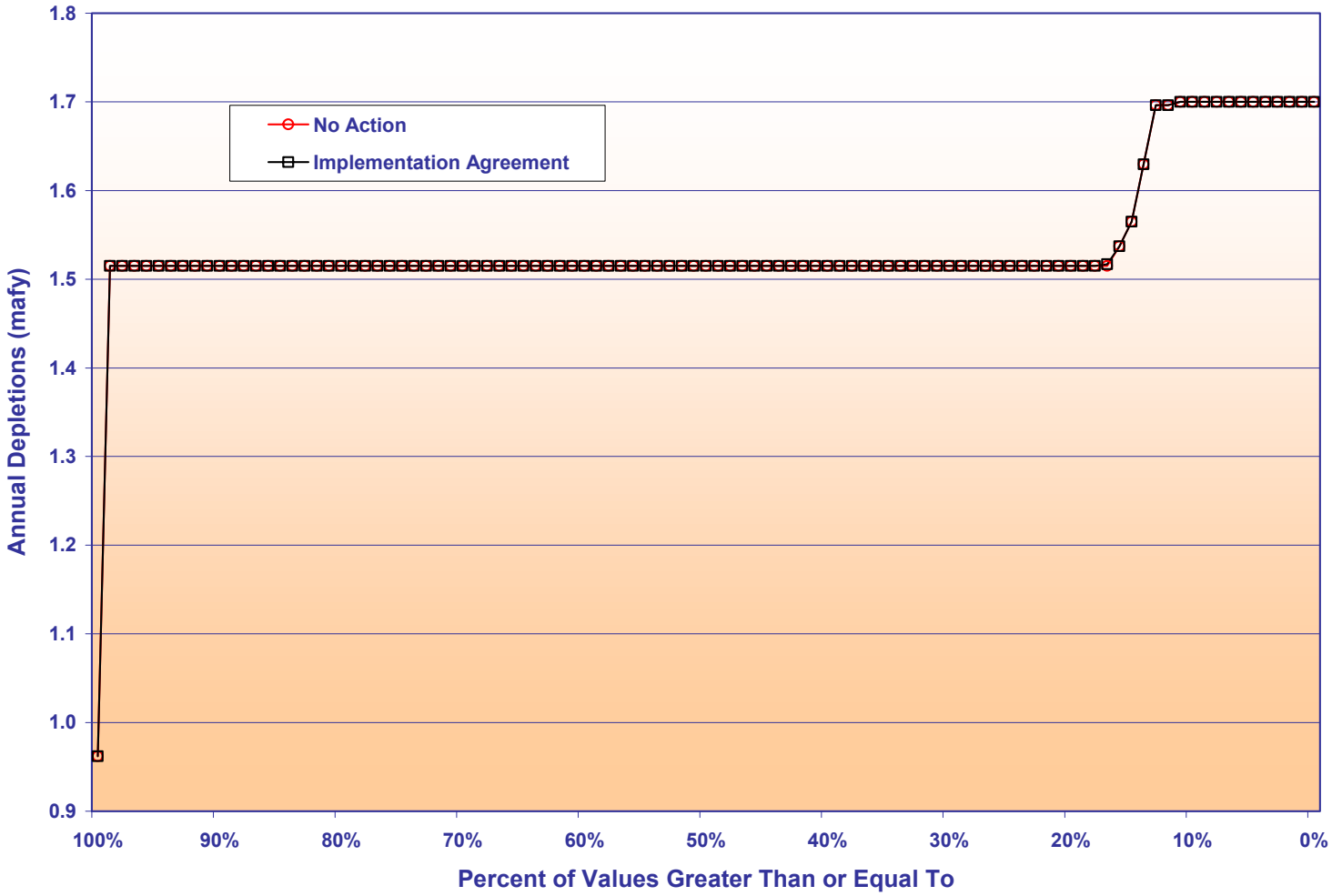


Figure 4.5-19
Mexico Modeled Depletions
Comparison of Implementation Agreement Conditions to No Action Conditions
Years 2002 to 2076

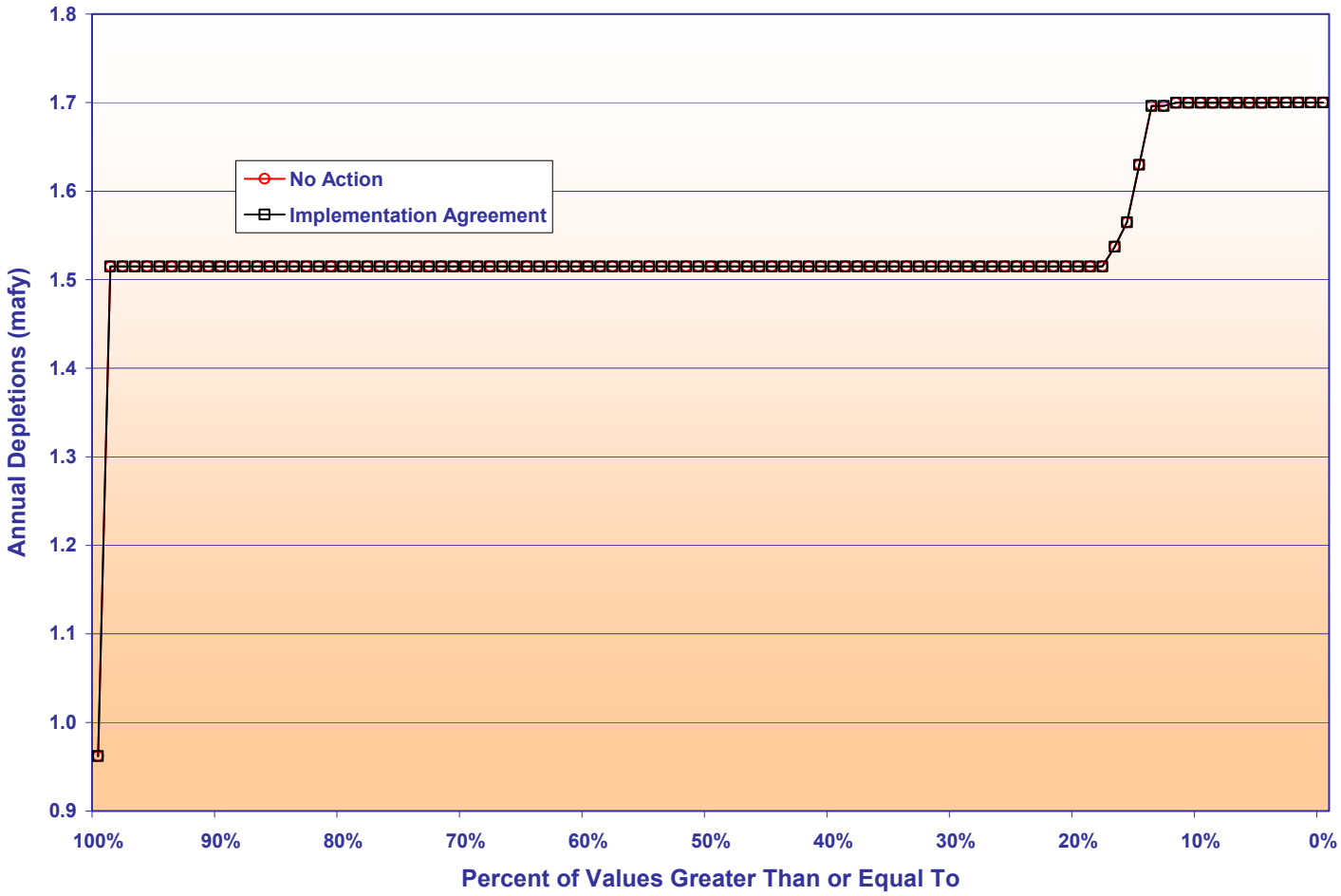


Figure 4.5-20 provides a comparison of the 90th, 50th and 10th percentile values for Mexico's depletions under the Implementation Agreement Conditions to those of the No Action Conditions. As noted in Figure 4.5-20, there is essentially no difference in the 90th percentile lines resulting from the Implementation Agreement Conditions when compared to those of the No Action Conditions. Both 90th percentile lines generally coincide with Mexico's full surplus depletion schedule through year 2045. After year 2045, both 90th percentile lines occasionally fall below the full surplus schedule, an indication of more limited surplus conditions.

The 50th and 10th percentile lines for the Implementation Agreement and the No Action conditions coincide with Mexico's normal depletion schedule, an indication of better than 90 percent probability that water deliveries to Mexico would meet or exceed its normal depletion schedule. Again, Level 2 shortage condition deliveries to Mexico were observed to occur in only 19 of the 85-modeled traces in both the No Action and Implementation Agreement conditions. In each of these 19 traces, deliveries of less than the normal depletion schedule amounts occurred in only one of the 75 years modeled.

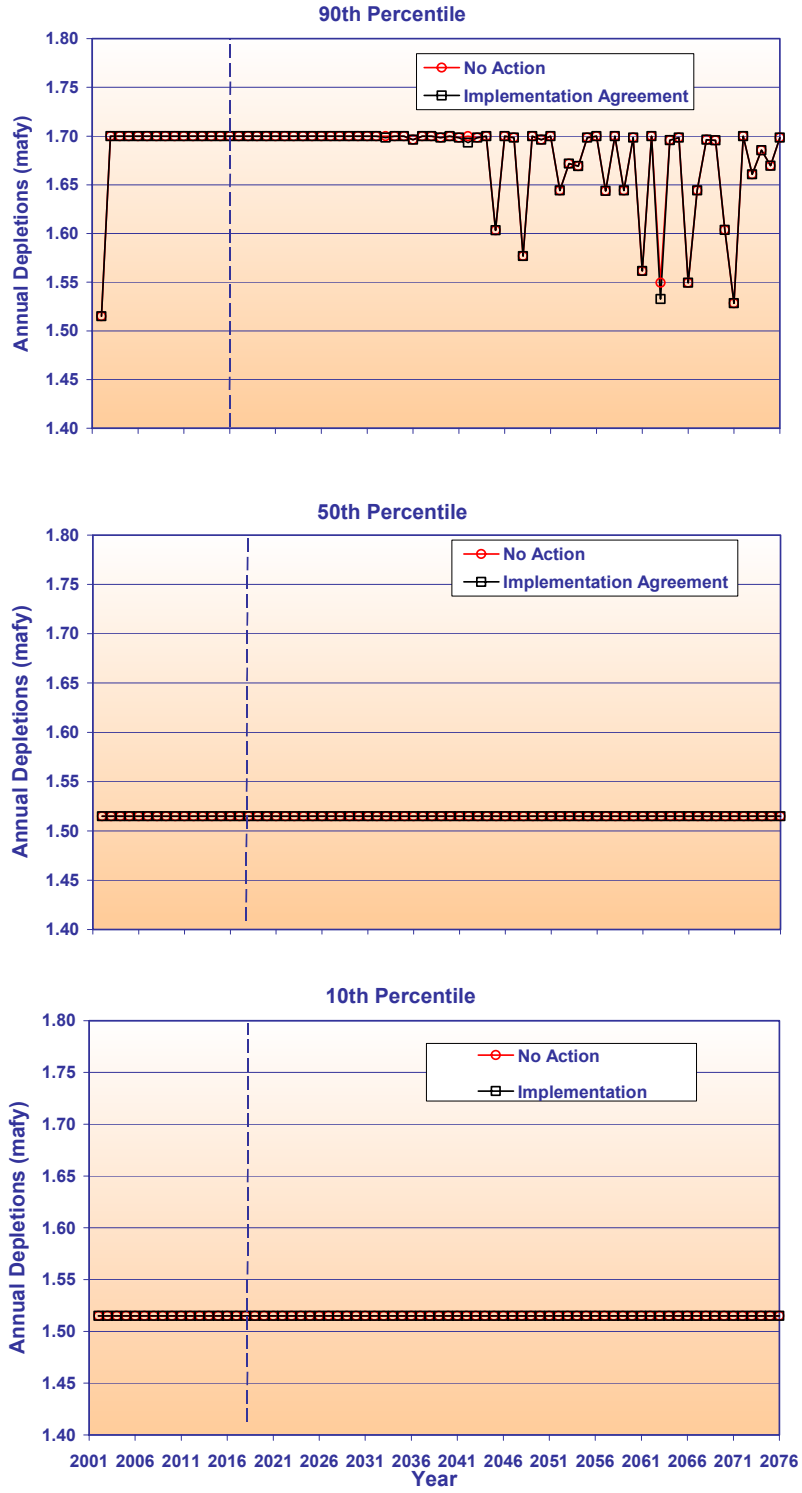
Figures 4.5-17, 4.5-18 and 4.5-19 presented comparisons of the distribution of Mexico's depletions under the Implementation Agreement Conditions to those of the No Action Conditions during the 15-year Interim Surplus Guidelines period (years 2002 to 2016), the 60-year period that follows the Interim Surplus Guidelines (years 2017 to 2076) and the entire 75-year period of analysis (years 2002 to 2076), respectively. Table 4.5-4 provides a tabular summary of the comparison for these three periods.

Table 4.5-4
Summary of Mexico Modeled Annual Depletions
Comparison of Implementation Agreement Conditions to No Action Conditions

	Years 2002 to 2016			Years 2017 to 2076			Years 2002 to 2076		
Alternative/Conditions	**Normal***	**Surplus**	**Shortage**	**Normal***	**Surplus**	**Shortage**	**Normal***	**Surplus**	**Shortage**
No Action	100%	21%	0%	99%	16%	1%	99%	17%	1%
Implementation Agreement	100%	21%	0%	99%	17%	1%	99%	17%	1%
*The values under normal represent the total percentage of time that depletions would be at or above the normal depletion conditions.									

The percentage values presented under the column heading labeled "Normal" in Table 4.5-4 represent the total percentage of time that depletions under the noted conditions would be at or above the normal depletion schedule amount. The values presented under the column labeled "Surplus" represent the total percentage of time that depletions under the noted conditions exceed the normal depletion schedule amount. The values presented under the column labeled "Shortage" represent the total percentage of time that depletions under the noted conditions would be below the normal depletion schedule amount.

Figure 4.5-20
Mexico Modeled Annual Depletions
Comparison of Implementation Agreement Conditions to No Action Conditions
90th, 50th and 10th Percentile Values



4.6 ANALYSIS OF CUMULATIVE EFFECTS

This section describes the results of the analysis that evaluates the potential cumulative impacts to the water deliveries to each of the Lower Basin states and Mexico resulting from the proposed implementation of all the water management programs contemplated under this Technical Memorandum. The modeled operational scenarios that are used to evaluate the cumulative effects of the various water management programs in this section consist of the Baseline for the Cumulative Analysis (Baseline) and the Cumulative Analysis Conditions. These scenarios are defined in Section 2.2.

4.6.1 STATE OF ARIZONA

This section presents the simulated water deliveries to Arizona under the Baseline and Cumulative Analysis Conditions. The analysis of Arizona's water supply concentrated on total Arizona water depletions.

4.6.1.1 MODELING RESULTS OF BASELINE

The water deliveries to Arizona are projected to fluctuate throughout the 75-year period of analysis reflecting variations in hydrologic conditions. The 90th, 50th and 10th percentile ranking of modeled water deliveries to Arizona under the Baseline conditions are presented in Figure 4.6-1.

With the exception of the first year modeled (2002), the 90th percentile line coincides with Arizona's depletion schedule during full surplus water supply conditions through year 2044 (compare Figure 4.6-1 to Figure 4.4-1). As indicated by this 90th percentile line, the probability that the Baseline Conditions would provide Arizona's full surplus depletion schedule is at least 10 percent during this period. After year 2044, the 90th percentile line occasionally falls below the full surplus schedule although it still remains close to Arizona's depletion schedule during full surplus water supply conditions and generally at or above 3.0 mafy.

The 50th percentile line represents the median annual depletion values. This 50th percentile line generally coincides with Arizona's projected depletion schedule under normal water supply conditions through year 2027 (see Figure 4.4-1). After 2027, the median values drop to approximately 2.4 mafy and remain at approximately that level for the remainder of the 75 year period of analysis.

Under the Baseline Conditions, the 10th percentile values generally coincide with Arizona's normal depletion schedule through year 2013. After 2013, the median values drop to approximately 2.4 maf and remain at approximately that level until year 2054. After 2054, the 10th percentile line falls below 2.4 mafy and remains below this amount for the remainder of the 75 year period of analysis, an indication of an increased frequency of Level 2 Shortage conditions.

As noted in Section 4.4.1, under shortage conditions, Arizona would bear 96 percent of the reduction and Nevada would bear four percent. In Arizona, the reduction would be shared prorata among CAP and non-CAP holders of fourth priority entitlements. To simplify the modeling process, the model sets the CAP's shortage water supply condition deliveries at 1.0 maf when the Lake Mead water level is between elevation 1000 feet msl and the assumed shortage protection line as discussed in Section 2.4. This modeling assumption kept Arizona's annual deliveries above 2.4 maf until further cuts to the CAP were necessary to maintain the Lake Mead water level above the 1000 feet msl elevation (a Level 2 shortage condition). Under the Baseline scenario modeled, Level 2 shortage water supply condition deliveries to Arizona below 2.4 maf were observed to occur less than seven percent of the time during the 75-year period of analysis.

Figure 4.6-1
Arizona Modeled Annual Depletions Under Baseline Conditions
90th, 50th and 10th Percentile Values

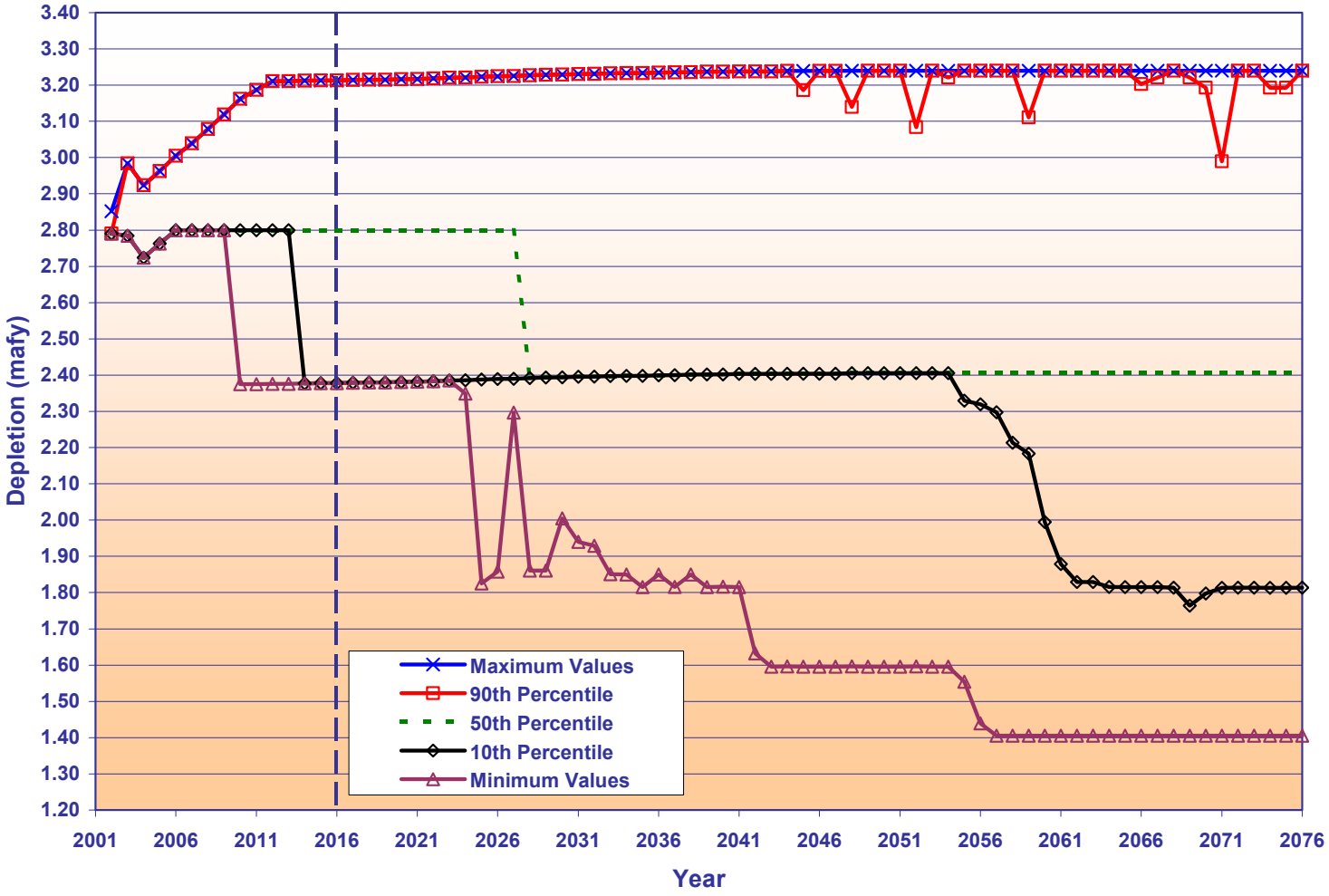


Figure 4.6-2 provides a comparison of the distribution of Arizona's depletions under the Cumulative Analysis Conditions to those of the Baseline Conditions during the 15-year Interim Surplus Guidelines period (years 2002 to 2016). This type of graph is used to represent the frequency that annual deliveries of different magnitudes occur in the respective period. The results presented in Figure 4.6-2 indicate a 74 percent probability that annual water deliveries to Arizona would meet or exceed its normal depletion schedule during this period under Baseline conditions. The probability that Arizona would receive surplus condition deliveries during this period was approximately 26 percent. The maximum surplus condition depletions under the Baseline Conditions were 3.213 maf during this period. The probability that Arizona would receive shortage condition deliveries was 26 percent. The minimum shortage condition depletion was 2.376 maf during this 15-year period.

Figure 4.6-3 provides a comparison of the distribution of the water deliveries to Arizona under the Cumulative Analysis Conditions to those of the Baseline Conditions for the 60-year period (years 2017 to 2076) that would follow the Interim Surplus Guidelines period. The results presented in Figure 4.6-3 indicate a 39 percent probability that water deliveries to Arizona would meet its normal depletion schedule during this period under the Baseline conditions. The probability that Arizona would receive surplus condition deliveries during this same period under the Baseline conditions was approximately 18 percent. The maximum surplus condition depletions under the Baseline Conditions were 3.24 maf during this period. The probability that Arizona would receive deliveries less than its normal schedule (Level 1 or Level 2 shortage condition deliveries) was approximately 61 percent. Second level shortage conditions occurred less than eight percent of the time during this period. The minimum shortage condition depletion was 1.405 maf.

Figure 4.6-4 provides a comparison of the distribution of the water deliveries to Arizona under the Cumulative Analysis Conditions to those of the Baseline Conditions for the entire 75-year period of analysis (years 2002 to 2076). The results presented in Figure 4.6-4 indicate a 46 percent probability that water deliveries to Arizona would meet or exceed its normal depletion schedule during this period under the Baseline Conditions. The probability that Arizona would receive surplus condition deliveries during this same period under the Baseline Conditions was approximately 20 percent. The maximum surplus condition depletions under the Baseline Conditions were 3.24 maf during this period. The probability that Arizona would receive deliveries less than its normal schedule (Level 1 or Level 2 shortage condition deliveries) was approximately 54 percent. Second level shortage conditions occurred less than seven percent of the time during this period. The minimum shortage condition depletion under the Baseline conditions was 1.405 maf.

Figure 4.6-2
Arizona Modeled Depletions
Comparison of Cumulative Analysis Conditions to Baseline Conditions
Years 2002 to 2016

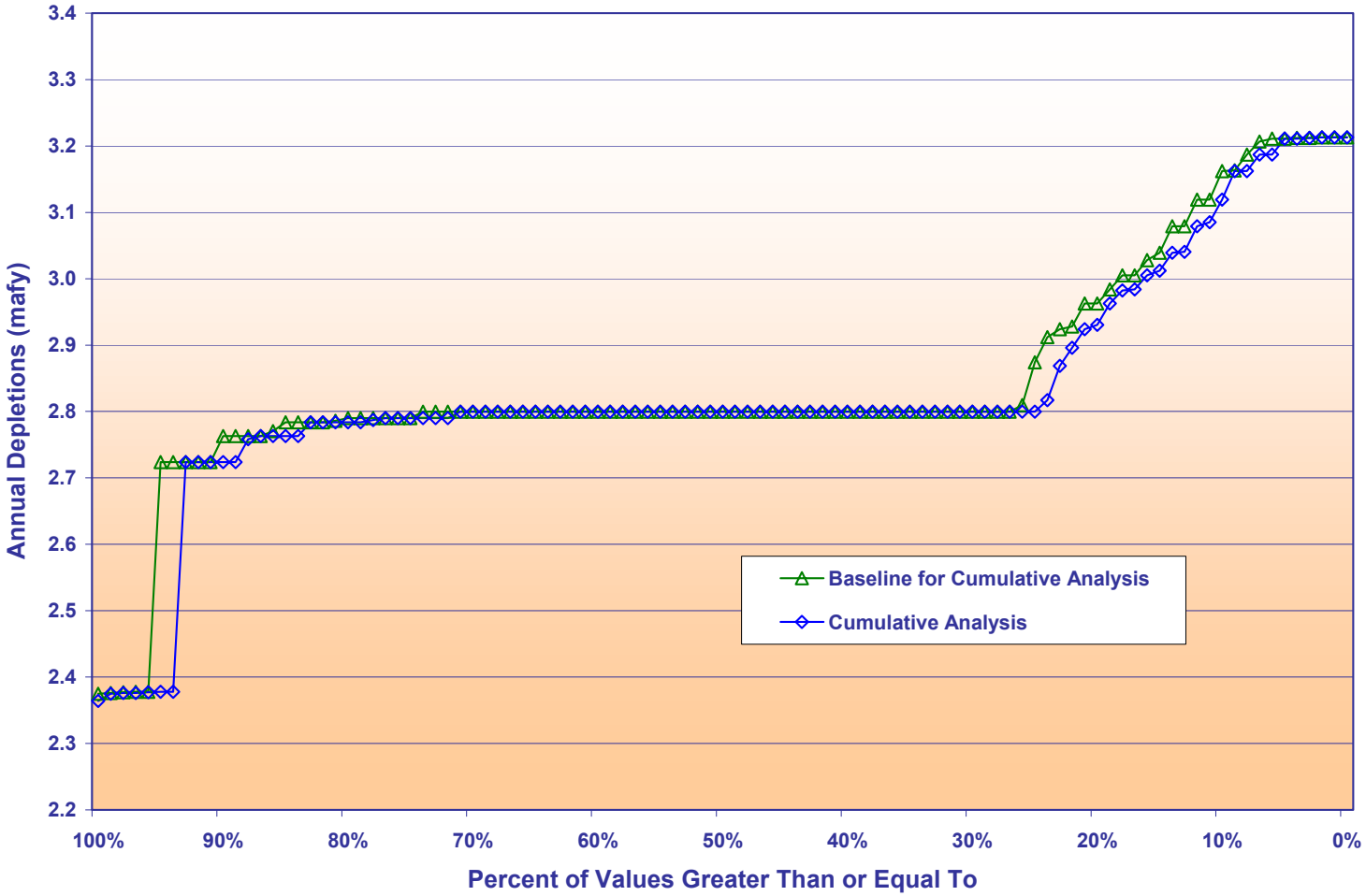


Figure 4.6-3
Arizona Modeled Depletions
Comparison of Cumulative Analysis Conditions to Baseline Conditions
Years 2017 to 2076

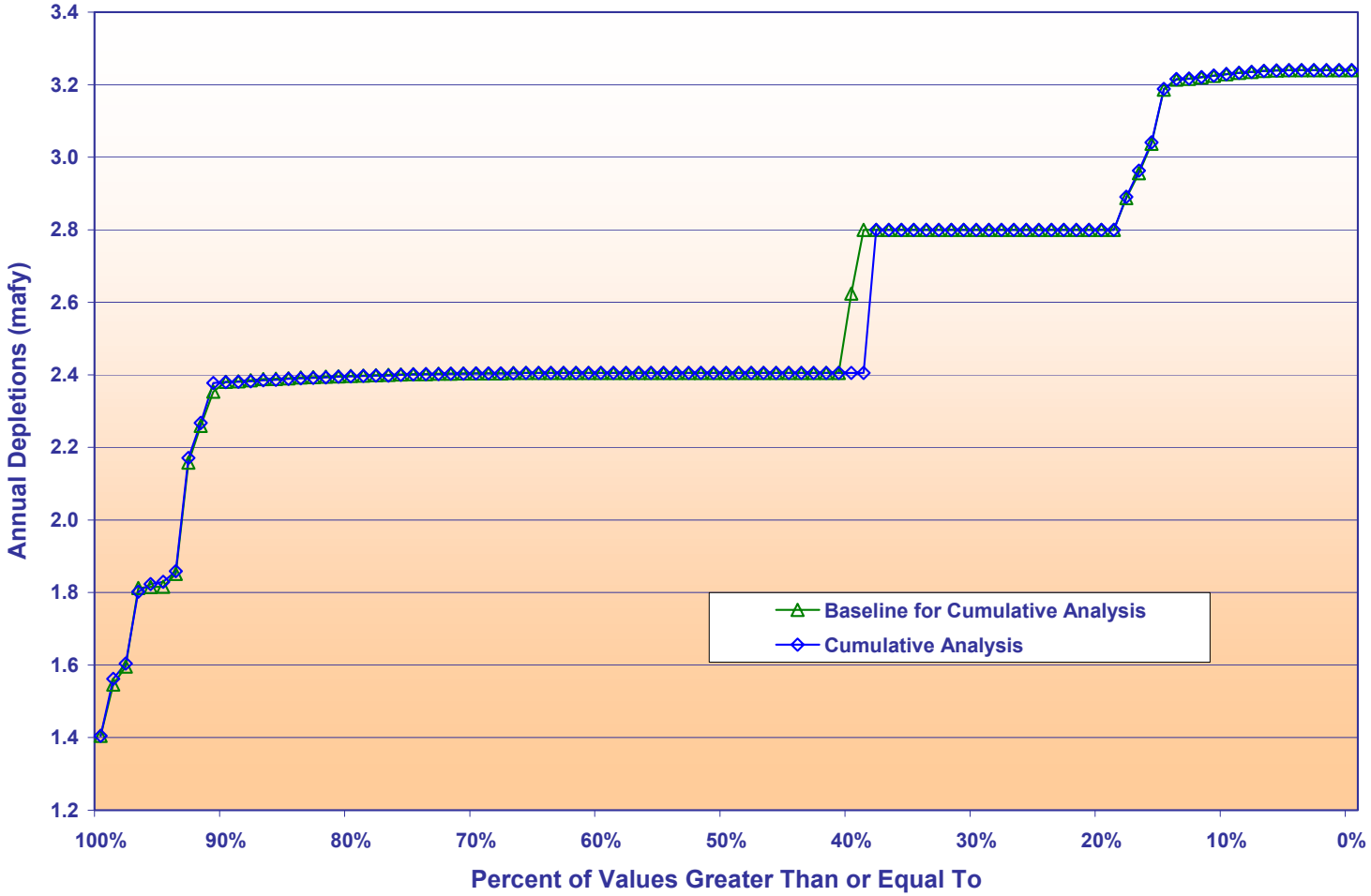
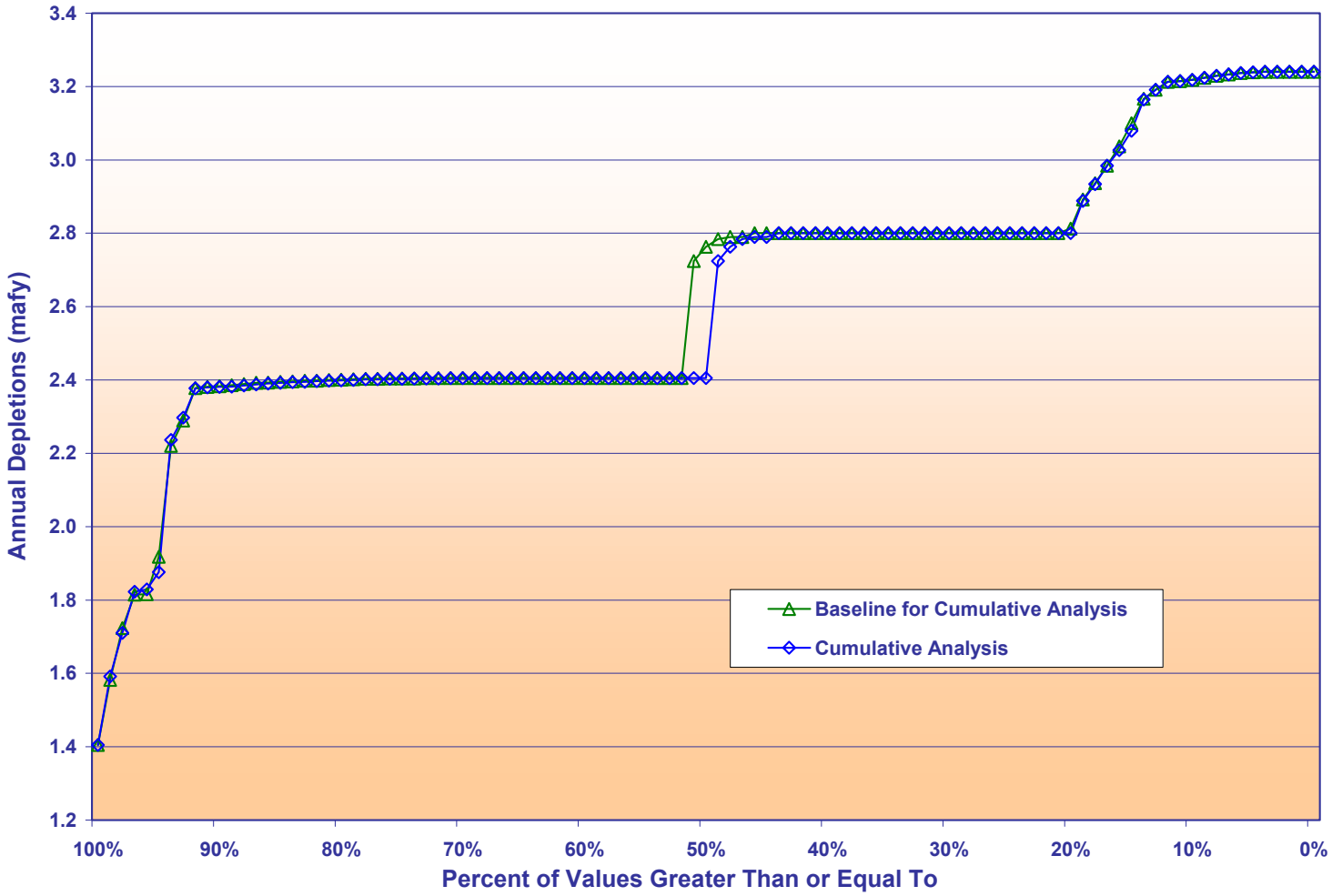


Figure 4.6-4
Arizona Modeled Depletions
Comparison of Cumulative Analysis Conditions to Baseline Conditions
Years 2002 to 2076



4.6.1.2 COMPARISON OF BASELINE TO CUMULATIVE ANALYSIS

Figure 4.6-5 provides a comparison of the 90th, 50th and 10th percentile values for Arizona's modeled depletions under the Baseline conditions to those of the Cumulative Analysis conditions. As depicted in Figure 4.6-5, there is little difference in the 90th percentile lines resulting from the Cumulative Analysis conditions as compared to those of the Baseline conditions. Both 90th percentile lines generally coincide with Arizona's full surplus depletion schedule through year 2044. After year 2044, both 90th percentile lines occasionally fall below the full surplus schedule. Nevertheless, both 90th percentile lines remain close to Arizona's depletion schedule during full surplus water supply conditions and generally at or above 3.0 mafy.

The 50th percentile lines for the Baseline and Cumulative Analysis conditions are identical to each other through year 2026 and coincide with Arizona's normal depletion schedule during this period. After year 2026, the 50th percentile values for the Cumulative Analysis Conditions fall due to the increasing probability of Level 1 shortage condition deliveries. The 50th percentile line for the Baseline Conditions continues to coincide with the normal depletion schedule through year 2027, one year more than under the Cumulative Analysis. After 2028, the 50th percentile lines for the Baseline Conditions also falls due to the increasing probability of the Level 1 shortages conditions, under this modeled scenario. The 50th percentile values for the Baseline and Cumulative Analysis conditions remain at approximately 2.4 mafy after year 2028.

The 10th percentile lines for the Baseline and the Cumulative Analysis conditions are essentially at or above Arizona's normal depletion schedule through year 2010. After 2010, the 10th percentile values of Cumulative Analysis Conditions fall below the normal depletion schedule to approximately 2.4 mafy, an indication of the occurrence of more frequent Level 1 shortage condition delivery. The 10th percentile values observed under the Baseline Conditions remain at or above Arizona's normal depletion schedule through year 2013. After 2010, the 10th percentile values of Cumulative Analysis Conditions fall below the normal depletion schedule to approximately 2.4 mafy, an indication of the occurrence of more frequent Level 1 shortage condition delivery. The 10th percentile lines for the Baseline and the Cumulative Analysis conditions at approximately 2.4 mafy until 2054 and 2056, respectively and then fall below 2.4 mafy, due to increasing frequency of Level 2 shortage condition deliveries.

Figures 4.6-2, 4.6-3 and 4.6-4 present comparisons of the cumulative distribution of Arizona's depletions under the Baseline and the Cumulative Analysis conditions during the 15-year Interim Surplus Guidelines period (years 2002 to 2016), the 60-year period that follows the Interim Surplus Guidelines (years 2017 to 2076), and the entire 75-year period of analysis (years 2002 to 2076), respectively. These graphs best illustrate the frequency that different amounts of annual Arizona water deliveries occur over these time frames. Table 4.6-1 provides a summary of the comparison for these three time periods.

Figure 4.6-5
Arizona Modeled Annual Depletions
Comparison of Baseline Conditions to Cumulative Analysis Conditions
90th, 50th and 10th Percentile Values

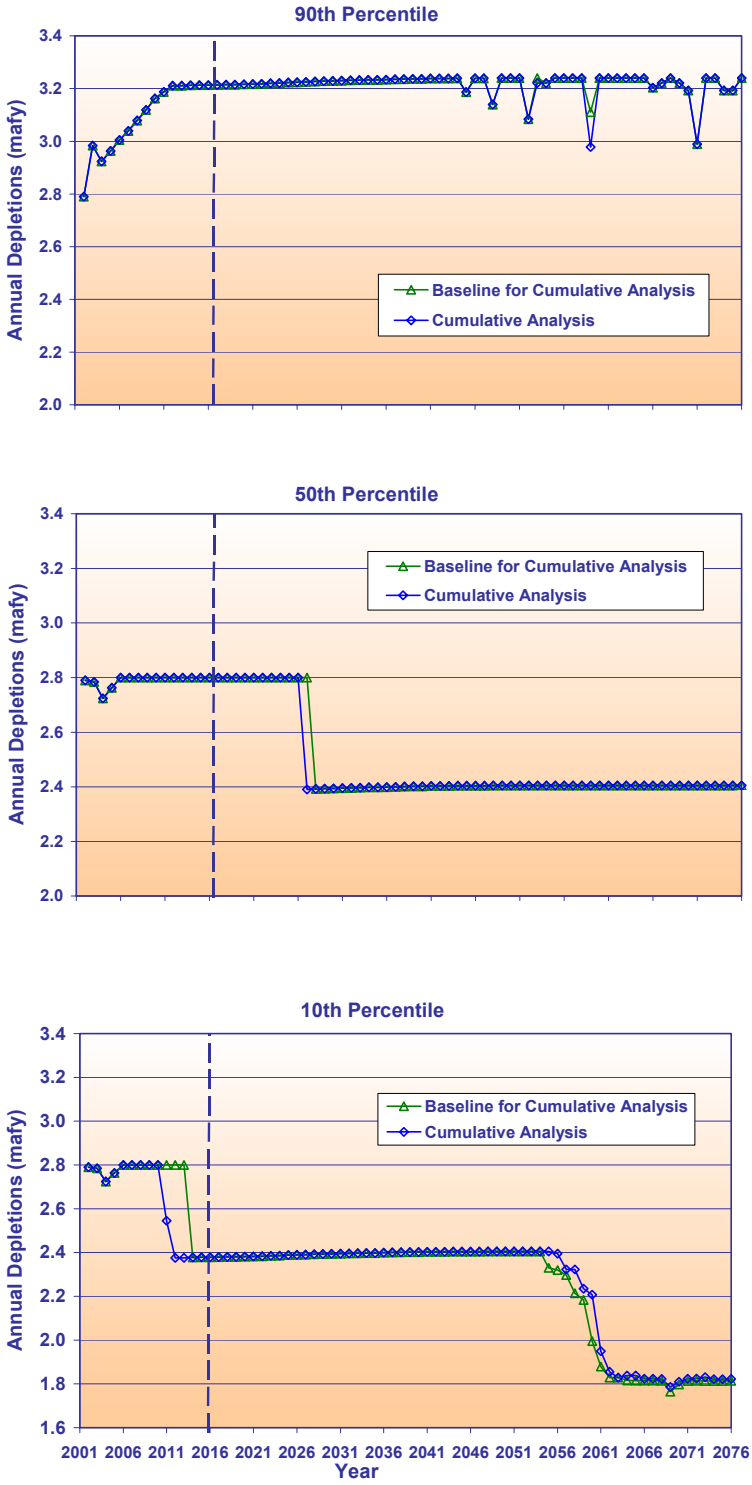


Table 4.6-1
Summary of Arizona Modeled Annual Depletions
Comparison of Cumulative Analysis Conditions to Baseline Conditions

Alternative/Conditions	Years 2002 to 2016			Years 2017 to 2076			Years 2002 to 2076		
	Normal*	Surplus	Shortage	Normal*	Surplus	Shortage	Normal*	Surplus	Shortage
Baseline	74%	26%	26%	39%	18%	61%	46%	20%	54%
Cumulative Analysis	71%	24%	29%	38%	18%	62%	44%	19%	56%
*The values under normal represent the total percentage of time that depletions would be at or above the normal depletion conditions.									

The percentage values presented under the column heading labeled "Normal" in Table 4.6-1 represent the total percentage of time that depletions under the noted conditions would be at or above the normal depletion schedule amount. The values presented under the column labeled "Surplus" represent the total percentage of time that depletions under the noted conditions exceed the normal depletion schedule amount. The values presented under the column labeled "Shortage" represent the total percentage of time that depletions under the noted conditions would be below the normal depletion schedule amount.

4.6.2 STATE OF CALIFORNIA

This section presents the simulated water deliveries to California under the Baseline and Cumulative Analysis conditions. The analysis of California's water supply concentrated on total California water depletions.

4.6.2.1 MODELING RESULTS OF BASELINE

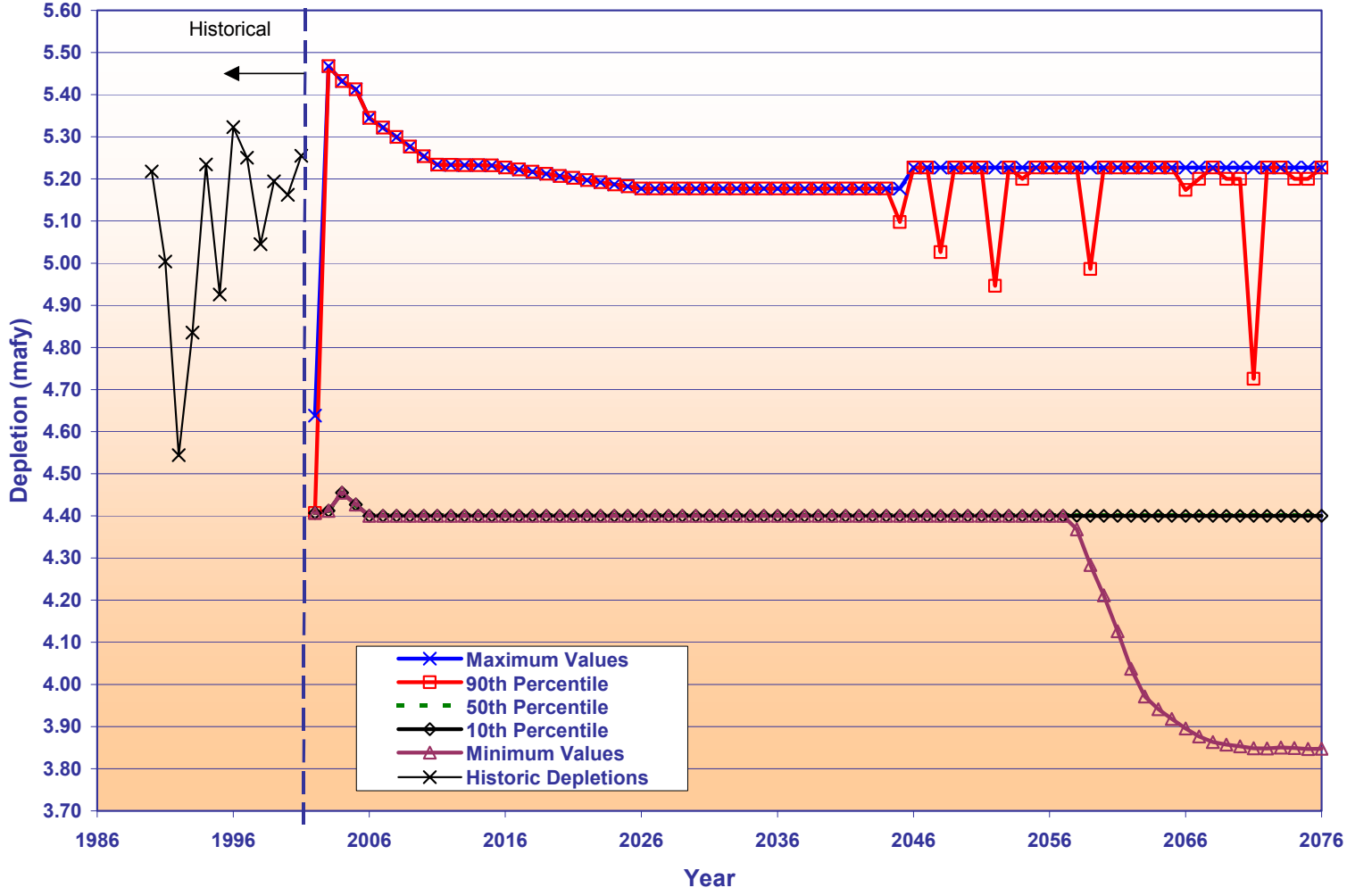
The water deliveries to California are projected to fluctuate throughout the 75-year period of analysis reflecting variations in hydrologic conditions. The 90th, 50th and 10th percentile rankings of modeled water deliveries to California under the Baseline Conditions are presented in Figure 4.6-6. The actual reported (historical) depletions (for years 1990 to 2001) have been added to this graph to provide a benchmark for comparison of the projected future depletion trends.

The observed 90th percentile values under the Baseline Conditions generally coincide with California's depletion schedule during full surplus water supply conditions through year 2044. The 90th percentile line represents the magnitude of surplus condition deliveries that would be available at least 10 percent of the time throughout the 75-year period of analysis. After year 2044, the 90th percentile line occasionally falls below the full surplus schedule, an indication of the occurrence of more frequent limited surplus conditions.

Under Baseline Conditions, the 50th and 10th percentile lines generally coincide with the normal depletion schedule throughout the 75-year period of analysis, and indication that water deliveries to California would meet or exceed its normal depletion schedule at least 90 percent of the time.

Annual water deliveries to California were observed to fall below California's normal apportionment of 4.4 maf (a Level 2 shortage condition) less than one percent of the time. The minimum observed delivery to California under baseline Conditions was 3.847 mafy.

Figure 4.6-6
California Modeled Annual Depletions Under Baseline Conditions
90th, 50th and 10th Percentile Values



4.6.2.2 COMPARISON OF BASELINE TO CUMULATIVE ANALYSIS

Figure 4.6-7 provides a comparison of the cumulative distribution of the observed California depletions under the Cumulative Analysis Conditions to those of the Baseline Conditions during the 15-year Interim Surplus Guidelines period (years 2002 to 2016). These graphs are best used to represent the frequency that different magnitude annual water deliveries to California occur in the respective period. The results presented in Figure 4.6-7 indicate a 100 percent probability that California's depletions would meet its normal depletion schedule during this period under the Baseline Conditions. The probability that California would receive surplus condition deliveries (any amount greater than 4.4 mafy) during this period under Baseline Conditions was approximately 47 percent. The maximum surplus condition depletions observed under the Baseline Conditions were 5.468 maf during this period.

Figure 4.6-8 provides a comparison of the cumulative distribution of the water deliveries to California under the Cumulative Analysis Conditions to those of the Baseline Conditions for the 60-year period (years 2017 to 2076) that follows the Interim Surplus Guidelines period. The results presented in Figure 4.6-8 indicate an approximate 99 percent probability that water deliveries to California would meet its normal depletion schedule during this period under the Baseline Conditions. Only one trace was observed to fall below the normal depletion schedule, an indication of a Level 2 shortage condition. The minimum delivery observed under this trace was 3.847 maf. The probability that California would receive surplus condition deliveries during this same period under the Baseline Conditions was approximately 18 percent. The maximum surplus condition depletions under the Baseline Conditions were 5.227 maf during this period.

Figure 4.6-9 provides a comparison of the cumulative distribution of the water deliveries to California under the Cumulative Analysis Conditions to those of the Baseline Conditions for the entire 75-year period of analysis (years 2002 to 2076). The results presented in Figure 4.6-9 also indicate an approximate 99 percent probability that water deliveries to California would meet its normal depletion schedule under the Baseline Conditions. Again, only one trace was observed to fall below the normal depletion schedule, an indication of a Level 2 shortage condition. The minimum delivery observed under this trace was 3.847 maf. The probability that California would receive surplus condition deliveries during this same period under the Baseline Conditions was approximately 24 percent. The maximum surplus condition depletions under the Baseline Conditions were 5.468 maf during this period.

Figure 4.6-7
California Modeled Depletions
Comparison of Cumulative Analysis Conditions to Baseline Conditions
Years 2002 to 2016

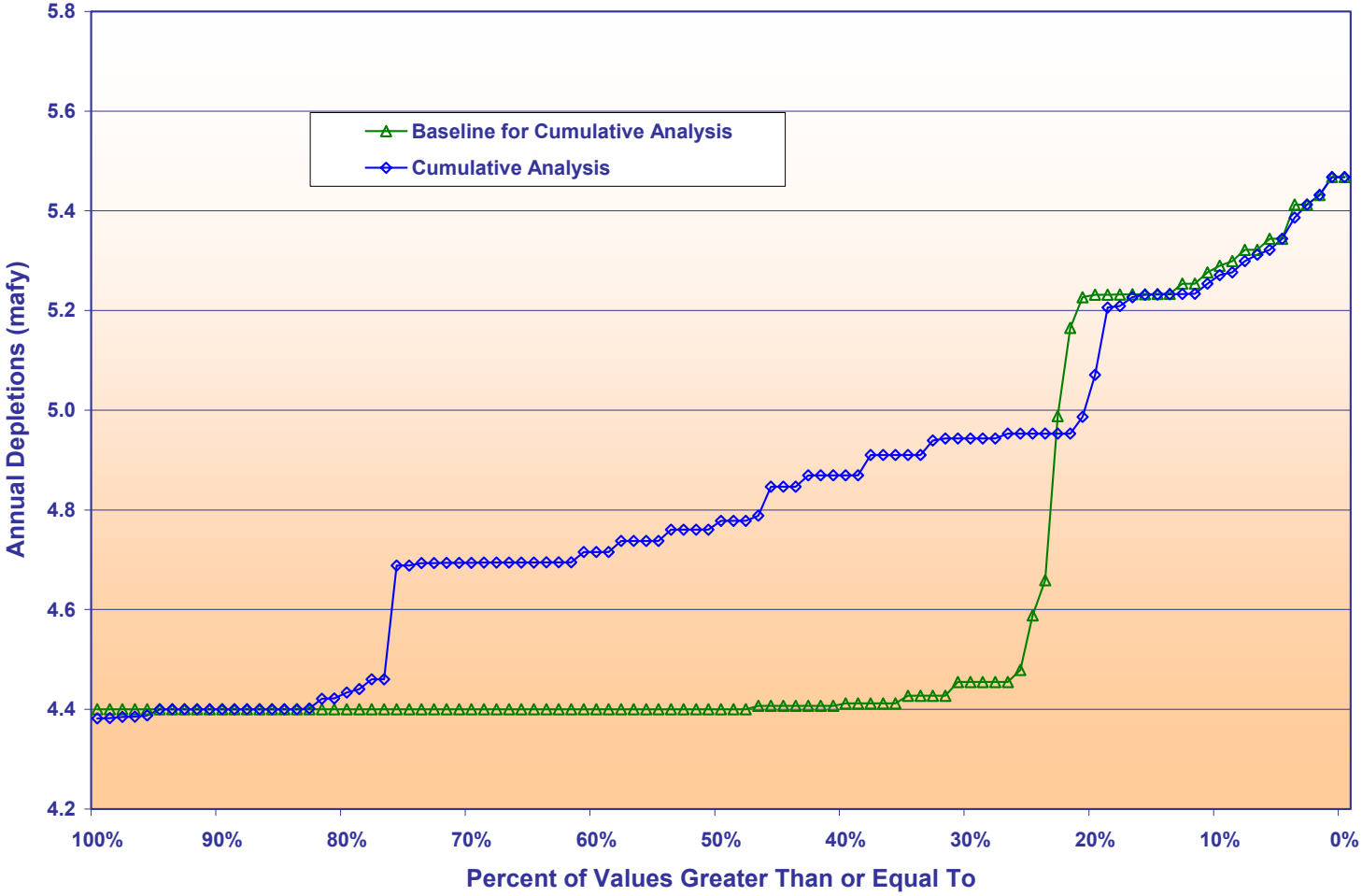


Figure 4.6-8
California Modeled Depletions
Comparison of Cumulative Analysis Conditions to Baseline Conditions
Years 2017 to 2076

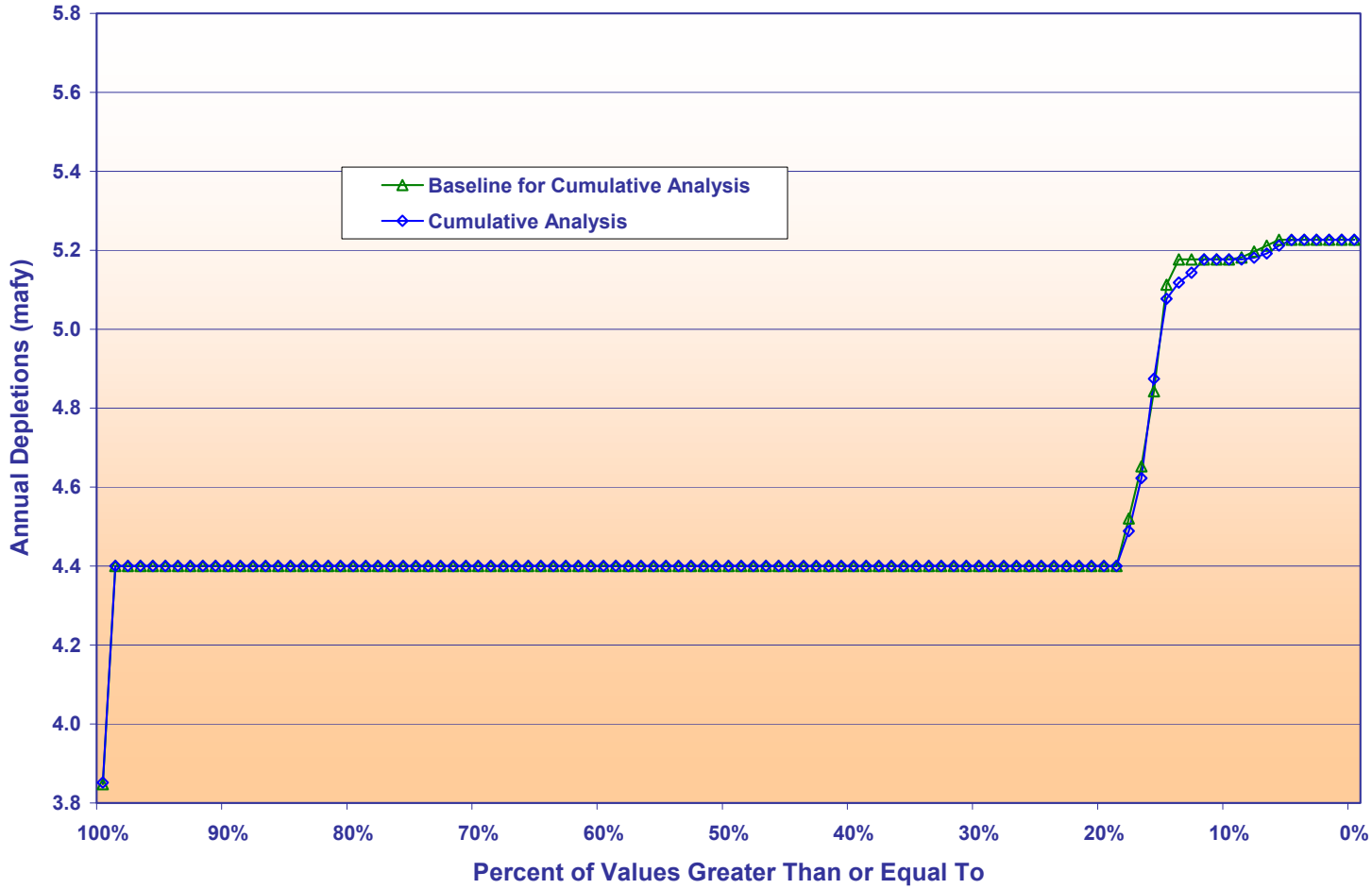


Figure 4.6-9
California Modeled Depletions
Comparison of Cumulative Analysis Conditions to Baseline Conditions
Years 2002 to 2076

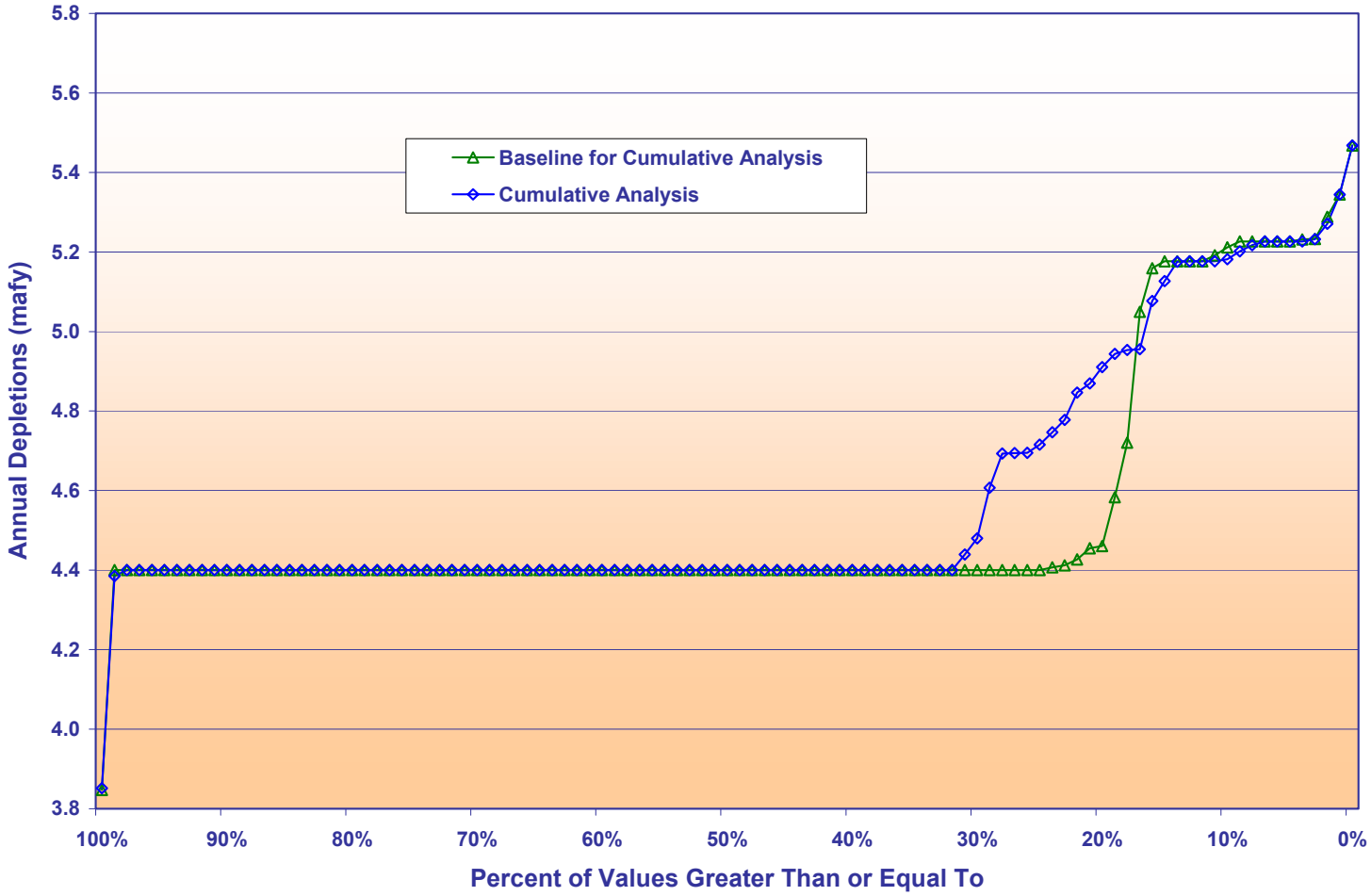
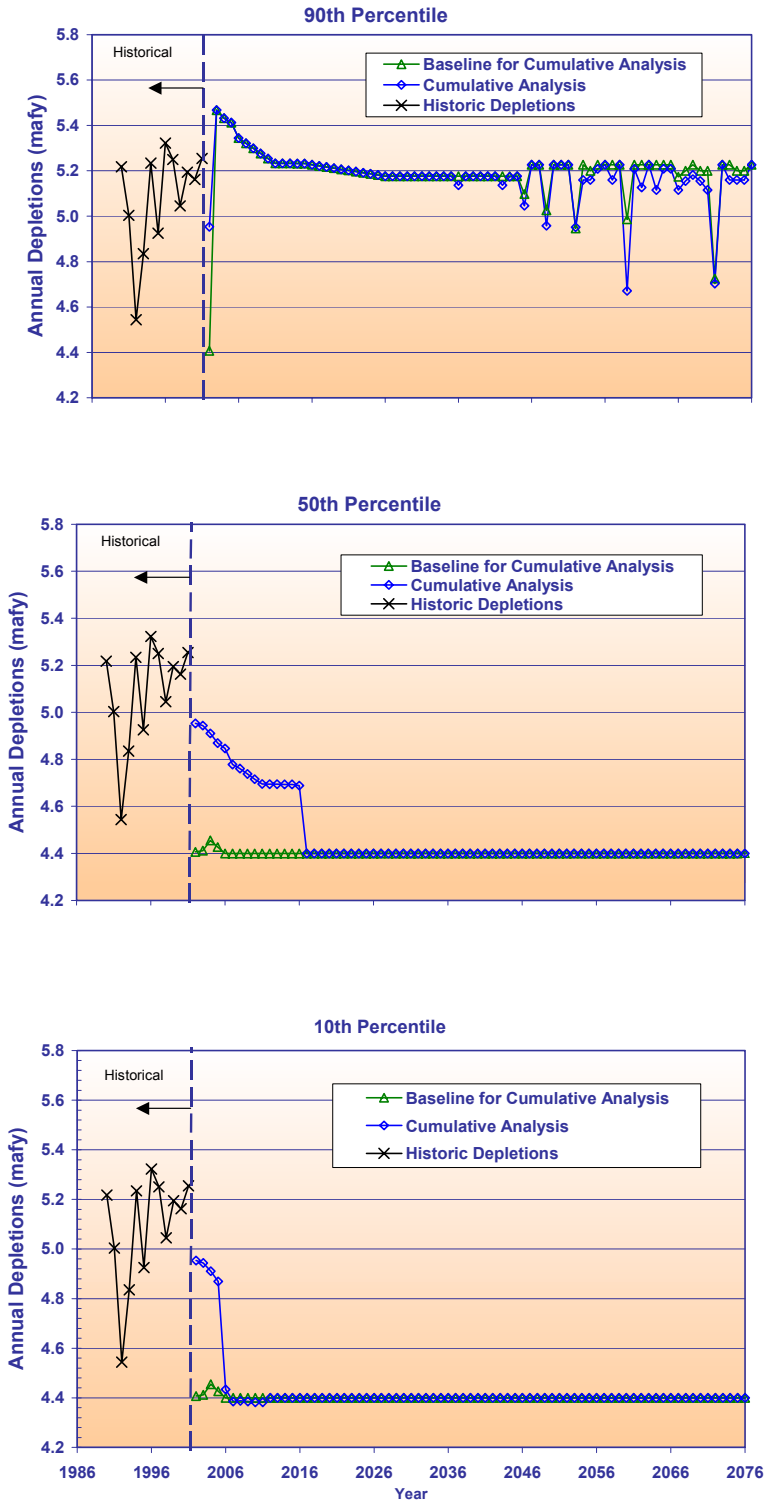


Figure 4.6-10 provides a comparison of the 90th, 50th and 10th percentile values for California's depletions under the Cumulative Analysis Conditions to those of the Baseline Conditions. The historical depletions (for years 1990 to 2001) have been added to this graph to provide a benchmark for comparison of the projected future depletion trends. As depicted in Figure 4.6-10, there is little difference in the 90th percentile values resulting from the Cumulative Analysis Conditions to those of the Baseline Conditions. Both 90th percentile values generally coincide with California's depletion schedule during full surplus water supply conditions through year 2044. After year 2044, both 90th percentile lines occasionally fall below the full surplus schedule suggesting an increased probability of limited surplus conditions.

The 50th percentile line for the Baseline Conditions generally coincide with California's normal depletion schedule throughout the 75-year period of analysis. However, the 50th percentile values for the Cumulative Analysis Conditions are above the normal depletion schedule (above 4.4 mafy) for the initial 15 years (2002 to 2016), an indication of the frequent availability of surplus flows. After 2016, the 50th percentile lines for the Cumulative Analysis Conditions coincide with California's normal depletion schedule.

The 10th percentile line for the Baseline Conditions also coincides with California's normal depletion schedule throughout the 75-year period of analysis. Similar to the median values, the 10th percentile values for the Cumulative Analysis Conditions are above the normal depletion schedule (above 4.4 mafy) for the initial 5 years (2002 to 2006), an indication of the frequent availability of surplus flows during these initial five years. After 2006, the 10th percentile lines for the Cumulative Analysis Conditions coincide with California's normal depletion schedule.

Figure 4.6-10
California Modeled Annual Depletions
Comparison of Cumulative Analysis Conditions to Baseline Conditions
90th, 50th and 10th Percentile Values



Figures 4.6-7, 4.6-8 and 4.6-9 presented comparisons of the cumulative distribution of California's depletions under the Cumulative Analysis Conditions to those of the Baseline Conditions during the Interim Surplus Guidelines period (years 2002 to 2016), the 60-year period that would follow the Interim Surplus Guidelines (years 2017 to 2076) and the entire period of analysis (years 2002 to 2076), respectively. Table 4.6-2 provides a tabular summary and comparison for these three periods.

Table 4.6-2
Summary of California Modeled Annual Depletions
Comparison of Cumulative Analysis Conditions to Baseline Conditions

Alternative/Conditions	Years 2002 to 2016			Years 2017 to 2076			Years 2002 to 2076		
	Normal*	Surplus	Shortage	Normal*	Surplus	Shortage	Normal*	Surplus	Shortage
Baseline	100%	47%	0%	99%	18%	1%	99%	24%	1%
Cumulative Analysis	95%	83%	5%	99%	18%	1%	98%	31%	2%
*The values under normal represent the total percentage of time that depletions would be at or above the normal depletion conditions.									

The percentage values presented under the column heading labeled “Normal” in Table 4.6-2 represent the total percentage of time that depletions under the noted conditions would be at or above the normal depletion schedule amount. The values presented under the column labeled “Surplus” represent the total percentage of time that depletions under the noted conditions exceed the normal depletion schedule amount. The values presented under the column labeled “Shortage” represent the total percentage of time that depletions under the noted conditions would be below the normal depletion schedule amount.

4.6.3 STATE OF NEVADA

This section presents the simulated water deliveries to Nevada under the Baseline and Cumulative Analysis conditions. The analysis of Nevada's water supply concentrated on total Nevada water depletions.

4.6.3.1 MODELING RESULTS OF BASELINE

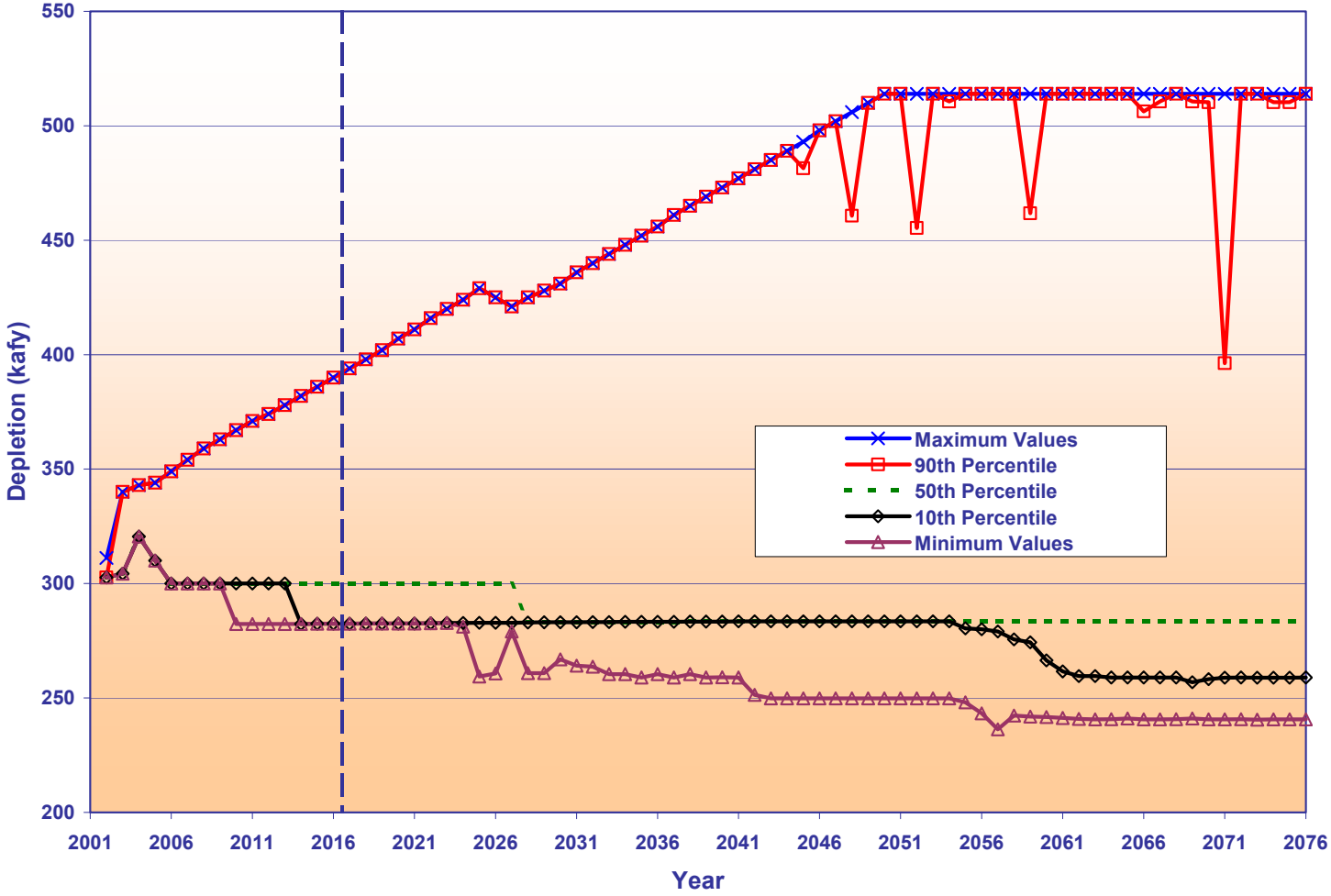
The water deliveries to Nevada are projected to fluctuate throughout the 75-year period of analysis reflecting variations in hydrologic conditions. The 90th, 50th and 10th percentile ranking of modeled water deliveries to Nevada under the Baseline Conditions is presented in Figure 4.6-11.

The 90th percentile values generally coincide with Nevada’s normal depletion schedule under Baseline Conditions through year 2047. After year 2047, the 90th percentile values occasionally fall below the full surplus schedule, an indication of the occurrence of more frequent limited surplus conditions.

From 2002 through 2027, under Baseline Conditions, the 50th percentile line for Nevada coincides with the normal depletion schedule. After 2027, the 50th percentile line coincides with Nevada's Level 1 shortage condition depletion schedule (approximately 280 kafy).

From 2002 through 2013, under Nevada Baseline Conditions, the 10th percentile line for Nevada also coincides with the normal depletion schedule. From 2013 to 2054, the 10th percentile line coincides with Arizona's Level 1 shortage condition depletion schedule. After 2054, under Baseline Conditions, the 10th percentile begins to fall below 280 mafy, an indication of frequent Level 2 shortage conditions. Under Baseline Conditions, deliveries to Nevada below 280 kaf occurred less than seven percent of the time during the 75-year period.

Figure 4.6-11
Nevada Modeled Annual Depletions Under Baseline Conditions
90th, 50th and 10th Percentile Values



4.6.3.2 COMPARISON OF BASELINE TO CUMULATIVE ANALYSIS

Figure 4.6-12 provides a comparison of the cumulative distribution of Nevada's depletions under the Cumulative Analysis Conditions to those of the Baseline Conditions during the Interim Surplus Guidelines period (years 2002 to 2016). This graph is best used to represent the frequency that different magnitude water deliveries to Nevada occurred during the 15-year Interim Surplus Guidelines period. The results presented in Figure 4.6-12 indicate a 95 percent probability that water deliveries to Nevada would meet or exceed its normal depletion schedule during this period under the Baseline Conditions. The probability that Nevada would receive surplus condition deliveries under the Baseline Conditions during this period was approximately 47 percent. The maximum surplus condition depletions under the Baseline Conditions were 390 kaf during this period. The probability that Nevada would receive shortage condition deliveries under Baseline Conditions was five percent. The minimum shortage condition depletion was 282.3 kaf.

Figure 4.6-13 provides a comparison of the cumulative distribution of the water deliveries to Nevada under the Cumulative Analysis Conditions to those of the Baseline Conditions for the 60-year period (years 2017 to 2076) that would follow the Interim Surplus Guidelines period. The results presented in Figure 4.6-13 indicate a 40 percent probability that water deliveries to Nevada would meet or exceed its normal depletion schedule during this period under the Baseline Conditions. The probability that Nevada would receive surplus condition deliveries during this same period under the Baseline Conditions was approximately 18 percent. The maximum surplus condition depletions under the Baseline Conditions were 514 kaf during this period. The probability that Nevada would receive shortage condition deliveries was approximately 60 percent. The minimum shortage condition depletion during this period was 236.3 kaf.

Figure 4.6-14 provides a comparison of the cumulative distribution of the water deliveries to Nevada under the Cumulative Analysis Conditions to those of the Baseline Conditions for the entire 75-year period of analysis (years 2002 to 2076). The results presented in Figure 4.6-14 indicate a 51 percent probability that water deliveries to Nevada would meet or exceed its normal depletion schedule during this period under the Baseline Conditions. The probability that Nevada would receive surplus condition deliveries during this same period under the Baseline Conditions was approximately 24 percent. The maximum surplus condition depletions under the Baseline Conditions were 514 kaf during this period. The probability that Nevada would receive shortage condition deliveries was approximately 49 percent. The minimum shortage condition depletion during this period was 236.3 kaf.

Figure 4.6-12
Nevada Modeled Depletions
Comparison of Cumulative Analysis Conditions to Baseline Conditions
Years 2002 to 2016

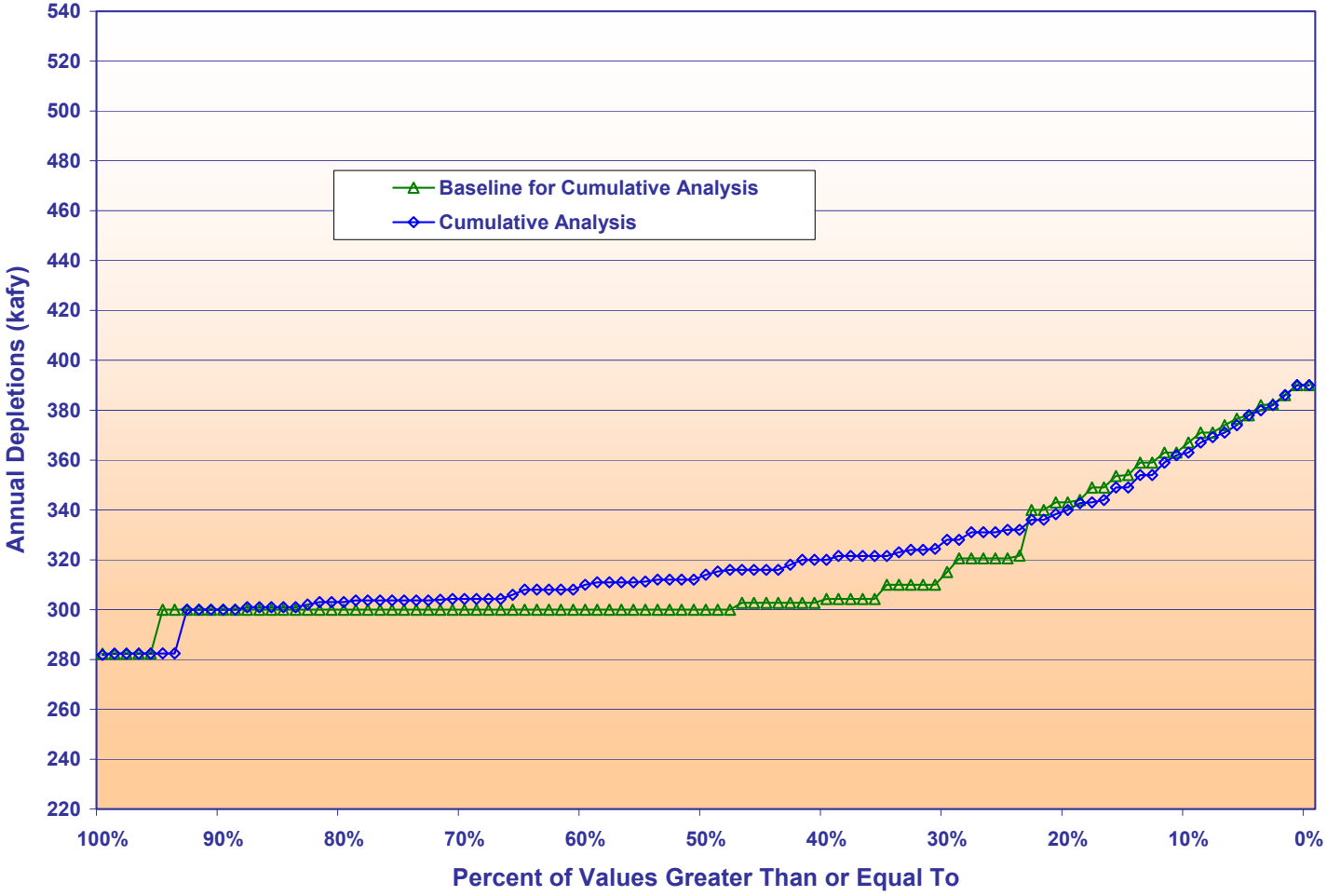


Figure 4.6-13
Nevada Modeled Depletions
Comparison of Cumulative Analysis Conditions to Baseline Conditions
Years 2017 to 2076

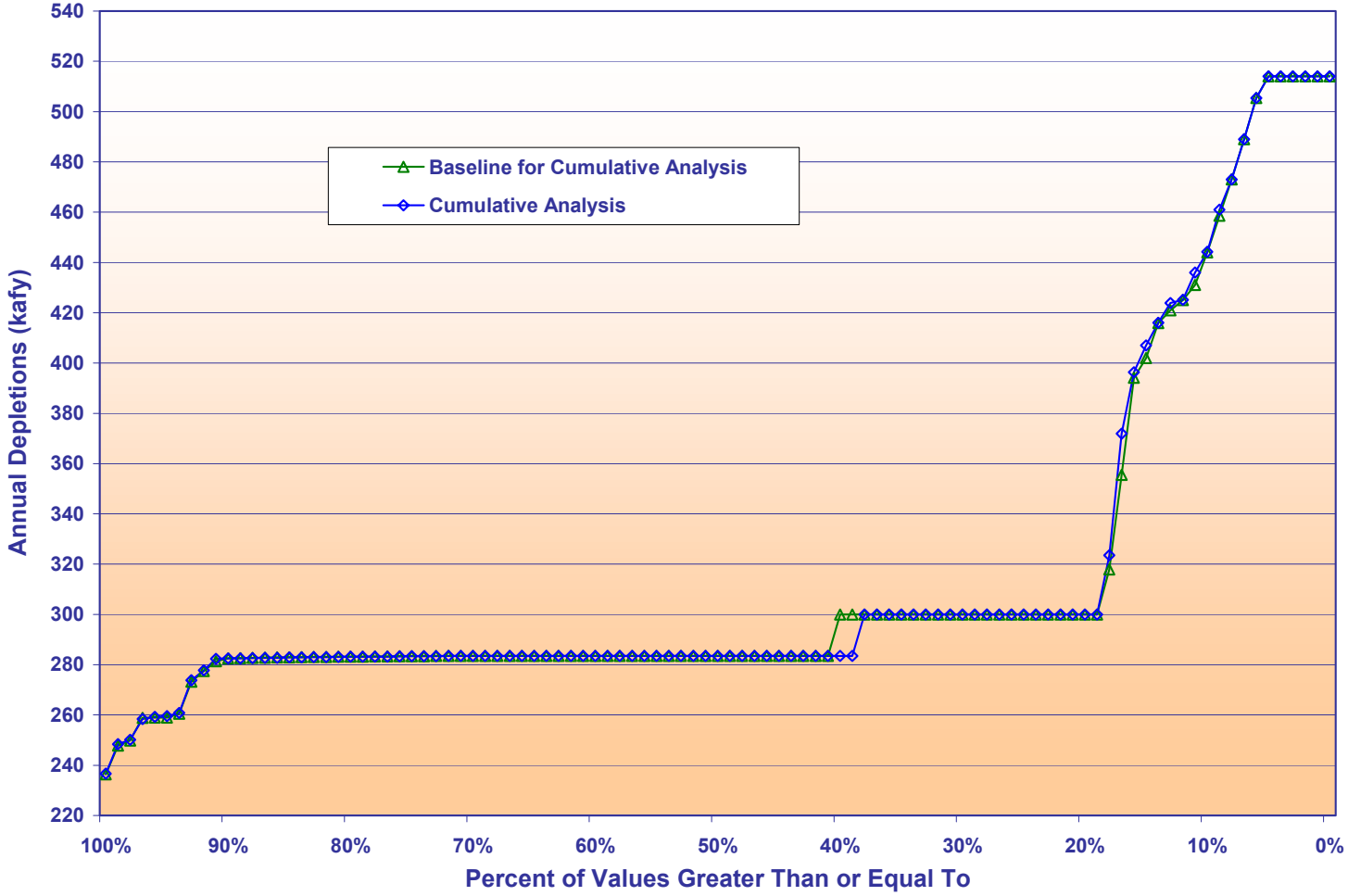


Figure 4.6-14
Nevada Modeled Depletions
Comparison of Cumulative Analysis Conditions to Baseline Conditions
Years 2002 to 2076

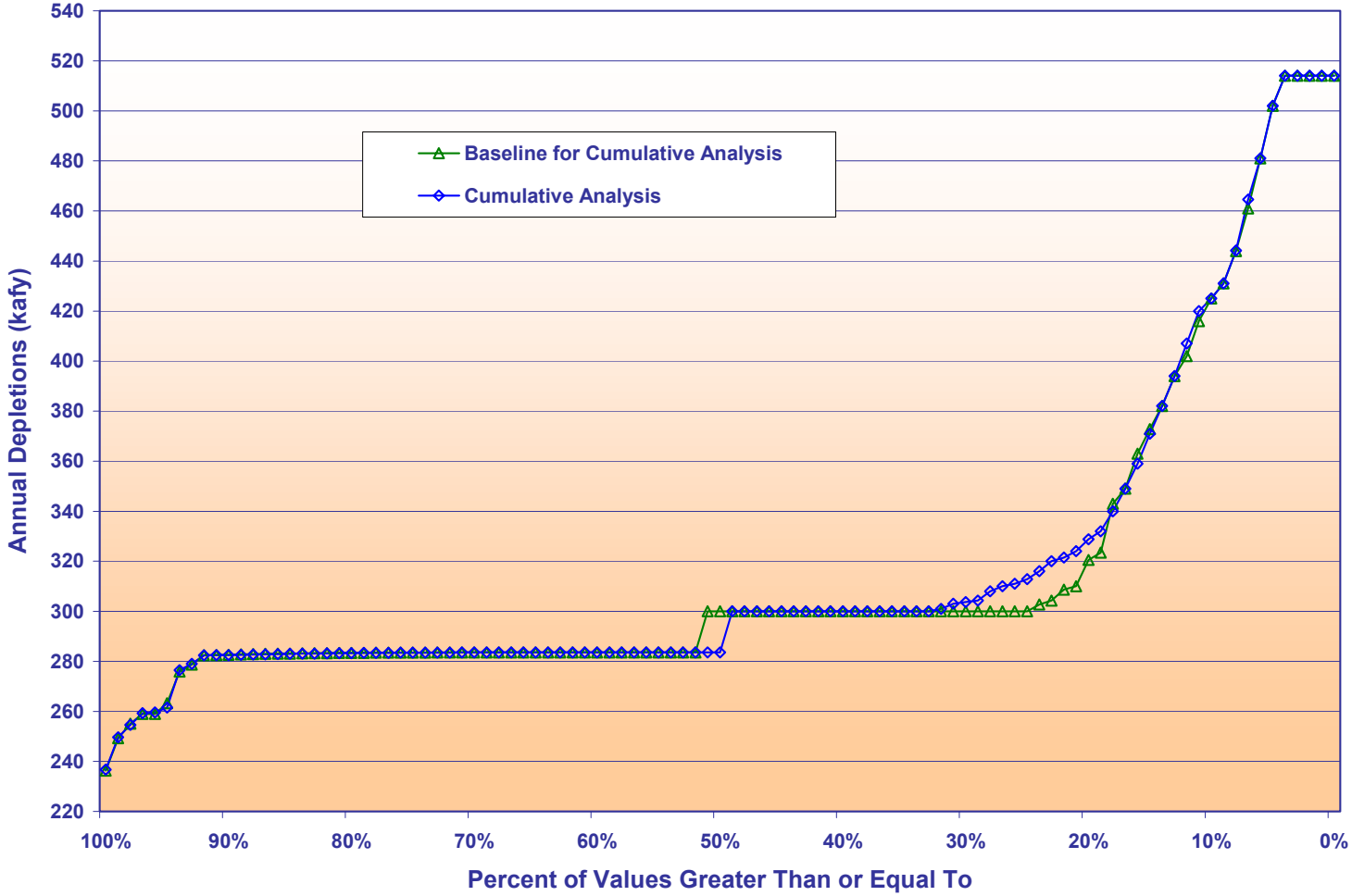


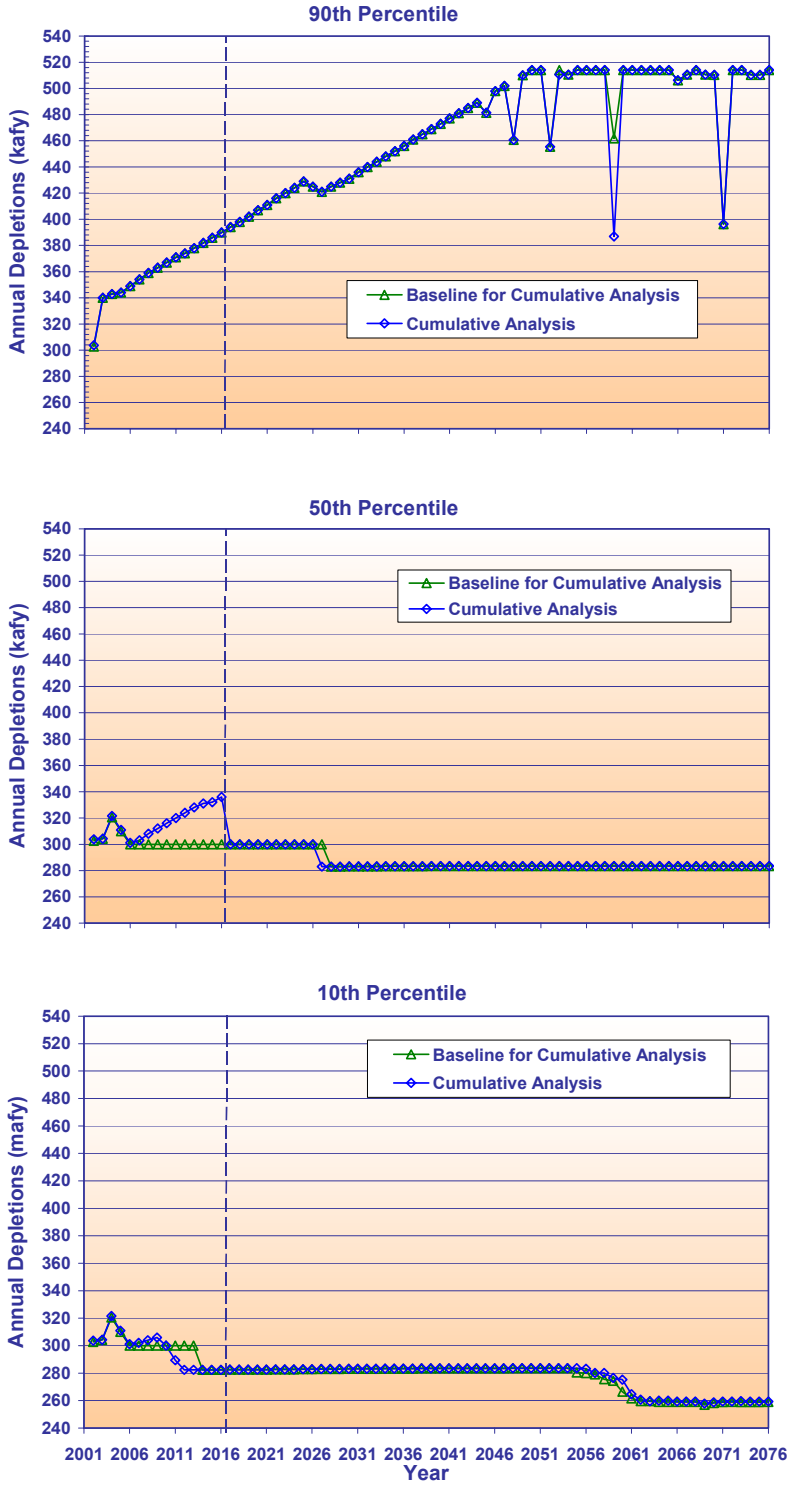
Figure 4.6-15 provides a comparison of the 90th, 50th and 10th percentile values for Nevada's depletions under the Baseline Conditions to those of the Cumulative Analysis Conditions. As noted in Figure 4.6-15, there is little difference between the 90th percentile values resulting from the Cumulative Analysis Conditions and those of the Baseline Conditions. Both 90th percentile lines generally coincide with Nevada's normal depletion schedule under Baseline Conditions through year 2047. After year 2047, both 90th percentile lines occasionally fall below the full surplus schedule, an indication of limited surplus conditions.

From 2002 through 2027, under Baseline Conditions, the 50th percentile line for Nevada coincides with the normal depletion schedule. After 2027, the 50th percentile line coincides with Nevada's Level 1 shortage condition depletion schedule (approximately 280 kafy). Under the Cumulative Analysis Conditions, the 50th percentile line is generally at or above Nevada's normal depletion schedule from year 2002 to 2016, an indication of better than average probability of the availability of limited surplus condition deliveries during this 15-year period. From 2016 to 2026, the 50th percentile values for Nevada under the Cumulative Analysis Conditions coincides with Nevada's normal depletion schedule. After 2026, the 50th percentile line under the Cumulative Analysis Conditions also falls to and thereafter coincides with Nevada's Level 1 shortage condition depletion schedule.

As noted in Figure 4.6-15, there is little difference between the 10th percentile values resulting from the Cumulative Analysis Conditions and those of the Baseline Conditions. From 2002 through 2013, under Baseline Conditions, the 10th percentile line for Nevada also coincides with the normal depletion schedule. From 2013 to 2054, the 10th percentile line of the Baseline Conditions coincides with Nevada's Level 1 shortage condition depletion schedule. After 2054, under Baseline Conditions, the 10th percentile begins to fall below 280 kafy. From 2002 through 2010, under Cumulative Analysis Conditions, the 10th percentile line for Nevada also coincides with the normal depletion schedule. However, this is approximately three years less than under the Baseline Conditions. From 2010 to 2059, the 10th percentile line coincides with Nevada's Level 1 shortage condition depletion schedule. After 2059, under Cumulative Analysis Conditions, the 10th percentile begins to fall below 280 kafy, an indication of the occurrence of more frequent Level 2 shortage condition deliveries.

Deliveries to Nevada below 280 kafy (Level 2 Shortage Condition deliveries) occurred less than seven percent of the time during the 75-year period of analysis under both the Baseline and Cumulative Analysis conditions.

Figure 4.6-15
Nevada Modeled Annual Depletions
Comparison of Cumulative Analysis Conditions to Baseline Conditions
90th, 50th and 10th Percentile Values



Figures 4.6-12, 4.6-13 and 4.6-14 presented comparisons of the cumulative distribution of Nevada's depletions under the Cumulative Analysis Conditions to those of the Baseline Conditions during the 15-year Interim Surplus Guidelines period (years 2002 to 2016), the 60-year period that would follow the Interim Surplus Guidelines (years 2017 to 2076), and the entire 75-year period of analysis (years 2002 to 2076), respectively. These graphs represent the frequency that different magnitude annual deliveries to Nevada occurred under each respective period. Table 4.6-3 provides a tabular summary of the comparison for these two periods.

Table 4.6-3
Summary of Nevada Modeled Annual Depletions
Comparison of Cumulative Analysis Conditions to Baseline Conditions

Alternative/Conditions	Years 2002 to 2016			Years 2017 to 2076			Years 2002 to 2076		
	Normal*	Surplus	Shortage	Normal*	Surplus	Shortage	Normal*	Surplus	Shortage
Baseline	95%	47%	5%	40%	18%	60%	51%	24%	49%
Cumulative Analysis	93%	88%	7%	38%	18%	62%	49%	32%	51%
*The values under normal represent the total percentage of time that depletions would be at or above the normal depletion conditions.									

The percentage values presented under the column heading labeled “Normal” in Table 4.6-3 represent the total percentage of time that depletions under the noted conditions would be at or above the normal depletion schedule amount. The values presented under the column labeled “Surplus” represent the total percentage of time that depletions under the noted conditions exceed the normal depletion schedule amount. The values presented under the column labeled “Shortage” represent the total percentage of time that depletions under the noted conditions would be below the normal depletion schedule amount.

4.6.4 UPPER BASIN STATES

There are no specific criteria in the *Law of the River* for surplus or shortage condition water deliveries to users within the Upper Basin states. The normal depletion schedule of the Upper Basin states would be met under both the Baseline and Cumulative Analysis conditions. The exceptions are potential reductions to certain Upper Basin users whose diversions are located upstream of Lake Powell. For these users, the potential reductions would be attributed to dry hydrologic conditions and inadequate regulating reservoir storage capacity upstream of their diversions.

The proposed water transfers were determined to have no effect on water deliveries to the Upper Basin states, including the Upper Basin Tribes. Therefore, detailed analyses were not necessary for the Upper Basin states' water supply.

4.6.5 MEXICO

This section presents the analyses of the simulated water deliveries to Mexico under the Baseline and Cumulative Analysis conditions. As discussed previously, Mexico's normal depletion schedule is modeled as 1.5 maf. An additional 15,000 af is included to account for typical scheduling errors and water that is ordered by the Lower Basin users but that is not diverted. Therefore, the normal annual depletion schedule deliveries to Mexico were modeled as 1.515 maf. Surplus deliveries to Mexico of up to 200 kaf are delivered under both Baseline and the Cumulative Analysis conditions only when Lake Mead makes flood control releases. Shortage deliveries to Mexico would only occur if the CAP diversions were reduced to zero and further reductions to MWD and Mexico were necessary to keep the Lake Mead water surface elevation above 1000 feet msl, a Level 2 shortage water supply condition. This condition was observed to occur less than one percent of the time during the 75-year period of analysis in both the Baseline and Cumulative Analysis conditions.

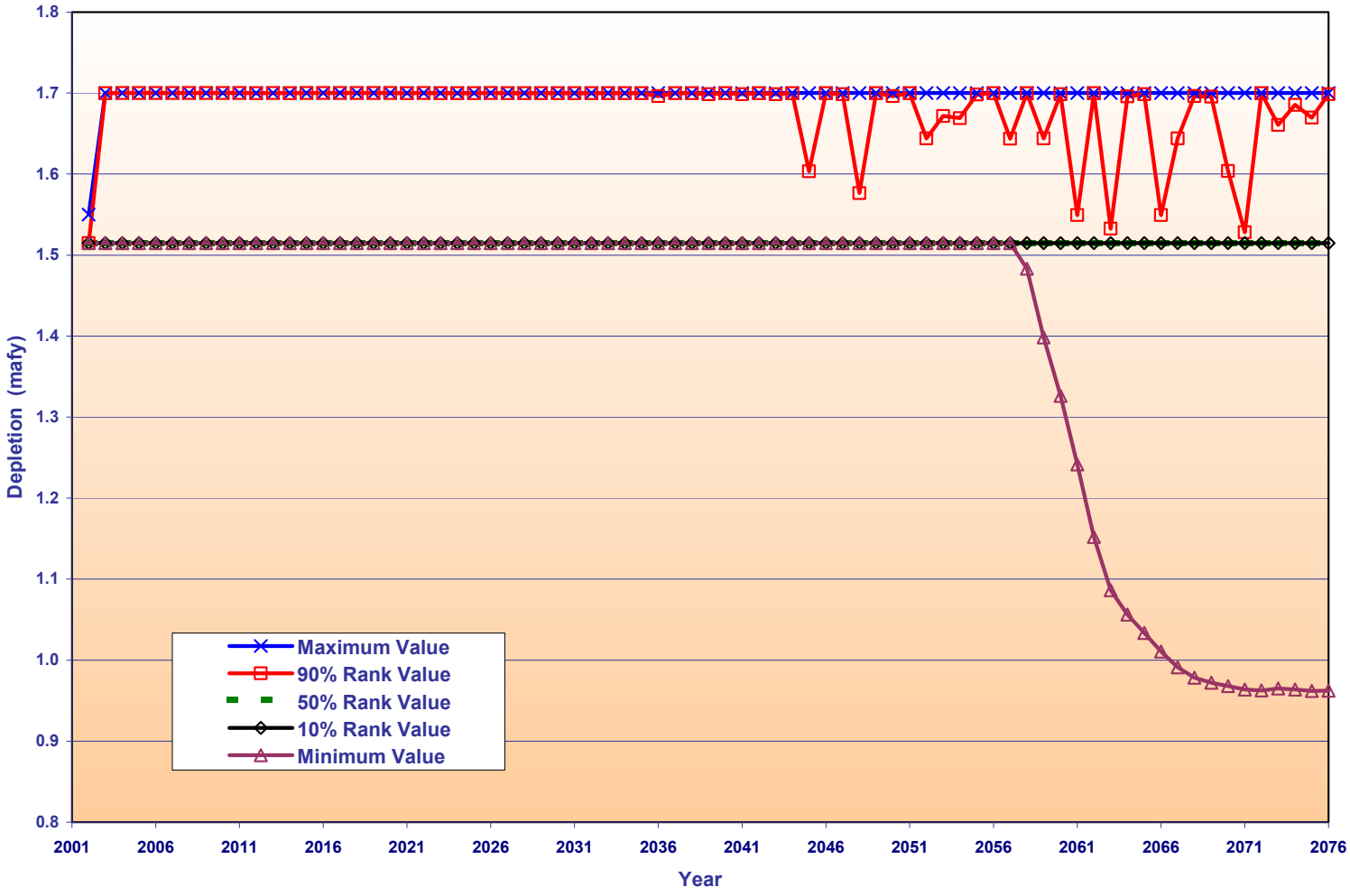
4.6.5.1 MODELING RESULTS OF BASELINE

The water deliveries to Mexico were observed to be mostly at or above Mexico's normal delivery schedule throughout the 75-year period of analysis. Under the Baseline Conditions, annual deliveries to Mexico that were less than its normal depletion schedule were observed to occur in only 19 of the 85-modeled traces, an indication of Level 2 shortage water supply conditions. In these 19 traces, the frequency of occurrence of annual deliveries to Mexico that were less than its normal depletion schedule was only one year of the 75 modeled years. The minimum observed delivery to Mexico was 962,019 af.

The 90th, 50th and 10th percentile ranking of modeled water deliveries to Mexico under the Baseline Conditions are presented in Figure 4.6-16. The 90th percentile line generally coincides with Mexico's full surplus condition schedule under Baseline Conditions through year 2044. After year 2044, the 90th percentile occasionally falls below the full surplus schedule, an indication of more frequent limited surplus conditions.

Under Baseline Conditions, the 50th and 10th percentile lines coincide with Mexico's normal depletion schedule. It is noted that the depletion amount depicted by both the 50th and 10th percentile lines is equal to 1.515 maf. The 15,000 af above the 1.5 maf Mexico apportionment was added to the model to account for typical scheduling errors and water that is ordered by the Lower Division users but that is not diverted. Under Baseline Conditions, deliveries to Mexico that were less than its normal depletion schedule were observed to occur less than one percent of the time during the 75-year period of analysis.

Figure 4.6-16
Mexico Modeled Annual Depletions Under Baseline Conditions
90th, 50th and 10th Percentile Values



4.6.5.2 COMPARISON OF BASELINE TO CUMULATIVE ANALYSIS

Figure 4.6-17 provides a comparison of the cumulative distribution of Mexico's depletions under the Cumulative Analysis Conditions to those of the Baseline Conditions during the 15-year Interim Surplus Guidelines period (years 2002 to 2016). Again, this type of graph is used to represent the frequency that annual deliveries of different magnitudes occur in the respective period. The results presented in Figure 4.6-17 indicate a 100 percent probability that Mexico's depletions would meet or exceed its normal depletion schedule during this period under the Baseline Conditions. The probability that Mexico would receive surplus condition deliveries during this period was approximately 23 percent under Baseline Conditions. The maximum surplus condition depletion under the Baseline Conditions was 1.7 maf during this period.

Figure 4.6-18 provides a comparison of the cumulative distribution of the water deliveries to Mexico under the Cumulative Analysis Conditions to those of the Baseline Conditions for the 60-year period (years 2017 to 2076) that would follow the Interim Surplus Guidelines period. The results presented in Figure 4.6-18 indicate an approximately 99 percent probability that water deliveries to Mexico would meet or exceed its normal depletion schedule during this period under the Baseline Conditions. The probability that Mexico would receive surplus condition deliveries during this same period under the Baseline Conditions was approximately 17 percent. The maximum surplus condition depletion under the Baseline Conditions was also 1.7 maf during this period.

Figure 4.6-19 provides a comparison of the cumulative distribution of the water deliveries to Mexico under the Cumulative Analysis Conditions to those of the Baseline Conditions for the entire 75-year period of analysis (years 2002 to 2076). The results presented in Figure 4.6-19 indicate an approximately 99 percent probability that water deliveries to Mexico would meet or exceed its normal depletion schedule during this period under the Baseline Conditions. The probability that Mexico would receive surplus condition deliveries during this same period under the Baseline Conditions was approximately 18 percent during this 75-year period. The maximum surplus condition depletion under the Baseline Conditions was also 1.7 maf during this period.

Figure 4.6-17
Mexico Modeled Depletions
Comparison of Cumulative Analysis Conditions to Baseline Conditions
Years 2002 to 2016

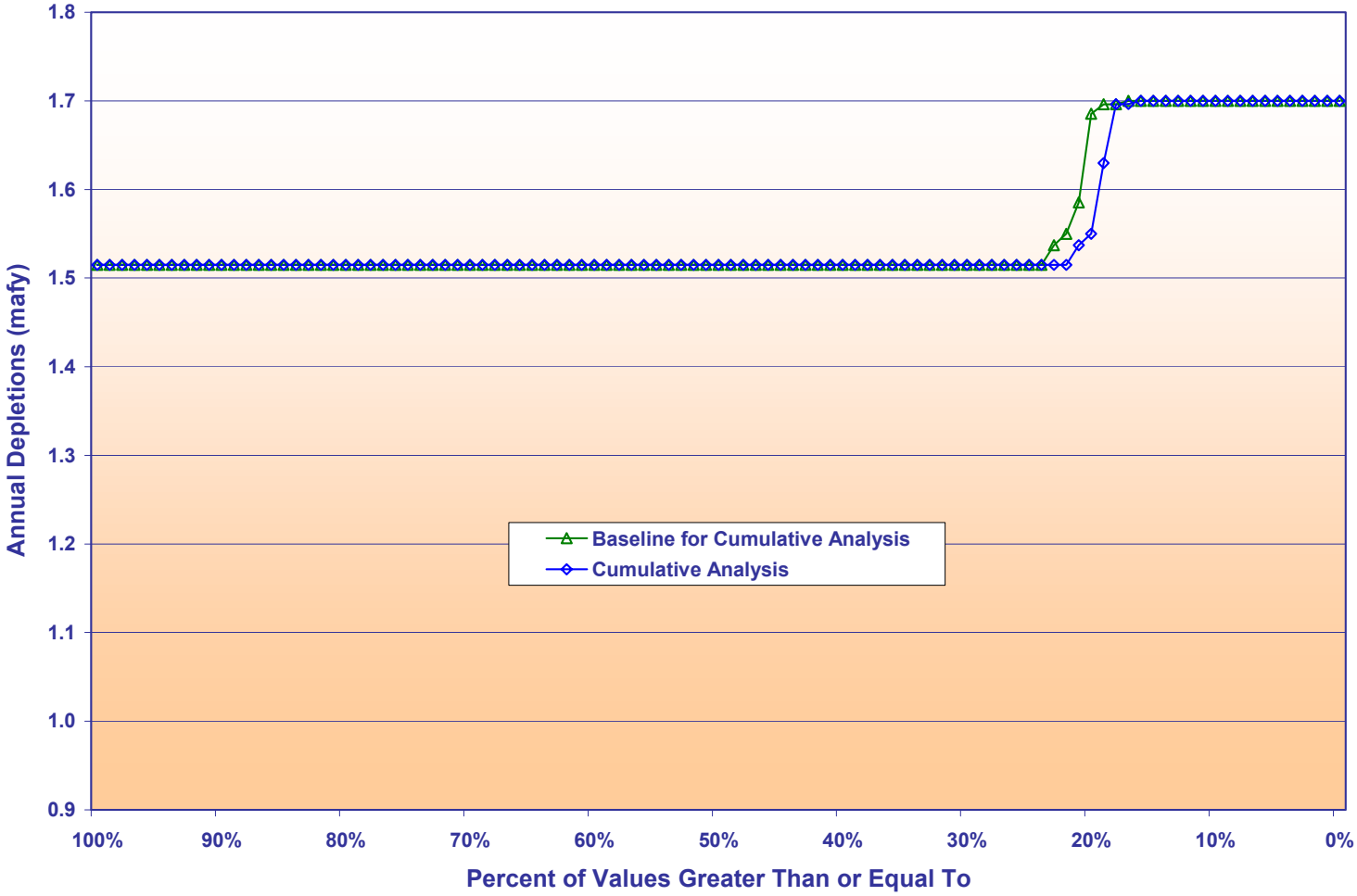


Figure 4.6-18
Mexico Modeled Depletions
Comparison of Cumulative Analysis Conditions to Baseline Conditions
Years 2017 to 2076

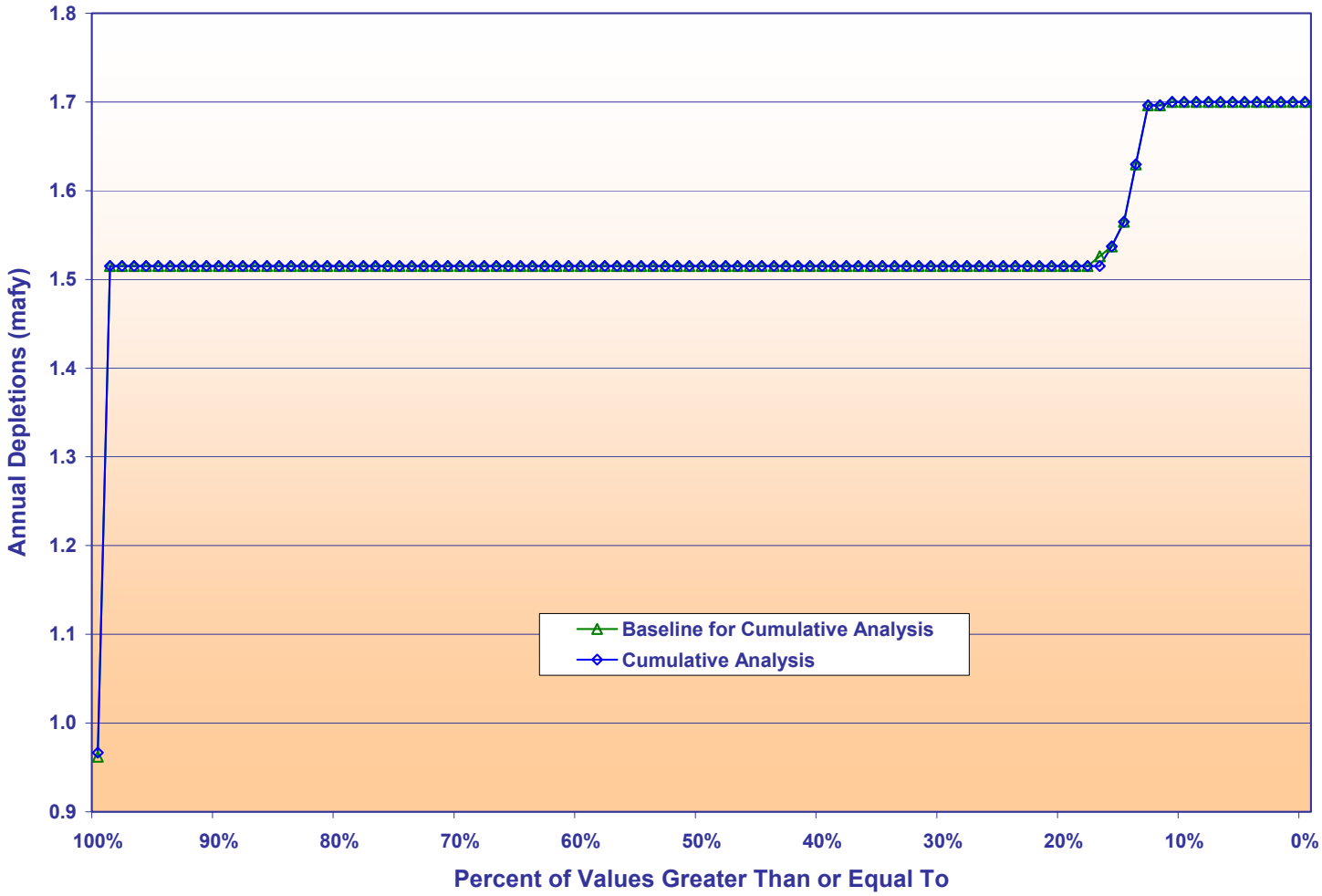


Figure 4.6-19
Mexico Modeled Depletions
Comparison of Cumulative Analysis Conditions to Baseline Conditions
Years 2002 to 2076

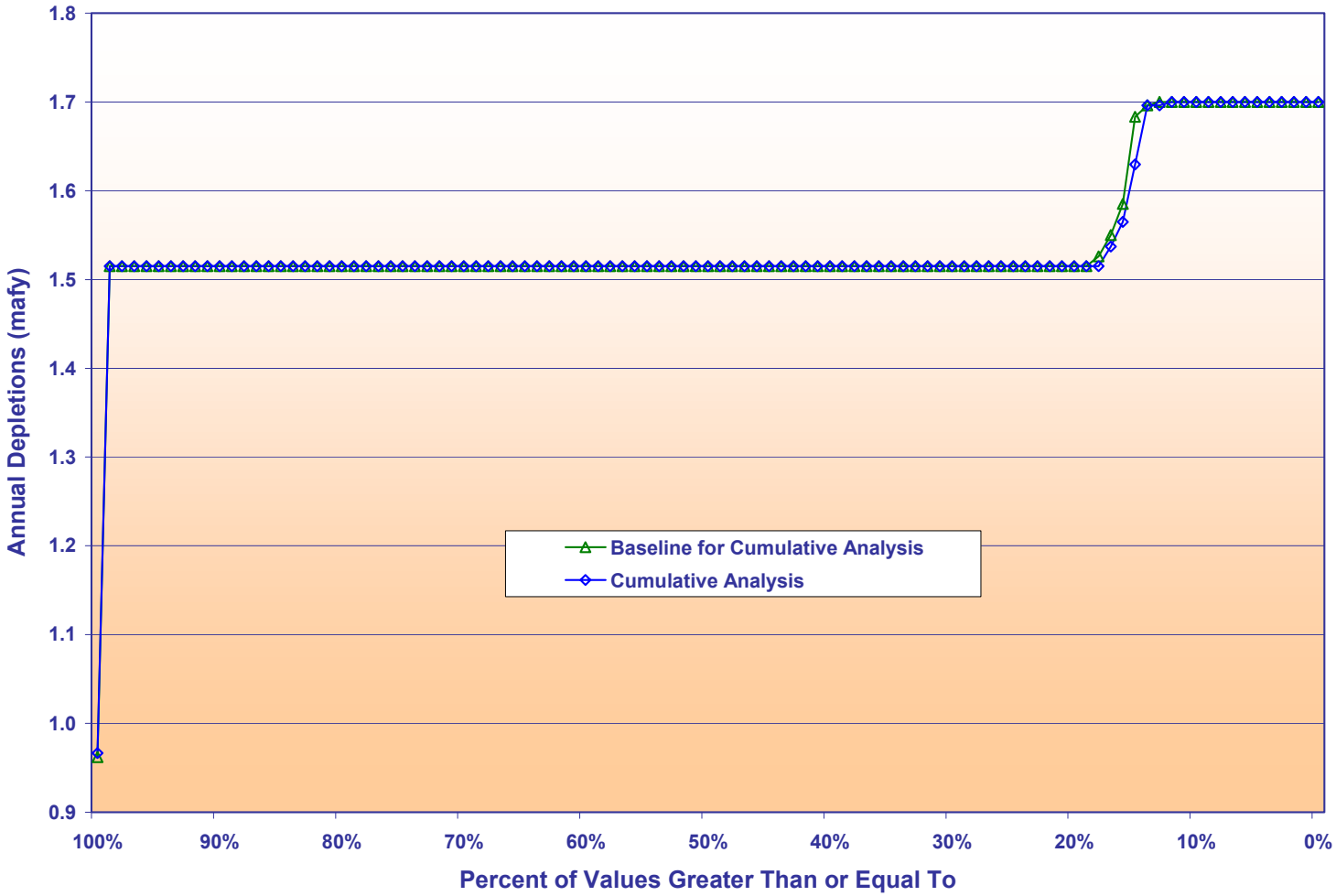


Figure 4.6-20 provides a comparison of the 90th, 50th and 10th percentile values for Mexico's depletions under the Cumulative Analysis Conditions to those of the Baseline Conditions. As noted in Figure 4.6-20, there is essentially no difference in the 90th percentile lines resulting from the Cumulative Analysis Conditions when compared to those of the Baseline Conditions. Both 90th percentile lines generally coincide with Nevada's normal depletion schedule under Baseline Conditions through year 2044. After year 2044, both 90th percentile lines occasionally fall below the full surplus schedule, an indication of limited surplus conditions.

The 50th and 10th percentile lines for the Cumulative Analysis and the Baseline conditions coincide with Mexico's normal depletion schedule, an indication of better than 90 percent probability that water deliveries to Mexico would meet or exceed its normal depletion schedule. Again, Level 2 shortage condition deliveries to Mexico were observed to occur in only 19 of the 85-modeled traces in both the Baseline and Cumulative Analysis conditions. In each of these 19 traces, deliveries of less than normal annual depletion conditions to Mexico were observed to occur in only one of the 75-year period modeled. Under Baseline and Cumulative Analysis conditions, deliveries to Mexico that were less than its normal depletion schedule were observed to occur less than one percent of the time during the 75-year period of analysis.

Figures 4.6-17, 4.6-18 and 4.6-19 presented comparisons of the guidelines cumulative distribution of Mexico's depletions under the Cumulative Analysis Conditions to those of the Baseline Conditions during the 15-year Interim Surplus Guidelines period (years 2002 to 2016), the 60-year period that follows the Interim Surplus Guidelines (years 2017 to 2076) and the entire 75-year period of analysis (years 2002 to 2076), respectively. Table 4.6-4 provides a tabular summary of the comparison for these two periods.

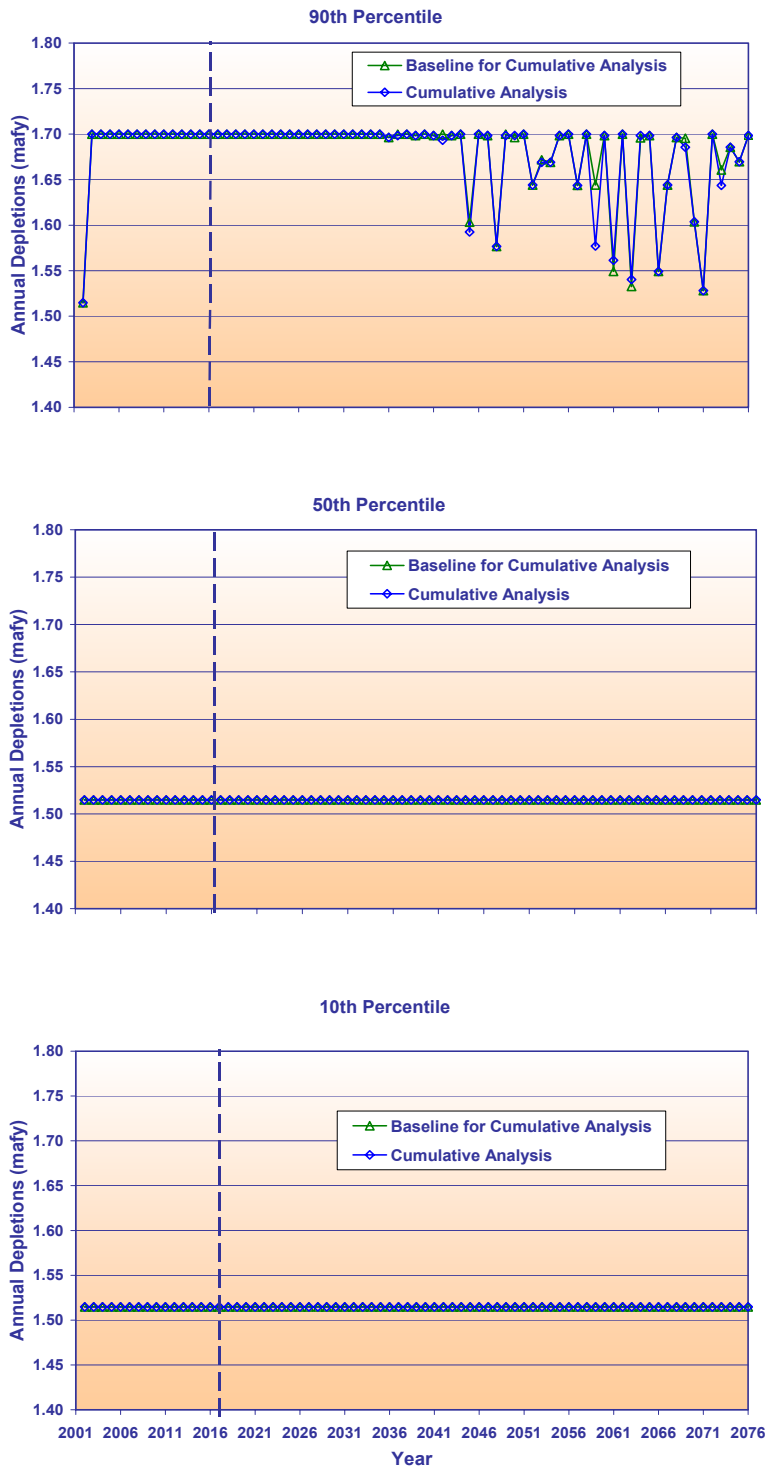
Table 4.6-4
Summary of Mexico Modeled Annual Depletions
Comparison of Cumulative Analysis Conditions to Baseline Conditions

Alternative/Conditions	Years 2002 to 2016			Years 2017 to 2076			Years 2002 to 2076		
	Normal*	Surplus	Shortage	Normal*	Surplus	Shortage	Normal*	Surplus	Shortage
Baseline	100%	23%	0%	99%	17%	1%	99%	18%	1%
Cumulative Analysis	100%	21%	0%	99%	16%	1%	99%	17%	1%

*The values under normal represent the total percentage of time that depletions would be at or above the normal depletion conditions.

The percentage values presented under the column heading labeled "Normal" in Table 4.6-4 represent the total percentage of time that depletions under the noted conditions would be at or above the normal depletion schedule amount. The values presented under the column labeled "Surplus" represent the total percentage of time that depletions under the noted conditions exceed the normal depletion schedule amount. The values presented under the column labeled "Shortage" represent the total percentage of time that depletions under the noted conditions would be below the normal depletion schedule amount.

Figure 4.6-20
Mexico Modeled Annual Depletions
Comparison of Cumulative Analysis Conditions to Baseline Conditions
90th, 50th and 10th Percentile Values



5.0 EXCESS FLOWS TO MEXICO

This section addresses the probability of excess flows in the Colorado River downstream of Morelos Dam, which is the diversion point for most of the water delivered to Mexico under the US-Mexico Water Treaty of 1944. There is a potential for Colorado River water to flow past Morelos Dam under three conditions: (1) as a result of operational activities upstream (e.g., canceled water orders in the United States, maintenance activities, etc.); (2) during a Gila River flood event; and (3) during flood control releases along the mainstream Colorado River. Each of these conditions may cause flows to reach Mexico that are in excess of Mexico's monthly or yearly water orders. However, Mexico has complete autonomy as to how it chooses to manage excess flows that arrive at Morelos Dam, so excess flows do not necessarily flow past Morelos Dam.

Water released from Parker Dam, in response to water orders from irrigation districts in Imperial Valley, Coachella Valley, and the lower Colorado River Valley, normally takes up to three days to reach its point of diversion. Occasionally, unforeseen events, such as localized precipitation, force the irrigation districts to cancel these water delivery orders after the water has been released at Parker Dam. Usually, this excess water is then diverted at Morelos Dam for use in Mexico; however, some of this water may flow past Morelos Dam. The volume of water passing by Morelos Dam is rarely enough to have much effect on species and habitat in Mexico below the NIB.

Gila River flood events are extremely rare. Only once has flow been recorded over 4,000 cfs at the Dome, Arizona, gaging station since 1941. In 1993, up to 27,500 cfs flowed past the Dome gaging station as a result of the 1993 Gila River flood (USGS, 1999). The 1993 flood created much of the habitat presently found along the Colorado River below its confluence with the Gila (Glenn, 2000).

Excess flows to Mexico are mostly caused by flood control releases originating at Hoover Dam. As discussed in Section 1.1.2, these flood control releases are dictated by the flood control criteria established for Lake Mead and Hoover Dam and are dependent upon hydrologic conditions.

5.1 ANALYSIS OF WATER TRANSFERS

This section analyzes the effects of the proposed water transfers through a comparison of the Implementation Agreement and No Action modeling results. Section 5.2 analyzes the cumulative effects through a comparison of the Baseline to the Cumulative Analysis modeling results.

5.1.1 NO ACTION CONDITIONS

The potential range of water deliveries to Mexico under the No Action Conditions were discussed in Section 3.2.4.4. Flows below Morelos Dam at various seasons were also

analyzed in Section 3.2.4.4. Both the frequency and magnitude of excess flows are important factors in restoring and maintaining riparian habitat below Morelos Dam and are analyzed in more detail in this section. It should be emphasized that Mexico's management decisions at and below Morelos Dam are not modeled. This is due to uncertainty of how Mexico may choose to use excess water. The assumption made for the hydrologic analyses is that annual flows in excess of Mexico's scheduled surplus deliveries (any amount greater than 1.7 mafy) would have the potential to flow past Morelos Dam.

Figure 5.1-1 presents a comparison of the frequency of occurrence of future delivery of excess flows to Mexico observed under the Implementation Agreement to those of No Action conditions.

The frequency of occurrence is compiled by counting the number of modeled traces for each year that have excess flows and dividing by the total number of traces (85 traces). As illustrated in Figure 5.1-1, the excess flows below Morelos Dam are generally similar under the Implementation Agreement and No Action conditions. The exception to this is the eight-year period between 2013 to 2020 where the excess flows observed under the Implementation Agreement are slightly higher than those observed under the No Action conditions. The average difference during this eight-year period is approximately 2.1 percent. The largest difference (4.7 percent) during this eight-year period occurs in year 2013.

The low frequency of occurrence of excess flows under the No Action conditions in the first year (2002) is attributable to the fact that the starting conditions used in the model include less-than-full reservoirs (for example, Lake Mead at approximately 35 feet below full content). Reservoir starting conditions are discussed in Section 2.3. The slightly higher excess flows observed in some traces under the Implementation Agreement can be attributed to the slightly higher Lake Mead water levels also observed under this condition. With higher reservoir levels, the frequency of flood control releases (which are the primary source of the excess flows) is increased.

The maximum frequency under No Action conditions is observed in 2007 (29.4 percent). Thereafter, a gradually declining tendency is observed to about 10.6 percent in 2071 and recovering back to about 16.5 percent by 2076. The gradual declining trend observed under both the No Action and Implementation Agreement conditions coincide with the Basin States' plans to use their water apportionments under the Colorado River Compact for agricultural, municipal and industrial purposes.

It has been estimated that periodic annual flows of 250,000 af or greater are necessary for maintaining the health of the Colorado River corridor in Mexico and the estuary at the upper end of the Sea of Cortez (Leucke *et al.,* 1999), and to help to restore floodplain habitat. Figure 5.1-2 presents the probability of occurrence of excess flows greater than 250,000 af and Figure 5.1-3 presents the probability of occurrence of excess flows greater than 1,000,000 af below the Mexico Diversion at Morelos Dam.

Figure 5.1-1
Probability of Occurrence of Excess Flows Below Mexico Diversion at Morelos Dam
Comparison of Implementation Agreement to No Action

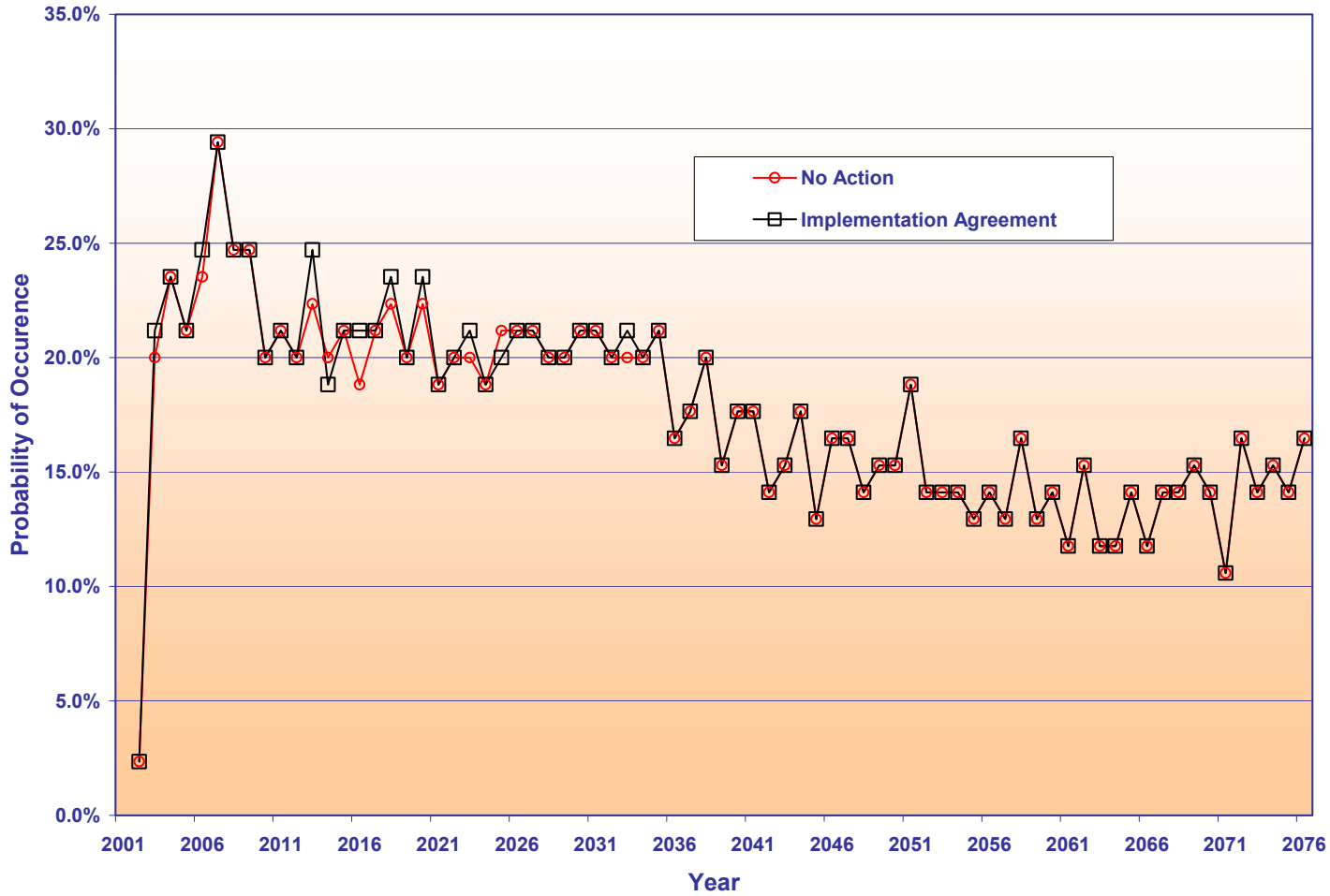


Figure 5.1-2
Probability of Occurrence of Excess Flows Greater than 250,000 Acre-Feet Below Mexico Diversions at Morelos Dam
Comparison of Implementation Agreement to No Action Conditions

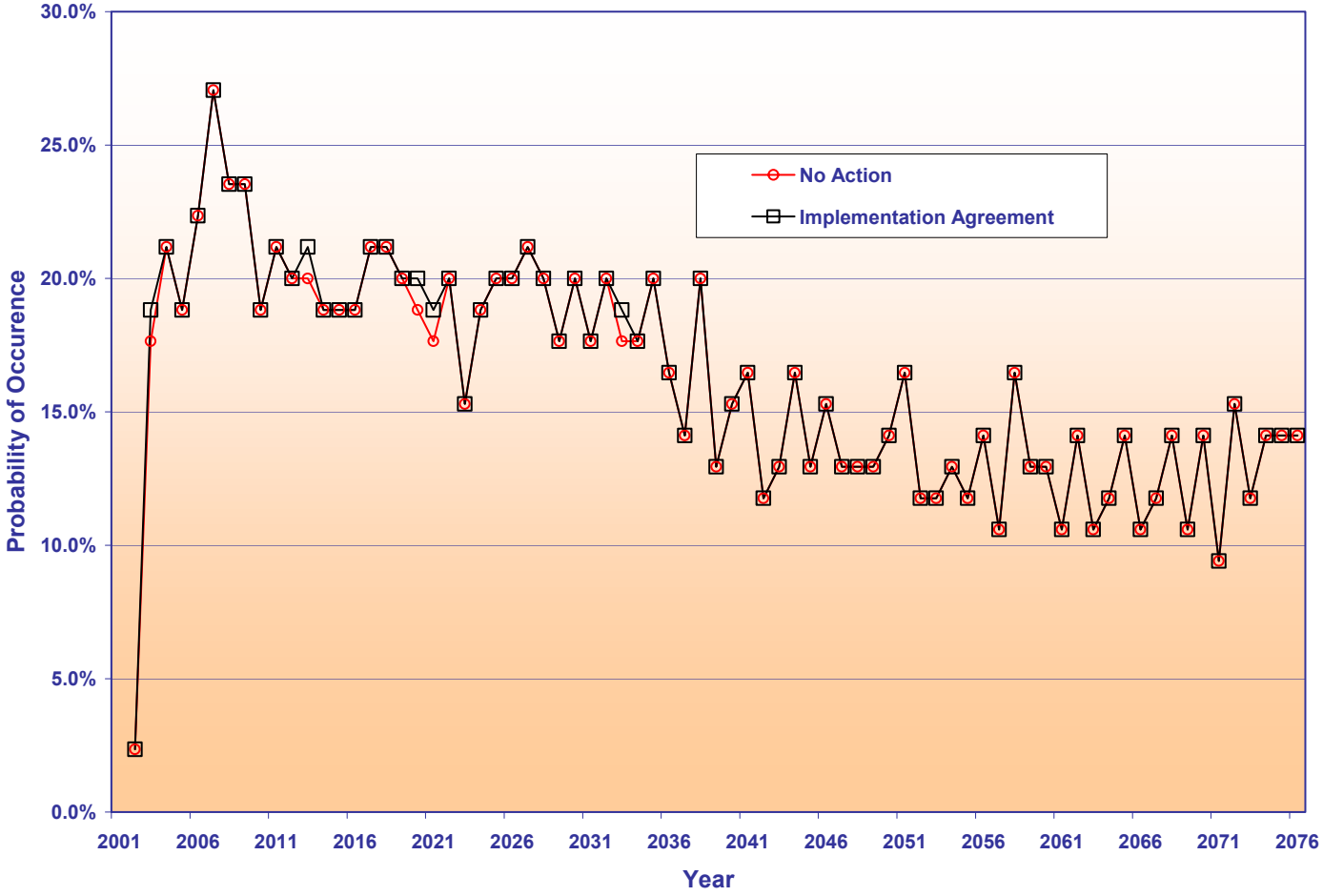
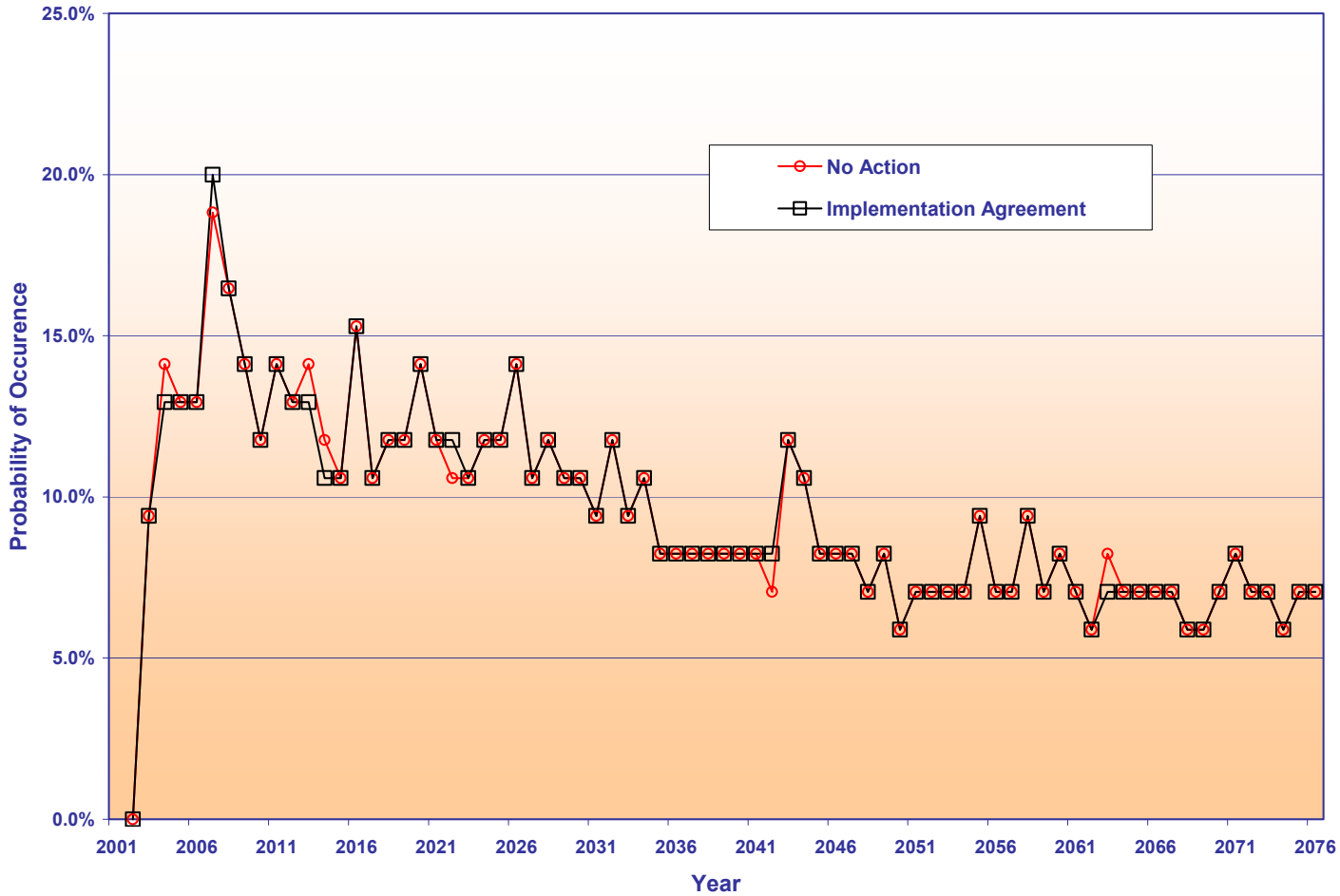


Figure 5.1-3
Probability of Occurrence of Excess Flows Greater Than 1,000,000 Acre-Feet
Below Mexico Diversion at Morelos Dam
Comparison of Implementation Agreement to No Action Conditions



5.1.2 COMPARISON OF IMPLEMENTATION AGREEMENT TO NO ACTION CONDITIONS

Figure 5.1-1 presented a graphical comparison of the probability of delivery of future excess flows to Mexico under the Implementation Agreement to those under the No Action conditions. A similar comparison for selected years is presented in tabular format in Table 5.1-1. In general, the Implementation Agreement provides a slightly higher frequency of excess flows than the No Action conditions. Differences between the two conditions were noted in only 14 of the 75 years modeled. The average of frequency differences that were noted in these 14 years was 1.6 percent. The largest difference in frequency observed occurs in year 2013 and is about 4.7 percent (rounded to 5.0 percent in table). This difference is reduced to approximately one percent by 2037. After 2037, there were no differences in frequency between the Implementation Agreement and No Action conditions.

Table 5.1-1
Frequency Occurrence of Excess Flows Below Mexico Diversion at Morelos Dam
Comparison of Implementation Agreement to No Action Conditions

Selected Year	No Action	Implementation Agreement	Difference
2002	2%	2%	0%
2003	20%	21%	1%
2004	24%	24%	0%
2005	21%	21%	0%
2006	24%	25%	1%
2007	29%	29%	0%
2008	25%	25%	0%
2009	25%	25%	0%
2010	20%	20%	0%
2011	20%	21%	1%
2012	20%	20%	0%
2013	20%	25%	5%
2014	19%	19%	0%
2015	20%	21%	1%
2016	19%	21%	2%
2020	21%	24%	3%
2025	21%	20%	1%
2030	21%	21%	0%
2035	21%	21%	0%
2040	18%	18%	0%
2045	13%	13%	0%
2050	15%	15%	0%
2055	13%	13%	0%
2060	14%	14%	0%
2065	14%	14%	0%
2070	14%	14%	0%
2075	14%	14%	0%

Figures 5.1-4 and 5.1-5 compare the cumulative distribution of annual volume of excess flows observed under the Implementation Agreement and No Action conditions for years 2016 and 2050, respectively. Although the frequency of occurrence of flows of a particular magnitude is increased, the range of excess flows is preserved under the Implementation Agreement when compared to No Action conditions. In the long-term, both frequency and magnitude between these two modeled conditions appear to be similar.

Alternatively, the potential magnitudes of excess flows for the 75th and 90th percentiles are shown in Figure 5.1-6. The 75th and 90th percentile values are also presented in tabular format for selected years between 2002 through 2026 in Table 5.1-2 and Table 5.1-3, respectively. The 75th percentile flow is defined as the flow that would not be exceeded 75 percent of the time (i.e., the minimum flow that would be expected to occur 25 percent of the time) and likewise, the 90th percentile flow would be expected to occur 10 percent of the time.

In summary, there are only minor differences in the potential magnitudes and potential frequencies of excess flows between No Action and the Implementation Agreement conditions. During the initial 15 years that were modeled (interim surplus guidelines period), the average frequency of occurrence of flows exceeding 250,000 af in any year is 18.9 percent for No Action conditions, which is slightly less than one year in five. This compares to a frequency of 19.7 percent for the Implementation Agreement (approximately one year in five). For the entire 75-year period of analysis, the average frequency of occurrence is approximately the same for the No Action and Implementation Agreement conditions (ranging between 15.9 percent and 16.2 percent or about one in every six years).

The above probabilities indicate conditions below Morelos Dam would be similar to those presumed to be beneficial. Leucke, et al, 1999 states it is not yet possible to quantify with certainty the volume and frequency of these high flows that would be beneficial.

The probable average frequency of approximately 15.9 percent under the No Action conditions would change to a probable average frequency of approximately 16.2 percent under the Implementation Agreement conditions, a slightly improved but still insignificant condition. As such, the potential change in benefits to species and habitat would likely be insignificant.

Mexico has complete discretion over the use of water entering that country. As stated previously, excess flows do not necessarily flow past Morelos Dam. The assumption made for the hydrologic analysis is that annual flows in excess of Mexico's scheduled surplus deliveries (any amount greater than 1.7 maf) would have the potential to flow past Morelos Dam.

Figure 5.1-4
Potential Magnitude of Excess Flows Below Mexico Diversion at Morelos Dam
Comparison of Implementation Agreement to No Action Conditions for Modeled Year 2016

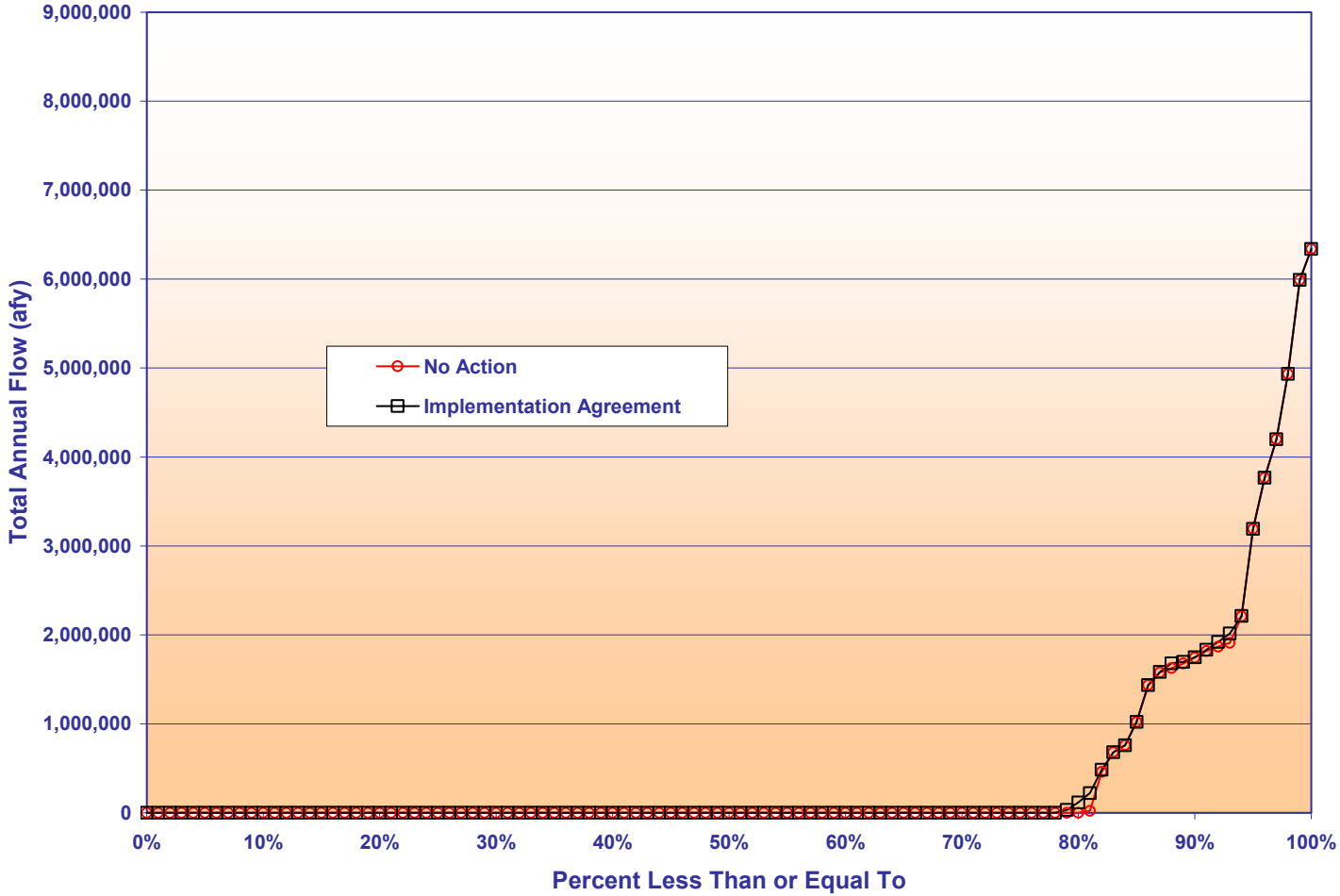


Figure 5.1-5
Potential Magnitude of Excess Flows Below Mexico Diversion at Morelos Dam
Comparison of Implementation Agreement to No Action Conditions for Modeled Year 2050

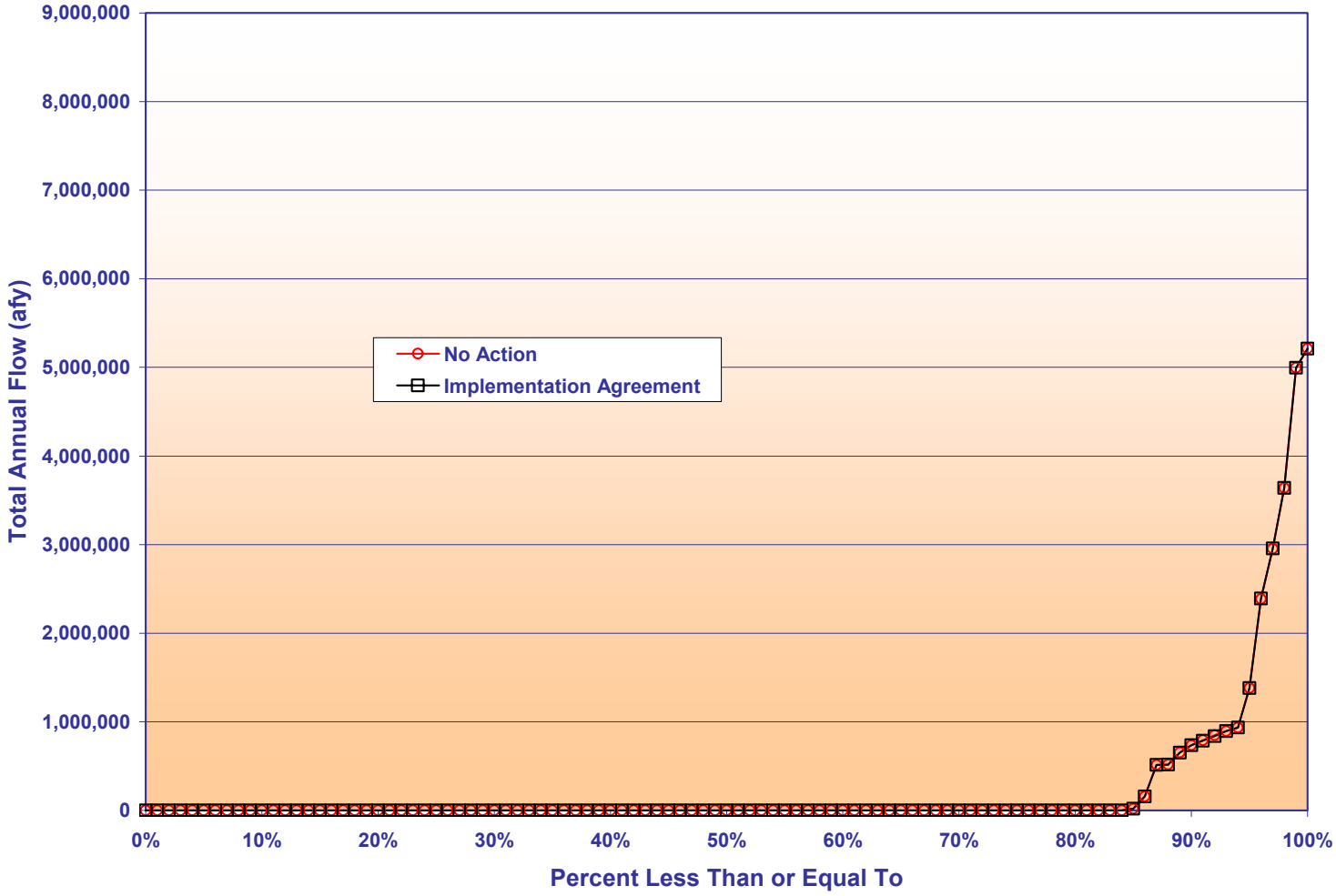


Figure 5.1- 6
Potential Magnitude of Excess Flows To Mexico
90th and 75th Percentile Values

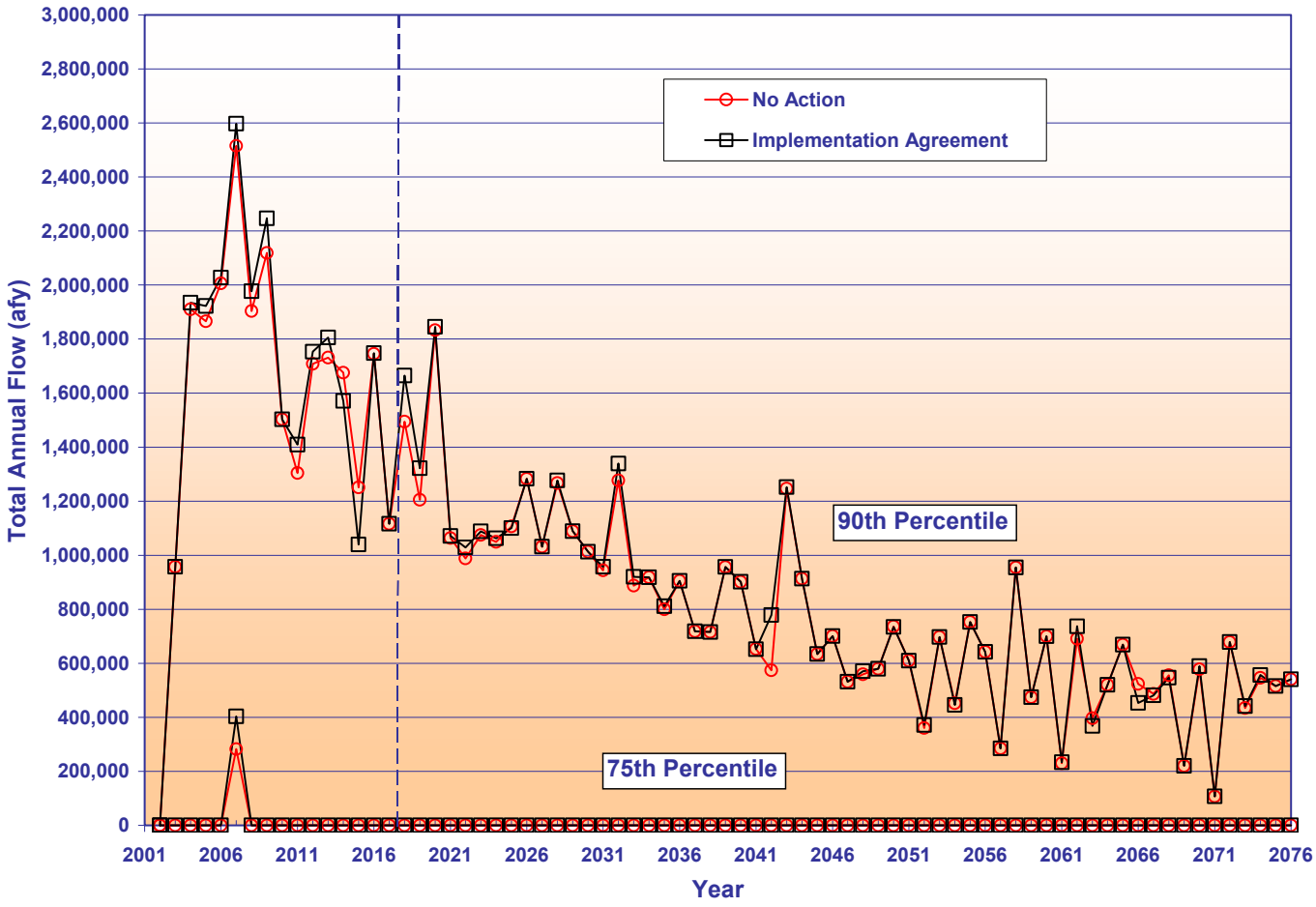


Table 5.1-2
Potential Excess Flows Below Mexico Diversion at Morelos Dam
Comparison of Implementation Agreement to No Action Conditions
75th Percentile Values for Selected Years (kaf)

Selected Years	No Action	Implementation Agreement
2002	0	0
2003	0	0
2004	0	0
2005	0	0
2006	0	0
2007	283	404
2008	0	0
2009	0	0
2010	0	0
2011	0	0
2012	0	0
2013	0	0
2014	0	0
2015	0	0
2016	0	0
2020	0	0
2025	0	0
2030	0	0
2035	0	0
2040	0	0
2045	0	0
2050	0	0
2055	0	0
2060	0	0
2065	0	0
2070	0	0
2075	0	0

Table 5.1-3
Potential Excess Flows Below Mexico Diversion at Morelos Dam
Comparison of Implementation Agreement to No Action Conditions
90th Percentile Values for Selected Years (kaf)

Selected Years	No Action	Implementation Agreement
2002	0	0
2003	957	957
2004	1,908	1,934
2005	1,836	1,922
2006	1,981	2,027
2007	2,445	2,597
2008	1,842	1,977
2009	2,015	2,247
2010	1,503	1,503
2011	1,214	1,409
2012	1,921	1,753
2013	1,580	1,806
2014	961	1,571
2015	900	1,039
2016	1,591	1,748
2020	1,833	1,846
2025	1,107	1,101
2030	1,013	1,013
2035	800	811
2040	902	902
2045	634	634
2050	734	734
2055	753	753
2060	700	700
2065	669	669
2070	577	589
2075	516	516

5.2 ANALYSIS OF CUMULATIVE EFFECTS

This section analyzes the cumulative effects through a comparison of the Cumulative Analysis and Baseline modeling results. The Baseline hereinafter refers to the Baseline for Cumulative Analysis Conditions as well as the No Action Condition for the Action Alternative.

5.2.1 BASELINE CONDITIONS

Figure 5.2-1 presents a comparison of the frequency of occurrence of future delivery of excess flows to Mexico observed under the Cumulative Analysis to those of Baseline conditions.

As previously noted, the frequency of occurrence is compiled by counting the number of modeled traces for each year that have excess flows and dividing by the total number of traces (85 traces). As illustrated in Figure 5.2-1, the excess flows below Morelos Dam are generally similar under the Cumulative Analysis and Baseline conditions. The exception to this is the eighteen-year period between 2002 to 2019 where the excess flows observed under the Cumulative Analysis are slightly lower than those observed under the Baseline conditions. The average difference during this eighteen-year period is approximately 1.9 percent. The largest difference (5.9 percent) during this eighteen-year period occurs in year 2012.

The low frequency of occurrence of excess flows under the Baseline conditions in the first year (2002) is attributable to the fact that the starting conditions used in the model include less-than-full reservoirs (for example, Lake Mead at approximately 35 feet below full content). The slightly higher excess flows observed in some traces under the Baseline conditions can be attributed to the slightly higher Lake Mead water levels also observed under this condition. With higher reservoir levels, the frequency of flood control events (which are the primary source of the excess flows) is increased.

The maximum frequency under Baseline conditions is observed in 2007 (29.4 percent). Thereafter, a gradual declining tendency is observed to about 10.6 percent in 2071 and recovering back to about 16.5 percent by 2076. The gradual declining trend observed under both the Baseline and Cumulative Analysis conditions coincide with the Basin States' plans to use their water apportionments under the Colorado River Compact for agricultural, municipal and industrial purposes.

Figure 5.2-2 presents the probability of occurrence of excess flows greater than 250,000 af. Figure 5.2-3 presents the probability of occurrence of excess flows greater than 1,000,000 af below the Mexico Diversion at Morelos Dam.

Figure 5.2-1
Probability of Occurrence of Excess Flows Below Mexico Diversion at Morelos Dam
Comparison of Cumulative Analysis to Baseline

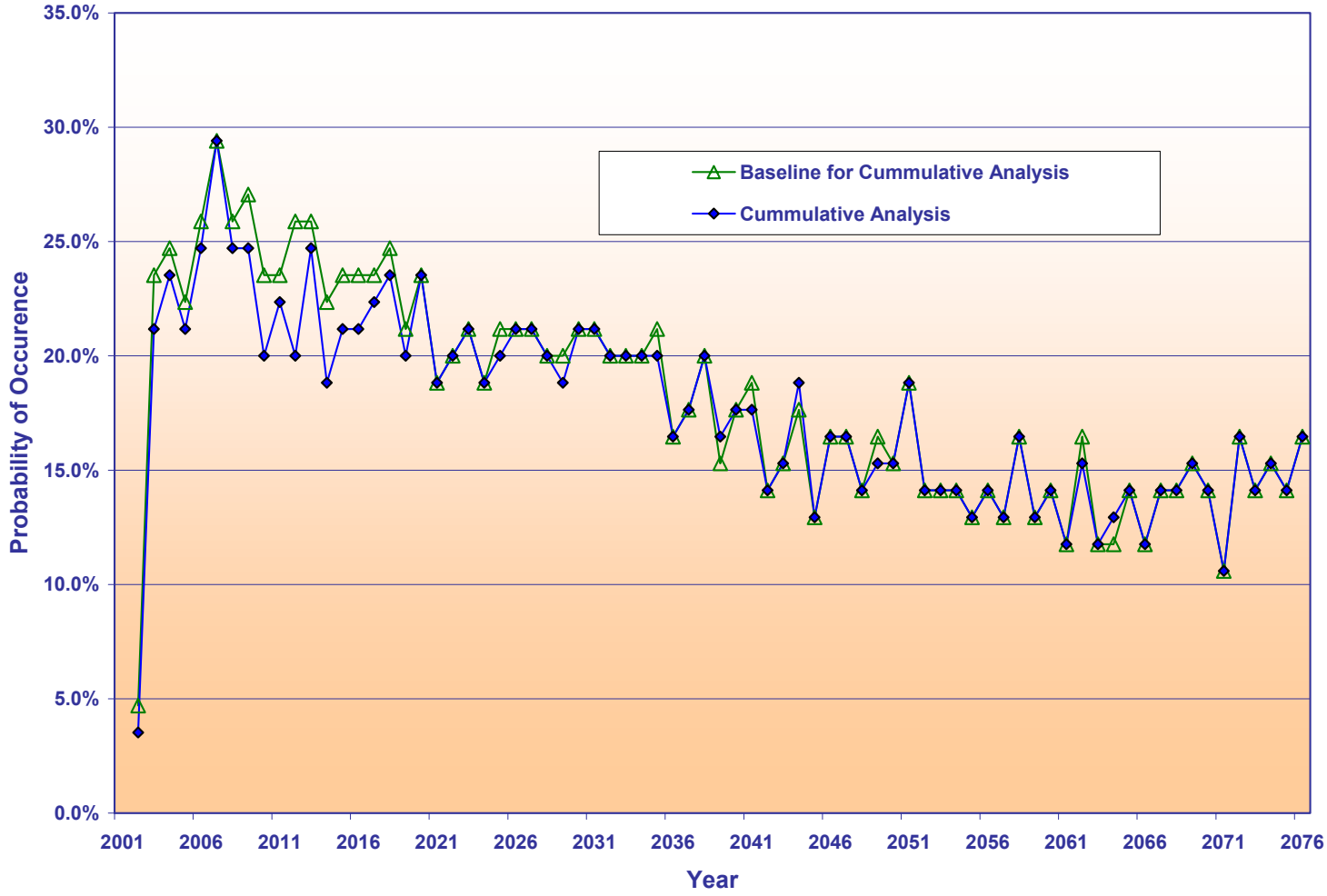


Figure 5.2-2
Probability of Occurrence of Excess Flows Greater than 250,000 Acre-Feet
Below Mexico Diversions at Morelos Dam
Comparison of Cumulative Analysis to Baseline Conditions

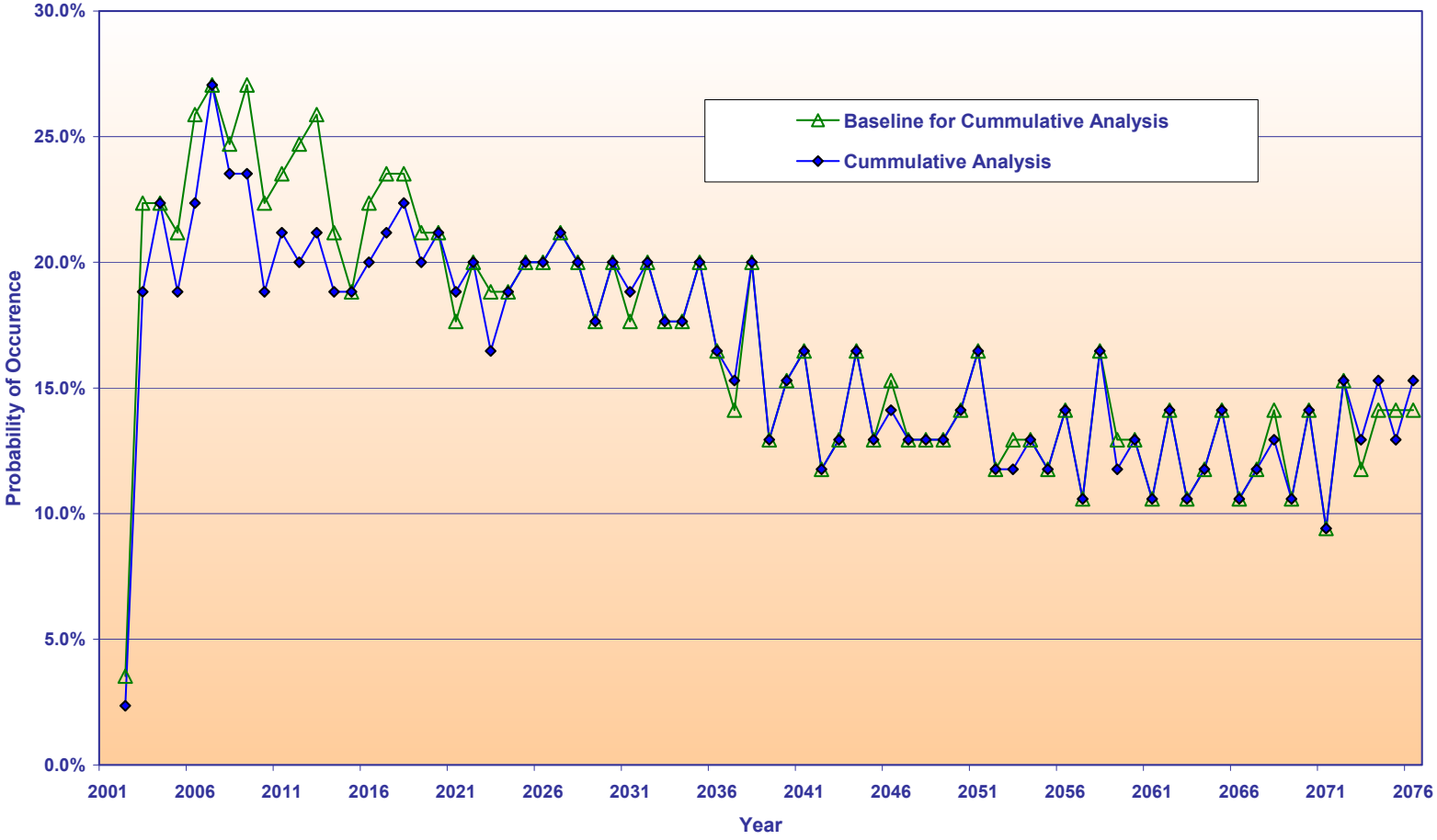
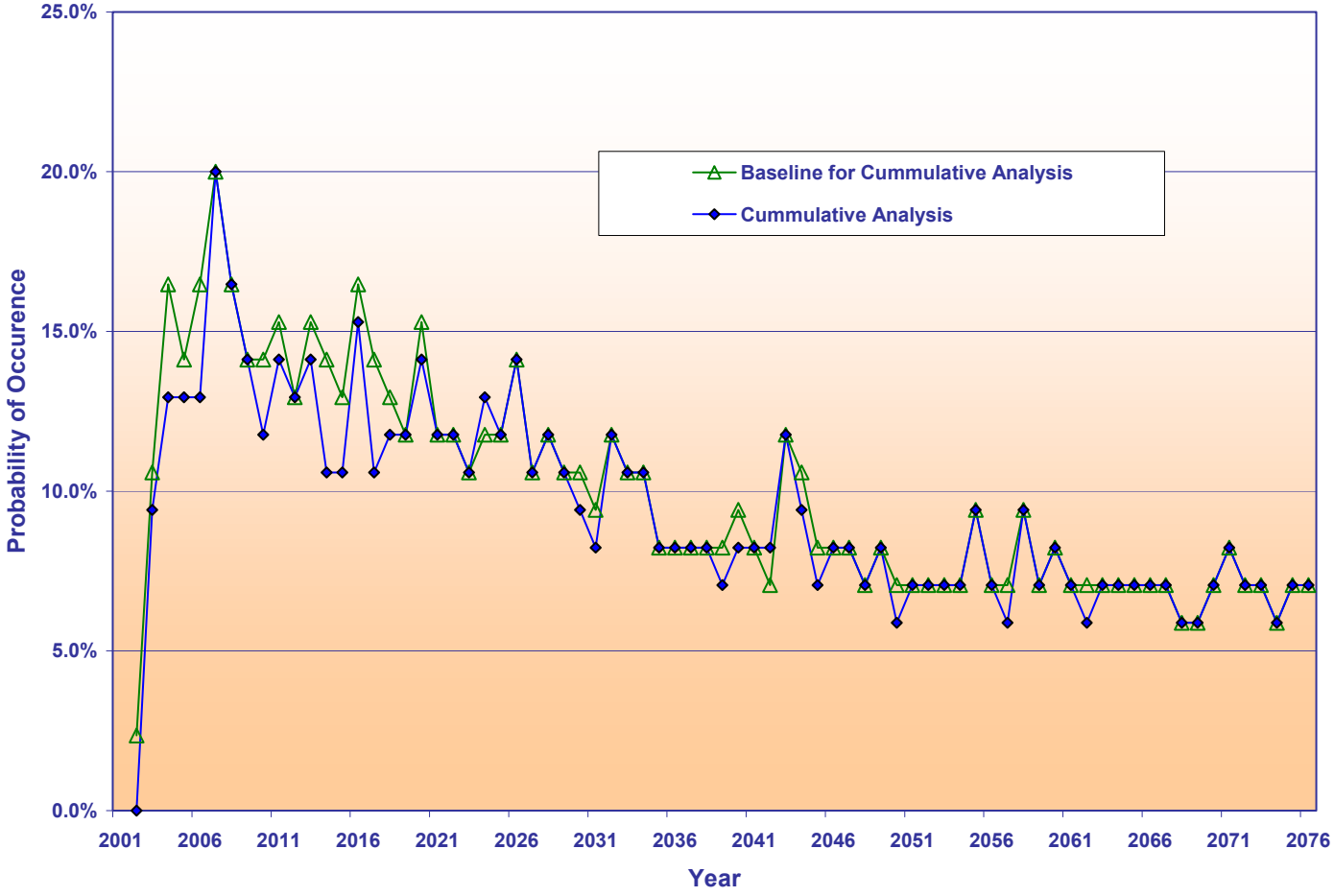


Figure 5.2-3
Probability of Occurrence of Excess Flows Greater Than 1,000,000 Acre-Feet
Below Mexico Diversion at Morelos Dam
Comparison of Cumulative Analysis to Baseline Conditions



5.2.2 COMPARISON OF CUMULATIVE ANALYSIS TO BASELINE CONDITIONS

Figure 5.2-1 presented a graphical comparison of the probability of delivery of future excess flows to Mexico under the Cumulative Analysis to those under the Baseline conditions. A similar comparison for selected years is presented in tabular format in Table 5.2-1. In general, the Cumulative Analysis conditions provide a slightly lower frequency than the Baseline. Differences between the two conditions were noted in approximately one third (26 years) of the 75 years modeled. The average of the observed differences in these 26 years was 1.4 percent. The largest difference in frequency occurs in year 2012 and is approximately 5.9 percent (rounded to 6.0 percent in table). Up to year 2035, the frequency of excess flows is slightly lower under the Cumulative Analysis conditions. However, after 2035, in the few years where differences occur, the conditions alternate in terms of higher frequency (+/- 1 to 2 percent). As such, after 2035, the observed differences can be considered negligible.

Table 5.2-1
Potential Frequency of Excess Flows Below Mexico Diversion at Morelos Dam
Comparison of Cumulative Analysis to Baseline Conditions

Selected Year	Baseline	Cumulative Analysis	Difference
2002	5%	4%	-1%
2003	24%	21%	-3%
2004	25%	24%	-1%
2005	22%	21%	-1%
2006	26%	25%	-1%
2007	29%	29%	0%
2008	26%	25%	-1%
2009	27%	25%	-2%
2010	24%	20%	-4%
2011	24%	22%	-2%
2012	26%	20%	-6%
2013	26%	25%	-1%
2014	22%	19%	-3%
2015	24%	21%	-3%
2016	24%	21%	-3%
2020	24%	24%	0%
2025	21%	20%	-1%
2030	21%	21%	0%
2035	21%	20%	-1%
2040	18%	18%	0%
2045	13%	13%	0%
2050	15%	15%	0%
2055	13%	13%	0%
2060	14%	14%	0%
2065	14%	14%	0%
2070	14%	14%	0%
2075	14%	14%	0%

Figures 5.2-4 and 5.2-5 compare the cumulative distributions of annual volume of excess flows observed under the Cumulative Analysis and Baseline conditions for years 2016 and 2050, respectively. Although the frequency of occurrence of flows of a particular magnitude is decreased, the range of excess flows is preserved for the Cumulative Analysis conditions when compared to Baseline conditions.

Table 5.2-2
Potential Excess Flows Below Mexico Diversion at Morelos Dam
Comparison of Cumulative Analysis to Baseline Conditions
75th Percentile Values for Selected Years (kaf)

Selected Years	Baseline	Cumulative Analysis
2002	0	0
2003	0	0
2004	0	0
2005	0	0
2006	526	0
2007	404	404
2008	56	0
2009	341	0
2010	0	0
2011	0	0
2012	206	0
2013	252	0
2014	0	0
2015	0	0
2016	0	0
2020	0	0
2025	0	0
2030	0	0
2035	0	0
2040	0	0
2045	0	0
2050	0	0
2055	0	0
2060	0	0
2065	0	0
2070	0	0
2075	0	0

Table 5.2-3
Potential Excess Flows Below Mexico Diversion at Morelos Dam
Comparison of Cumulative Analysis to Baseline Conditions
90th Percentile Values for Selected Years (kaf)

Selected Years	Baseline	Cumulative Analysis
2002	0	0
2003	1,100	957
2004	1,954	1,911
2005	2,520	1,933
2006	2,577	2,052
2007	2,772	2,518
2008	2,134	2,028
2009	2,285	2,088
2010	1,582	1,518
2011	1,751	1,433
2012	1,767	1,887
2013	2,214	1,748
2014	1,452	1,482
2015	1,366	1,039
2016	1,822	1,710
2020	2,118	1,831
2025	1,107	1,121
2030	1,013	949
2035	822	822
2040	949	902
2045	634	544
2050	779	766
2055	753	753
2060	700	700
2065	712	691
2070	577	597
2075	516	516

Figure 5.2-4
Potential Magnitude of Excess Flows Below Mexico Diversion at Morelos Dam
Comparison of Cumulative Analysis to Baseline Conditions for Modeled Year 2016

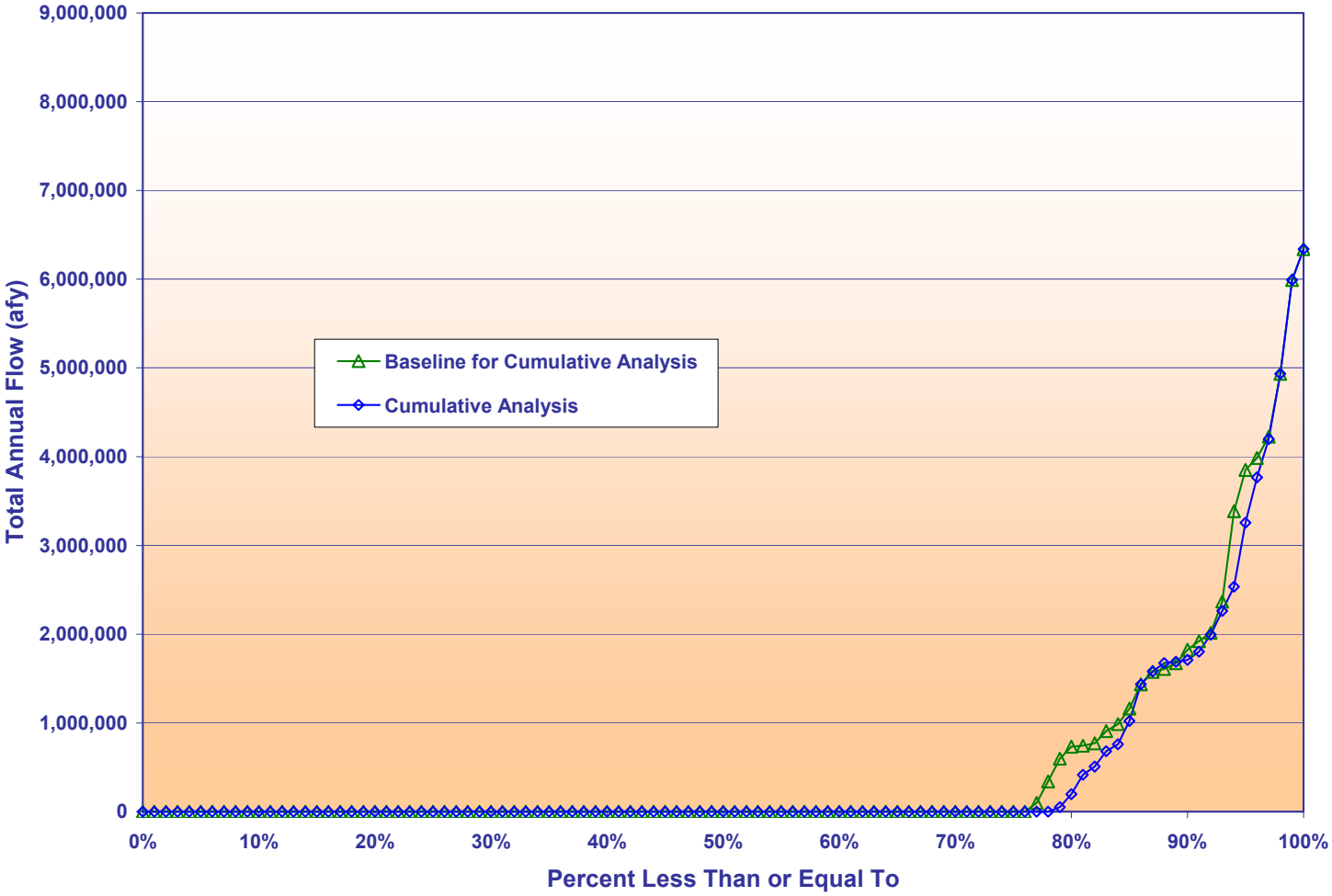
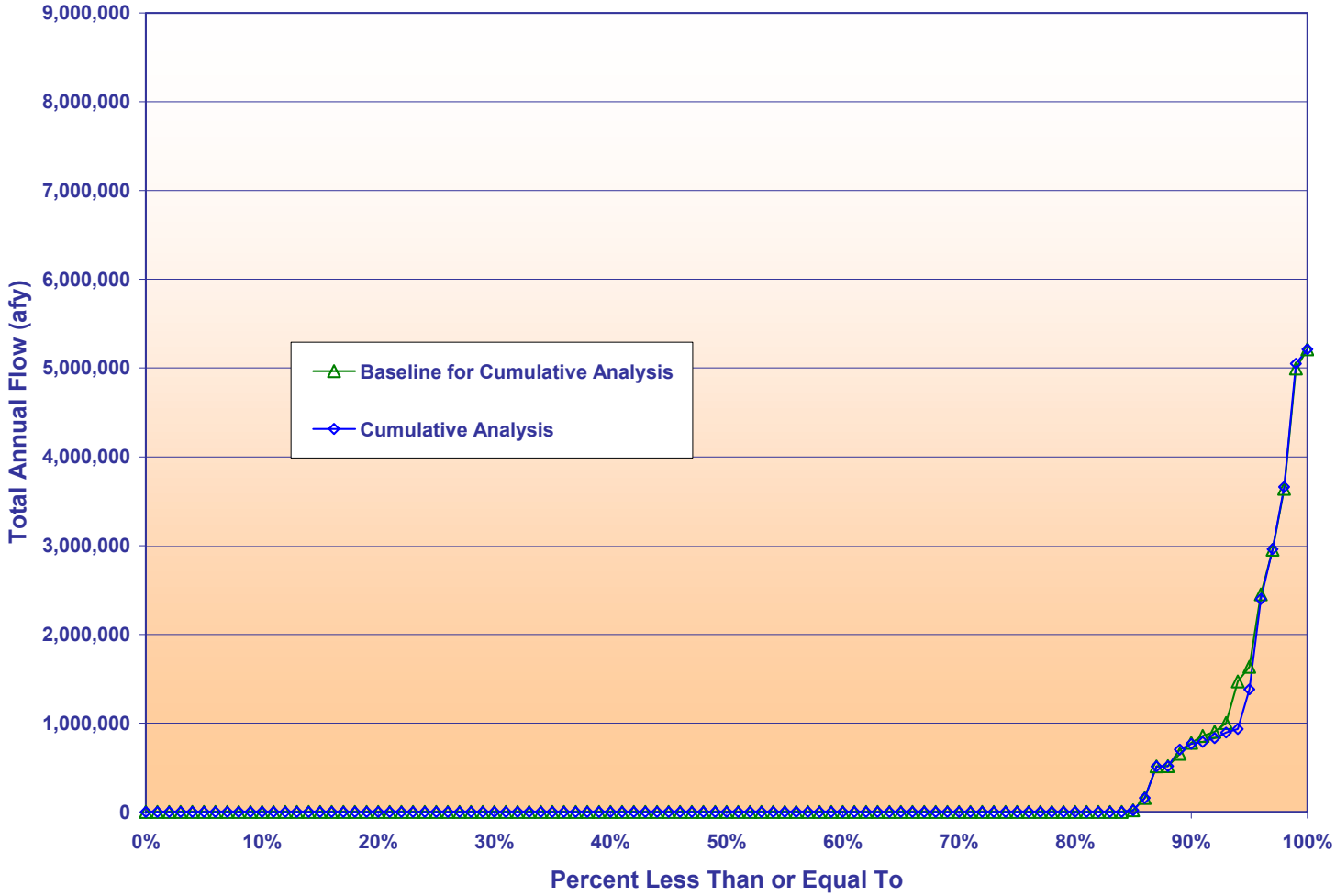


Figure 5.2-5
Potential Magnitude of Excess Flows Below Mexico Diversion at Morelos Dam
Comparison of Cumulative Analysis to Baseline Conditions for Modeled Year 2050



Alternatively, the potential magnitudes of excess flows for the 75th and 90th percentiles are shown in Figure 5.2-6. The 75th and 90th percentile values are also presented in tabular format for selected years between 2002 through 2076 in Table 5.2-2 and Table 5.2-3, respectively. The 75th percentile flow is defined as the flow that would not be exceeded 75 percent of the time (i.e., the minimum flow that would be expected to occur 25 percent of the time) and likewise, the 90th percentile flow would be expected to occur 10 percent of the time.

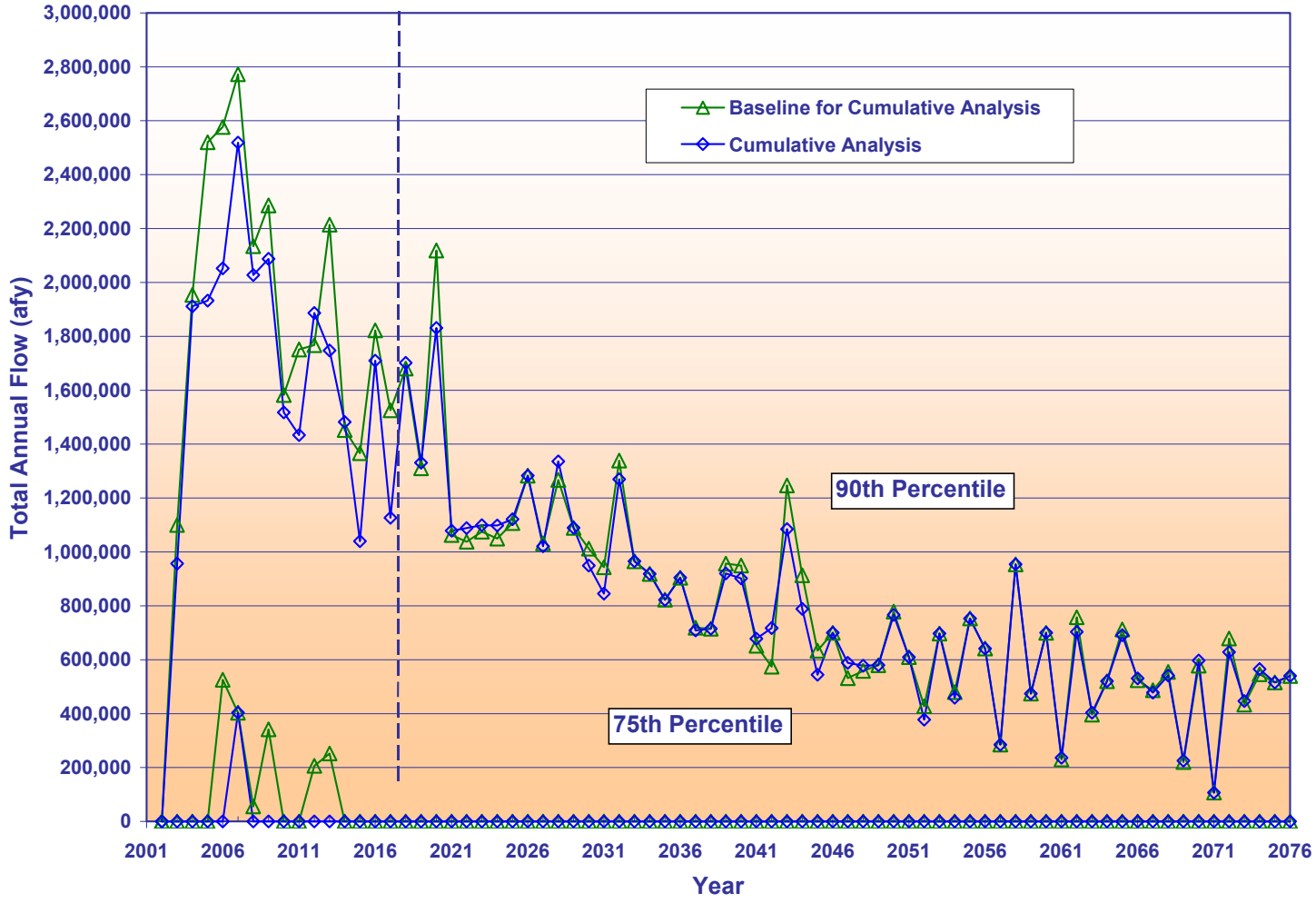
In summary, there are only minor differences in the potential magnitudes and potential frequencies of excess flows between Baseline and the Cumulative Analysis conditions. During the initial 15 years that were modeled (interim surplus guidelines period), the average frequency of occurrence of flows exceeding 250,000 af in any year is 22.2 percent for Baseline conditions, which is slightly better than one year in five. This compares to a frequency of 19.8 percent for the Cumulative Analysis (approximately one year in five). For the entire 75-year period of analysis, the average frequency of occurrence is approximately the same for the Baseline and Cumulative Analysis (ranging between 16.8 percent and 16.3 percent or about one in every six years).

The above probabilities indicate conditions below Morelos Dam would be similar to those presumed to be beneficial. Leucke, et al, 1999 states it is not yet possible to quantify with certainty the volume and frequency of these high flows that would be beneficial.

The probable average frequency of approximately 16.8 percent under the Baseline would change to a probable average frequency of approximately 16.3 percent under the Cumulative Analysis conditions, a slightly reduced yet insignificant condition. On this basis, the change in benefits to species and habitat would likely be insignificant.

Mexico has complete discretion over the use of water entering that country. As stated before, excess flows are generally diverted by Mexico when possible. Thus, the species and habitat can benefit only when the amount of water arriving at Mexico is in excess of that which can be diverted.

Figure 5.2-6
Potential Magnitude of Excess Flows To Mexico
90th and 75th Percentile Values



6.0 COLORADO RIVER SALINITY

This section addresses potential changes in salinity concentrations of Colorado River water from Lake Mead to Imperial Dam. The water transfers under the Secretarial Implementation Agreement could affect the salinity of Colorado River water, which affects municipal and industrial uses in the Lower Basin. "Salinity" refers to "total dissolved solids" (TDS), consisting of all of the soluble constituents dissolved in a river. The two terms are used interchangeably in this document.

6.1 BACKGROUND

The Colorado River increases in salinity from its headwaters to its mouth, carrying an average salt load of nine million tons annually past Hoover Dam. Approximately half (47 percent) of the salinity concentration is naturally caused and 53 percent of the concentration results from human activities including agricultural runoff, evaporation and municipal and industrial sources (Forum, 1999).

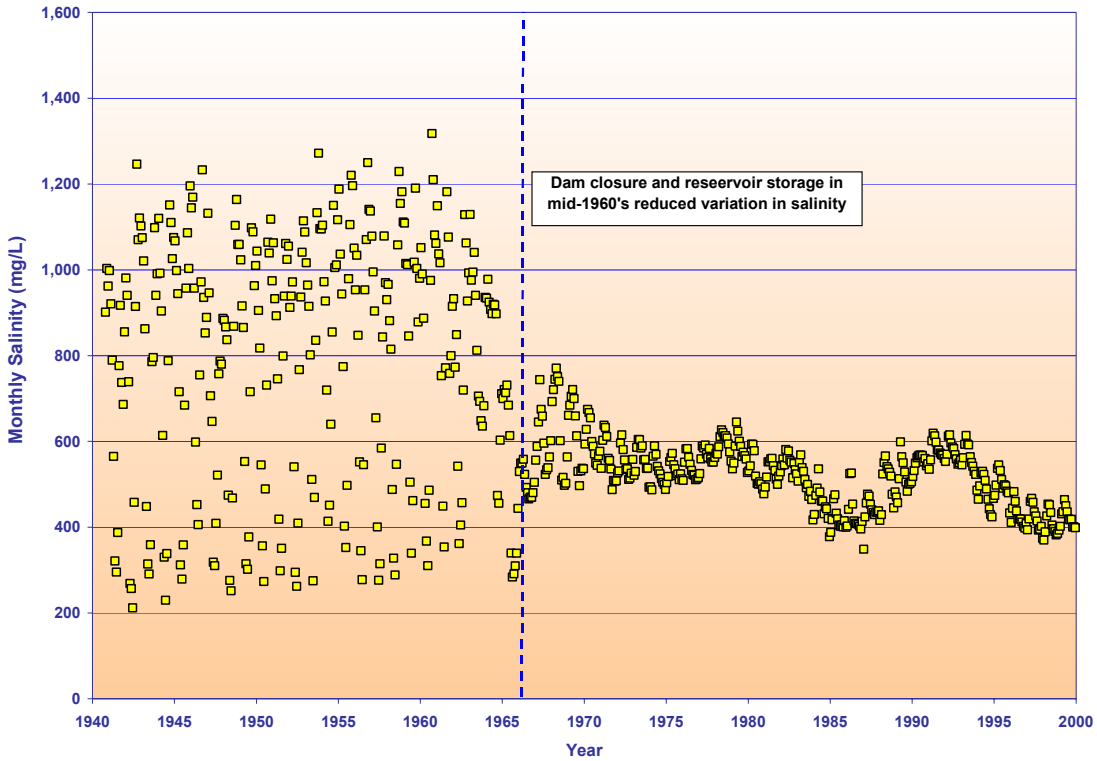
6.1.1 HISTORICAL SALINITY

Salinity of the river has fluctuated significantly over the period of record 1941 through 1997. Below Hoover Dam, annual salinity concentrations have ranged from 833 milligrams per liter (mg/l) in 1956 to 517 mg/l in 1986. However, the maximum monthly fluctuation in any year is approximately 50 mg/l. Salinity of the river is influenced by numerous factors including reservoir storage, water resource development (and associated return flows), salinity control, climatic conditions and natural runoff.

The impact of reservoir storage has almost eliminated seasonal fluctuations in salinity. As shown in Figure 6-1, the salinity of the river varied by as much as 1000 mg/l prior to the construction of Glen Canyon Dam in 1961 (Interior, 1999). By the 1980s, that variation was reduced to about 200 mg/l due to the mixing and dampening effect of the large volume of storage in Lake Powell.

Annual variations in salinity continue to occur, caused primarily by natural, climatic variations in precipitation and snowmelt runoff. The relationships between mainstream flows and salinity are described in the Interim Surplus Criteria Final EIS (USBR 2000, Pages 3.5-4 and 3.5-5).

Figure 6-1
Historical Monthly Salinity Concentrations Below Glen Canyon Dam (1940-1995)



6.1.2 REGULATORY REQUIREMENTS AND SALINITY CONTROL PROGRAM

In 1972, the EPA promulgated regulations requiring water quality standards for salinity, numeric criteria and a plan of implementation for salinity control. The Seven Colorado River Basin States, acting through the Forum, adopted numeric criteria for flow-weighted average annual salinity, at three points on the river as shown below:

Below Hoover Dam	723 mg/l
Below Parker Dam	747 mg/l
At Imperial Dam	879 mg/l

These criteria applied only to the lower portion of the Colorado River from Hoover Dam to Imperial Dam. Below Imperial Dam, salinity control is a federal responsibility to meet the terms of Minute 242 to the U.S.-Mexico Water Treaty of 1944. Minute 242 requires that salinity concentrations upstream of Mexico's diversion be no more than

115 mg/l ± 30 mg/l TDS higher than the average salinity of water arriving at Imperial Dam.

In 1974, the Colorado River Basin Salinity Control Act (P.L. 93-320) was enacted. The Act contains two Titles: 1) Title I provides the means for the United States to meet its commitment to Mexico; and 2) Title II creates a salinity control program within the Colorado River Basin in order that the numeric criteria will be met while the Basin States continue to develop their apportionment of Colorado River water.

It is estimated that 1,478,000 tons of salt will need to be removed or prevented from entering the Colorado River system to maintain the salinity concentration at or below the criteria through 2015. To date, over 720,000 tons have been controlled and an additional 756,000 tons will need to be controlled through 2015.

The federal/state salinity control program is designed to maintain the flow-weighted average annual salinity at or below the numeric criteria. The program is not intended to counteract short-term salinity variations resulting from short-term hydrologic conditions. Federal regulations provide for temporary increases above the criteria due to natural variations in flows.

The seven Basin States, acting through the Forum, review the numeric criteria and plan of implementation every three years and makes changes in the plan of implementation to accommodate changes salinity. The latest review was in 1999 (Forum, 1999). The review is currently undergoing adoption by the Basin States and approval by EPA.

At each triennial review, the current and future water uses are analyzed for their impact on the salinity of the Colorado River. If needed, additional salinity control projects are added to the plan to assure compliance with the standards.

The need for one or more additional salinity control projects is determined by monitoring the salinity of the river and making near-term projections of changes in diversions from and return flows to the river system. When an additional project is needed, it is selected from a list of potential projects that have undergone feasibility investigation. A proposal to implement the project is made through coordination with the Basin States. In selecting a project, considerable weight is given to the relative cost-effectiveness of the project. Cost-effectiveness is measured as the cost per ton of salt removed from the river system or prevented from entering the river system. Other factors are also considered, including environmental feasibility and institutional acceptability.

6.2 METHODOLOGY

Reclamation's model for salinity is used to create salinity reduction targets for the Colorado River Basin Salinity Control Program (SCP). To do this, the model simulates the effects of scheduled water development projects to predict future salinity levels. This data is then used to compute the amount of new salinity control projects required to reduce the river's salinity to meet the standards at some point in the future (2015). The model itself does not include future salinity controls because implementation schedules for future salinity control projects are not fixed and vary considerably. The salinity control standards are purposefully designed to be long-term (nondegradation) goals, rather than exceedance standards used for industry or drinking water.

By definition, the SCP is designed to be flexible enough to adjust for any changes caused by the water transfers and other operational changes addressed in this Technical Memorandum. Thus, it could be concluded that there would be no change in compliance with the standards from the implementation of the operational changes. However, if a change in river operation affects one of the factors influencing salinity (for example, if it changes the diluting effect of river flow on dissolved minerals) then that change in operation could increase or decrease the burden of the SCP to maintain the salinity standards on the river.

Such an increase or decrease can be inferred from the results of the salinity model operation in the following manner. For each future scenario (e.g., No Action Conditions or Implementation Agreement Conditions) the model produces different future TDS values, year by year, if the scenarios differ in their influence on river salinity. Thus the tendency of a future scenario to increase or decrease salinity relative to another scenario could be detected by comparing their modeled TDS values.

This approach was used to analyze the effect of the water transfers relative to no action, and of the cumulative conditions relative to the Baseline for Cumulative Analysis. Referring again to the assumption that the SCP would maintain the salinity control criteria listed above, the results are expressed in terms of the departures from the numeric criteria prior to any action by the Forum to address the changes.

6.3 ANALYSIS OF WATER TRANSFERS

The effect of the Implementation Agreement on the salinity of Colorado River water is expressed in terms of its differences from No Action Conditions. As discussed above under Methodology, the salinity under No Action Contusions is assumed to be at the numeric standards for the three locations along the lower Colorado River, and the effects of the water transfers are expressed as a departure from the numeric standards. The differences in salinity concentration between Implementation Agreement Conditions and No Action Conditions are presented in Table 6-1. The "Value" column for each measuring station and year cited shows 1) the TDS concentration assumed or the No Action Condition, and 2) the TDS concentration that would occur with the water transfers prior to any action by the Forum to address the changes. The "Effects" column shows the incremental change, with a negative entry indicating a reduction in TDS concentration.

As shown on Table 6-1 the Implementation Agreement would have no significant effect at Hoover Dam and Parker Dam. At Imperial Dam, the Implementation Agreement would tend to cause an increase in TDS concentration of several parts per million, in effect placing more of a burden on future salinity control projects. However, continued implementation of the CRB Salinity Control Program will ensure that the average salinity levels will be maintained at or below the numeric criteria levels.

Table 6-1
Estimated Effects on Colorado River Salinity

Condition Analyzed	Effect of Condition Analyzed					
	Hoover Dam		Parker Dam		Imperial Dam	
	Value	Effect	Value	Effect	Value	Effect
2016						
No Action	723	NA	747	NA	879	NA
Implementation Agreement	724	1	748	1	886	7
Baseline for Cumulative Analysis	723	NA	747	NA	879	NA
Cumulative analysis	721	-2	746	-1	879	-4
2050						
No Action	723	NA	747	NA	879	NA
Implementation Agreement	723	0	748	1	887	8
Baseline for Cumulative Analysis	723	NA	747	NA	879	NA
Cumulative analysis	723	0	746	-1	870	-9
2076						
No Action	723	NA	747	NA	879	NA
Implementation Agreement	723	0	748	1	887	8
Baseline for Cumulative Analysis	723	NA	747	NA	879	NA
Cumulative analysis	723	0	748	1	869	-10

6.4 ANALYSIS OF CUMULATIVE EFFECTS

The effect of the Cumulative Analysis Conditions on the salinity of Colorado River water is expressed in terms of its differences from Baseline for Cumulative Analysis. As discussed above under Methodology, the salinity under the Baseline for Cumulative Analysis is assumed to be at the numeric standards for the three locations along the lower Colorado River, and the effects of the Cumulative Analysis Conditions are expressed as a departure from the numeric standards.

The differences in salinity concentration between Cumulative Analysis Conditions and Baseline for Cumulative Analysis are also presented in Table 6-1. The "Value" column for each measuring station and year cited shows 1) the TDS concentration assumed for the Baseline for Cumulative Analysis, and 2) the TDS concentration that would occur under the Cumulative Analysis Conditions prior to any action by the Forum to address the changes. The "Effects" column shows the incremental change, with a negative entry indicating a reduction in TDS concentration.

As shown on Table 6-1 the Cumulative Analysis Conditions would have no significant effect at Hoover Dam and Parker Dam. However, at Imperial Dam, the Cumulative Analysis Conditions would tend to cause a reduction in salinity. In other words, the Cumulative Analysis scenario would reduce the burden on future salinity control projects. These results show that the tendency of the water transfers to increase salinity would be more than compensated for by other actions included in the Cumulative Analysis Conditions.

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REFERENCES

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Attachment A
Lower Basin Normal Depletion Schedules

Attachment A
Lower Basin Normal Depletion Schedules

As discussed in Section 2.0, four operational scenarios were modeled, labeled the No Action, Implementation Agreement, Baseline for Cumulative Analysis, and Cumulative Analysis scenarios. The primary areas of difference between the scenarios lie in the assumed schedules under normal conditions for certain California entities and the criteria used to determine surplus conditions. The differences in surplus determination are explained in Appendix C. This appendix focuses on the differences in the schedules under normal conditions (i.e., the "normal schedules").

Within each state, individual entities (or aggregations of individual entities) are represented in the model and normal schedules are provided as input. Since this DEIS is primarily concerned with the effect of the water transfers within California as defined by the Quantification Settlement Agreement (QSA), the schedules for the entities in Arizona and Nevada are consistent for all scenarios modeled. Similarly, since the QSA involves only the Metropolitan Water District (MWD), the Imperial Irrigation District (IID), and the Coachella Valley Water District (CVWD), all other California entities' schedules (with the exception of the Palo Verde Irrigation District (PVID)) are consistent for all of the scenarios. PVID's schedule varies only under the Cumulative Analysis scenario.

This leads to a logical presentation, which breaks out those entities in California (MWD, IID, CVWD and PVID) whose normal depletions may change between the operational scenarios. For this presentation, all California entities represented in the model except MWD, IID, CVWD, and PVID are termed "California Other Users".

Normal Schedules Consistent for All Operational Scenarios

As previously mentioned, the normal schedules for all entities within the states of Arizona and Nevada, as well as for the California Other Users, are assumed to be consistent for all operational scenarios.

The normal schedules used to model the normal depletions for the states of Arizona and Nevada are the same as those used in the Interim Surplus Criteria Final Environmental Impact Statement (Reclamation, 2000), extended to year 2076. These schedules are presented in Tables A-1 and A-2.

The normal schedules used for the California Other Users (as defined in this report) were the same as those used in the Interim Surplus Criteria Final Environmental Impact Statement (Reclamation, 2000), extended to year 2076. These schedules are presented in Table A-3.

Under the Law of the River, the Lower Division states' depletions total 7.5 maf under normal conditions. Of that total, California, Arizona, and Nevada are apportioned 4.4 maf, 2.8 maf, and 0.3 maf respectively; however, any apportionment unused by one state may be used by another state.

Arizona's unused apportionment in years 2002 - 2005 (as shown in Table A-1) has been allocated to MWD and the Southern Nevada Water Authority (SNWA) on a percentage basis (70% and 30% respectively) for all scenarios.

Although the individual schedules for MWD, IID, CVWD, and PVID may vary between scenarios, California's normal depletion schedule totals 4.4 maf in all years after 2005. Furthermore, Lower Division States Normal depletion schedules under all scenarios total 7.5 maf for all years, 2002-2076.

Normal Schedules for the No Action Scenario

Under the No Action scenario, no water transfers are assumed to take place (i.e., no QSA), other than the approximately 110 kaf transfer from the IID - MWD water conservation program under the IID/MWD 1988 Agreement and subsequent modifications in 1989 (the "1988/89 Agreements"). Table A-4 presents the normal depletion schedules for California under these assumptions.

Normal Schedules for the Implementation Agreement Scenario

Under the Implementation Agreement scenario, water transfers (in addition to the approximately 110 kaf transfer from the IID - MWD water conservation program under the 1988/89 Agreements) are assumed to take place consistent with the QSA. Table A-5 presents the normal depletion schedules for California under these assumptions.

Normal Schedules for the Baseline for Cumulative Analysis Scenario

Under the Baseline for Cumulative Analysis scenario, no water transfers are assumed to take place (i.e., no QSA), other than the 110 kaf transfer from IID to MWD under the 1988/89 Agreement. Consequently, the depletion schedules for all entities are identical to those used for the No Action scenario.

Normal Schedules for Cumulative Analysis Scenario

Under the Cumulative Analysis scenario, water transfers (in addition to the 110 kaf transfer from IID to MWD under the 1988/89 Agreement) are assumed to take place consistent with the QSA. Furthermore, an additional transfer from PVID to MWD under the Land Management, Crop Rotation, and Water Supply Program in the Palo Verde Irrigation District (PVID/MWD Program) is assumed to take place. The modeled transfer amount varies between 100 kaf and 111 kaf through the 75-year modeling period and was provided to Reclamation by MWD in April, 2001. Table A-6 presents the normal depletion schedules for California under these assumptions.

Transfers Considered In The Normal Schedules

A breakdown of the water transfers and conservation measures considered in the normal schedules under the Implementation Agreement and Cumulative Analysis scenarios is presented in Table A-7. The set of transfers and conservation measures was modeled to analyze the "worse case scenario", for the purpose of evaluating potential impacts with regards to reductions in river flow from Parker Dam to Imperial Dam. This table also provides the net subtotals for each affected entity (MWD, IID, CVWD & PVID). Information of the water transfers used to model the normal schedules under the previous Interim Surplus Guidelines EIS are also provided for comparison and reference purposes.

Table A-1
State of Arizona – Normal Depletion Schedules (kaf)

Year	CAP	Lake Mead NRA	Kingman	Fort Mohave Indian Res.	Mohave Valley I&DD	Mohave Valley M&I	Havasu NWR	Parker Ag.	Unused Depletion	Town of Parker et. al.	Imperial NWR	Cibola NWR	CRIR	CRIR Pumped	Gila Gravity Main Canal	Cocopah Ind. Res.	City of Yuma	Yuma Co. WUA	Arizona Pumpers	Total Arizona
2002	1,458	0	0	46	25	4	5	14	0	18	9	6	343	0	549	13	25	267	10	2,790
2003	1,447	0	0	50	25	4	5	13	0	19	9	6	351	0	543	13	25	264	10	2,784
2004	1,382	0	0	55	24	4	5	13	0	19	9	6	359	0	537	13	25	262	10	2,724
2005	1,415	0	0	60	24	4	5	13	0	20	9	7	367	0	531	13	25	259	10	2,763
2006	1,447	0	0	63	24	4	5	13	0	21	10	7	376	0	526	13	26	257	10	2,800
2007	1,441	0	0	65	24	4	5	13	0	22	10	7	386	0	521	13	26	255	10	2,800
2008	1,436	0	0	68	23	4	5	13	0	22	10	8	395	0	516	12	26	252	10	2,800
2009	1,431	0	0	70	23	4	5	13	0	23	10	8	405	0	510	12	26	250	10	2,800
2010	1,425	0	0	73	23	4	5	13	0	24	10	8	414	0	505	12	27	248	10	2,800
2011	1,425	0	0	73	22	4	5	12	0	24	10	8	424	0	499	12	27	245	10	2,800
2012	1,424	0	0	73	22	4	5	12	0	24	10	8	434	0	494	12	27	242	10	2,800
2013	1,424	0	0	73	21	4	5	12	0	24	10	8	443	0	487	12	27	239	10	2,800
2014	1,423	0	0	73	20	4	5	12	0	24	10	8	453	0	482	12	27	237	10	2,800
2015	1,422	0	0	73	20	5	5	12	0	24	9	8	463	0	477	12	27	234	10	2,800
2016	1,422	0	0	73	19	5	5	12	0	25	9	8	463	0	476	12	28	234	10	2,800
2017	1,421	0	0	73	19	5	5	12	0	25	9	8	463	0	477	12	28	234	10	2,800
2018	1,420	0	0	73	18	5	5	12	0	26	9	8	463	0	477	12	29	234	10	2,800
2019	1,420	0	0	73	18	5	5	12	0	26	9	8	463	0	476	12	29	234	10	2,800
2020	1,419	0	0	73	17	5	5	12	0	27	9	8	463	0	477	12	30	234	10	2,800
2021	1,418	0	0	73	17	5	5	12	0	27	9	9	463	0	477	12	30	233	10	2,800
2022	1,417	0	0	73	17	5	5	12	0	27	9	10	463	0	476	12	31	233	10	2,800
2023	1,415	0	0	73	17	5	5	12	0	28	10	10	463	0	477	12	32	233	10	2,800
2024	1,414	0	0	73	17	5	5	12	0	28	10	11	463	0	477	12	32	232	10	2,800
2025	1,412	0	0	73	17	5	5	12	0	28	10	12	463	0	477	12	33	232	10	2,800
2026	1,411	0	0	73	17	5	5	12	0	29	10	13	463	0	477	12	33	232	10	2,800
2027	1,410	0	0	73	17	5	5	12	0	29	10	14	463	0	476	12	34	231	10	2,800
2028	1,408	0	0	73	17	5	5	12	0	29	10	14	463	0	477	12	34	231	10	2,800
2029	1,407	0	0	73	17	6	5	12	0	30	10	15	463	0	477	12	35	230	10	2,800
2030	1,406	0	0	73	17	6	5	12	0	30	10	16	463	0	476	12	35	229	11	2,800
2031	1,405	0	0	73	17	6	5	12	0	30	10	16	463	0	476	12	36	229	11	2,800
2032	1,404	0	0	73	17	6	5	12	0	30	10	16	463	0	476	12	36	230	11	2,800
2033	1,403	0	0	73	17	6	5	12	0	30	10	16	463	0	476	12	37	230	11	2,800
2034	1,402	0	0	73	17	6	5	12	0	31	10	16	463	0	477	12	38	230	11	2,800
2035	1,402	0	0	73	17	6	5	12	0	31	10	16	463	0	476	12	38	229	11	2,800
2036	1,401	0	0	73	17	6	5	12	0	31	10	16	463	0	476	12	39	229	11	2,800
2037	1,400	0	0	73	17	6	5	12	0	31	10	16	463	0	476	12	39	230	11	2,800
2038	1,399	0	0	73	17	6	5	12	0	31	10	16	463	0	477	12	40	230	11	2,800
2039	1,398	0	0	73	17	6	5	12	0	32	10	16	463	0	477	12	40	230	11	2,800
2040	1,398	0	0	73	17	6	5	12	0	32	10	16	463	0	476	12	41	229	11	2,800
2041	1,397	0	0	73	17	6	5	12	0	32	10	16	463	0	477	12	41	230	11	2,800
2042	1,397	0	0	73	17	6	5	12	0	32	10	16	463	0	477	12	41	230	11	2,800
2043	1,397	0	0	73	17	6	5	12	0	32	10	16	463	0	476	12	41	230	11	2,800
2044	1,396	0	0	73	17	6	5	12	0	33	10	16	463	0	477	12	41	230	11	2,800
2045	1,396	0	0	73	17	6	5	12	0	33	10	16	463	0	477	12	41	230	11	2,800
2046	1,396	0	0	73	17	6	5	12	0	33	10	16	463	0	477	12	41	230	11	2,800
2047	1,396	0	0	73	17	6	5	12	0	33	10	16	463	0	476	12	41	230	11	2,800
2048	1,395	0	0	73	17	6	5	12	0	34	10	16	463	0	477	12	41	230	11	2,800
2049	1,395	0	0	73	17	6	5	12	0	34	10	16	463	0	477	12	41	230	11	2,800
2050	1,395	0	0	73	17	6	5	12	0	34	10	16	463	0	476	12	41	230	11	2,800
2051	1,395	0	0	73	17	6	5	12	0	34	10	16	463	0	476	12	41	230	11	2,800
2052	1,395	0	0	73	17	6	5	12	0	34	10	16	463	0	476	12	41	230	11	2,800
2053	1,395	0	0	73	17	6	5	12	0	34	10	16	463	0	476	12	41	230	11	2,800
2054	1,395	0	0	73	17	6	5	12	0	34	10	16	463	0	476	12	41	230	11	2,800
2055	1,395	0	0	73	17	6	5	12	0	34	10	16	463	0	476	12	41	230	11	2,800
2056	1,395	0	0	73	17	6	5	12	0	34	10	16	463	0	476	12	41	230	11	2,800
2057	1,395	0	0	73	17	6	5	12	0	34	10	16	463	0	476	12	41	230	11	2,800
2058	1,395	0	0	73	17	6	5	12	0	34	10	16	463	0	476	12	41	230	11	2,800
2059	1,395	0	0	73	17	6	5	12	0	34	10	16	463	0	476	12	41	230	11	2,800
2060	1,395	0	0	73	17	6	5	12	0	34	10	16	463	0	476	12	41	230	11	2,800
2061	1,395	0	0	73	17	6	5	12	0	34	10	16	463	0	476	12	41	230	11	2,800
2062	1,395	0	0	73	17	6	5	12	0	34	10	16	463	0	476	12	41	230	11	2,800
2063	1,395	0	0	73	17	6	5	12	0	34	10	16	463	0	476	12	41	230	11	2,800
2064	1,395	0	0	73	17	6	5	12	0	34	10	16	463	0	476	12	41	230	11	2,800
2065	1,395	0	0	73	17	6	5	12	0	34	10	16	463	0	476	12	41	230	11	2,800
2066	1,395	0	0	73	17	6	5	12	0	34	10	16	463	0	476	12	41	230	11	2,800
2067	1,395	0	0	73	17	6	5	12	0	34	10	16	463	0	476	12	41	230	11	2,800
2068	1,395	0	0	73	17	6	5	12	0	34	10	16	463	0	476	12	41	230	11	2,800
2069	1,395	0	0	73	17	6	5	12	0	34	10	16	463	0	476	12	41	230	11	2,800
2070	1,395	0	0	73	17	6	5	12	0	34	10	16	463	0	476	12	41	230	11	2,800
2071	1,395	0	0	73	17	6	5	12	0	34	10	16	463	0	476	12	41	230	11	2,800
2072	1,395	0	0	73	17	6	5	12	0	34	10	16	463	0	476	12	41	230	11	2,800
2073	1,395	0	0	73	17	6	5	12	0	34	10	16	463	0	476	12	41	230	11	2,800
2074	1,395	0	0	73	17	6	5	12	0	34	10	16	463	0	476	12	41	230	11	2,800
2075	1,395	0	0	73	17	6	5	12	0	34	10	16	463	0	476	12	41	230	11	2,800
2076	1,395	0	0	73	17	6	5	12	0	34	10	16	463	0	476	12	41	230	11	2,800

Table A-2
State of Nevada – Normal Depletion Schedules (kaf)

Date	Laughlin M&I	Mohave Steam Plant	Ft. Mohave Ind. Res.	Total Nevada	SNWA	Total NV
2002	4	16	6	26	277	303
2003	4	16	6	26	278	304
2004	4	16	7	27	294	321
2005	4	16	8	28	282	310
2006	4	16	8	28	272	300
2007	4	16	8	28	272	300
2008	4	16	9	29	271	300
2009	4	16	9	29	271	300
2010	4	16	9	29	271	300
2011	4	16	9	29	271	300
2012	4	16	9	29	271	300
2013	4	16	9	29	271	300
2014	4	16	9	29	271	300
2015	4	16	9	29	271	300
2016	4	16	9	29	271	300
2017	4	16	9	29	271	300
2018	4	16	9	29	271	300
2019	4	16	9	29	271	300
2020	4	16	9	29	271	300
2021	4	16	9	29	271	300
2022	4	16	9	29	271	300
2023	4	16	9	29	271	300
2024	4	16	9	29	271	300
2025	4	16	9	29	271	300
2026	4	8	9	21	279	300
2027	4	0	9	13	287	300
2028	4	0	9	13	287	300
2029	4	0	9	13	287	300
2030	4	0	9	13	287	300
2031	4	0	9	13	287	300
2032	4	0	9	13	287	300
2033	4	0	9	13	287	300
2034	4	0	9	13	287	300
2035	4	0	9	13	287	300
2036	4	0	9	13	287	300
2037	4	0	9	13	287	300
2038	4	0	9	13	287	300
2039	4	0	9	13	287	300
2040	4	0	9	13	287	300
2041	4	0	9	13	287	300
2042	4	0	9	13	287	300
2043	4	0	9	13	287	300
2044	4	0	9	13	287	300
2045	4	0	9	13	287	300
2046	4	0	9	13	287	300
2047	4	0	9	13	287	300
2048	4	0	9	13	287	300
2049	4	0	9	13	287	300
2050	4	0	9	13	287	300
2051	4	0	9	13	287	300
2052	4	0	9	13	287	300
2053	4	0	9	13	287	300
2054	4	0	9	13	287	300
2055	4	0	9	13	287	300
2056	4	0	9	13	287	300
2057	4	0	9	13	287	300
2058	4	0	9	13	287	300
2059	4	0	9	13	287	300
2060	4	0	9	13	287	300
2061	4	0	9	13	287	300
2062	4	0	9	13	287	300
2063	4	0	9	13	287	300
2064	4	0	9	13	287	300
2065	4	0	9	13	287	300
2066	4	0	9	13	287	300
2067	4	0	9	13	287	300
2068	4	0	9	13	287	300
2069	4	0	9	13	287	300
2070	4	0	9	13	287	300
2071	4	0	9	13	287	300
2072	4	0	9	13	287	300
2073	4	0	9	13	287	300
2074	4	0	9	13	287	300
2075	4	0	9	13	287	300
2076	4	0	9	13	287	300

Table A-3
State of California – Other Users – Normal Depletion Schedules (kaf)

Year	Ft. Mohave Ind. Res.	City of Needles	Havasu NWR	Chemehuevi Ind. Res.	Others & Misc. PPRs	Imperial NWR	CRIR Ind. Res.	Unused Depletion	AAC Yuma Project Bard Unit	AAC Yuma Project Unit Quechan	California Pumpers	Other Pumpers Below NIB	Total California Other
2002	14	1	0	2	2	0	5	0	18	19	0	0	61
2003	13	1	0	2	2	0	7	0	18	21	0	0	63
2004	13	1	0	3	2	0	8	0	18	22	0	0	65
2005	12	1	0	3	2	0	9	0	18	23	0	0	68
2006	12	1	0	3	2	0	11	0	18	24	0	0	71
2007	12	1	0	4	2	0	13	0	18	25	0	0	75
2008	12	1	0	4	2	0	15	0	18	27	0	0	78
2009	12	1	0	5	2	0	17	0	18	28	0	0	82
2010	12	1	0	5	2	0	19	0	18	29	0	0	86
2011	12	1	0	6	2	0	23	0	18	30	0	0	92
2012	12	1	0	6	2	0	27	0	18	32	0	0	98
2013	12	1	0	7	2	0	31	0	18	33	0	0	104
2014	12	1	0	7	2	0	35	0	18	35	0	0	110
2015	12	1	0	8	2	0	39	0	18	36	0	0	116
2016	12	1	0	8	2	0	39	0	18	36	0	0	116
2017	12	1	0	8	2	0	39	0	18	36	0	0	116
2018	12	1	0	8	2	0	39	0	18	36	0	0	116
2019	12	1	0	8	2	0	39	0	18	36	0	0	116
2020	12	1	0	8	2	0	39	0	18	36	0	0	116
2021	12	1	0	8	2	0	39	0	18	36	0	0	116
2022	12	1	0	8	2	0	39	0	18	36	0	0	116
2023	12	1	0	8	2	0	39	0	18	36	0	0	116
2024	12	1	0	8	2	0	39	0	18	36	0	0	116
2025	12	1	0	8	2	0	39	0	18	36	0	0	116
2026	12	1	0	8	2	0	39	0	18	36	0	0	116
2027	12	1	0	8	2	0	39	0	18	36	0	0	116
2028	12	1	0	8	2	0	39	0	18	36	0	0	116
2029	12	1	0	8	2	0	39	0	18	36	0	0	116
2030	12	1	0	8	2	0	39	0	18	36	0	0	116
2031	12	1	0	8	2	0	39	0	18	36	0	0	116
2032	12	1	0	8	2	0	39	0	18	36	0	0	116
2033	12	1	0	8	2	0	39	0	18	36	0	0	116
2034	12	1	0	8	2	0	39	0	18	36	0	0	116
2035	12	1	0	8	2	0	39	0	18	36	0	0	116
2036	12	1	0	8	2	0	39	0	18	36	0	0	116
2037	12	1	0	8	2	0	39	0	18	36	0	0	116
2038	12	1	0	8	2	0	39	0	18	36	0	0	116
2039	12	1	0	8	2	0	39	0	18	36	0	0	116
2040	12	1	0	8	2	0	39	0	18	36	0	0	116
2041	12	1	0	8	2	0	39	0	18	36	0	0	116
2042	12	1	0	8	2	0	39	0	18	36	0	0	116
2043	12	1	0	8	2	0	39	0	18	36	0	0	116
2044	12	1	0	8	2	0	39	0	18	36	0	0	116
2045	12	1	0	8	2	0	39	0	18	36	0	0	116
2046	12	1	0	8	2	0	39	0	18	36	0	0	116
2047	12	1	0	8	2	0	39	0	18	36	0	0	116
2048	12	1	0	8	2	0	39	0	18	36	0	0	116
2049	12	1	0	8	2	0	39	0	18	36	0	0	116
2050	12	1	0	8	2	0	39	0	18	36	0	0	116
2051	12	1	0	8	2	0	39	0	18	36	0	0	116
2052	12	1	0	8	2	0	39	0	18	36	0	0	116
2053	12	1	0	8	2	0	39	0	18	36	0	0	116
2054	12	1	0	8	2	0	39	0	18	36	0	0	116
2055	12	1	0	8	2	0	39	0	18	36	0	0	116
2056	12	1	0	8	2	0	39	0	18	36	0	0	116
2057	12	1	0	8	2	0	39	0	18	36	0	0	116
2058	12	1	0	8	2	0	39	0	18	36	0	0	116
2059	12	1	0	8	2	0	39	0	18	36	0	0	116
2060	12	1	0	8	2	0	39	0	18	36	0	0	116
2061	12	1	0	8	2	0	39	0	18	36	0	0	116
2062	12	1	0	8	2	0	39	0	18	36	0	0	116
2063	12	1	0	8	2	0	39	0	18	36	0	0	116
2064	12	1	0	8	2	0	39	0	18	36	0	0	116
2065	12	1	0	8	2	0	39	0	18	36	0	0	116
2066	12	1	0	8	2	0	39	0	18	36	0	0	116
2067	12	1	0	8	2	0	39	0	18	36	0	0	116
2068	12	1	0	8	2	0	39	0	18	36	0	0	116
2069	12	1	0	8	2	0	39	0	18	36	0	0	116
2070	12	1	0	8	2	0	39	0	18	36	0	0	116
2071	12	1	0	8	2	0	39	0	18	36	0	0	116
2072	12	1	0	8	2	0	39	0	18	36	0	0	116
2073	12	1	0	8	2	0	39	0	18	36	0	0	116
2074	12	1	0	8	2	0	39	0	18	36	0	0	116
2075	12	1	0	8	2	0	39	0	18	36	0	0	116
2076	12	1	0	8	2	0	39	0	18	36	0	0	116

Table A-4
State of California - Normal Depletion Schedules WITHOUT QSA (kaf)

Year	CA Others	MWD	IID	CVWD	PVID	CA Total
2002	61	643	2,990	330	383	4,407
2003	63	647	2,990	330	381	4,412
2004	65	689	2,990	330	380	4,455
2005	68	660	2,990	330	379	4,427
2006	71	631	2,990	330	378	4,400
2007	75	629	2,990	330	377	4,400
2008	78	626	2,990	330	375	4,400
2009	82	624	2,990	330	374	4,400
2010	86	621	2,990	330	373	4,400
2011	92	617	2,990	330	372	4,400
2012	98	612	2,990	330	370	4,400
2013	104	608	2,990	330	369	4,400
2014	110	603	2,990	330	367	4,400
2015	116	598	2,990	330	366	4,400
2016	116	598	2,990	330	366	4,400
2017	116	598	2,990	330	366	4,400
2018	116	598	2,990	330	366	4,400
2019	116	598	2,990	330	366	4,400
2020	116	598	2,990	330	366	4,400
2021	116	598	2,990	330	366	4,400
2022	116	598	2,990	330	366	4,400
2023	116	598	2,990	330	366	4,400
2024	116	598	2,990	330	366	4,400
2025	116	598	2,990	330	366	4,400
2026	116	598	2,990	330	366	4,400
2027	116	598	2,990	330	366	4,400
2028	116	598	2,990	330	366	4,400
2029	116	598	2,990	330	366	4,400
2030	116	598	2,990	330	366	4,400
2031	116	598	2,990	330	366	4,400
2032	116	598	2,990	330	366	4,400
2033	116	598	2,990	330	366	4,400
2034	116	598	2,990	330	366	4,400
2035	116	598	2,990	330	366	4,400
2036	116	598	2,990	330	366	4,400
2037	116	598	2,990	330	366	4,400
2038	116	598	2,990	330	366	4,400
2039	116	598	2,990	330	366	4,400
2040	116	598	2,990	330	366	4,400
2041	116	598	2,990	330	366	4,400
2042	116	598	2,990	330	366	4,400
2043	116	598	2,990	330	366	4,400
2044	116	598	2,990	330	366	4,400
2045	116	598	2,990	330	366	4,400
2046	116	598	2,990	330	366	4,400
2047	116	598	2,990	330	366	4,400
2048	116	598	2,990	330	366	4,400
2049	116	598	2,990	330	366	4,400
2050	116	598	2,990	330	366	4,400
2051	116	598	2,990	330	366	4,400
2052	116	598	2,990	330	366	4,400
2053	116	598	2,990	330	366	4,400
2054	116	598	2,990	330	366	4,400
2055	116	598	2,990	330	366	4,400
2056	116	598	2,990	330	366	4,400
2057	116	598	2,990	330	366	4,400
2058	116	598	2,990	330	366	4,400
2059	116	598	2,990	330	366	4,400
2060	116	598	2,990	330	366	4,400
2061	116	598	2,990	330	366	4,400
2062	116	598	2,990	330	366	4,400
2063	116	598	2,990	330	366	4,400
2064	116	598	2,990	330	366	4,400
2065	116	598	2,990	330	366	4,400
2066	116	598	2,990	330	366	4,400
2067	116	598	2,990	330	366	4,400
2068	116	598	2,990	330	366	4,400
2069	116	598	2,990	330	366	4,400
2070	116	598	2,990	330	366	4,400
2071	116	598	2,990	330	366	4,400
2072	116	598	2,990	330	366	4,400
2073	116	598	2,990	330	366	4,400
2074	116	598	2,990	330	366	4,400
2075	116	598	2,990	330	366	4,400
2076	116	598	2,990	330	366	4,400

Table A-5
State of California - Normal Depletion Schedules WITH QSA (kaf)

Year	CA Others	MWD	IID	CVWD	PVID	CA Total
2002	61	679	2,959	326	383	4,407
2003	63	693	2,939	335	381	4,412
2004	65	770	2,919	321	380	4,455
2005	68	783	2,877	321	379	4,427
2006	71	778	2,852	321	378	4,400
2007	75	847	2,781	321	377	4,400
2008	78	864	2,761	321	375	4,400
2009	82	887	2,736	321	374	4,400
2010	86	910	2,711	321	373	4,400
2011	92	930	2,686	321	372	4,400
2012	98	930	2,681	321	370	4,400
2013	104	931	2,676	321	369	4,400
2014	110	931	2,671	321	367	4,400
2015	116	932	2,666	321	366	4,400
2016	116	937	2,661	321	366	4,400
2017	116	942	2,656	321	366	4,400
2018	116	947	2,651	321	366	4,400
2019	116	952	2,646	321	366	4,400
2020	116	957	2,641	321	366	4,400
2021	116	962	2,636	321	366	4,400
2022	116	967	2,631	321	366	4,400
2023	116	972	2,626	321	366	4,400
2024	116	977	2,621	321	366	4,400
2025	116	982	2,616	321	366	4,400
2026	116	987	2,611	321	366	4,400
2027	116	987	2,611	321	366	4,400
2028	116	987	2,611	321	366	4,400
2029	116	987	2,611	321	366	4,400
2030	116	987	2,611	321	366	4,400
2031	116	987	2,611	321	366	4,400
2032	116	987	2,611	321	366	4,400
2033	116	987	2,611	321	366	4,400
2034	116	987	2,611	321	366	4,400
2035	116	987	2,611	321	366	4,400
2036	116	987	2,611	321	366	4,400
2037	116	987	2,611	321	366	4,400
2038	116	987	2,611	321	366	4,400
2039	116	987	2,611	321	366	4,400
2040	116	987	2,611	321	366	4,400
2041	116	987	2,611	321	366	4,400
2042	116	987	2,611	321	366	4,400
2043	116	987	2,611	321	366	4,400
2044	116	987	2,611	321	366	4,400
2045	116	987	2,611	321	366	4,400
2046	116	987	2,611	321	366	4,400
2047	116	937	2,661	321	366	4,400
2048	116	937	2,661	321	366	4,400
2049	116	937	2,661	321	366	4,400
2050	116	937	2,661	321	366	4,400
2051	116	937	2,661	321	366	4,400
2052	116	937	2,661	321	366	4,400
2053	116	937	2,661	321	366	4,400
2054	116	937	2,661	321	366	4,400
2055	116	937	2,661	321	366	4,400
2056	116	937	2,661	321	366	4,400
2057	116	937	2,661	321	366	4,400
2058	116	937	2,661	321	366	4,400
2059	116	937	2,661	321	366	4,400
2060	116	937	2,661	321	366	4,400
2061	116	937	2,661	321	366	4,400
2062	116	937	2,661	321	366	4,400
2063	116	937	2,661	321	366	4,400
2064	116	937	2,661	321	366	4,400
2065	116	937	2,661	321	366	4,400
2066	116	937	2,661	321	366	4,400
2067	116	937	2,661	321	366	4,400
2068	116	937	2,661	321	366	4,400
2069	116	937	2,661	321	366	4,400
2070	116	937	2,661	321	366	4,400
2071	116	937	2,661	321	366	4,400
2072	116	937	2,661	321	366	4,400
2073	116	937	2,661	321	366	4,400
2074	116	937	2,661	321	366	4,400
2075	116	937	2,661	321	366	4,400
2076	116	937	2,661	321	366	4,400

Table A-6
State of California - Normal Depletion Schedules Used for Cumulative Analysis (With Additional Transfers from PVID to MWD, kaf)

Year	CA Others	MWD	IID	CVWD	PVID	CA Total
2002	61	711	2,959	326	351	4,407
2003	63	793	2,939	335	281	4,412
2004	65	870	2,919	321	280	4,455
2005	68	883	2,877	321	279	4,427
2006	71	878	2,852	321	278	4,400
2007	75	947	2,781	321	277	4,400
2008	78	964	2,761	321	275	4,400
2009	82	987	2,736	321	274	4,400
2010	86	1,010	2,711	321	273	4,400
2011	92	1,030	2,686	321	272	4,400
2012	98	1,030	2,681	321	270	4,400
2013	104	1,031	2,676	321	269	4,400
2014	110	1,031	2,671	321	267	4,400
2015	116	1,032	2,666	321	266	4,400
2016	116	1,037	2,661	321	266	4,400
2017	116	1,042	2,656	321	266	4,400
2018	116	1,047	2,651	321	266	4,400
2019	116	1,052	2,646	321	266	4,400
2020	116	1,057	2,641	321	266	4,400
2021	116	1,062	2,636	321	266	4,400
2022	116	1,067	2,631	321	266	4,400
2023	116	1,072	2,626	321	266	4,400
2024	116	1,077	2,621	321	266	4,400
2025	116	1,082	2,616	321	266	4,400
2026	116	1,087	2,611	321	266	4,400
2027	116	1,088	2,611	321	264	4,400
2028	116	1,098	2,611	321	255	4,400
2029	116	1,098	2,611	321	255	4,400
2030	116	1,098	2,611	321	255	4,400
2031	116	1,098	2,611	321	255	4,400
2032	116	1,098	2,611	321	255	4,400
2033	116	1,098	2,611	321	255	4,400
2034	116	1,098	2,611	321	255	4,400
2035	116	1,098	2,611	321	255	4,400
2036	116	1,098	2,611	321	255	4,400
2037	116	1,096	2,611	321	257	4,400
2038	116	1,087	2,611	321	266	4,400
2039	116	1,087	2,611	321	266	4,400
2040	116	1,087	2,611	321	266	4,400
2041	116	1,087	2,611	321	266	4,400
2042	116	1,087	2,611	321	266	4,400
2043	116	1,087	2,611	321	266	4,400
2044	116	1,087	2,611	321	266	4,400
2045	116	1,087	2,611	321	266	4,400
2046	116	1,087	2,611	321	266	4,400
2047	116	1,037	2,661	321	266	4,400
2048	116	1,037	2,661	321	266	4,400
2049	116	1,037	2,661	321	266	4,400
2050	116	1,037	2,661	321	266	4,400
2051	116	1,037	2,661	321	266	4,400
2052	116	1,037	2,661	321	266	4,400
2053	116	1,037	2,661	321	266	4,400
2054	116	1,037	2,661	321	266	4,400
2055	116	1,037	2,661	321	266	4,400
2056	116	1,037	2,661	321	266	4,400
2057	116	1,037	2,661	321	266	4,400
2058	116	1,037	2,661	321	266	4,400
2059	116	1,037	2,661	321	266	4,400
2060	116	1,037	2,661	321	266	4,400
2061	116	1,037	2,661	321	266	4,400
2062	116	1,038	2,661	321	264	4,400
2063	116	1,048	2,661	321	255	4,400
2064	116	1,048	2,661	321	255	4,400
2065	116	1,048	2,661	321	255	4,400
2066	116	1,048	2,661	321	255	4,400
2067	116	1,048	2,661	321	255	4,400
2068	116	1,048	2,661	321	255	4,400
2069	116	1,048	2,661	321	255	4,400
2070	116	1,048	2,661	321	255	4,400
2071	116	1,048	2,661	321	255	4,400
2072	116	1,046	2,661	321	257	4,400
2073	116	1,037	2,661	321	266	4,400
2074	116	1,037	2,661	321	266	4,400
2075	116	1,037	2,661	321	266	4,400
2076	116	1,037	2,661	321	266	4,400

Table A-7
Comparison of Modeled Transfers Between the Interim Surplus Guidelines, Implementation Agreement and Cumulative Impacts Analysis Conditions

Modeled Transfer	Interim Surplus Guidelines Modeled Transfers (KAFY)	Implementation Agreement Modeled Transfers (KAFY)	Cumulative Analysis Modeled Transfers (KAFY)
MWD			
IID/SCWA Water Conservation and Transfer Agreement	200.0	200.0	200.0
First and Second 50 KAFY	0.0	100.0[2]	100.0
All American Canal Lining	67.7	67.7	67.7
Coachella Canal Lining	26.0	26.0	26.0
Miscellaneous and Federal PPRs	14.0	14.0	14.0
1988 IID/MWD Agreement, and Subsequent Agreements, as Modified by the QSA	(20.0)	(20.0)	(20.0)
MWD/CVWD SWP Exchange and Transfer	(35.0)	0.0	0.0
PVID/MWD Program [1]	0.0	0.0	110.0
Subtotal MWD	**253**	**388[2]**	**498**
CVWD			
First and Second 50 KAFY	100.0	0.0	0.0
1988 IID/MWD Agreement, and Subsequent Agreements, as Modified by the QSA	20.0	20.0	20.0
MWD/CVWD SWP Exchange and Transfer	35.0	0.0	0.0
Miscellaneous and Federal PPRs	(3.0)	(3.0)	(3.0)
Coachella Canal Lining	(26.0)	(26.0)	(26.0)
Subtotal CVWD	**126.0**	**(9.0)**	**(9.0)**
IID			
IID/SCWA Water Conservation and Transfer Agreement	(200.0)	(200.0)	(200.0)
First and Second 50 KAFY	(100.0)	(100.0)[2]	(100.0)
All American Canal Lining	(67.7)	(67.7)	(67.7)
Miscellaneous and Federal PPRs	(11.5)	(11.5)	(11.5)
Subtotal IID	**(379)**	**(379)[2]**	**(379)**
PVID			
PVID/MWD Program [1]	0.0	0.0	(110.0)
Subtotal PVID	**0**	**0**	**(110)**
Total CVWD+IID+PVID	**(253)**	**(388)[2]**	**(498)**

Notes:

1 The transfers between PVID and MWD that are associated with the PVID/MWD Program vary from 100 KAFY to 111 KAFY during the 75-year modeled period.

2 It is assumed that after year 45 (2046), the 2nd 50 is not available to MWD, reducing the total transfer to MWD to 338 KAF; similarly, the total transfer from IID is reduced to 329 KAF in year 2047.

Attachment B
Upper Division Depletion Schedule

Attachment B
Upper Division Depletion Schedule

This attachment consists of a table displaying the schedule of projected Colorado River system depletions, or consumptive use, by the Upper Division. These depletions were used to model the operation of the river system under No Action, Implementation Agreement, Baseline for Cumulative Analysis, and the Cumulative Analysis modeled conditions. Shown in the table are projected depletions of the Upper Division states and Arizona's apportionment of water from the Upper Basin. The depletion schedule was developed by the Upper Basin states and was compiled and provided by the Upper Colorado River Commission in December 1999. This is the depletion schedule that was used to model the various alternatives considered in the Interim Surplus Guideline EIS.

Table B-1
Upper Basin Depletion Schedules

Calendar Year	Colorado	Utah	Wyoming	New Mexico	Arizona	Total Upper Basin W/O Evap.	Reservoir Evaporation	Total Upper Basin
2002	2,419	859	501	449	45	4,273	574	4,847
2003	2,433	873	503	466	45	4,320	574	4,894
2004	2,447	886	505	484	45	4,367	574	4,941
2005	2,494	899	507	501	45	4,446	574	5,020
2006	2,501	913	508	510	45	4,477	574	5,051
2007	2,509	926	510	520	45	4,510	574	5,084
2008	2,517	940	512	529	45	4,543	574	5,117
2009	2,524	953	514	539	45	4,575	574	5,149
2010	2,580	1,009	517	548	50	4,704	574	5,278
2011	2,583	1,013	519	552	50	4,717	574	5,291
2012	2,586	1,017	520	557	50	4,730	574	5,304
2013	2,588	1,020	522	561	50	4,741	574	5,315
2014	2,591	1,024	524	565	50	4,754	574	5,328
2015	2,594	1,028	526	570	50	4,768	574	5,342
2016	2,597	1,032	527	573	50	4,779	574	5,353
2017	2,600	1,036	529	576	50	4,791	574	5,365
2018	2,603	1,041	531	579	50	4,804	574	5,378
2019	2,606	1,045	532	583	50	4,816	574	5,390
2020	2,626	1,055	535	589	50	4,855	574	5,429
2021	2,629	1,062	537	590	50	4,868	574	5,442
2022	2,633	1,069	540	591	50	4,883	574	5,457
2023	2,636	1,077	542	593	50	4,898	574	5,472
2024	2,639	1,084	544	594	50	4,911	574	5,485
2025	2,643	1,091	547	595	50	4,926	574	5,500
2026	2,646	1,099	549	597	50	4,941	574	5,515
2027	2,649	1,107	551	599	50	4,956	574	5,530
2028	2,652	1,114	553	600	50	4,969	574	5,543
2029	2,656	1,122	556	602	50	4,986	574	5,560
2030	2,675	1,129	571	604	50	5,029	574	5,603
2031	2,677	1,134	575	604	50	5,040	574	5,614
2032	2,679	1,139	580	604	50	5,052	574	5,626
2033	2,680	1,145	584	604	50	5,063	574	5,637
2034	2,682	1,150	588	604	50	5,074	574	5,648
2035	2,684	1,155	593	605	50	5,087	574	5,661
2036	2,686	1,160	597	605	50	5,098	574	5,672
2037	2,688	1,165	601	605	50	5,109	574	5,683
2038	2,689	1,171	605	605	50	5,120	574	5,694
2039	2,691	1,176	610	605	50	5,132	574	5,706
2040	2,703	1,177	615	605	50	5,150	574	5,724
2041	2,708	1,180	622	605	50	5,165	574	5,739
2042	2,712	1,184	629	605	50	5,180	574	5,754
2043	2,717	1,187	637	605	50	5,196	574	5,770
2044	2,721	1,190	644	605	50	5,210	574	5,784
2045	2,726	1,194	651	605	50	5,226	574	5,800
2046	2,731	1,197	658	605	50	5,241	574	5,815
2047	2,735	1,200	665	605	50	5,255	574	5,829
2048	2,740	1,203	673	605	50	5,271	574	5,845
2049	2,744	1,207	680	605	50	5,286	574	5,860
2050	2,776	1,207	687	605	50	5,325	574	5,899
2051	2,776	1,209	694	605	50	5,334	574	5,908
2052	2,777	1,212	701	605	50	5,345	574	5,919
2053	2,777	1,214	708	605	50	5,354	574	5,928
2054	2,777	1,216	715	605	50	5,363	574	5,937
2055	2,778	1,219	722	605	50	5,374	574	5,948
2056	2,778	1,221	729	605	50	5,383	574	5,957
2057	2,778	1,223	736	605	50	5,392	574	5,966
2058	2,778	1,225	743	605	50	5,401	574	5,975
2059	2,779	1,228	750	605	50	5,412	574	5,986
2060	2,784	1,230	760	605	50	5,429	574	6,003
2061	2,784	1,230	760	605	50	5,429	574	6,003
2062	2,784	1,230	760	605	50	5,429	574	6,003
2063	2,784	1,230	760	605	50	5,429	574	6,003
2064	2,784	1,230	760	605	50	5,429	574	6,003
2065	2,784	1,230	760	605	50	5,429	574	6,003
2066	2,784	1,230	760	605	50	5,429	574	6,003
2067	2,784	1,230	760	605	50	5,429	574	6,003
2068	2,784	1,230	760	605	50	5,429	574	6,003
2069	2,784	1,230	760	605	50	5,429	574	6,003
2070	2,784	1,230	760	605	50	5,429	574	6,003
2071	2,784	1,230	760	605	50	5,429	574	6,003
2072	2,784	1,230	760	605	50	5,429	574	6,003
2073	2,784	1,230	760	605	50	5,429	574	6,003
2074	2,784	1,230	760	605	50	5,429	574	6,003
2075	2,784	1,230	760	605	50	5,429	574	6,003
2076	2,784	1,230	760	605	50	5,429	574	6,003

Attachment C
Lower Basin Surplus Strategies and Depletion Schedules

Attachment C
Lower Basin Surplus Strategies and Depletion Schedules

As documented in Section 2.0, the following surplus strategies were used for each operational scenario:

- No Action Scenario:
  - Interim Surplus Guidelines, 2002-2016
  - 70R Strategy, 2017-2076
- Implementation Agreement Scenario:
  - Interim Surplus Guidelines, 2002-2016
  - 70R Strategy, 2017-2076
- Baseline for Cumulative Analysis Scenario:
  - 70R Strategy, 2002-2076
- Cumulative Analysis Scenario:
  - Interim Surplus Guidelines, 2002-2016
  - 70R Strategy, 2017-2076

This appendix presents a brief description of each strategy and documents the depletion schedules that were used to model each strategy for the four operational scenarios studied (No Action, Implementation Agreement, Baseline for Cumulative Analysis, and Cumulative Analysis).

INTERIM SURPLUS GUIDELINES

As stated in the Interim Surplus Guidelines Record of Decision (USBR, 2001) determination of Lake Mead surplus operation during the interim period (2002 - 2016) is as follows:

1. Partial Domestic Surplus (Lake Mead elevation between 1125 ft. and 1145 ft.)

   In years when Lake Mead storage is projected to be between elevation 1125 ft. and elevation 1145 ft. on January 1, the Secretary shall determine a Partial Domestic Surplus. The amount of such Surplus shall equal:

   a. For Direct Delivery Domestic Use by MWD, 1.212 maf reduced by:

      (1) the amount of basic apportionment available to MWD and

      (2) the amount of its domestic demand which MWD offsets in such year by offstream groundwater withdrawals or other options. The amount offset under (2) shall not be less than 400,000 af in 2002 and will be reduced by 20,000 af/yr over the Interim Period so as to equal 100,000 af in 2016.

   b. For use by SNWA, one half of the Direct Delivery Domestic Use within the SNWA service area in excess of the State of Nevada's basic apportionment.

   c. For Arizona, one half of the Direct Delivery Domestic Use in excess of the State of Arizona's basic apportionment.

2. Full Domestic Surplus (Lake Mead above Elevation 1145 ft. and below 70R Strategy)

   In years when Lake Mead content is projected to be above elevation 1145 ft., but less than the amount which would initiate a Surplus under B.3. 70R Strategy or B.4. Flood Control Surplus

hereof on January 1, the Secretary shall determine a Full Domestic Surplus. The amount of such Surplus shall equal:

a. For Direct Delivery Domestic Use by MWD, 1.250 maf reduced by the amount of basic apportionment available to MWD.

b. For use by SNWA, the Direct Delivery Domestic Use within the SNWA service area in excess of the State of Nevada's basic apportionment.

c. For use in Arizona, the Direct Delivery Domestic Use in excess of Arizona's basic apportionment.

3. Quantified Surplus

In years when the Secretary determines that water should be released for beneficial consumptive use to reduce the risk of potential reservoir spills based on the 70R Strategy the Secretary shall determine and allocate a Quantified Surplus sequentially as follows:

a. Establish the volume of the Quantified Surplus.

b. Allocate and distribute the Quantified Surplus 50% to California, 46% to Arizona and 4% to Nevada, subject to c. through e. that follow.

c. Distribute California's share first to meet basic apportionment demands and MWD's Direct Delivery Domestic Use and Off-stream Banking demands, and then to California Priorities 6 and 7 and other surplus contracts. Distribute Nevada's share first to meet basic apportionment demands and then to the remaining Direct Delivery Domestic Use and Off-stream Banking demands. Distribute Arizona's share to surplus demands in Arizona including Off-stream Banking and interstate banking demands. Arizona, California and Nevada agree that Nevada would get first priority for interstate banking in Arizona.

d. Distribute any unused share of the Quantified Surplus in accordance with Section 1.0, Allocation of Unused Basic Apportionment Water Under Article II(B)(6).

e. Determine whether MWD, SNWA and Arizona have received the amount of water they would have received under Section 2.B.2., Full Domestic Surplus if a Quantified Surplus had not been declared. If they have not, then determine and meet all demands provided for in Section 2.B.2. Full Domestic Surplus (a), (b) and (c).

4. Flood Control Surplus

In years in which the Secretary makes space-building or flood control releases pursuant to the Field Working Agreement, the Secretary shall determine a Flood Control Surplus for the remainder of that year or the subsequent year as specified in Section 7. In such years, releases will be made to satisfy all beneficial uses within the United States, including unlimited off-stream banking. Under current practice, surplus declarations under the Treaty for Mexico are declared when flood control releases are made. Modeling assumptions used in the FEIS are based on this practice. The proposed action is not intended to identify, or change in any manner, conditions when Mexico may schedule up to an additional 0.2 maf. Any issues relating to the implementation of the Treaty, including any potential changes in approach relating to surplus declarations under the Treaty, must be addressed in a bilateral fashion with the Republic of Mexico.

70R STRATEGY

Under the R surplus strategies, a surplus condition is based on the system space requirement at the beginning of each year. Based on an assumed runoff, Upper and Lower Basin depletion schedules,

and Lake Powell and Lake Mead contents at the beginning of the year, the volume of water in excess of the system space requirement at the end of the year is estimated. If that volume is greater than zero, a surplus is declared and full surplus schedules are met for the year. It should be noted that variations of the R strategies include a "volume limited" surplus, where just the computed surplus volume is distributed to certain Lower Division States' users (i.e., a full surplus is not assumed). This variation is used for the Quantified Surplus level in the Interim Surplus Guidelines.

The assumed runoff corresponds to a particular percentile historical runoff. For example, the 70R strategy assumes a runoff corresponding to the 70th percentile (70% of the historical values are less than that value, or approximately 17.4 maf of natural inflow into Lake Powell).

Based on the original CRSS implementation, the Surplus Volume (SurVol) is computed using the following equation:

$$\text{SurVol} = (\text{PowellStorage} + \text{MeadStorage} - \text{maxStorage}) \times (1.0 + \text{aveBankStorCoeff}) + \text{runoff} - \text{Ubdemand} - \text{Lbdemand}$$

Where:

PowellStorage =	Lake Powell content at the beginning of the year
MeadStorage =	Lake Mead content at the beginning of the year
maxStorage =	Maximum combined storage at Lakes Powell and Mead that will meet the system space requirement at the beginning of the year, assuming 30% of that requirement will be met by the reservoirs upstream of Powell (live capacity of Lakes Powell and Mead - 0.7 x 5.35 maf = 47.96 maf)
aveBankStorageCoeff =	Average of Lake Powell and Lake Mead bank storage coefficients
Runoff =	assumed percentile runoff
Ubdemand =	Upper Basin depletion scheduled for the year + the average evaporation loss in the Upper Basin (same as assumed in equalization, 560 kaf)
Lbdemand =	sum of the depletions below Powell + the evaporation losses in the Lower Basin mainstream reservoirs (average loss of 900 kaf at Mead and computed for Lakes Mohave and Havasu, based on the target storage) – average gains between Powell and Mead (801 kaf) – average gains below Mead (427 kaf)

SURPLUS SCHEDULES COMMON TO ALL SCENARIOS

For all scenarios, a "flood control" surplus is declared when Lake Mead releases water in excess of normal downstream demand under the Army Corps of Engineers flood control procedures. All scenarios utilize this strategy for the entire length of the run. As previously noted, for time periods not utilizing the Interim Surplus Guidelines (i.e., the period 2017-2076 for the No Action, Implementation Agreement, and Cumulative Analysis scenarios, as well as the period 2002-2076 for the Baseline for Cumulative Analysis scenario) the 70R Strategy is used. It was assumed that the 70R Strategy would trigger a "full" surplus for these periods, allowing the same amount of water to be delivered as under Flood Control surplus. Table C-1 presents the surplus schedules utilized for Flood Control and Full surplus declarations. Schedules of other entities that do not receive surplus water have been included to yield the total Lower Basin depletion.

Table C-1
Flood Control Surplus and Full Surplus Schedules, (kaf)

Date	MWD	IID	CVWD	PVID	CA Other	CA Total	AZ Other	CAP	AZ Total	NV Other	SNWP	NV Total	Total L.B.
2002	1,250	3,208	585	383	61	5,487	1,332	1,658	2,990	26	312	338	8,815
2003	1,250	3,188	585	381	64	5,468	1,337	1,647	2,984	26	314	340	8,792
2004	1,250	3,152	585	380	66	5,433	1,342	1,582	2,924	27	316	343	8,700
2005	1,250	3,132	585	379	68	5,414	1,348	1,615	2,963	28	316	344	8,721
2006	1,250	3,061	585	378	71	5,345	1,353	1,652	3,005	28	321	349	8,699
2007	1,250	3,036	585	377	74	5,322	1,359	1,680	3,039	28	326	354	8,715
2008	1,250	3,011	585	375	79	5,300	1,364	1,715	3,079	29	330	359	8,738
2009	1,250	2,986	585	374	82	5,277	1,369	1,750	3,119	29	334	363	8,759
2010	1,250	2,961	585	373	86	5,255	1,375	1,787	3,162	29	338	367	8,784
2011	1,250	2,936	585	372	91	5,234	1,375	1,812	3,187	29	342	371	8,792
2012	1,250	2,931	585	370	98	5,234	1,376	1,835	3,211	29	345	374	8,819
2013	1,250	2,926	585	369	103	5,233	1,376	1,835	3,211	29	349	378	8,822
2014	1,250	2,921	585	367	110	5,233	1,377	1,835	3,212	29	353	382	8,827
2015	1,250	2,916	585	366	116	5,233	1,378	1,835	3,213	29	357	386	8,832
2016	1,250	2,911	585	366	116	5,228	1,378	1,835	3,213	29	361	390	8,831
2017	1,250	2,906	585	366	116	5,223	1,379	1,835	3,214	29	365	394	8,831
2018	1,250	2,901	585	366	116	5,218	1,380	1,835	3,215	29	369	398	8,831
2019	1,250	2,896	585	366	116	5,213	1,380	1,835	3,215	29	373	402	8,830
2020	1,250	2,891	585	366	116	5,208	1,381	1,835	3,216	29	378	407	8,831
2021	1,250	2,886	585	366	116	5,203	1,382	1,835	3,217	29	382	411	8,831
2022	1,250	2,881	585	366	116	5,198	1,383	1,835	3,218	29	387	416	8,832
2023	1,250	2,876	585	366	116	5,193	1,385	1,835	3,220	29	391	420	8,833
2024	1,250	2,871	585	366	116	5,188	1,386	1,835	3,221	29	395	424	8,833
2025	1,250	2,866	585	366	116	5,183	1,388	1,835	3,223	29	400	429	8,835
2026	1,250	2,861	585	366	116	5,178	1,389	1,835	3,224	21	404	425	8,827
2027	1,250	2,861	585	366	116	5,178	1,390	1,835	3,225	13	408	421	8,824
2028	1,250	2,861	585	366	116	5,178	1,392	1,835	3,227	13	412	425	8,830
2029	1,250	2,861	585	366	116	5,178	1,393	1,835	3,228	13	415	428	8,834
2030	1,250	2,861	585	366	116	5,178	1,394	1,835	3,229	13	418	431	8,838
2031	1,250	2,861	585	366	116	5,178	1,395	1,835	3,230	13	423	436	8,844
2032	1,250	2,861	585	366	116	5,178	1,396	1,835	3,231	13	427	440	8,849
2033	1,250	2,861	585	366	116	5,178	1,397	1,835	3,232	13	431	444	8,854
2034	1,250	2,861	585	366	116	5,178	1,398	1,835	3,233	13	435	448	8,859
2035	1,250	2,861	585	366	116	5,178	1,398	1,835	3,233	13	439	452	8,863
2036	1,250	2,861	585	366	116	5,178	1,399	1,835	3,234	13	443	456	8,868
2037	1,250	2,861	585	366	116	5,178	1,400	1,835	3,235	13	448	461	8,874
2038	1,250	2,861	585	366	116	5,178	1,401	1,835	3,236	13	452	465	8,879
2039	1,250	2,861	585	366	116	5,178	1,402	1,835	3,237	13	456	469	8,884
2040	1,250	2,861	585	366	116	5,178	1,402	1,835	3,237	13	460	473	8,888
2041	1,250	2,861	585	366	116	5,178	1,403	1,835	3,238	13	464	477	8,893
2042	1,250	2,861	585	366	116	5,178	1,403	1,835	3,238	13	468	481	8,897
2043	1,250	2,861	585	366	116	5,178	1,403	1,835	3,238	13	472	485	8,901
2044	1,250	2,861	585	366	116	5,178	1,404	1,835	3,239	13	476	489	8,906
2045	1,250	2,861	585	366	116	5,178	1,404	1,835	3,239	13	480	493	8,910
2046	1,250	2,911	585	366	116	5,228	1,404	1,835	3,239	13	485	498	8,965
2047	1,250	2,911	585	366	116	5,228	1,404	1,835	3,239	13	489	502	8,969
2048	1,250	2,911	585	366	116	5,228	1,405	1,835	3,240	13	493	506	8,974
2049	1,250	2,911	585	366	116	5,228	1,405	1,835	3,240	13	497	510	8,978
2050	1,250	2,911	585	366	116	5,228	1,405	1,835	3,240	13	501	514	8,982
2051	1,250	2,911	585	366	116	5,228	1,405	1,835	3,240	13	501	514	8,982
2052	1,250	2,911	585	366	116	5,228	1,405	1,835	3,240	13	501	514	8,982
2053	1,250	2,911	585	366	116	5,228	1,405	1,835	3,240	13	501	514	8,982
2054	1,250	2,911	585	366	116	5,228	1,405	1,835	3,240	13	501	514	8,982
2055	1,250	2,911	585	366	116	5,228	1,405	1,835	3,240	13	501	514	8,982
2056	1,250	2,911	585	366	116	5,228	1,405	1,835	3,240	13	501	514	8,982
2057	1,250	2,911	585	366	116	5,228	1,405	1,835	3,240	13	501	514	8,982
2058	1,250	2,911	585	366	116	5,228	1,405	1,835	3,240	13	501	514	8,982
2059	1,250	2,911	585	366	116	5,228	1,405	1,835	3,240	13	501	514	8,982
2060	1,250	2,911	585	366	116	5,228	1,405	1,835	3,240	13	501	514	8,982
2061	1,250	2,911	585	366	116	5,228	1,405	1,835	3,240	13	501	514	8,982
2062	1,250	2,911	585	366	116	5,228	1,405	1,835	3,240	13	501	514	8,982
2063	1,250	2,911	585	366	116	5,228	1,405	1,835	3,240	13	501	514	8,982
2064	1,250	2,911	585	366	116	5,228	1,405	1,835	3,240	13	501	514	8,982
2065	1,250	2,911	585	366	116	5,228	1,405	1,835	3,240	13	501	514	8,982
2066	1,250	2,911	585	366	116	5,228	1,405	1,835	3,240	13	501	514	8,982
2067	1,250	2,911	585	366	116	5,228	1,405	1,835	3,240	13	501	514	8,982
2068	1,250	2,911	585	366	116	5,228	1,405	1,835	3,240	13	501	514	8,982
2069	1,250	2,911	585	366	116	5,228	1,405	1,835	3,240	13	501	514	8,982
2070	1,250	2,911	585	366	116	5,228	1,405	1,835	3,240	13	501	514	8,982
2071	1,250	2,911	585	366	116	5,228	1,405	1,835	3,240	13	501	514	8,982
2072	1,250	2,911	585	366	116	5,228	1,405	1,835	3,240	13	501	514	8,982
2073	1,250	2,911	585	366	116	5,228	1,405	1,835	3,240	13	501	514	8,982
2074	1,250	2,911	585	366	116	5,228	1,405	1,835	3,240	13	501	514	8,982
2075	1,250	2,911	585	366	116	5,228	1,405	1,835	3,240	13	501	514	8,982
2076	1,250	2,911	585	366	116	5,228	1,405	1,835	3,240	13	501	514	8,982

For scenarios utilizing the Interim Surplus Guidelines (i.e., the No Action, Implementation Agreement, and Cumulative Analysis scenarios), a common schedule was used for the Quantified Surplus level. This schedule is presented in Table C-2.

Table C-2
Quantified Surplus Schedules, (kaf)

Date	MWD	IID	CVWD	PVID	CA Other	CA Total	AZ Other	CAP	AZ Total	NV Other	SNWP	NV Total	Total L.B.
2002	1,250	3,130	489	383	61	5,313	1,332	1,658	2,990	26	312	338	8,641
2003	1,250	3,110	483	381	63	5,287	1,337	1,647	2,984	26	314	340	8,611
2004	1,250	3,073	478	380	65	5,246	1,342	1,582	2,924	27	316	343	8,513
2005	1,250	3,053	485	379	68	5,235	1,348	1,615	2,963	28	316	344	8,542
2006	1,250	2,982	485	378	71	5,166	1,353	1,652	3,005	28	321	349	8,520
2007	1,250	2,957	490	377	75	5,149	1,359	1,680	3,039	28	326	354	8,542
2008	1,250	2,932	495	375	78	5,130	1,364	1,715	3,079	29	330	359	8,568
2009	1,250	2,907	500	374	82	5,113	1,369	1,750	3,119	29	334	363	8,595
2010	1,250	2,882	505	373	86	5,096	1,375	1,787	3,162	29	338	367	8,625
2011	1,250	2,857	510	372	92	5,081	1,375	1,812	3,187	29	342	371	8,639
2012	1,250	2,852	515	370	98	5,085	1,376	1,835	3,211	29	345	374	8,670
2013	1,250	2,847	520	369	104	5,090	1,376	1,835	3,211	29	349	378	8,679
2014	1,250	2,842	525	367	110	5,094	1,377	1,835	3,212	29	353	382	8,688
2015	1,250	2,837	530	366	116	5,099	1,378	1,835	3,213	29	357	386	8,698
2016	1,250	2,832	535	366	116	5,099	1,378	1,835	3,213	29	361	390	8,702

PARTIAL AND FULL DOMESTIC SURPLUS SCHEDULES FOR NO ACTION

For the No Action scenario, the Interim Surplus Guidelines were in effect from 2002 through 2016 and no water transfers were assumed among the California entities. Tables C-3 and C-4 present the Partial Domestic and Full Domestic surplus schedules respectively for the No Action Scenario. Schedules of other entities that do not receive surplus water have been included to yield the total Lower Basin depletion for each surplus declaration.

Table C-3
Partial Domestic Surplus Schedules Under No Action, (kaf)

Date	MWD	IID	CVWD	PVID	CA Other	CA Total	AZ Other	CAP	AZ Total	NV Other	SNWP	NV Total	Total L.B.
2002	832	2,990	330	383	61	4,596	1,332	1,458	2,790	26	278	304	7,690
2003	852	2,990	330	381	63	4,616	1,337	1,447	2,784	26	278	304	7,704
2004	839	2,990	330	380	65	4,604	1,342	1,382	2,724	27	295	322	7,650
2005	825	2,990	330	379	68	4,592	1,348	1,415	2,763	28	283	311	7,666
2006	812	2,990	330	378	71	4,581	1,353	1,447	2,800	28	273	301	7,682
2007	795	2,990	330	377	75	4,567	1,359	1,441	2,800	28	274	302	7,669
2008	779	2,990	330	375	78	4,552	1,364	1,436	2,800	29	275	304	7,656
2009	762	2,990	330	374	82	4,538	1,369	1,431	2,800	29	277	306	7,644
2010	762	2,990	330	373	86	4,541	1,375	1,425	2,800	29	279	308	7,649
2011	762	2,990	330	372	92	4,546	1,375	1,425	2,800	29	281	310	7,656
2012	762	2,990	330	370	98	4,550	1,376	1,424	2,800	29	283	312	7,662
2013	782	2,990	330	369	104	4,575	1,376	1,424	2,800	29	285	314	7,689
2014	802	2,990	330	367	110	4,599	1,377	1,423	2,800	29	287	316	7,715
2015	822	2,990	330	366	116	4,624	1,378	1,422	2,800	29	287	316	7,740
2016	842	2,990	330	366	116	4,644	1,378	1,422	2,800	29	289	318	7,762

Table C-4
Full Domestic Surplus Schedules Under No Action, (kaf)

Date	MWD	IID	CVWD	PVID	CA Other	CA Total	AZ Other	CAP	AZ Total	NV Other	SNWP	NV Total	Total L.B.
2002	1,250	2,990	330	383	61	5,014	1,332	1,458	2,790	26	278	304	8,108
2003	1,250	2,990	330	381	63	5,014	1,337	1,447	2,784	26	278	304	8,102
2004	1,217	2,990	330	380	65	4,982	1,342	1,382	2,724	27	295	322	8,028
2005	1,183	2,990	330	379	68	4,950	1,348	1,415	2,763	28	283	311	8,024
2006	1,150	2,990	330	378	71	4,919	1,353	1,447	2,800	28	273	301	8,020
2007	1,113	2,990	330	377	75	4,885	1,359	1,441	2,800	28	275	303	7,988
2008	1,077	2,990	330	375	78	4,850	1,364	1,436	2,800	29	279	308	7,958
2009	1,040	2,990	330	374	82	4,816	1,369	1,431	2,800	29	283	312	7,928
2010	1,020	2,990	330	373	86	4,799	1,375	1,425	2,800	29	287	316	7,915
2011	1,000	2,990	330	372	92	4,784	1,375	1,425	2,800	29	291	320	7,904
2012	980	2,990	330	370	98	4,768	1,376	1,424	2,800	29	295	324	7,892
2013	980	2,990	330	369	104	4,773	1,376	1,424	2,800	29	299	328	7,901
2014	980	2,990	330	367	110	4,777	1,377	1,423	2,800	29	302	331	7,908
2015	980	2,990	330	366	116	4,782	1,378	1,422	2,800	29	303	332	7,914
2016	980	2,990	330	366	116	4,782	1,378	1,422	2,800	29	307	336	7,918

A further explanation of the Partial and Full Domestic schedules for MWD under the No Action scenario is warranted. In the Interim Surplus Guidelines Record of Decision, benchmark quantities for agricultural use of Colorado River water in California were specified as shown in Table C-5.

Table C-5
Interim Surplus Guidelines Benchmarks for
Quantity of California Agricultural Use of Colorado River Water, (kaf)

Year	Benchmark Quantity	Required Reduction (from 3,850)
2003	3,740	110
2006	3,640	210
2009	3,530	320
2012	3,470	380

Since these benchmarks would not be met through water transfers under the No Action scenario, it was assumed that MWD would reduce its use to permit the benchmarks to be met and therefore keep the Interim Surplus Guidelines in effect. The first benchmark (110 kaf in 2003) was assumed to be met by the 1988/89 Agreements among IID, MWD, and CVWD. Further reductions necessary to meet the benchmarks were imposed linearly over time. It was also assumed that no reductions were necessary for the higher levels of surplus (Quantified and Flood Control). Table C-6 presents a comparison of the affected surplus schedules for MWD.

Table C-6
Comparison of MWD Surplus Schedules
With and Without Benchmark Reductions (kaf)

Year	Partial Domestic Surplus		Full Domestic Surplus	
	With	Without	With	Without
2002	832	832	1,250	1,250
2003	852	852	1,250	1,250
2004	839	872	1,217	1,250
2005	825	892	1,183	1,250
2006	812	912	1,150	1,250
2007	795	932	1,113	1,250
2008	779	952	1,077	1,250
2009	762	972	1,040	1,250
2010	762	992	1,020	1,250
2011	762	1,012	1,000	1,250
2012	762	1,032	980	1,250
2013	782	1,052	980	1,250
2014	802	1,072	980	1,250
2015	822	1,092	980	1,250
2016	842	1,112	980	1,250

PARTIAL AND FULL DOMESTIC SURPLUS SCHEDULES FOR IMPLEMENTATION AGREEMENT

For the Implementation Agreement scenario, the Interim Surplus Guidelines were in effect from 2002 through 2016 and water transfers as detailed in Attachment A were assumed among the California entities. Tables C-7 and C-8 present the Partial Domestic and Full Domestic surplus schedules respectively for the Implementation Agreement scenario. Schedules of other entities that do not receive surplus water have been included to yield the total Lower Basin depletion for each surplus declaration. A column has been added to show the difference (due to the water transfers) between the Implementation Agreement and No Action scenarios. This difference is the basis for the slight increases in lake elevations observed under the Implementation Agreement as noted in Section 3.1.

Table C-7
Partial Domestic Surplus Schedules for Implementation Agreement, (kaf)

Date	MWD	IID	CVWD	PVID	CA Other	CA Total	AZ Other	CAP	AZ Total	NV Other	SNWP	NV Total	Total LB	Difference from Baseline [1]
2002	832	2,959	326	383	61	4,561	1,332	1,458	2,790	26	278	304	7,655	-35
2003	852	2,939	335	381	63	4,570	1,337	1,447	2,784	26	278	304	7,658	-46
2004	872	2,919	321	380	65	4,557	1,342	1,382	2,724	27	295	322	7,603	-47
2005	892	2,877	321	379	68	4,537	1,348	1,415	2,763	28	283	311	7,611	-55
2006	912	2,852	321	378	71	4,534	1,353	1,447	2,800	28	273	301	7,635	-47
2007	932	2,781	321	377	75	4,486	1,359	1,441	2,800	28	274	302	7,588	-81
2008	952	2,761	321	375	78	4,487	1,364	1,436	2,800	29	275	304	7,591	-65
2009	972	2,736	321	374	82	4,485	1,369	1,431	2,800	29	277	306	7,591	-53
2010	992	2,711	321	373	86	4,483	1,375	1,425	2,800	29	279	308	7,591	-58
2011	1,012	2,686	321	372	92	4,483	1,375	1,425	2,800	29	281	310	7,593	-63
2012	1,032	2,681	321	370	98	4,502	1,376	1,424	2,800	29	283	312	7,614	-48
2013	1,052	2,676	321	369	104	4,522	1,376	1,424	2,800	29	285	314	7,636	-53
2014	1,072	2,671	321	367	110	4,541	1,377	1,423	2,800	29	287	316	7,657	-58
2015	1,092	2,666	321	366	116	4,561	1,378	1,422	2,800	29	287	316	7,677	-63
2016	1,112	2,661	321	366	116	4,576	1,378	1,422	2,800	29	289	318	7,694	-68

Notes:
1. The numbers shown in the column entitled "Difference from Baseline" reflect the differences in Total Lower Basin Depletions between the schedules used in the No Action alternative (Table C-3) and this schedule (Implementation Agreement) for each respective year.

Table C-8
Full Domestic Surplus Schedules for Implementation Agreement, (kaf)

Date	MWD	IID	CVWD	PVID	CA Other	CA Total	AZ Other	CAP	AZ Total	NV Other	SNWP	NV Total	Total L.B.	Difference from Baseline [1]
2002	1,250	2,959	326	383	61	4,979	1,332	1,458	2,790	26	278	304	8,073	-35
2003	1,250	2,939	335	381	63	4,968	1,337	1,447	2,784	26	278	304	8,056	-46
2004	1,250	2,919	321	380	65	4,935	1,342	1,382	2,724	27	295	322	7,981	-47
2005	1,250	2,877	321	379	68	4,895	1,348	1,415	2,763	28	283	311	7,969	-55
2006	1,250	2,852	321	378	71	4,872	1,353	1,447	2,800	28	273	301	7,973	-47
2007	1,250	2,781	321	377	75	4,804	1,359	1,441	2,800	28	275	303	7,907	-81
2008	1,250	2,761	321	375	78	4,785	1,364	1,436	2,800	29	279	308	7,893	-65
2009	1,250	2,736	321	374	82	4,763	1,369	1,431	2,800	29	283	312	7,875	-53
2010	1,250	2,711	321	373	86	4,741	1,375	1,425	2,800	29	287	316	7,857	-58
2011	1,250	2,686	321	372	92	4,721	1,375	1,425	2,800	29	291	320	7,841	-63
2012	1,250	2,681	321	370	98	4,720	1,376	1,424	2,800	29	295	324	7,844	-48
2013	1,250	2,676	321	369	104	4,720	1,376	1,424	2,800	29	299	328	7,848	-53
2014	1,250	2,671	321	367	110	4,719	1,377	1,423	2,800	29	302	331	7,850	-58
2015	1,250	2,666	321	366	116	4,719	1,378	1,422	2,800	29	303	332	7,851	-63
2016	1,250	2,661	321	366	116	4,714	1,378	1,422	2,800	29	307	336	7,850	-68

Notes:
1. The numbers shown in the column entitled "Difference from Baseline" reflect the differences in Total Lower Basin Depletions between the schedules used in the No Action alternative (Table C-4) and this schedule (Implementation Agreement) for each respective year.

PARTIAL AND FULL DOMESTIC SURPLUS SCHEDULES FOR CUMULATIVE ANALYSIS

For the Cumulative Analysis scenario, the Interim Surplus Guidelines were in effect from 2002 through 2016 and water transfers as detailed in Attachment A were assumed among the California entities. Tables C-9 and C-10 present the Partial Domestic and Full Domestic surplus schedules respectively for the Cumulative Analysis scenario. Schedules of other entities that do not receive surplus water have been included to yield the total Lower Basin depletion for each surplus declaration.

Table C-9
Partial Domestic Surplus Schedules for Cumulative Analysis, (kaf)

Date	MWD	IID	CVWD	PVID	CA Other	CA Total	AZ Other	CAP	AZ Total	NV Other	SNWP	NV Total	Total L.B.
2002	832	2,959	326	351	61	4,529	1,332	1,458	2,790	26	278	304	7,623
2003	852	2,939	335	281	63	4,470	1,337	1,447	2,784	26	278	304	7,558
2004	872	2,919	321	280	65	4,457	1,342	1,382	2,724	27	295	322	7,503
2005	892	2,877	321	279	68	4,437	1,348	1,415	2,763	28	283	311	7,511
2006	912	2,852	321	278	71	4,434	1,353	1,447	2,800	28	273	301	7,535
2007	932	2,781	321	277	75	4,386	1,359	1,441	2,800	28	274	302	7,488
2008	952	2,761	321	275	78	4,387	1,364	1,436	2,800	29	275	304	7,491
2009	972	2,736	321	274	82	4,385	1,369	1,431	2,800	29	277	306	7,491
2010	992	2,711	321	273	86	4,383	1,375	1,425	2,800	29	279	308	7,491
2011	1,012	2,686	321	272	92	4,383	1,375	1,425	2,800	29	281	310	7,493
2012	1,032	2,681	321	270	98	4,402	1,376	1,424	2,800	29	283	312	7,514
2013	1,052	2,676	321	269	104	4,422	1,376	1,424	2,800	29	285	314	7,536
2014	1,072	2,671	321	267	110	4,441	1,377	1,423	2,800	29	287	316	7,557
2015	1,092	2,666	321	266	116	4,461	1,378	1,422	2,800	29	287	316	7,577
2016	1,112	2,661	321	266	116	4,476	1,378	1,422	2,800	29	289	318	7,594

Table C-10
Full Domestic Surplus Schedules for Cumulative Analysis, (kaf)

Date	MWD	IID	CVWD	PVID	CA Other	CA Total	AZ Other	CAP	AZ Total	NV Other	SNWP	NV Total	Total L.B.
2002	1,250	2,959	326	358	61	4,954	1,332	1,458	2,790	26	278	304	8,048
2003	1,250	2,939	335	356	63	4,943	1,337	1,447	2,784	26	278	304	8,031
2004	1,250	2,919	321	355	65	4,910	1,342	1,382	2,724	27	295	322	7,956
2005	1,250	2,877	321	354	68	4,870	1,348	1,415	2,763	28	283	311	7,944
2006	1,250	2,852	321	353	71	4,847	1,353	1,447	2,800	28	273	301	7,948
2007	1,250	2,781	321	352	75	4,779	1,359	1,441	2,800	28	275	303	7,882
2008	1,250	2,761	321	350	78	4,760	1,364	1,436	2,800	29	279	308	7,868
2009	1,250	2,736	321	349	82	4,738	1,369	1,431	2,800	29	283	312	7,850
2010	1,250	2,711	321	348	86	4,716	1,375	1,425	2,800	29	287	316	7,832
2011	1,250	2,686	321	347	92	4,696	1,375	1,425	2,800	29	291	320	7,816
2012	1,250	2,681	321	345	98	4,695	1,376	1,424	2,800	29	295	324	7,819
2013	1,250	2,676	321	344	104	4,695	1,376	1,424	2,800	29	299	328	7,823
2014	1,250	2,671	321	342	110	4,694	1,377	1,423	2,800	29	302	331	7,825
2015	1,250	2,666	321	341	116	4,694	1,378	1,422	2,800	29	303	332	7,826
2016	1,250	2,661	321	341	116	4,689	1,378	1,422	2,800	29	307	336	7,825

Attachment D
Sensitivity Analysis of Shortage Protection Assumptions

Attachment D
Sensitivity Analysis of Shortage Protection Assumptions

Overview

This attachment to the Technical Memorandum presents the results of a sensitivity analysis conducted to assess the effects of using different Lake Mead shortage protection criteria in the modeling of the Implementation Agreement and the Cumulative Assessment Conditions. As discussed in Section 2.4 of the Technical Memorandum, it was assumed that the Lake Mead water surface elevation of 1083 feet msl would be protected with a certain degree of confidence (approximately 80 percent of the time). Also, separate modeling studies were used to determine a "protection line" or trigger such that if Lake Mead's water surface elevation falls below the specified protection line, a Level 1 shortage is declared. A representation of the modeled 1083 feet msl protection line is shown on Figure D-1. It should be noted that while an 80 percent level of confidence was desired, with respect to the protection of this Lake Mead water surface elevation, the actual assurance achieved was less than this amount. The actual assurance achieved is approximately 100 percent during the initial nine years. Thereafter, the assurance level decreases over time with the minimum assurance achieved being approximately 57 percent. As shown on Figure 3.2-9 of this Technical Memorandum, the assurance level drops below 80% in 2021.

The lower level of confidence achieved after 2021 can be attributed to the independently produced shortage protection line values and their integration with the index sequential method used in the RiverWare model simulation of the Colorado River system operation. However, while a lower level of confidence was achieved, the validity of the comparisons between the modeled operation scenarios is not compromised since all of the modeled conditions use the same shortage protection assumptions.

For the sensitivity analysis, the modeling assumptions included a lower protection line than was used for the analysis in the Technical Memorandum (one that was intended to protect Lake Mead water surface elevation of 1050 feet msl approximately 80% of the time). The lower protection line (i.e., the shortage protection triggers) used for this purpose is also presented graphically in Figure D-1. The actual assurance levels achieved with respect to the protection of the Lake Mead water level of 1050 foot msl were similar to those observed under the 1083 foot msl water level protection criteria. The actual assurance achieved under the 1050 foot msl water level protection criteria is approximately 100 percent during the initial nine years. Thereafter, the assurance level decreases over time with the minimum assurance achieved being approximately 55 percent.

The sensitivity analysis evaluates the effect that a change in shortage protection assumptions would have on the modeling results for the Implementation Agreement Conditions and the Cumulative Assessment Conditions. The effect is expressed as differences in Lake Powell and Lake Mead water surface levels observed under the two different modeled Lake Mead shortage protection criteria (1050 feet msl and 1083 feet msl Lake Mead protection lines). In general, the 1050 foot msl Lake Mead water level protection criteria resulted in lower Lake Mead water levels under the Implementation Agreement Conditions and the

Cumulative Assessment Conditions. At Lake Powell, the use of the 1050-foot msl protection line for Lake Mead produced little to no difference in water levels compared to the use of the 1083-foot protection line.

Lake Mead Water Surface Elevations

Comparisons of Lake Mead water surface elevations were made for the Implementation Agreement Conditions and for the Cumulative Analysis Conditions. The results of these two comparisons are presented on Figures D-2 and D-3, respectively.

Figure D-2 compares the Lake Mead water surface elevations observed under the modeled Implementation Agreement Condition that uses the1050-feet msl protection line to those under Implementation Agreement Condition that uses the1083-feet msl protection line. Specifically, the 90th, 50th and 10th percentile values of the observed Lake Mead water surface elevations from these two-modeled conditions are compared to each other. This figure may be compared to Figure 3.2-7 in the Technical Memorandum, which also presents Lake Mead water surface elevations under Implementation Agreement Conditions based on the 1083-foot protection level.

Figure D-2 shows that the 90th percentile values are essentially the same under the 1050-foot and 1083-foot modeled shortage protection conditions. The observed 50th percentile values (median values) under the 1050-foot protection conditions are also essentially the same as those observed under the 1083-foot protection conditions until 2016. Thereafter, the median elevations under the 1050-foot protection conditions fall below and remain at a lower level than those observed under the 1083-foot shortage protection conditions. The maximum departure between the two sets of median elevations is approximately 14.33 feet. The 10th percentile values observed under the 1050-foot protection conditions are the same as those observed under the 1083-foot protection conditions until 2009. Thereafter, the 10th percentile values observed under the 1050-foot protection conditions fall below and remain at a lower level than those observed under the 1083-foot shortage protection conditions. Table D-1 lists the observed maximum, minimum and average departures of the observed 90th, 50th and 10th percentile values of the 1050-foot shortage protection modeling results from those of the 1083-foot shortage protection conditions.

Table D-1
Lake Mead Water Surface Elevations
90th, 50th and 10th Percentile Values for Implementation Agreement Conditions
Departure of 1050-foot from 1083-foot Shortage Protection Modeled Conditions

	Departures (75-year Period)		
	90th Percentile Values	50th Percentile Values	10th Percentile Values
Maximum Departure	3.24	14.33	14.47
Minimum Departure	-3.65	0.00	0.00
Average Departure	0.32	5.39	4.15

Figure D-3 compares the Lake Mead water surface elevations observed under modeled Cumulative Analysis Condition that uses the1050-feet msl protection line to those under Cumulative Analysis Condition that uses the1083-feet msl protection line. Specifically, the 90th, 50th and 10th percentile values of the observed Lake Mead water surface elevations from these two-modeled conditions are compared to each other. This figure may be compared to Figure 3.3-7 in the Technical

Memorandum, which also presents Lake Mead water surface elevations under Cumulative Analysis Conditions based on the 1083-foot protection level.

Figure D-3 shows that the 90th percentile values are essentially the same under the 1050-foot and 1083-foot modeled shortage protection condition. The observed median values under the 1050-foot protection conditions are essentially the same as those observed under the 1083-foot protection condition until 2016. Thereafter, the median elevations under the 1050-foot protection condition fall and remain at a lower level than those observed under the 1083-foot shortage protection condition. The maximum departure between the two sets of median elevations is approximately 15.49 feet. The 10th percentile values observed under the 1050-foot protection conditions are also essentially the same as those observed under the 1083-foot protection condition until 2011. Thereafter, the 10th percentile elevations under the 1050-foot protection condition fall and remain at a lower level than those observed under the 1083-foot shortage protection condition. Table D-2 lists the observed maximum, minimum and average departures of the observed 90th, 50th and 10th percentile values of the 1050-foot shortage protection modeling results from those of the 1083-foot shortage protection conditions.

Table D-2
Lake Mead Water Surface Elevations
90th, 50th and 10th Percentile Values for Cumulative Analysis Conditions
Departure of 1050-foot from 1083-foot Shortage Protection Modeled Conditions

	Departures (75-year Period)		
	90th Percentile Values	50th Percentile Values	10th Percentile Values
Maximum Departure	2.95	15.49	14.01
Minimum Departure	-3.91	0.00	0.00
Average Departure	0.30	5.40	4.24

The lower Lake Mead levels observed under the 1050-foot protection condition can be attributed to a more liberal availability of surplus water, allowing Lake Mead to be drawn down lower before the shortage triggers takes effect and further water delivery reductions begin.

Lake Powell Water Surface Elevations

Comparisons of Lake Powell water surface elevations were made for the Implementation Agreement Conditions and for the Cumulative Analysis Conditions. The results of these two comparisons are presented on Figures D-4 and D-5, respectively.

Figure D-4 compares the Lake Powell water surface elevations observed under the modeled Implementation Agreement Condition that uses the 1050-foot msl protection line to those under Implementation Agreement Condition that uses the 1083-foot msl protection line. Specifically, the 90th, 50th and 10th percentile values of the observed Lake Powell water surface elevations from these two-modeled conditions are compared to each other. It should be noted that the shortage protection criteria (triggers) are applied to the Lake Mead operations in the model. As such, any effect that this criterion would have on Lake Powell water levels would result from equalization.

Figure D-4 shows that the 90th, 50th and 10th percentile values are essentially the same under the 1050-foot and 1083-foot modeled shortage protection conditions. Table D-3 lists the observed maximum, minimum and average departures of the observed 90th, 50th and 10th percentile values of

1050-foot shortage protection modeling results from those of the 1083-foot shortage protection conditions.

Table D3
Lake Powell Water Surface Elevations
90th, 50th and 10th Percentile Values for Implementation Agreement Conditions
Departure of 1050-foot from 1083-foot Shortage Protection Modeled Conditions

	Departures (75-year Period)		
	90th Percentile Values	**50th Percentile Values**	**10th Percentile Values**
Maximum Departure	0.56	0.85	0.00
Minimum Departure	0.00	0.00	0.00
Average Departure	0.01	0.01	0.00

Figure D-5 compares the Lake Powell water surface elevations observed under the modeled Cumulative Analysis Condition that uses the 1050-foot msl protection line to those under the Cumulative Analysis that uses the 1083-foot msl protection line. Figure D-5 shows that the 90th, 50th and 10th percentile values are essentially the same under the 1050-foot and 1083-foot modeled shortage protection conditions. Table D-4 lists the observed maximum, minimum and average departures of the observed 90th, 50th and 10th percentile values of 1050-foot shortage protection modeling results from those of the 1083-foot shortage protection conditions.

Table D-4
Lake Powell Water Surface Elevations
90th, 50th and 10th Percentile Values for Cumulative Analysis Conditions
Departure of 1050-foot from 1083-foot Shortage Protection Modeled Conditions

	Departures (75-year Period)		
	90th Percentile Values	**50th Percentile Values**	**10th Percentile Values**
Maximum Departure	0.38	0.69	0.00
Minimum Departure	0.00	0.00	0.00
Average Departure	0.01	0.01	0.00

Table D-5 lists the figures that were referenced above and that that are enclosed in the back of this attachment.

Table D-5
List of Figures

D-1	Lake Mead Level 1 Shortage Triggers
D-2	Lake Mead End-of-December Water Elevations Comparison of Shortage Assumptions for Implementation Agreement Conditions 90th, 50th, and 10th Percentile
D-3	Lake Mead End-of-December Water Elevations Comparison of Shortage Assumptions for Cumulative Assessment Conditions 90th, 50th, and 10th Percentile Values
D-4	Lake Powell End-of-July Water Elevations Comparison of Shortage Assumptions for Implementation Agreement Conditions 90th, 50th, and 10th Percentile Values
D-5	Lake Powell End-of-July Water Elevations Comparison of Shortage Assumptions for Cumulative Assessment Conditions 90th, 50th, and 10th Percentile Values

Figure D-1
Lake Mead Level 1 Shortage Triggers

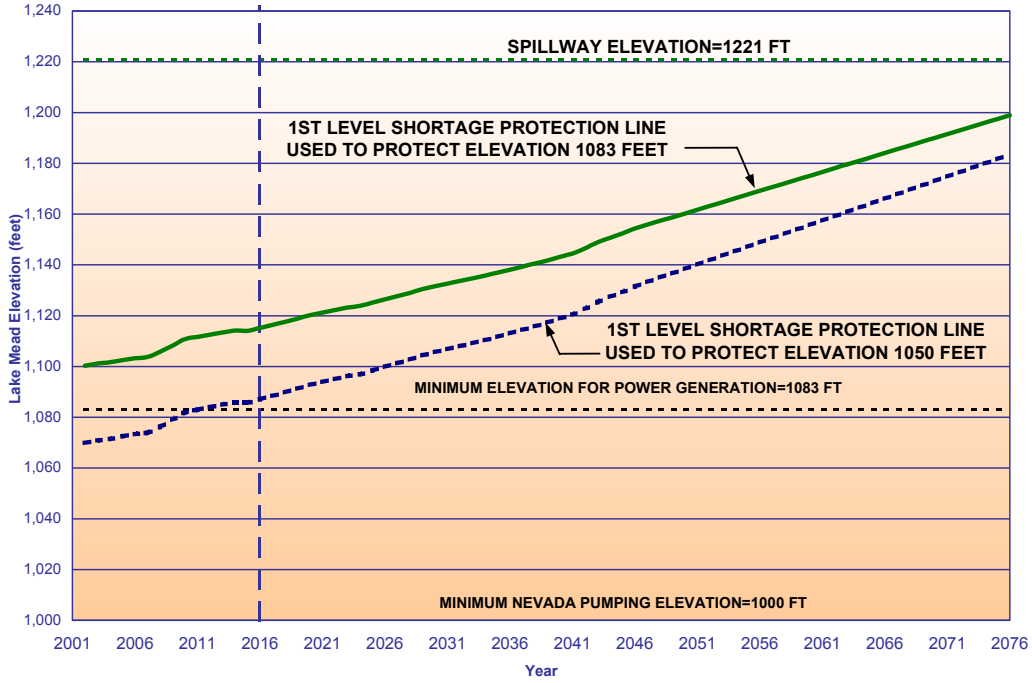


Figure D-2
Lake Mead End-of-December Water Elevations
Comparison of Shortage Assumptions for Implementation Agreement Conditions
90th, 50th, and 10th Percentile

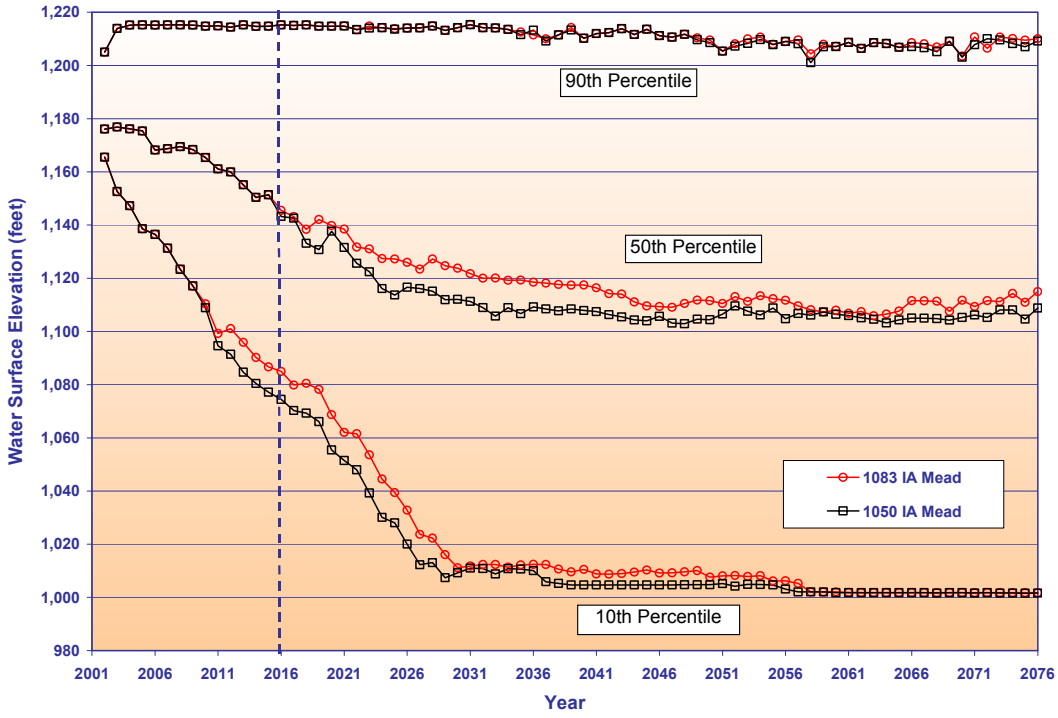


Figure D-3
Lake Mead End-of-December Water Elevations
Comparison of Shortage Assumptions for Cumulative Assessment Conditions
90th, 50th, and 10th Percentile Values

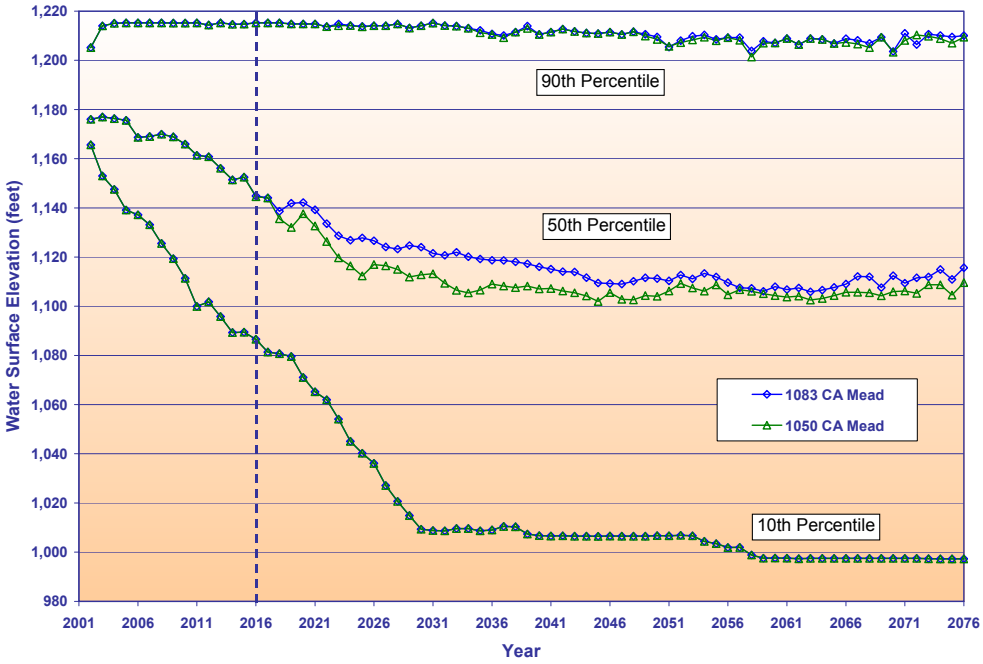


Figure D-4
Lake Powell End-of-July Water Elevations
Comparison of Shortage Assumptions for Implementation Agreement Conditions
90th, 50th, and 10th Percentile Values

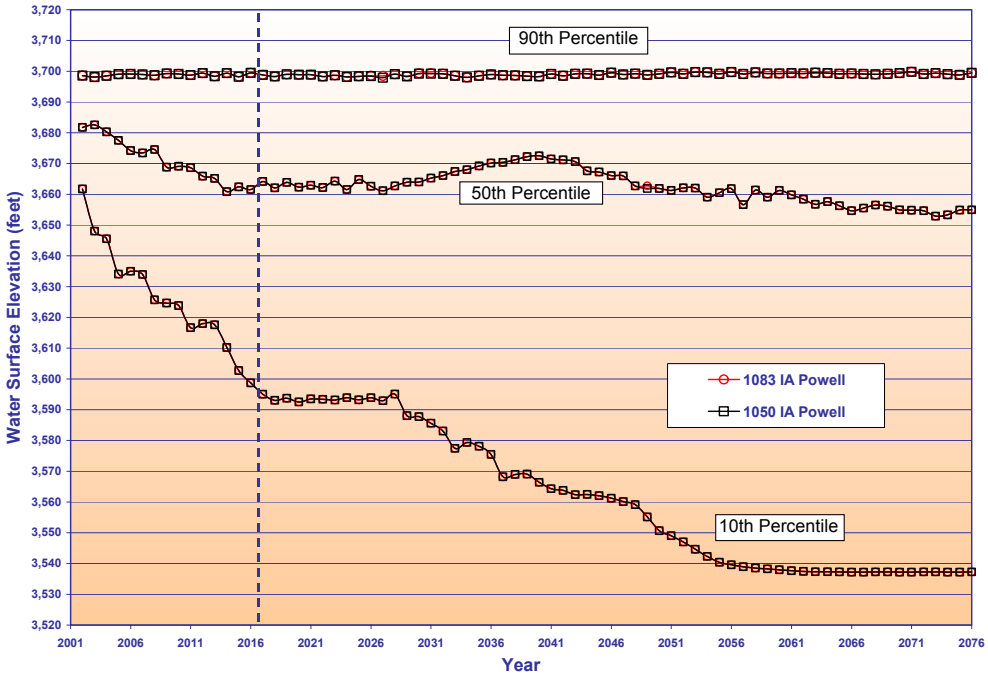
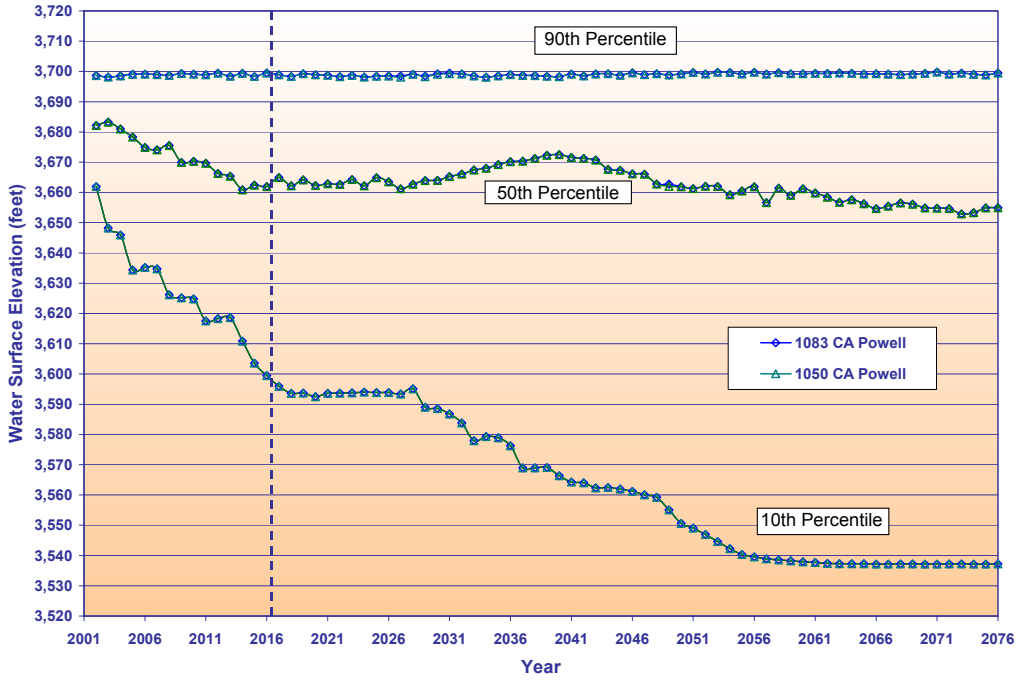


Figure D-5
Lake Powell End-of-July Water Elevations
Comparison of Shortage Assumptions for Cumulative Assessment Conditions
90th, 50th, and 10th Percentile Values



Attachment E
Volume-Elevation Relationships for Lakes Mead and Powell

Attachment E

Volume-Elevation Relationships for Lakes Mead and Powell

OVERVIEW

This attachment provides the relationship of water surface elevation to reservoir volume (or content) for Lake Mead and Lake Powell, in both tabular and graphical format. Figure E-1 provides a curve that represents the Lake Mead volume to elevation relationship and Figure E-2 provides the same for Lake Powell. The tabular data for lakes Mead and Powell are provided in Tables E-1 and E-2, respectively. The data can be used to determine the elevation effect of a given change in volume. The relationship for Lake Powell has been derived from data collected in a 1986 lake survey (Ferrari, 1988); the relationship for Lake Mead was derived from data collected in a 1964 lake survey (Lara and Sanders, 1970). Both derivations used Reclamation's Area-Capacity Program (ACAP). Additional information concerning ACAP can be found at www.usbr.gov/rsmg/xxx.

REFERENCES

Ferrari, R.L., 1970, "1986 Lake Powell Survey", U.S. Bureau of Reclamation, Surface Water Branch, Denver, CO

Lara, J.M., and Sanders, J.I., "The 1963-64 Lake Mead Survey", Office of Chief Engineer, U.S. Bureau of Reclamation, Denver, CO (Reference number REC-OCE-70-21)

Figure E-1
Lake Mead Volume-Elevation Relationship

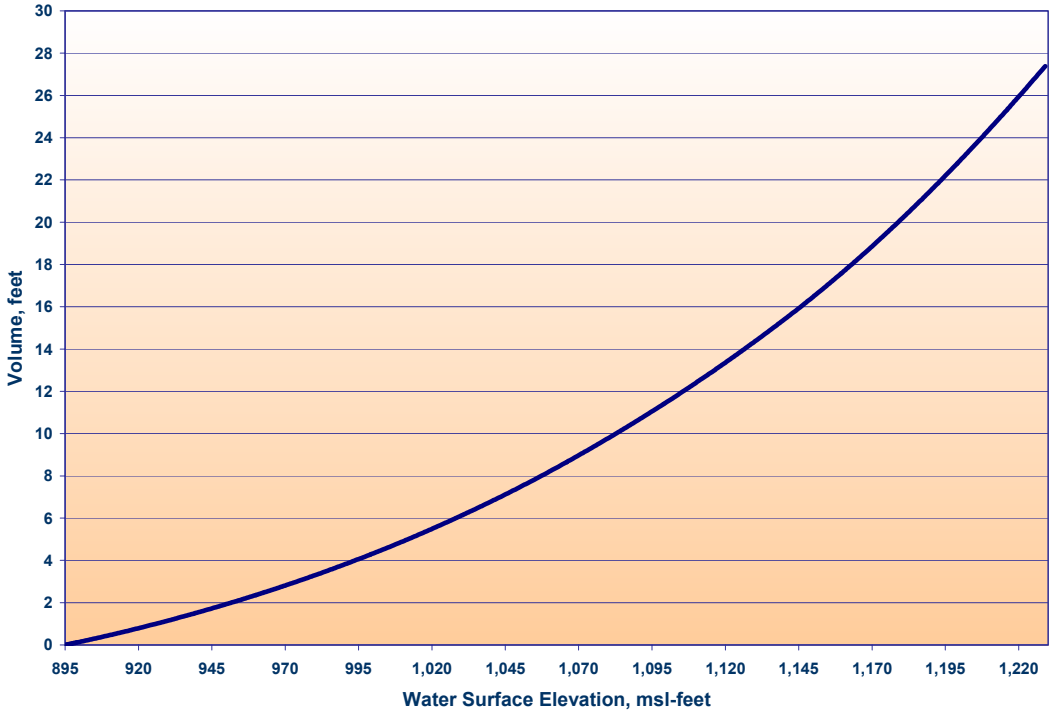


Figure E-2
Lake Powell Volume-Elevation Relationship

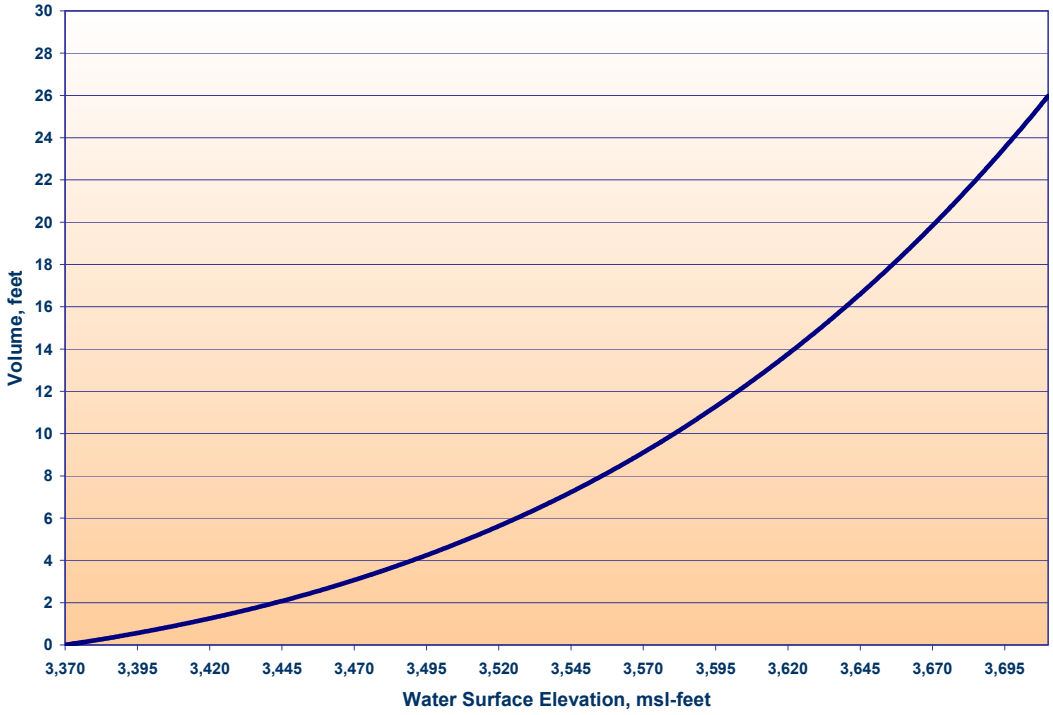


Table E-1
Lake Mead Water Surface Elevation to Storage Content Relationship (Table 1 of 2)

Elevation (msl-feet)	Volume (acre-feet)	Elevation (msl-feet)	Volume (acre-feet)	Elevation (msl-feet)	Volume (acre-feet)	Elevation (msl-feet)	Volume (acre-feet)	Elevation (msl-feet)	Volume (acre-feet)	Elevation (msl-feet)	Volume (acre-feet)
895.00	0	926.00	1,004,527	957.00	2,228,830	988.00	3,695,177	1,019.00	5,430,319	1,050.00	7,470,864
895.50	14,478	926.50	1,022,540	957.50	2,250,476	988.50	3,720,870	1,019.50	5,460,778	1,050.50	7,506,554
896.00	29,011	927.00	1,040,609	958.00	2,272,188	989.00	3,746,628	1,020.00	5,491,315	1,051.00	7,542,340
896.50	43,597	927.50	1,058,735	958.50	2,293,967	989.50	3,772,451	1,020.50	5,521,932	1,051.50	7,578,223
897.00	58,234	928.00	1,076,918	959.00	2,315,812	990.00	3,798,338	1,021.00	5,552,628	1,052.00	7,614,201
897.50	72,924	928.50	1,095,157	959.50	2,337,723	990.50	3,824,294	1,021.50	5,583,402	1,052.50	7,650,276
898.00	87,665	929.00	1,113,452	960.00	2,359,701	991.00	3,850,325	1,022.00	5,614,254	1,053.00	7,686,447
898.50	102,458	929.50	1,131,804	960.50	2,381,745	991.50	3,876,431	1,022.50	5,645,185	1,053.50	7,722,713
899.00	117,303	930.00	1,150,212	961.00	2,403,855	992.00	3,902,611	1,023.00	5,676,195	1,054.00	7,759,077
899.50	132,200	930.50	1,168,677	961.50	2,426,032	992.50	3,928,865	1,023.50	5,707,283	1,054.50	7,795,536
900.00	147,153	931.00	1,187,199	962.00	2,448,275	993.00	3,955,194	1,024.00	5,738,449	1,055.00	7,832,091
900.50	162,157	931.50	1,205,777	962.50	2,470,585	993.50	3,981,597	1,024.50	5,769,694	1,055.50	7,868,743
901.00	177,220	932.00	1,224,411	963.00	2,492,960	994.00	4,008,074	1,025.00	5,801,018	1,056.00	7,905,490
901.50	192,340	932.50	1,243,102	963.50	2,515,403	994.50	4,034,626	1,025.50	5,832,420	1,056.50	7,942,334
902.00	207,519	933.00	1,261,850	964.00	2,537,911	995.00	4,061,252	1,026.00	5,863,901	1,057.00	7,979,274
902.50	222,757	933.50	1,280,654	964.50	2,560,486	995.50	4,087,953	1,026.50	5,895,460	1,057.50	8,016,310
903.00	238,052	934.00	1,299,515	965.00	2,583,127	996.00	4,114,728	1,027.00	5,927,098	1,058.00	8,053,442
903.50	253,406	934.50	1,318,432	965.50	2,605,835	996.50	4,141,578	1,027.50	5,958,815	1,058.50	8,090,670
904.00	268,818	935.00	1,337,405	966.00	2,628,609	997.00	4,168,502	1,028.00	5,990,610	1,059.00	8,127,995
904.50	284,288	935.50	1,356,435	966.50	2,651,449	997.50	4,195,500	1,028.50	6,022,483	1,059.50	8,165,415
905.00	299,817	936.00	1,375,522	967.00	2,674,356	998.00	4,222,573	1,029.00	6,054,435	1,060.00	8,202,932
905.50	315,404	936.50	1,394,665	967.50	2,697,329	998.50	4,249,721	1,029.50	6,086,466	1,060.50	8,240,541
906.00	331,049	937.00	1,413,865	968.00	2,720,369	999.00	4,276,942	1,030.00	6,118,575	1,061.00	8,278,239
906.50	346,753	937.50	1,433,121	968.50	2,743,474	999.50	4,304,238	1,030.50	6,150,763	1,061.50	8,316,026
907.00	362,515	938.00	1,452,433	969.00	2,766,646	1,000.00	4,331,609	1,031.00	6,183,029	1,062.00	8,353,902
907.50	378,335	938.50	1,471,803	969.50	2,789,885	1,000.50	4,359,056	1,031.50	6,215,374	1,062.50	8,391,867
908.00	394,213	939.00	1,491,228	970.00	2,813,190	1,001.00	4,386,583	1,032.00	6,247,797	1,063.00	8,429,920
908.50	410,150	939.50	1,510,711	970.50	2,836,560	1,001.50	4,414,189	1,032.50	6,280,299	1,063.50	8,468,062
909.00	426,145	940.00	1,530,249	971.00	2,859,995	1,002.00	4,441,874	1,033.00	6,312,879	1,064.00	8,506,293
909.50	442,198	940.50	1,549,844	971.50	2,883,494	1,002.50	4,469,638	1,033.50	6,345,538	1,064.50	8,544,613
910.00	458,310	941.00	1,569,495	972.00	2,907,058	1,003.00	4,497,482	1,034.00	6,378,275	1,065.00	8,583,022
910.50	474,480	941.50	1,589,201	972.50	2,930,687	1,003.50	4,525,405	1,034.50	6,411,091	1,065.50	8,621,520
911.00	490,708	942.00	1,608,964	973.00	2,954,380	1,004.00	4,553,407	1,035.00	6,443,986	1,066.00	8,660,106
911.50	506,994	942.50	1,628,782	973.50	2,978,137	1,004.50	4,581,488	1,035.50	6,476,959	1,066.50	8,698,781
912.00	523,339	943.00	1,648,656	974.00	3,001,959	1,005.00	4,609,649	1,036.00	6,510,011	1,067.00	8,737,546
912.50	539,742	943.50	1,668,586	974.50	3,025,846	1,005.50	4,637,889	1,036.50	6,543,141	1,067.50	8,776,399
913.00	556,203	944.00	1,688,572	975.00	3,049,797	1,006.00	4,666,208	1,037.00	6,576,350	1,068.00	8,815,340
913.50	572,723	944.50	1,708,613	975.50	3,073,813	1,006.50	4,694,606	1,037.50	6,609,637	1,068.50	8,854,371
914.00	589,300	945.00	1,728,711	976.00	3,097,893	1,007.00	4,723,084	1,038.00	6,643,003	1,069.00	8,893,490
914.50	605,937	945.50	1,748,864	976.50	3,122,038	1,007.50	4,751,641	1,038.50	6,676,447	1,069.50	8,932,699
915.00	622,631	946.00	1,769,073	977.00	3,146,247	1,008.00	4,780,277	1,039.00	6,709,970	1,070.00	8,971,996
915.50	639,384	946.50	1,789,338	977.50	3,170,521	1,008.50	4,808,992	1,039.50	6,743,571	1,070.50	9,011,382
916.00	656,195	947.00	1,809,659	978.00	3,194,859	1,009.00	4,837,787	1,040.00	6,777,251	1,071.00	9,050,857
916.50	673,064	947.50	1,830,035	978.50	3,219,262	1,009.50	4,866,660	1,040.50	6,811,019	1,071.50	9,090,420
917.00	689,992	948.00	1,850,468	979.00	3,243,729	1,010.00	4,895,613	1,041.00	6,844,882	1,072.00	9,130,073
917.50	706,977	948.50	1,870,956	979.50	3,268,261	1,010.50	4,924,646	1,041.50	6,878,842	1,072.50	9,169,814
918.00	724,022	949.00	1,891,500	980.00	3,292,857	1,011.00	4,953,757	1,042.00	6,912,897	1,073.00	9,209,644
918.50	741,124	949.50	1,912,100	980.50	3,317,518	1,011.50	4,982,948	1,042.50	6,947,049	1,073.50	9,249,563
919.00	758,285	950.00	1,932,756	981.00	3,342,244	1,012.00	5,012,218	1,043.00	6,981,297	1,074.00	9,289,571
919.50	775,504	950.50	1,953,472	981.50	3,367,034	1,012.50	5,041,567	1,043.50	7,015,641	1,074.50	9,329,668
920.00	792,781	951.00	1,974,256	982.00	3,391,888	1,013.00	5,070,996	1,044.00	7,050,082	1,075.00	9,369,853
920.50	810,116	951.50	1,995,105	982.50	3,416,808	1,013.50	5,100,503	1,044.50	7,084,618	1,075.50	9,410,128
921.00	827,507	952.00	2,016,021	983.00	3,441,791	1,014.00	5,130,090	1,045.00	7,119,251	1,076.00	9,450,491
921.50	844,955	952.50	2,037,003	983.50	3,466,839	1,014.50	5,159,757	1,045.50	7,153,979	1,076.50	9,490,943
922.00	862,459	953.00	2,058,052	984.00	3,491,952	1,015.00	5,189,502	1,046.00	7,188,804	1,077.00	9,531,484
922.50	880,020	953.50	2,079,167	984.50	3,517,129	1,015.50	5,219,327	1,046.50	7,223,725	1,077.50	9,572,114
923.00	897,637	954.00	2,100,348	985.00	3,542,371	1,016.00	5,249,231	1,047.00	7,258,742	1,078.00	9,612,832
923.50	915,311	954.50	2,121,596	985.50	3,567,677	1,016.50	5,279,214	1,047.50	7,293,856	1,078.50	9,653,640
924.00	933,041	955.00	2,142,910	986.00	3,593,048	1,017.00	5,309,277	1,048.00	7,329,065	1,079.00	9,694,536
924.50	950,828	955.50	2,164,291	986.50	3,618,483	1,017.50	5,339,418	1,048.50	7,364,370	1,079.50	9,735,521
925.00	968,671	956.00	2,185,737	987.00	3,643,983	1,018.00	5,369,639	1,049.00	7,399,772	1,080.00	9,776,595
925.50	986,571	956.50	2,207,251	987.50	3,669,548	1,018.50	5,399,939	1,049.50	7,435,270	1,080.50	9,817,756

Table E-1 (Continued)
Lake Mead Water Surface Elevation to Storage Content Relationship (Table 2 of 2)

Elevation (msl-feet)	Volume (acre-feet)	Elevation (msl-feet)	Volume (acre-feet)	Elevation (msl-feet)	Volume (acre-feet)	Elevation (msl-feet)	Volume (acre-feet)	Elevation (msl-feet)	Volume (acre-feet)
1,081.00	9,859,002	1,112.00	12,593,397	1,143.00	15,711,770	1,174.00	19,366,247	1,205.00	23,654,596
1,081.50	9,900,334	1,112.50	12,640,524	1,143.50	15,765,770	1,174.50	19,430,437	1,205.50	23,728,704
1,082.00	9,941,751	1,113.00	12,687,749	1,144.00	15,819,930	1,175.00	19,494,796	1,206.00	23,802,971
1,082.50	9,983,253	1,113.50	12,735,072	1,144.50	15,874,250	1,175.50	19,559,324	1,206.50	23,877,395
1,083.00	10,024,841	1,114.00	12,782,492	1,145.00	15,928,731	1,176.00	19,624,022	1,207.00	23,951,978
1,083.50	10,066,514	1,114.50	12,830,010	1,145.50	15,983,371	1,176.50	19,688,889	1,207.50	24,026,720
1,084.00	10,108,272	1,115.00	12,877,626	1,146.00	16,038,172	1,177.00	19,753,925	1,208.00	24,101,619
1,084.50	10,150,116	1,115.50	12,925,339	1,146.50	16,093,133	1,177.50	19,819,130	1,208.50	24,176,677
1,085.00	10,192,045	1,116.00	12,973,149	1,147.00	16,148,255	1,178.00	19,884,505	1,209.00	24,251,893
1,085.50	10,234,059	1,116.50	13,021,058	1,147.50	16,203,536	1,178.50	19,950,049	1,209.50	24,327,267
1,086.00	10,276,159	1,117.00	13,069,064	1,148.00	16,258,978	1,179.00	20,015,762	1,210.00	24,402,800
1,086.50	10,318,344	1,117.50	13,117,167	1,148.50	16,314,580	1,179.50	20,081,644	1,210.50	24,478,485
1,087.00	10,360,614	1,118.00	13,165,369	1,149.00	16,370,342	1,180.00	20,147,696	1,211.00	24,554,316
1,087.50	10,402,970	1,118.50	13,213,668	1,149.50	16,426,264	1,180.50	20,213,915	1,211.50	24,630,293
1,088.00	10,445,411	1,119.00	13,262,064	1,150.00	16,482,347	1,181.00	20,280,298	1,212.00	24,706,417
1,088.50	10,487,937	1,119.50	13,310,558	1,150.50	16,538,589	1,181.50	20,346,847	1,212.50	24,782,687
1,089.00	10,530,549	1,120.00	13,359,150	1,151.00	16,594,992	1,182.00	20,413,560	1,213.00	24,859,103
1,089.50	10,573,246	1,120.50	13,407,845	1,151.50	16,651,555	1,182.50	20,480,439	1,213.50	24,935,665
1,090.00	10,616,028	1,121.00	13,456,647	1,152.00	16,708,279	1,183.00	20,547,482	1,214.00	25,012,373
1,090.50	10,658,901	1,121.50	13,505,558	1,152.50	16,765,162	1,183.50	20,614,690	1,214.50	25,089,228
1,091.00	10,701,869	1,122.00	13,554,576	1,153.00	16,822,206	1,184.00	20,682,064	1,215.00	25,166,229
1,091.50	10,744,933	1,122.50	13,603,703	1,153.50	16,879,410	1,184.50	20,749,602	1,215.50	25,243,376
1,092.00	10,788,092	1,123.00	13,652,937	1,152.00	16,936,774	1,185.00	20,817,305	1,216.00	25,320,669
1,092.50	10,831,347	1,123.50	13,702,279	1,154.50	16,994,298	1,185.50	20,885,173	1,216.50	25,398,109
1,093.00	10,874,698	1,124.00	13,751,730	1,155.00	17,051,983	1,186.00	20,953,206	1,217.00	25,475,695
1,093.50	10,918,143	1,124.50	13,801,288	1,155.50	17,109,828	1,186.50	21,021,404	1,217.50	25,553,427
1,094.00	10,961,685	1,125.00	13,850,954	1,156.00	17,167,833	1,187.00	21,089,767	1,218.00	25,631,305
1,094.50	11,005,322	1,125.50	13,900,728	1,156.50	17,225,998	1,187.50	21,158,295	1,218.50	25,709,330
1,095.00	11,049,054	1,126.00	13,950,610	1,157.00	17,284,323	1,188.00	21,226,987	1,219.00	25,787,500
1,095.50	11,092,882	1,126.50	14,000,600	1,157.50	17,342,809	1,188.50	21,295,845	1,219.50	25,865,817
1,096.00	11,136,805	1,127.00	14,050,698	1,158.00	17,401,454	1,189.00	21,364,868	1,220.00	25,944,281
1,096.50	11,180,824	1,127.50	14,100,904	1,158.50	17,460,260	1,189.50	21,434,055	1,220.50	26,022,895
1,097.00	11,224,939	1,128.00	14,151,218	1,159.00	17,519,226	1,190.00	21,503,408	1,221.00	26,101,666
1,097.50	11,269,149	1,128.50	14,201,640	1,159.50	17,578,353	1,190.50	21,572,918	1,221.50	26,180,592
1,098.00	11,313,454	1,129.00	14,252,169	1,160.00	17,637,639	1,191.00	21,642,579	1,222.00	26,259,675
1,098.50	11,357,855	1,129.50	14,302,807	1,160.50	17,697,090	1,191.50	21,712,390	1,222.50	26,338,914
1,099.00	11,402,352	1,130.00	14,353,553	1,161.00	17,756,711	1,192.00	21,782,352	1,223.00	26,418,310
1,099.50	11,446,944	1,130.50	14,404,406	1,161.50	17,816,501	1,192.50	21,852,464	1,223.50	26,497,861
1,100.00	11,491,631	1,131.00	14,455,368	1,162.00	17,876,460	1,193.00	21,922,727	1,224.00	26,577,569
1,100.50	11,536,415	1,131.50	14,506,437	1,162.50	17,936,588	1,193.50	21,993,141	1,224.50	26,657,433
1,101.00	11,581,297	1,132.00	14,557,615	1,163.00	17,996,885	1,194.00	22,063,705	1,225.00	26,737,453
1,101.50	11,626,277	1,132.50	14,608,900	1,163.50	18,057,352	1,194.50	22,134,420	1,225.50	26,817,629
1,102.00	11,671,354	1,133.00	14,660,293	1,164.00	18,117,988	1,195.00	22,205,285	1,226.00	26,897,962
1,102.50	11,716,528	1,133.50	14,711,795	1,164.50	18,178,793	1,195.50	22,276,301	1,226.50	26,978,451
1,103.00	11,761,801	1,134.00	14,763,404	1,165.00	18,239,767	1,196.00	22,347,468	1,227.00	27,059,095
1,103.50	11,807,171	1,134.50	14,815,121	1,165.50	18,300,911	1,196.50	22,418,785	1,227.50	27,139,896
1,104.00	11,852,638	1,135.00	14,866,946	1,166.00	18,362,224	1,197.00	22,490,252	1,228.00	27,220,854
1,104.50	11,898,203	1,135.50	14,918,879	1,166.50	18,423,706	1,197.50	22,561,870	1,228.50	27,301,967
1,105.00	11,943,866	1,136.00	14,970,920	1,167.00	18,485,357	1,198.00	22,633,639	1,229.00	27,383,237
1,105.50	11,989,627	1,136.50	15,023,069	1,167.50	18,547,178	1,198.50	22,705,558		
1,106.00	12,035,485	1,137.00	15,075,326	1,168.00	18,609,168	1,199.00	22,777,628		
1,106.50	12,081,440	1,137.50	15,127,691	1,168.50	18,671,327	1,199.50	22,849,849		
1,107.00	12,127,494	1,138.00	15,180,164	1,169.00	18,733,655	1,200.00	22,922,220		
1,107.50	12,173,645	1,138.50	15,232,745	1,169.50	18,796,153	1,200.50	22,994,745		
1,108.00	12,219,893	1,139.00	15,285,433	1,170.00	18,858,820	1,201.00	23,067,429		
1,108.50	12,266,240	1,139.50	15,338,230	1,170.50	18,921,656	1,201.50	23,140,271		
1,109.00	12,312,683	1,140.00	15,391,135	1,171.00	18,984,661	1,202.00	23,213,271		
1,109.50	12,359,225	1,140.50	15,444,173	1,171.50	19,047,836	1,202.50	23,286,429		
1,110.00	12,405,864	1,141.00	15,497,372	1,172.00	19,111,179	1,203.00	23,359,746		
1,110.50	12,452,601	1,141.50	15,550,731	1,172.50	19,174,692	1,203.50	23,433,221		
1,111.00	12,499,435	1,142.00	15,604,251	1,173.00	19,238,375	1,204.00	23,506,855		
1,111.50	12,546,367	1,142.50	15,657,930	1,173.50	19,302,226	1,204.50	23,580,646		

Table E-2
Lake Powell Water Surface Elevation to Storage Content Relationship (Table 1 of 2)

Elevation (msl-feet)	Volume (acre-feet)	Elevation (msl-feet)	Volume (acre-feet)	Elevation (msl-feet)	Volume (acre-feet)	Elevation (msl-feet)	Volume (acre-feet)	Elevation (msl-feet)	Volume (acre-feet)	Elevation (msl-feet)	Volume (acre-feet)
3,370.00	0	3,401.00	719,827	3,432.00	1,632,024	3,463.00	2,775,184	3,494.00	4,196,921	3,525.00	5,926,566
3,370.50	10,174	3,401.50	732,982	3,432.50	1,648,472	3,463.50	2,795,845	3,494.50	4,222,235	3,525.50	5,957,319
3,371.00	20,393	3,402.00	746,187	3,433.00	1,664,978	3,464.00	2,816,580	3,495.00	4,247,626	3,526.00	5,988,168
3,371.50	30,657	3,402.50	759,442	3,433.50	1,681,542	3,464.50	2,837,388	3,495.50	4,273,093	3,526.50	6,019,114
3,372.00	40,966	3,403.00	772,747	3,434.00	1,698,165	3,465.00	2,858,271	3,496.00	4,298,636	3,527.00	6,050,156
3,372.50	51,320	3,403.50	786,101	3,434.50	1,714,845	3,465.50	2,879,228	3,496.50	4,324,256	3,527.50	6,081,295
3,373.00	61,719	3,404.00	799,506	3,435.00	1,731,584	3,466.00	2,900,259	3,497.00	4,349,953	3,528.00	6,112,531
3,373.50	72,162	3,404.50	812,960	3,435.50	1,748,381	3,466.50	2,921,363	3,497.50	4,375,725	3,528.50	6,143,863
3,374.00	82,651	3,405.00	826,463	3,436.00	1,765,236	3,467.00	2,942,542	3,498.00	4,401,575	3,529.00	6,175,292
3,374.50	93,185	3,405.50	840,017	3,436.50	1,782,149	3,467.50	2,963,794	3,498.50	4,427,500	3,529.50	6,206,818
3,375.00	103,764	3,406.00	853,620	3,437.00	1,799,120	3,468.00	2,985,120	3,499.00	4,453,502	3,530.00	6,238,440
3,375.50	114,387	3,406.50	867,274	3,437.50	1,816,150	3,468.50	3,006,521	3,499.50	4,479,580	3,530.50	6,270,159
3,376.00	125,056	3,407.00	880,977	3,438.00	1,833,237	3,469.00	3,027,995	3,500.00	4,505,735	3,531.00	6,301,974
3,376.50	135,770	3,407.50	894,729	3,438.50	1,850,383	3,469.50	3,049,543	3,500.50	4,531,972	3,531.50	6,333,886
3,377.00	146,529	3,408.00	908,532	3,439.00	1,867,587	3,470.00	3,071,165	3,501.00	4,558,298	3,532.00	6,365,895
3,377.50	157,332	3,408.50	922,384	3,439.50	1,884,850	3,470.50	3,092,861	3,501.50	4,584,713	3,532.50	6,398,000
3,378.00	168,181	3,409.00	936,286	3,440.00	1,902,170	3,471.00	3,114,631	3,502.00	4,611,216	3,533.00	6,430,202
3,378.50	179,074	3,409.50	950,238	3,440.50	1,919,555	3,471.50	3,136,475	3,502.50	4,637,808	3,533.50	6,462,501
3,379.00	190,013	3,410.00	964,240	3,441.00	1,937,011	3,472.00	3,158,392	3,503.00	4,664,488	3,534.00	6,494,896
3,379.50	200,996	3,410.50	978,291	3,441.50	1,954,537	3,472.50	3,180,384	3,503.50	4,691,257	3,534.50	6,527,388
3,380.00	212,025	3,411.00	992,393	3,442.00	1,972,134	3,473.00	3,202,450	3,504.00	4,718,115	3,535.00	6,559,976
3,380.50	223,101	3,411.50	1,006,544	3,442.50	1,989,802	3,473.50	3,224,589	3,504.50	4,745,061	3,535.50	6,592,661
3,381.00	234,226	3,412.00	1,020,745	3,443.00	2,007,541	3,474.00	3,246,803	3,505.00	4,772,096	3,536.00	6,625,443
3,381.50	245,401	3,412.50	1,034,995	3,443.50	2,025,350	3,474.50	3,269,090	3,505.50	4,799,220	3,536.50	6,658,321
3,382.00	256,625	3,413.00	1,049,296	3,444.00	2,043,231	3,475.00	3,291,451	3,506.00	4,826,432	3,537.00	6,691,296
3,382.50	267,899	3,413.50	1,063,646	3,444.50	2,061,182	3,475.50	3,313,886	3,506.50	4,853,733	3,537.50	6,724,368
3,383.00	279,222	3,414.00	1,078,046	3,445.00	2,079,204	3,476.00	3,336,396	3,507.00	4,881,122	3,538.00	6,757,536
3,383.50	290,595	3,414.50	1,092,496	3,445.50	2,097,296	3,476.50	3,358,979	3,507.50	4,908,600	3,538.50	6,790,801
3,384.00	302,017	3,415.00	1,106,995	3,446.00	2,115,460	3,477.00	3,381,636	3,508.00	4,936,167	3,539.00	6,824,162
3,384.50	313,489	3,415.50	1,121,545	3,446.50	2,133,694	3,477.50	3,404,367	3,508.50	4,963,822	3,539.50	6,857,620
3,385.00	325,010	3,416.00	1,136,144	3,447.00	2,151,999	3,478.00	3,427,171	3,509.00	4,991,566	3,540.00	6,891,175
3,385.50	336,581	3,416.50	1,150,793	3,447.50	2,170,375	3,478.50	3,450,050	3,509.50	5,019,399	3,540.50	6,924,832
3,386.00	348,201	3,417.00	1,165,492	3,448.00	2,188,821	3,479.00	3,473,003	3,510.00	5,047,320	3,541.00	6,958,600
3,386.50	359,871	3,417.50	1,180,240	3,448.50	2,207,338	3,479.50	3,496,029	3,510.50	5,075,330	3,541.50	6,992,477
3,387.00	371,590	3,418.00	1,195,038	3,449.00	2,225,927	3,480.00	3,519,130	3,511.00	5,103,428	3,542.00	7,026,464
3,387.50	383,359	3,418.50	1,209,886	3,449.50	2,244,585	3,480.50	3,542,307	3,511.50	5,131,615	3,542.50	7,060,561
3,388.00	395,177	3,419.00	1,224,784	3,450.00	2,263,315	3,481.00	3,565,558	3,512.00	5,159,891	3,543.00	7,094,767
3,388.50	407,045	3,419.50	1,239,732	3,450.50	2,282,115	3,481.50	3,588,887	3,512.50	5,188,255	3,543.50	7,129,083
3,389.00	418,962	3,420.00	1,254,729	3,451.00	2,300,987	3,482.00	3,612,291	3,513.00	5,216,708	3,544.00	7,163,509
3,389.50	430,929	3,420.50	1,269,782	3,451.50	2,319,928	3,482.50	3,635,773	3,513.50	5,245,250	3,544.50	7,198,045
3,390.00	442,945	3,421.00	1,284,891	3,452.00	2,338,941	3,483.00	3,659,330	3,514.00	5,273,880	3,545.00	7,232,690
3,390.50	455,011	3,421.50	1,300,059	3,452.50	2,358,025	3,483.50	3,682,964	3,514.50	5,302,599	3,545.50	7,267,445
3,391.00	467,126	3,422.00	1,315,285	3,453.00	2,377,179	3,484.00	3,706,674	3,515.00	5,331,406	3,546.00	7,302,309
3,391.50	479,291	3,422.50	1,330,570	3,453.50	2,396,404	3,484.50	3,730,461	3,515.50	5,360,302	3,546.50	7,337,284
3,392.00	491,505	3,423.00	1,345,912	3,454.00	2,415,700	3,485.00	3,754,324	3,516.00	5,389,287	3,547.00	7,372,368
3,392.50	503,769	3,423.50	1,361,313	3,454.50	2,435,066	3,485.50	3,778,263	3,516.50	5,418,360	3,547.50	7,407,561
3,393.00	516,082	3,424.00	1,376,772	3,455.00	2,454,504	3,486.00	3,802,279	3,517.00	5,447,522	3,548.00	7,442,864
3,393.50	528,445	3,424.50	1,392,289	3,455.50	2,474,012	3,486.50	3,826,371	3,517.50	5,476,773	3,548.50	7,478,277
3,394.00	540,857	3,425.00	1,407,864	3,456.00	2,493,591	3,487.00	3,850,540	3,518.00	5,506,112	3,549.00	7,513,800
3,394.50	553,319	3,425.50	1,423,497	3,456.50	2,513,240	3,487.50	3,874,785	3,518.50	5,535,540	3,549.50	7,549,433
3,395.00	565,830	3,426.00	1,439,189	3,457.00	2,532,961	3,488.00	3,899,106	3,519.00	5,565,056	3,550.00	7,585,175
3,395.50	578,391	3,426.50	1,454,938	3,457.50	2,552,752	3,488.50	3,923,504	3,519.50	5,594,661	3,550.50	7,621,026
3,396.00	591,001	3,427.00	1,470,746	3,458.00	2,572,614	3,489.00	3,947,978	3,520.00	5,624,355	3,551.00	7,656,988
3,396.50	603,661	3,427.50	1,486,612	3,458.50	2,592,547	3,489.50	3,972,528	3,520.50	5,654,141	3,551.50	7,693,059
3,397.00	616,370	3,428.00	1,502,536	3,459.00	2,612,551	3,490.00	3,997,155	3,521.00	5,684,024	3,552.00	7,729,240
3,397.50	629,129	3,428.50	1,518,519	3,459.50	2,632,625	3,490.50	4,021,859	3,521.50	5,714,004	3,552.50	7,765,530
3,398.00	641,937	3,429.00	1,534,559	3,460.00	2,652,770	3,491.00	4,046,638	3,522.00	5,744,080	3,553.00	7,801,930
3,398.50	654,795	3,429.50	1,550,658	3,460.50	2,672,987	3,491.50	4,071,494	3,522.50	5,774,253	3,553.50	7,838,440
3,399.00	667,702	3,430.00	1,566,815	3,461.00	2,693,279	3,492.00	4,096,427	3,523.00	5,804,522	3,554.00	7,875,060
3,399.50	680,659	3,430.50	1,583,030	3,461.50	2,713,644	3,492.50	4,121,436	3,523.50	5,834,888	3,554.50	7,911,789
3,400.00	693,665	3,431.00	1,599,303	3,462.00	2,734,083	3,493.00	4,146,521	3,524.00	5,865,351	3,555.00	7,948,628
3,400.50	706,721	3,431.50	1,615,635	3,462.50	2,754,597	3,493.50	4,171,683	3,524.50	5,895,910	3,555.50	7,985,577

Table E-2 (Continued)
Lake Powell Water Surface Elevation to Storage Content Relationship (Table 2 of 2)

Elevation (msl-feet)	Volume (acre-feet)	Elevation (msl-feet)	Volume (acre-feet)	Elevation (msl-feet)	Volume (acre-feet)	Elevation (msl-feet)	Volume (acre-feet)	Elevation (msl-feet)	Volume (acre-feet)
3,556.00	8,022,635	3,587.00	10,551,106	3,618.00	13,552,426	3,649.00	17,091,550	3,680.00	21,258,040
3,556.50	8,059,803	3,587.50	10,595,701	3,618.50	13,604,929	3,649.50	17,153,548	3,680.50	21,330,959
3,557.00	8,097,081	3,588.00	10,640,418	3,619.00	13,657,565	3,650.00	17,215,706	3,681.00	21,404,066
3,557.50	8,134,468	3,588.50	10,685,256	3,619.50	13,710,331	3,650.50	17,278,024	3,681.50	21,477,363
3,558.00	8,171,965	3,589.00	10,730,216	3,620.00	13,763,230	3,651.00	17,340,503	3,682.00	21,550,848
3,558.50	8,209,572	3,589.50	10,775,297	3,620.50	13,816,271	3,651.50	17,403,142	3,682.50	21,624,523
3,559.00	8,247,288	3,590.00	10,820,500	3,621.00	13,869,463	3,652.00	17,465,942	3,683.00	21,698,387
3,559.50	8,285,114	3,590.50	10,865,824	3,621.50	13,922,806	3,652.50	17,528,903	3,683.50	21,772,440
3,560.00	8,323,050	3,591.00	10,911,270	3,622.00	13,976,301	3,653.00	17,592,024	3,684.00	21,846,683
3,560.50	8,361,101	3,591.50	10,956,837	3,622.50	14,029,947	3,653.50	17,655,306	3,684.50	21,921,114
3,561.00	8,399,273	3,592.00	11,002,526	3,623.00	14,083,745	3,654.00	17,718,748	3,685.00	21,995,735
3,561.50	8,437,566	3,592.50	11,048,336	3,623.50	14,137,695	3,654.50	17,782,351	3,685.50	22,070,545
3,562.00	8,475,981	3,593.00	11,094,268	3,624.00	14,191,796	3,655.00	17,846,115	3,686.00	22,145,544
3,562.50	8,514,516	3,593.50	11,140,321	3,624.50	14,246,048	3,655.50	17,910,039	3,686.50	22,220,733
3,563.00	8,553,172	3,594.00	11,186,496	3,625.00	14,300,453	3,656.00	17,974,123	3,687.00	22,296,111
3,563.50	8,591,950	3,594.50	11,232,792	3,625.50	14,355,008	3,656.50	18,038,368	3,687.50	22,371,678
3,564.00	8,630,848	3,595.00	11,279,210	3,626.00	14,409,716	3,657.00	18,102,774	3,688.00	22,447,434
3,564.50	8,669,868	3,595.50	11,325,749	3,626.50	14,464,575	3,657.50	18,167,340	3,688.50	22,523,379
3,565.00	8,709,009	3,596.00	11,372,410	3,627.00	14,519,585	3,658.00	18,232,067	3,689.00	22,599,514
3,565.50	8,748,271	3,596.50	11,419,192	3,627.50	14,574,747	3,658.50	18,296,954	3,689.50	22,675,838
3,566.00	8,787,653	3,597.00	11,466,096	3,628.00	14,630,061	3,659.00	18,362,002	3,690.00	22,752,350
3,566.50	8,827,157	3,597.50	11,513,121	3,628.50	14,685,526	3,659.50	18,427,211	3,690.50	22,829,053
3,567.00	8,866,782	3,598.00	11,560,268	3,629.00	14,741,142	3,660.00	18,492,580	3,691.00	22,905,944
3,567.50	8,906,528	3,598.50	11,607,536	3,629.50	14,796,911	3,660.50	18,558,122	3,691.50	22,983,025
3,568.00	8,946,396	3,599.00	11,654,926	3,630.00	14,852,830	3,661.00	18,623,848	3,692.00	23,060,295
3,568.50	8,986,384	3,599.50	11,702,437	3,630.50	14,908,902	3,661.50	18,689,758	3,692.50	23,137,754
3,569.00	9,026,493	3,600.00	11,750,070	3,631.00	14,965,125	3,662.00	18,755,853	3,693.00	23,215,402
3,569.50	9,066,724	3,600.50	11,797,829	3,631.50	15,021,499	3,662.50	18,822,132	3,693.50	23,293,239
3,570.00	9,107,075	3,601.00	11,845,721	3,632.00	15,078,025	3,663.00	18,888,595	3,694.00	23,371,266
3,570.50	9,147,548	3,601.50	11,893,743	3,632.50	15,134,703	3,663.50	18,955,243	3,694.50	23,449,482
3,571.00	9,188,141	3,602.00	11,941,898	3,633.00	15,191,532	3,664.00	19,022,075	3,695.00	23,527,887
3,571.50	9,228,856	3,602.50	11,990,185	3,633.50	15,248,513	3,664.50	19,089,092	3,695.50	23,606,481
3,572.00	9,269,692	3,603.00	12,038,603	3,634.00	15,305,645	3,665.00	19,156,292	3,696.00	23,685,265
3,572.50	9,310,648	3,603.50	12,087,153	3,634.50	15,362,929	3,665.50	19,223,678	3,696.50	23,764,238
3,573.00	9,351,726	3,604.00	12,135,835	3,635.00	15,420,365	3,666.00	19,291,247	3,697.00	23,843,400
3,573.50	9,392,925	3,604.50	12,184,648	3,635.50	15,477,952	3,666.50	19,359,001	3,697.50	23,922,751
3,574.00	9,434,245	3,605.00	12,233,594	3,636.00	15,535,690	3,667.00	19,426,939	3,698.00	24,002,291
3,574.50	9,475,687	3,605.50	12,282,671	3,636.50	15,593,580	3,667.50	19,495,062	3,698.50	24,082,021
3,575.00	9,517,249	3,606.00	12,331,880	3,637.00	15,651,622	3,668.00	19,563,369	3,699.00	24,161,940
3,575.50	9,558,932	3,606.50	12,381,220	3,637.50	15,709,815	3,668.50	19,631,860	3,699.50	24,242,048
3,576.00	9,600,736	3,607.00	12,430,693	3,638.00	15,768,160	3,669.00	19,700,536	3,700.00	24,322,345
3,576.50	9,642,662	3,607.50	12,480,297	3,638.50	15,826,656	3,669.50	19,769,396	3,700.50	24,402,840
3,577.00	9,684,708	3,608.00	12,530,033	3,639.00	15,885,304	3,670.00	19,838,440	3,701.00	24,483,541
3,577.50	9,726,876	3,608.50	12,579,901	3,639.50	15,944,104	3,670.50	19,907,669	3,701.50	24,564,448
3,578.00	9,769,165	3,609.00	12,629,901	3,640.00	16,003,055	3,671.00	19,977,082	3,702.00	24,645,562
3,578.50	9,811,574	3,609.50	12,680,032	3,640.50	16,062,163	3,671.50	20,046,679	3,702.50	24,726,881
3,579.00	9,854,105	3,610.00	12,730,295	3,641.00	16,121,431	3,672.00	20,116,461	3,703.00	24,808,406
3,579.50	9,896,757	3,610.50	12,780,690	3,641.50	16,180,859	3,672.50	20,186,427	3,703.50	24,890,138
3,580.00	9,939,530	3,611.00	12,831,217	3,642.00	16,240,448	3,673.00	20,256,577	3,704.00	24,972,075
3,580.50	9,982,424	3,611.50	12,881,875	3,642.50	16,300,197	3,673.50	20,326,912	3,704.50	25,054,219
3,581.00	10,025,440	3,612.00	12,932,665	3,643.00	16,360,107	3,674.00	20,397,431	3,705.00	25,136,569
3,581.50	10,068,577	3,612.50	12,983,587	3,643.50	16,420,178	3,674.50	20,468,135	3,705.50	25,219,125
3,582.00	10,111,836	3,613.00	13,034,641	3,644.00	16,480,409	3,675.00	20,539,022	3,706.00	25,301,886
3,582.50	10,155,216	3,613.50	13,085,826	3,644.50	16,540,800	3,675.50	20,610,095	3,706.50	25,384,854
3,583.00	10,198,718	3,614.00	13,137,144	3,645.00	16,601,353	3,676.00	20,681,351	3,707.00	25,468,028
3,583.50	10,242,341	3,614.50	13,188,593	3,645.50	16,662,065	3,676.50	20,752,792	3,707.50	25,551,408
3,584.00	10,286,086	3,615.00	13,240,174	3,646.00	16,722,939	3,677.00	20,824,417	3,708.00	25,634,995
3,584.50	10,329,952	3,615.50	13,291,886	3,646.50	16,783,973	3,677.50	20,896,227	3,708.50	25,718,787
3,585.00	10,373,940	3,616.00	13,343,731	3,647.00	16,845,167	3,678.00	20,968,221	3,709.00	25,802,785
3,585.50	10,418,049	3,616.50	13,395,707	3,647.50	16,906,522	3,678.50	21,040,399	3,709.50	25,886,990
3,586.00	10,462,280	3,617.00	13,447,815	3,648.00	16,968,038	3,679.00	21,112,762	3,710.00	25,971,400
3,586.50	10,506,632	3,617.50	13,500,055	3,648.50	17,029,714	3,679.50	21,185,309		