Appendix A

CRSS Model Documentation

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Appendix A. CRSS Model Documentation

A.1 Background

The Colorado River Simulation System (CRSS), developed by the Bureau of Reclamation in the 1980s, has long been a foundational tool for long-term policy and planning studies on the Colorado River. Initially built in Fortran and run on a Cyber mainframe, the original CRSS modeled twelve major reservoirs and approximately 115 aggregate diversion points across the Upper and Lower Basins on a monthly time step. However, a key limitation of the Fortran-based CRSS was that the operating policies or rules were hardwired into the modeling code, making modification of those policies difficult.

To address emerging needs of the Interim Surplus Criteria Environmental Impact Statement (EIS) in the early 1990s, particularly for surplus and shortage studies in the Lower Basin, Reclamation created CRSSez, a simplified annual time step model implemented in Visual Basic (Bureau of Reclamation 1998). This model focused on Lake Powell and Lake Mead, simplifying upstream and downstream systems.

In 1994, Reclamation partnered with the University of Colorado and the Tennessee Valley Authority to develop RiverWare™, a more flexible and general-purpose modeling tool. Unlike its predecessors, RiverWare™ allowed users to define and prioritize operational rules through a graphical interface, enabling more dynamic and efficient scenario analysis (Zagona et al. 2001). By 1996, CRSS was fully transitioned into RiverWare™, maintaining the original model's structure and data while allowing for more adaptable rule sets.

Since then, CRSS has continued to evolve, with new rule sets developed to reflect current policies and improvements made to physical process methodologies. In 2005, CRSS-Lite was introduced as a faster, more efficient alternative to CRSSez, built within RiverWare™. It retained the complexity and accuracy of CRSS while significantly reducing execution time, making it a valuable tool for evaluating a wide range of operational strategies in the 2007 Interim Guidelines EIS.

In the 2010s, CRSS was used in various studies to identify current and future imbalances in water supply and demand across the Basin as part of the Colorado River Basin Water Supply and Demand Study and Tribal Water Study. CRSS also facilitated decision-making during the negotiation of the 2019 Drought Contingency Plans and Minute 323 in 2017.

In 2023, Reclamation revised CRSS to reduce model bias and better characterize the variability and range of Upper Basin depletions. To address these issues, the updated model includes "not pre-shorted" Upper Basin demands (rather than "pre-shorted" demands), as well as logic that limits the natural flow available for diversion by the Upper Basin agricultural water users by calibrating to historical Upper Basin gage records. This effort also included adding three new Upper Basin reservoirs to better model exports from the Basin and to more accurately model the seasonal timing of tributary water use. This version of CRSS – deemed CRSS version 6 – served as the baseline model used for this DEIS.

A.2 Overview

CRSS simulates the operation of the major reservoirs on the Colorado River system and provides information regarding the projected future state of the system on a monthly basis. CRSS models 15 reservoirs, as shown in **Map A-1**, and approximately 359 water users aggregated on 184 modeled diversions (demands and return flows). The model is initialized on December 31st, 2026 and run for 34 years, simulating conditions through December 31st, 2060. Output variables include the volume of water in storage, reservoir elevations, releases from the dams, energy generation, streamflow, and diversions to and return flows from water users throughout the system.

Input data include physical parameters (such as individual reservoir storage capacity, evaporation rates, and reservoir release capabilities), initial reservoir conditions (**Appendix G**), demand schedules for entities in the Upper Division States (**Appendix L**), Lower Division States (**Appendix N**) and the United Mexican States (Mexico), and future hydrologic natural flows at 29 locations (**Section A.3** and **Appendix F**). This appendix focuses on the assumptions regarding reservoir operations, particularly at Lake Powell and Lake Mead, as those vary by alternative, and other physical process calculations in CRSS (energy generation and salinity). Additional modeling assumptions had to be developed to model the storage and delivery mechanisms for conserved water and are included in **Appendix B**.

A.2.1 Model Uncertainty

CRSS projections are subject to multiple sources of uncertainty. One source is the model, which is a simplified representation of a complex system. Another component of uncertainty is the need to estimate physical processes, such as reservoir evaporation and transpiration from plants. The most impactful source of uncertainty is the future itself; models rely on assumptions about how the hydrology, water demand, and policy and operations will unfold. Reclamation works with stakeholders and scientists to develop the best modeling practices and most appropriate assumptions in light of the purpose of the model. It is important to understand the purpose, approach, and assumptions associated with projections and their inherent uncertainty to properly interpret the information they provide. Within this context, CRSS remains the most suitable and robust tool available for the comparative purposes of this DEIS.

Projections are most sensitive to assumptions about future hydrology, and future flows are highly uncertain. Assumptions about future hydrology can produce very different pictures of risk. To address this challenge, the EIS applies a Decision Making Under Deep Uncertainty (DMDU) framework, described in **Appendix E**, which enables evaluation of outcomes across a wide range of plausible future hydrologic conditions.

BUREAU OF RECLAMATION

Map A-1
CRSS Modeled Reservoirs

Reservoir modeled in CRSS

Colorado River

Major Colorado River tributary

Colorado River Basin, Upper and Lower Basins

States in the Colorado River Basin (Wyoming, Colorado, Utah, and New Mexico are Upper Division states, and Arizona, California, and Nevada are Lower Division states)

The TMD Reservoir was excluded because it represents an aggregation of Colorado western slope transmountain diversion storage facilities, including Lake Granby, Willow Creek Reservoir, Dillon Reservoir, and Homestake Reservoir.

A.3 Hydrology

Hydrology inputs to CRSS are natural flows, which are the flows that would have been observed at a stream gage adjusted to remove the effects of upstream reservoirs and depletions. There are 21 Upper Basin natural flow points and 8 Lower Basin natural flow points as shown in **Map A-2**. The historical record for naturals flows is developed using the method published in Prairie and Callejo (2005). Starting with the release of the 1906-2020 natural flows in December 2022, the Lower Basin phreatophyte losses are no longer explicitly modeled in the development of natural flows. As such, these losses are now reflected in the computed intervening natural flows in the three reaches downstream of Hoover dam.

There are several methods for projecting possible future natural flow sequences or hydrology scenarios for the 29 natural flow points in CRSS. Because CRSS is a long-term model capable of projecting decades into the future, hydrologic inputs are derived from methods designed to represent future uncertainty in hydrologic variability and long-term change. These methods include resampling the historical record (either from the measured record or a derived record using a "proxy" such as tree-ring data), deriving future inflow data by preserving key statistics from the historical record while adding a random component, and using physically based hydrology models to simulate runoff based on general circulation model projections of temperature and precipitation. Reclamation chose 400 unique hydrologic sequences, or traces, to run through CRSS for the purposes of this DEIS to explore basin conditions under a broad range of flow characteristics and patterns. For more information about these traces and how they were selected, see **Appendix F**.

A.3.1 Glen Canyon Dam to Lees Ferry Accretion Flows

Geographically, the Lees Ferry subbasin (**Map A-2**) encompasses areas both upstream and downstream of Glen Canyon Dam, with the Lees Ferry gage serving as the downstream boundary. In CRSS, the Lees Ferry intervening natural flow is split such that a portion of the estimated gains and losses is introduced into the model above Glen Canyon Dam and a portion is introduced below it. The portion of the flow added to the reach below Glen Canyon Dam follows a monthly pattern based on historical data as shown in **Table A-1**, while the remaining portion of the Lees Ferry intervening natural flow is introduced to the reach above Glen Canyon Dam. The data in **Table A-1** are derived from the average difference between the Lees Ferry gaged flow and the Glen Canyon Dam releases from 2006 through 2021. Using this distribution, approximately 70 percent of the Lees Ferry intervening natural flow occurs above Lake Powell with the remaining 30 percent below Glen Canyon Dam.

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Map A-2
Colorado River Natural Flow Basins

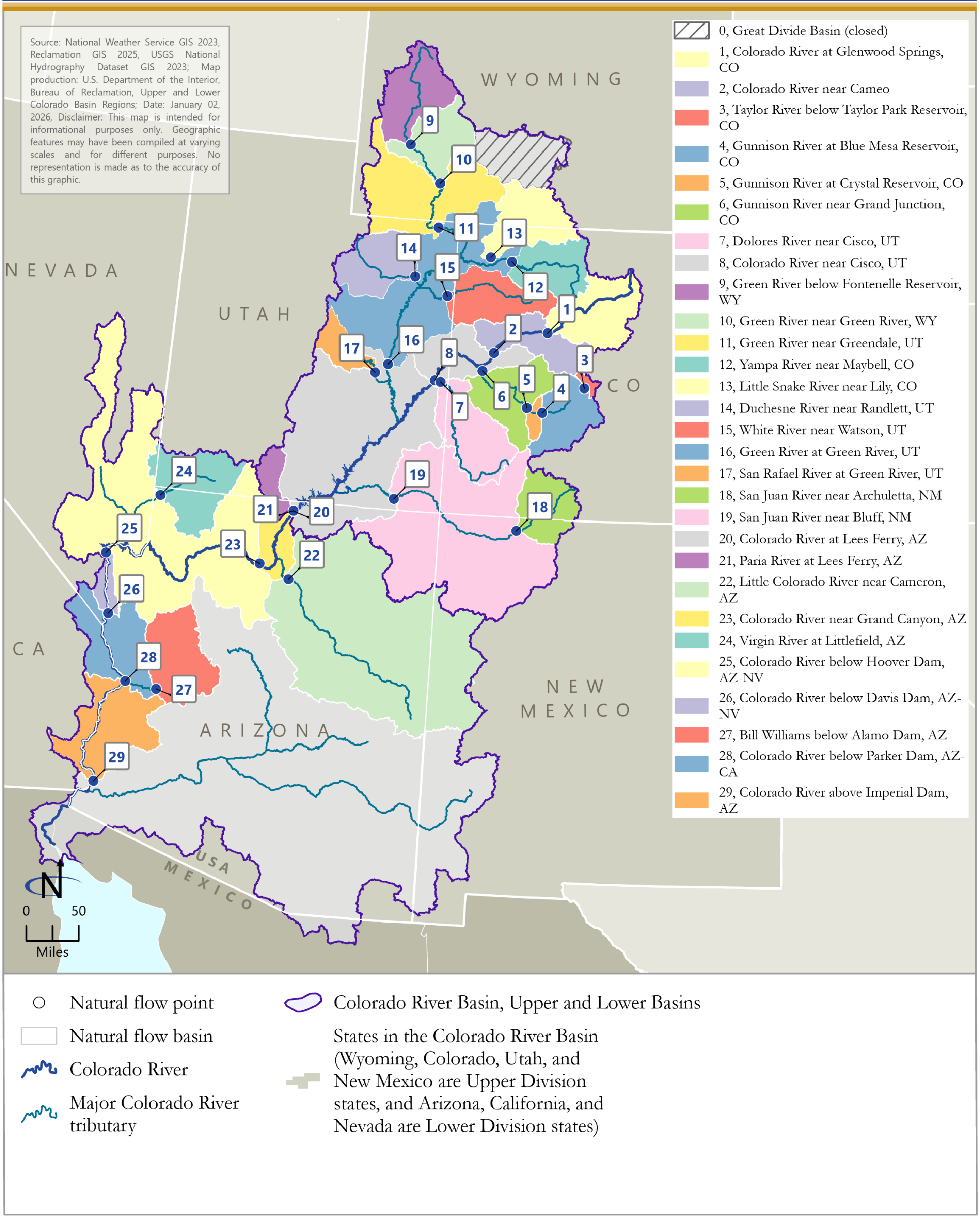


Table A-1
Gains & Losses for the Glen Canyon Dam to Lees Ferry Reach

Month	Average Gains & Losses (acre-feet)
January	11,200
February	8,800
March	9,700
April	12,200
May	13,100
June	13,500
July	19,400
August	19,100
September	14,300
October	11,300
November	6,000
December	7,900

A.4 Initial Reservoir Conditions

CRSS was initialized with three sets of initial conditions to cover a range of possible system conditions on December 31st, 2026. The initial conditions are described in **Appendix G**.

The changes in volume of water storage in all reservoirs are calculated by CRSS using relationship curves that are programmed into the model. These relationship curves relate the water surface elevation to live capacity, total capacity, and surface area for each respective reservoir. The latest available curves for Lake Powell and Lake Mead are available in Bradley and Collins (2022) and Reclamation (2011), respectively. The assumed maximum capacity of reservoirs that are used in one or more alternatives to determine Lake Powell or Lake Mead operations are provided in **Table A-2**.

Table A-2
Assumed Maximum Reservoir Storage from CRSS

Reservoir	Maximum Storage (1000 acre-ft)
Flaming Gorge	3,671
Blue Mesa	828
Navajo	1,648
Lake Powell	23,314
Lake Mead*	26,120
Lake Mohave	1,810
Lake Havasu	619

*Excluding 1.5 maf exclusive flood control space.

A.5 Operations Upstream of Lake Powell

In CRSS, 12 Upper Basin reservoirs and 222 Upper Basin water users are modeled. Upper Basin water users are distributed among the tributaries of the Upper Basin and aggregated by use sector. These sectors include agriculture, energy, environment, reservoir evaporation, exports, lease, municipal and industrial (M&I), and minerals. Each water user has a corresponding diversion and depletion schedule input into CRSS (see **Appendix L**). To achieve the full scheduled depletion, sufficient natural flow must be available within the corresponding reach to meet all scheduled diversions. When available natural flow is not available, users are unable to meet their "not pre-shorted" depletion schedules.

Upper Basin reservoirs modeled operations are consistent with their individual operation plans. Some facilities are operated to meet storage or elevation targets, while others feature environmentally regulated, controlled, consistent releases. Within the model, each reservoir has a set of rules to guide the specific operations. The model solves by using the logic in those operating rules. The following briefly describes the various Upper Basin reservoirs along with a high-level description of the logic in RiverWare for simulating operations within the Upper Basin. The operations of the Upper Basin reservoirs above Lake Powell are modeled the same for all alternatives except during Lake Powell infrastructure protection (PIP) releases (**Section A.5.11**).

In a rule-based model, general assumptions must be made for the model to solve. The rules developed for CRSS are, ideally, the best representation of operations that can be projected. In practice, however, there are sometimes differences between the projected operations produced by the model and actual operations. For example, many reservoirs in the Upper Basin are operated following the principles of adaptive management. As such, operations may be altered to meet various objectives of the reservoirs' adaptive management work groups on an ad hoc or experimental basis. Such ad hoc or experimental operations cannot be known in advance. As such, CRSS projections may differ from actual operations, even under similar hydrologic conditions.[1]

A.5.1 Available Water to Upper Basin Agricultural Water Users

Upper Basin agricultural water users are subject to limits on the natural flow available for diversion. CRSS applies a "percent available" factor, which represents that only a limited volume of natural flow is available to users on high tributaries that are not explicitly modeled. The "percent available" factors are calibrated in each reach to minimize streamflow bias at gaged locations during the historical verification period (2000 through 2024). In reaches where modeled streamflow underestimates observed flows (i.e., exhibits a negative bias), calibration reduces the percentage of natural flow available for diversion. This adjustment decreases depletions, increases modeled Upper Basin shortages and streamflow, and thereby reduces bias between modeled and historical streamflow.

[1] The Upper Initial Unit elevations reflected in this appendix are provided for NEPA analysis purposes only and do not reflect a federal position on what operations are appropriate or possible at low reservoir elevations. At Flaming Gorge, for example, operations that approach the low elevations described would likely reflect emergency operations where there is enough water remaining in Flaming Gorge for approximately one year of operations above minimum operating levels. Flaming Gorge operations at such low levels are likely inappropriate for non-emergency operations.

A.5.2 Fontenelle Reservoir

Fontenelle Reservoir is on the Green River about 24 miles southeast of La Barge, Wyoming. Fontenelle Reservoir is operated to meet various target elevations throughout the year while staying within practical and authorized limits.

A.5.3 Flaming Gorge Reservoir

Flaming Gorge Reservoir is on the Green River about 32 miles downstream of the Utah-Wyoming border and upstream of the confluence with the Yampa River. The operations of Flaming Gorge Reservoir meet the requirements detailed in the 2006 Record of Decision for the Operation of Flaming Gorge Dam Final Environmental Impact Statement (2006 Flaming Gorge ROD; Reclamation 2006a) that were designed to achieve the authorized purposes of the Colorado River Storage Project Act, while addressing environmental requirements. The 2006 Flaming Gorge ROD outlines the operational guidelines of Flaming Gorge and implements, to the extent possible, recommendations to assist in the recovery of four endangered fish species, outlined in the 2000 Flow and Temperature Recommendations for Endangered Fish in the Green River Downstream of Flaming Gorge Dam (Muth 2000).

Flaming Gorge operations are governed by the April through July unregulated inflow into the reservoir, which determines the corresponding hydrologic classification, spring peak, and base flow targets from the 2006 Flaming Gorge ROD (Reclamation 2006a) for the year. The April through July releases are modeled at the daily time step in CRSS to approximate the sub-monthly component of the spring peak targets. The model logic determines typical daily operations from April through July before summing up to a monthly release. During the March to April transition period, Flaming Gorge operations try to achieve a May 1 storage target (upper limit drawdown elevation). Actual annual operations at Flaming Gorge are determined in a consultation process with other agencies. CRSS cannot model these adaptive management decisions; therefore, model results do not include possible future adaptive management decision changes to the logic described above.

A.5.4 Strawberry Reservoir

Strawberry Reservoir is located in central Utah and is the terminal reservoir of the Strawberry Aqueduct and Collection System, which is part of the Central Utah Projection. Releases from Strawberry Reservoir operates to meet downstream flow targets and storage objectives. Diversions from the reservoir are made to the Utah Lake System based on the available volume in storage. Diversions are adjusted when Strawberry Reservoir's pool elevation is greater than 7,576.34 feet. Flood control releases are made from March through October if the storage exceeds 1.02 maf.

A.5.5 Starvation Reservoir

Starvation Reservoir is on the Strawberry River downstream of Strawberry Reservoir near Duchesne, Utah. Releases from Starvation Reservoir are set based on monthly flow targets and flood control operations. Flood control releases are made from March through October if the storage exceeds 165 kaf.

A.5.6 TMD Reservoir

The TMD Reservoir is an aggregate representation of Colorado western slope transmountain diversion (TMD) storage facilities, including Lake Granby, Willow Creek Reservoir, Dillon

Reservoir, and Homestake Reservoir. TMD Reservoir storage varies monthly based on hydrologic conditions and is reduced when downstream senior water rights, such as the Shoshone Powerplant or Grand Valley, experience shortages. Diversions from the TMD Reservoir are adjusted according to natural flow conditions, decreasing when supplies are abundant and increasing when they are limited. Outflows occur when the reservoir nears capacity and must release excess water. These modeled outflows are not meant to directly represent operations at the individual reservoirs.

A.5.7 Taylor Park Reservoir

Taylor Park Reservoir is on the Taylor River, a tributary of the Gunnison River on the western slope of Colorado's Rocky Mountains. Taylor Park Reservoir is operated with a rule curve to meet various target elevations throughout the year, while staying within practical and authorized limits.

A.5.8 Aspinall Unit Reservoirs – Blue Mesa, Morrow Point, and Crystal

The Aspinall Unit consists of three reservoirs—Blue Mesa, Morrow Point, and Crystal—in series along the Gunnison River in western Colorado. The operations of the Aspinall Unit meet the requirements detailed in the April 2012 Record of Decision for the Aspinall Unit Operations Final Environmental Impact Statement (2012 Aspinall ROD; Reclamation 2012) and the decree quantifying the Federal Reserved Water Right for the Black Canyon of the Gunnison, which specify the spring peak outflow hydrographs and base flows for the rest of the year based on the hydrologic conditions upstream of Blue Mesa Reservoir. The 2012 Aspinall ROD provides specifications to avoid jeopardizing the continued existence of fish listed under the Endangered Species Act and to ensure the dam's operations do not result in the destruction or adverse modification of critical habitat in the Gunnison River.

Aspinall Unit operations are governed by the April through July unregulated inflow into the reservoir, which determines spring peak and base flow targets for the rest of the year based on the hydrologic conditions above Blue Mesa Reservoir. CRSS approximates daily flow targets in the 2012 Aspinall ROD and Federal Reserved Water Right for the Black Canyon of the Gunnison by first modeling typical daily operations for both the spring and baseflow periods and then summing to a monthly release. Morrow Point and Crystal Reservoirs are modeled to maintain elevation targets of 7,153.73 and 6,753.04 feet, respectively.

A.5.9 McPhee Reservoir

McPhee Reservoir is the primary storage facility of the Dolores Project, located on the Dolores River in southwestern Colorado. Inflows to the McPhee Reservoir are derived from the Cisco-Dolores natural flow with volumes split between the Dolores River and McPhee Reservoir based on hydrologic conditions. An environmental pool is tracked in McPhee Reservoir and can be used to meet target monthly environmental releases. The environmental pool is reset every October to the minimum of either 13% of the previous month's storage or the maximum environmental pool capacity of 29,300 acre-feet. Water stored in McPhee Reservoir is primarily used to meet the demands of the Dolores Project, with inflows used first and stored water, excluding the environmental pool, used when inflows are insufficient.

A.5.10 Navajo Reservoir

Navajo Reservoir is on the San Juan River above the confluence with the Animas River. The reservoir is operated to meet environmental requirements outlined in the July 2006 Record of Decision for the Navajo Reservoir Operations, Navajo Unit-San Juan River New Mexico, Colorado, Utah Final Environmental Impact Statement (Reclamation 2006b). Navajo Reservoir also provides for the diversion of Navajo Indian Irrigation Project (NIIP) water from Navajo Reservoir, and other municipal and industrial uses throughout the San Juan Basin. The minimum active storage at Navajo Reservoir is at 5,990 feet; at that point, the NIIP can no longer divert water.

Navajo Reservoir operations are modeled to first meet the environmental baseflow requirements at downstream gages stated in the July 2006 Record of Decision for the Navajo Reservoir Operations, Navajo Unit-San Juan River New Mexico, Colorado, Utah Final Environmental Impact Statement (Reclamation 2006b); because of the CRSS spatial scale, it is assumed that all flow targets are for the San Juan River near Bluff, New Mexico. If available additional water is released as a spring peak, a spring release pattern is selected to bring Navajo Reservoir closest to the September 30 storage target, while staying within practical and authorized limits, including maintaining NIIP diversions. If the reservoir pool elevation is projected to go below 5,990 feet, the minimum elevation for NIIP diversions, the outflow, and NIIP diversions are proportionally reduced.

A.5.11 Powell Infrastructure Protection Releases

Powell Infrastructure Protection (PIP) releases are modeled as releases from Upper Initial Units under low elevation conditions at Lake Powell in the Continued Current Strategies comparative baseline, Basic Coordination Alternative, and Supply-Driven Alternative. The PIP release modeling assumptions are simplifications of the actual PIP process, which, like the Drought Response Operations Agreement, involves collaborative decision-making among stakeholder workgroups and includes subjective judgments that cannot be captured in a model. The modeled PIP releases represent a potential range of releases actual releases may be lower, higher, or may not occur, and do not reflect the views of all stakeholders. These modeling assumptions are intended solely for NEPA analysis and do not reflect a position by Reclamation on operations that might be implemented under a PIP collaborative process.

Continued Current Strategies

The PIP release method under Continued Current Strategies is described below.

Powell Trigger

PIP releases from the Upper Initial Units (Flaming Gorge, Blue Mesa, and Navajo Reservoirs) are triggered when Lake Powell is projected to fall below elevation 3,525 feet. In April and August, CRSS uses a regression model to project the following March 31 Lake Powell pool elevation by estimating Powell inflows based on monthly natural flow and Upper Basin demands (see **Section A.6.2**, *Lake Powell Inflow Forecast*). Using these projected inflows and the projected Lake Powell release, CRSS determines the expected Lake Powell pool elevation. If the projection indicates that Lake Powell will drop below 3,525 feet, CRSS calculates the volume needed to reach the protection elevation of 3,525 feet (deficit volume) and initiates PIP releases to address the deficit.

Available Volume

The total volume from each UIU available for contribution to PIP releases is limited to the amount of water stored above the designated lower limit elevation. For each reservoir, a forecasting algorithm estimates the elevation for the future annual operating target month. These forecasts assume daily spring flow release patterns followed by baseflow releases under the same hydrologic conditions throughout the forecast period.

The lower limit elevation and annual operating target month for each reservoir is listed below:

- Flaming Gorge: 5,890 feet in April (May 1), which is 19 feet above minimum power pool. Typical May 1 targets range from 6,027 to 6,023 feet depending on the hydrologic conditions.
- Blue Mesa: 7,424.21 feet in December, reflecting the minimum water surface elevation (7,393 feet) plus 80,000 acre-feet of Uncompahgre Project contract water storage. In a typical year, Blue Mesa is operated to achieve a December elevation of 7,490 feet to prevent icing.
- Navajo: Minimum end of water year storage target (EOWST) in September, which increases from 6,030 feet in 2027 to 6,052 feet in 2045. These elevations are based on minimum water surface elevation of 5,990 feet, and account for contract water storage (33,500 acre-feet for the Jicarilla Apache Nation and 23,000 acre-feet for the Hammond Water Conservancy District) and NIIP build-out. In years without PIP releases, CRSS forecasts if sufficient water will be available above the EOWST elevation of 6,050 feet to conduct a spring release. After 2043, Navajo will no longer participate in PIP releases because its minimum EOWYST will exceed the 6,050-foot threshold required for a standard spring release.

Lower limit elevations are used to determine the available volume and the annual operational targets, but rules do not protect and/or maintain lower limit storage on a month-to-month basis. UIUs can fall below lower limits, which may prevent them from meeting future environmental targets.

Releases

Maximum Annual Release

There is no maximum annual release specified.

Distribution of Releases

The total contribution to PIP releases is determined by the volume needed to reach 3,525 feet or by the total volume available in the UIUs, whichever is smaller. CRSS allocates this total contribution proportionally between Flaming Gorge and Blue Mesa based on the volume available above each reservoir's lower elevation limit. Navajo contributes during spring operations using any volume available beyond the volume used in a normal spring release. This contribution is factored into the proportional distribution between Flaming Gorge and Blue Mesa. Flaming Gorge's assigned contribution is increased if the proportional contributions do not equal the forecast deficit.

UIU Operational Adjustments
Each UIU's operations are adjusted within their Records of Decision to release an additional volume equal to the assigned contribution by modifying their operating targets. Annual contributions for each UIU are estimated at the end of each UIU's operating year.

Flaming Gorge
Flaming Gorge's May 1 target is lowered by its assigned contribution. If the reservoir did not reach its normal May 1 target in the previous year due to PIP releases, the prior May 1 elevation is adjusted by the new assigned contribution. The May 1 target elevation cannot be lower than 5,890 feet (lower limit elevation). Operations are adjusted based on the sub annual flow regime as follows:

- Spring: No changes to the Spring operations are modeled. Spring operations are modeled by a daily hydrograph which ramps up from baseflow to peak and back to baseflow. Operations vary by hydrologic classification and peak timing.
- Baseflow: The release in baseflow is the greater of the steady release to achieve the May 1 target or the minimum for Reach 2 (Jensen, UT) for the hydrologic classification. The release in all baseflow months is constrained further by the minimum and maximum for Reach 1 (below Flaming Gorge). All maximum and minimum flows are from the 2022 Drought Response Operation Plan[2], which uses the +/- 40% or 25% flexibility in the Record of Decision and vary by season.

Transition: Releases during the transition period in March and April are constrained to a maximum of 2,000 cfs, which is based on an operator estimate of F&WS/Recovery Program preference [3].

Blue Mesa
Monthly releases from Blue Mesa are the greater of three criteria: the flow required to meet the Whitewater Target for the current hydrologic classification under the Record of Decision, the Federal Reserve Water Right in the Black Canyon of the Gunnison National Park, and the flow needed to meet the guide curve storage target. Blue Mesa operations are adjusted by lowering the monthly guide curve by the assigned contribution; therefore, PIP releases only occur when the modified guide curve becomes the controlling factor. If PIP releases occurred in the prior year, the starting elevation is adjusted downward. The guide curve reduction increases gradually each month until December, when the full assigned volume is reached. The monthly guide curve storage target cannot drop below 7,424.21 feet. Releases from August through April are further limited by the Crystal Powerplant capacity.

Navajo
Navajo's PIP releases occur only during the spring release period and are based on the volume available above the EOWYST of 6,050 feet after meeting baseflow requirements. Increased releases outside of spring do not help achieve Record of Decision operational targets. Navajo's total assigned contribution is the volume above its lower limit EOWYST minus the volume used in normal spring operations. Navajo will only participate in UIU contributions in April, not August and must recover

[2] Attachment C - Appendix 1, Estimated Normal / Maximum / Minimum Summer to Winter Baseflows in the Green River downstream from Flaming Gorge Dam, page 84-85.
[3] Typically, the transition period is the unconstrained release to achieve the May 1 target.

before contributing again, which occurs once it is at or above 6,063 feet at the end of the water year or conducts a spring peak release lasting at least 21 days.

Recovery

Recovery of the UIUs is not explicitly modeled. Instead, the reservoirs naturally recover in years without PIP releases as they return to their normal annual operating targets.

No Action Alternative

There are no PIP releases modeled in the No Action Alternative.

Basic Coordination Alternative

The PIP release method under the Basic Coordination Alternative is identical to that of Continued Current Strategies.

Enhanced Coordination Alternative

There are no PIP releases modeled in the Enhanced Coordination Alternative.

Maximum Operational Flexibilities Alterative

There are no PIP releases modeled in the Maximum Operational Flexibilities Alterative.

Supply-Driven Alternative

The PIP release method under the Supply-Driven Alternative is the same as that of Continued Current Strategies except as noted in the following sections.

Powell Trigger

PIP releases are triggered when Lake Powell falls below elevation 3,525 feet in any month. If Lake Powell is below the protection elevation of 3,525 feet, CRSS calculates the volume needed to reach the protection elevation and initiates PIP releases to address the deficit.

Available Volume

The modeling assumptions for the Available Volume are the same as Continued Current Strategies except only Flaming Gorge is assumed to participate in PIP releases.

Releases

Maximum Annual Release

The maximum annual release from Flaming Gorge is 500 kaf.

Distribution of Releases

The total contribution to PIP releases is determined by the volume needed to reach 3,525 feet or by the total volume available in the Flaming Gorge, whichever is less.

UIU Operational Adjustments

The UIU operational adjustments for Flaming Gorge are identical to assumptions in Continued Current Strategies.

Recovery
Flaming Gorge can naturally recover by returning to its normal annual operating targets once Lake Powell is above 3,535 feet.

A.6 Lake Powell Operation

Lake Powell is the most downstream reservoir in the Upper Basin; it is impounded by Glen Canyon Dam near Page, Arizona, Glen Canyon Dam is 17 miles upstream of Lee Ferry, the delineation point between the Upper and Lower Basins.

Section A.6.1 describes modeling assumptions common to all alternatives. **Sections A.6.2** through **A.6.7** describe model assumptions for Lake Powell operating strategies for the comparative baseline and each alternative. The Lake Powell mechanism for the storage and delivery of conserved system and non-system water is summarized in **Appendix B**.

A.6.1 Assumptions Common to All Alternatives

Lake Powell operates on a water year (October through September) basis with an annual operating year release set at the beginning of the water year with possible adjustments throughout the year.

Disaggregation from Annual to Monthly Release

Lake Powell operating year releases are disaggregated to monthly releases using the Long-term Experimental and Management Plan release patterns. The Lake Powell assumed monthly releases for CRSS are in **Table Attachment A1-1**. In CRSS, the operating year release pattern that is less than or equal to the operating year release is selected from **Table Attachment A1-1**. The monthly release is then calculated by multiplying the remaining operating year release by the proportion of flow released in the given month relative to the remainder of the water year for the determined release pattern. The minimum monthly release is set to 6,521 cfs, which is consistent with the Long-term Experimental and Management Plan daily minimum release.

Safe Operating Capacity Operations

If Lake Powell is nearing maximum capacity, Lake Powell's outflow is set to a volume needed to reach seasonal storage targets designed to maintain a safe operating capacity. For January through July, the model calculates the monthly release needed to meet the July Powell storage target (500 kaf below live capacity). Likewise, for August through December, the model calculates a monthly outflow needed to meet the December Powell storage target (2.422 maf below live capacity). The monthly constrained release (i.e., through the powerplant and river outlet works) is a maximum of 48,100 cfs.

Infrastructure Constraints at Low Elevations

The monthly releases can be constrained due to physical limitations at Glen Canyon Dam. Water can be released through the powerplant turbines until the pool elevation drops below 3,490 feet. Once Lake Powell is below 3,490 feet, releases are made through four river outlet works. The capacity of the river outlet works varies with the elevation of Lake Powell; the higher the pool elevation, the higher the potential release through the river outlet works. CRSS computes the maximum monthly release based on the Lake Powell elevation using **Table A-3** and interpolates for the capacity between elevations. The release capacity for each river outlet work is provided in the LaFond (2024) technical decision memorandum. For modeling purposes, three out of four river outlet works are assumed to be available for use at any given time; this is because of the need for periodic inspections and any associated maintenance activities. Reclamation believes this is a reasonable estimation given the historical and future operations and maintenance requirements for the river outlet works. If a monthly release is constrained, the volume is tracked and is attempted to be released later in the operating year to maintain the desired operating year release, if possible.

Table A-3
CRSS Modeled River Outlet Works' Capacity by Lake Powell Elevation

Lake Powell Elevation	Capacity (1 river outlet work)		Capacity (3 river outlet works)	
feet	cfs	kaf/yr	cfs	kaf/yr
3,390	0	0	0	0
3,400	1,200	869	3,600	2,606
3,410	1,800	1,303	5,400	3,909
3,420	2,200	1,593	6,600	4,778
3,430	2,439	1,766	7,317	5,297
3,440	2,580	1,868	7,740	5,604
3,450	2,711	1,963	8,133	5,888
3,460	2,837	2,054	8,511	6,162
3,470	2,958	2,141	8,874	6,424
3,480	3,073	2,225	9,219	6,674
3,490	3,185	2,306	9,555	6,918

A.6.2 Continued Current Strategies

The Continued Current Strategies comparative baseline assumes that existing agreements, including the 2007 Interim Guidelines, 2017 Minute 323, and 2019 DCP continue through the analysis period (2027-2060). In January, Lake Powell operating tiers are determined based on the previous end-of-calendar-year (EOCY) pool elevation at Lake Powell. This is a modeling simplification, rather than using an August based projection of December 31 conditions, as specified in the 2007 Interim Guidelines. For October through December of the current water year, 2.0 maf is released consistent with 8.23 maf monthly release pattern unless Lake Powell is in Safe Operating Capacity Operations (**Section A.6.1**) or otherwise specified based on water year releases at 7.48 maf or lower (**Table Attachment A1-1**). In January, CRSS sets the Lake Powell operating tier and operating year release as follows:

- If the Lake Powell EOCY pool elevation is greater than or equal to the Equalization Level (**Table A-6**), the Equalization Tier operations govern the operating year releases.
- If the Lake Powell EOCY pool elevation is less than the Equalization Level and greater than or equal to 3,575 feet, the Upper Elevation Balancing Tier governs the operating year releases.

- If the Lake Powell EOCY pool elevation is less than 3,575 feet and greater than or equal to 3,525 feet, the Mid-Elevation Release Tier governs the operating year releases.
- If the Lake Powell EOCY pool elevation is less than 3,525 feet, the Lower Elevation Balancing Tier governs the operating year releases.

Additional details on modeled operations in each of these tiers are included in the following sections.

Lake Powell Inflow Forecast

The Lake Powell inflow forecast is used to estimate future Lake Powell storage. The unregulated Lake Powell inflow forecast from the current month through the forecasted month is computed as:

$$unregulated\ Lake\ Powell\ inflow = natural\ flow\ above\ Lake\ Powell - estimated\ Upper\ Basin\ depletions + the\ forecast\ error$$

The *estimated Upper Basin depletions* (consumptive use) are computed using a logistic regression equation. The following formula operates at a monthly level, using the parameters outlined in **Table A-4**. The coefficients were estimated using modeled CRSS depletions as the predicant, and monthly input natural flow and Upper Basin demands as the predictors using data from the Colorado River Post-2026 Operations Exploration Tool[4].

$$UBDep_i = p1_i * \left(1.0 - \frac{1.0}{1 + e^{2.718 - p3_i * (NF_i - p2_i)}}\right) - p4_i * \left(\frac{UBDem_{Ann}}{1 + e^{2.718 - p6_i * (NF_i - p5_i)}}\right)$$

where:

i = month,
$UBDep$ = estimated total Upper Basin depletion (use) for month i in maf,
NF = total natural flow above Lees Ferry for month i in af,
$UBDem_{Ann}$ = total Upper Basin demand for the year in maf, and
$p1, p2, p3, p4, p5, p6$ = coefficients for the logistic regression equation (**Table A-4**).

Table A-4
Monthly Estimated Upper Basin Depletion Equation Coefficients

Month	*p1* (af)	*p2* (af)	*p3* (1/af)	*p4* (none)	*p5* (af)	*p6* (1/af)
January	0.7775	-4.5631	0.6096	0.7962	8.6430	0.5274
February	0.5652	-13.4136	0.1904	0.1406	8.5226	0.3441
March	0.0582	-2.3241	-5.5242	0.0121	-0.1326	2.8745
April	0.0900	0.2109	-6.1404	0.0347	-0.3668	1.0723
May	0.7588	0.1828	-0.8157	2.348E-09	-6.9129	-4.9230
June	1.1473	0.6672	-0.7058	2.129E-05	-7.4173	-13.9783
July	3.5042	-6.7974	4.8519	0.1977	0.5144	1.2987

[4] www.crbpost2026dmdu.org

Month	*p1* (af)	*p2* (af)	*p3* (1/af)	*p4* (none)	*p5* (af)	*p6* (1/af)
August	0.2381	-5.7046	-3.7719	0.0797	0.4006	3.0123
September	0.1087	-2.2124	-5.8441	0.0539	-0.0214	2.7065
October	0.0478	-1.6741	-7.1793	0.0277	-0.1222	3.2833
November	1.3998	-4.0494	0.9816	0.0149	-0.0457	1.7068
December	1.0081	-1.2688	2.2497	0.0182	0.2702	2.9061

The *forecast error* is computed using equations derived from an analysis of past Colorado River forecasts and runoff data for the period 1947 to 1983. An analysis of these data reveals two strongly established patterns: (1) high runoff years are under-forecast, and low runoff years are over-forecast; and (2) the error in the current month's seasonal forecast is strongly correlated with the error in the preceding month's forecast (Reclamation 1985). A regression model was developed to aid in determining the error to be incorporated into the seasonal forecast for each month from January to June. The error in months after June is assumed to be negligible compared to the error during the runoff season. The error is the sum of a deterministic component and a random component. The deterministic component is computed from the regression equation. The random component is computed by multiplying the standard error of the regression equation by a random mean deviation selected from a standard normal distribution. The forecast error equation has the following form (all runoff units are maf):

$$E_i = a_i X_i + b_i E_{(i-1)} + c_i + Z_r d_i$$

where:

i = month,
E_i = error in the forecast for month i,
X_i = natural runoff into Lake Powell from month i through July,
a_i = linear regression coefficient for X_i,
$E_{(i-1)}$ = previous month's forecast error,
b_i = linear regression coefficient for $E_{(i-1)}$,
c_i = constant term in regression equation for month i,
Z_r = randomly determined deviation, and
d_i = standard error of estimate for regression equation for month i.

Table A-5 summarizes the regression equation coefficients for each month.

Table A-5
Lake Powell Inflow Forecast Regression Equation Coefficients

Month	a_i	b_i	c_i	d_i
January	0.70	0.00	-8.195	1.270
February	0.00	0.80	-0.278	0.977
March	0.00	0.90	0.237	0.794
April	0.00	0.76	0.027	0.631
May	0.00	0.85	0.132	0.377
June	0.24	0.79	0.150	0.460

The magnitude of the June forecast error is constrained to not exceed 50 percent of the May forecast error and the July forecast error is equal to 25 percent of the June forecast error.

Predicting End-of-Water-Year Volumes of Lake Powell and Lake Mead

Lake Powell end-of-water-year (EOWY) volume is predicted each month by taking the end of the previous month's storage, adding the forecasted inflow as described in the previous section, subtracting the estimated release, and subtracting the estimate of evaporation and change in bank storage. All estimated values are for the period from the current month through September. The estimated release is based on the operation of the alternative. The estimated evaporation and bank storage losses are based on an initial estimate of the EOWY volume.

Similarly, the Lake Mead EOWY volume is predicted each month by taking the end of previous month's volume, adding the estimated Lake Powell release, subtracting the estimated Lake Mead release, adding the average gain between Lake Powell and Lake Mead, subtracting the Southern Nevada depletion, and subtracting the estimate of evaporation and change in bank storage. Again, all values are for the period from the current month through September. Lake Mead's release is estimated as the sum of the depletions downstream of Lake Mead and the reservoir regulation requirements (including evaporation losses) for Lake Mohave and Lake Havasu minus/plus the gains/losses below Lake Mead.

Equalization Tier

Under Continued Current Strategies, the equalization of storage between Lake Powell and Lake Mead is modeled with a rule that first determines if equalization needs to occur, and if so, then the rule determines how much water would be released to equalize Lakes Powell and Mead. The rule is in effect from January through September of each year. The rule states that equalization occurs if two criteria are met: (1) if the previous end-of-year Lake Powell elevation is greater than or equal to the Equalization Level (see **Table A-6**); and (2) if the projected EOWY storage in Lake Powell is greater than or equal to the projected EOWY storage in Lake Mead (the previous section describes EOWY projections). For modeling purposes, the Equalization Level used in Continued Current Strategies extends the 2007 Interim Guidelines Equalization Level through 2060, using the same calculation and parameters that were used to develop the 2007 Interim Guidelines Equalization Level. **Appendix J** describes the 602(a) storage calculation, which forms the basis for the Equalization Level under the 2007 Interim Guidelines. It documents the parameters used in the 2007 calculation, which are also used in this extension through 2060. **Appendix J** also presents a comparison illustrating how different parameter assumptions would influence the resulting 602(a) storage values.

If operating in the Equalization Tier, the operating year release is computed as the release required to balance the contents of Lake Powell and Lake Mead by the end of the water year and constrained such that the release does not cause Lake Powell to decline below the Equalization Level unless Lake Mead is less than 1,105 feet. If Lake Mead is projected to decline below 1,105 feet, then Lake Powell's release is increased until the first of the following three conditions occurs: 1) the reservoirs storage is equal, 2) Lake Mead EOWY storage is 1,105 feet, or 3) Lake Powell EOWY elevation is 20 feet below the Equalization Level Line. The monthly release from Lake Powell is then calculated using the method as described under **Section A.6.1**, *Disaggregation from Annual to Monthly Release*.

Table A-6
Lake Powell Equalization Level Table

Year	Equalization Elevation (feet)	Year	Equalization Elevation (feet)
2027	3,667	2044	3,688
2028	3,668	2045	3,689
2029	3,670	2046	3,690
2030	3,671	2047	3,691
2031	3,672	2048	3,692
2032	3,673	2049	3,693
2033	3,674	2050	3,694
2034	3,675	2051	3,695
2035	3,677	2052	3,695
2036	3,678	2053	3,696
2037	3,679	2054	3,696
2038	3,680	2055	3,697
2039	3,682	2056	3,697
2040	3,683	2057	3,697
2041	3,684	2058	3,698
2042	3,686	2059	3,698
2043	3,687	2060	3,698

Upper Elevation Balancing Tier

Operations in the Upper Elevation Balancing Tier differ depending on the month. In January through March, if the Lake Mead EOCY pool elevation is less than 1,075 feet, the operating year release necessary to balance Lake Powell and Lake Mead projected EOWY storage (as calculated in **Section A.6.2,** *Predicting End-of-Water-Year Volumes of Lake Powell and Lake Mead*) is calculated but constrained to be within the range of 7.0 to 9.0 maf. If the Lake Mead EOCY pool elevation is greater than or equal to 1,075 feet, then set the operating year release to 8.23 maf.

In April, Lake Powell can switch to equalization operations if the projected Lake Powell EOWY pool elevation is above the Equalization Level and the projected Lake Powell EOWY storage is greater than the projected Lake Mead EOWY storage. If operating in equalization, the operating year release is set based on equalization logic (described in the previous section) and constrained to a minimum of 8.23 maf.

Otherwise, if Lake Powell's projected EOWY pool elevation is less than or equal to the Equalization Level, Lake Powell's releases are modeled as follows:

- If the year started by balancing contents between Lake Powell and Lake Mead constrained between 7.0 and 9.0 maf, continue these operations for the remainder of the water year
- If the April projected Lake Mead EOWY pool elevation is less than 1,075 feet and the April projected Lake Powell EOWY pool elevation is greater than 3,575 feet, then compute the operating year release necessary to balance Lake Powell and Lake Mead projected EOWY storage, constrained between 8.23 maf and 9.0 maf.
- Otherwise (the April projected Lake Mead EOWY pool elevation is greater than 1,075 feet or the April projected Lake Powell EOWY pool elevation is less than 3,575 feet), continue with an operating year release of 8.23 maf.

The monthly release from Lake Powell is then calculated using the method as described under **Section A.6.1**, *Disaggregation from Annual to Monthly Release*.

Mid-Elevation Release Tier

At the beginning of the water year, if Lake Powell elevation is less than 3,575 feet and greater than or equal to 3,525 feet, and Mead is greater than or equal to 1,025 feet, Lake Powell will release a 1.58 maf over the months of October through December opposed to a 2.0 maf release. At the beginning of the calendar year, the Lake Powell operating tier is set. If the operating tier is the Mid-Elevation Release Tier, CRSS will check the Lake Mead EOCY pool elevation. If the Lake Mead EOCY pool elevation is greater than or equal to 1,025 feet, Lake Powell's operating year release is set to 7.48 maf. Otherwise, the operating year release is set to 8.23 maf. The monthly release from Lake Powell is then calculated using the method described in **Section A.6.1**, *Disaggregation from Annual to Monthly Release*.

Lower Elevation Balancing Tier

The Lower Elevation Balancing Tier (Lake Powell elevation less than 3,525 feet) is modeled by calculating the release necessary to balance Lake Powell and Lake Mead's projected EOWY storage (as calculated in **Section A.6.2**, *Predicting End-of-Water-Year Volumes of Lake Powell and Lake Mead*) but constrained to be within the range of 7.0 to 9.5 maf. The monthly release from Lake Powell is then calculated using the method described in **Section A.6.1**, *Disaggregation from Annual to Monthly Release*.

Reduced Releases in the Mid-Elevation Release and Lower Elevation Balancing Tiers

The 2024 Near-term Colorado River Operations Final Supplemental Environmental Impact Statement (Reclamation 2024) states:

> When operating in the Mid-Elevation Release Tier or the Lower Elevation Balancing Tier, Reclamation will consider all tools that are available during the interim period to avoid Lake Powell elevation declining below 3,500 feet. If the minimum probable 24-Month Study projects in any month an elevation below 3,500 feet in the next 12 months, the Secretary shall begin planning to reduce releases, as needed, to not less

than 6.0 maf from Lake Powell in the Water Year to maintain an elevation of 3,500 feet[5].

In CRSS, this is modeled by assuming Lake Powell operations can be adjusted to protect 3,500 feet in any month when Lake Powell is operating in the Mid-Elevation Release Tier or Lower Elevation Balancing Tier. CRSS first checks the current month's Lake Powell pool elevation and the projected EOWY Lake Powell pool elevation with an assumed 6 maf release to determine the monthly release.

- If the projected EOWY Lake Powell pool elevation with a 6 maf is less than 3,500 feet, the operating year release is set to 6.0 maf and the monthly release is calculated using the method described in **Section A.6.1**, *Disaggregation from Annual to Monthly Release*
- If the current Lake Powell pool elevation is below 3,500 feet but the projected EOWY Lake Powell pool elevation is greater than 3,500 feet, the current month's release is decreased such that the Lake Powell pool elevation is maintained at or above 3,500 feet; however, it is subject to the following constraints: the minimum water year release is 6.0 maf, and the monthly release will be no less than the volume necessary to meet the minimum daily LTEMP release (6,521 cfs).

If releases are adjusted to protect 3,500 feet during a given month of the water year and Lake Powell pool elevation increases above 3,500 feet, monthly releases can be increased to release up to the original operating year release for the given Lake Powell operating tier.

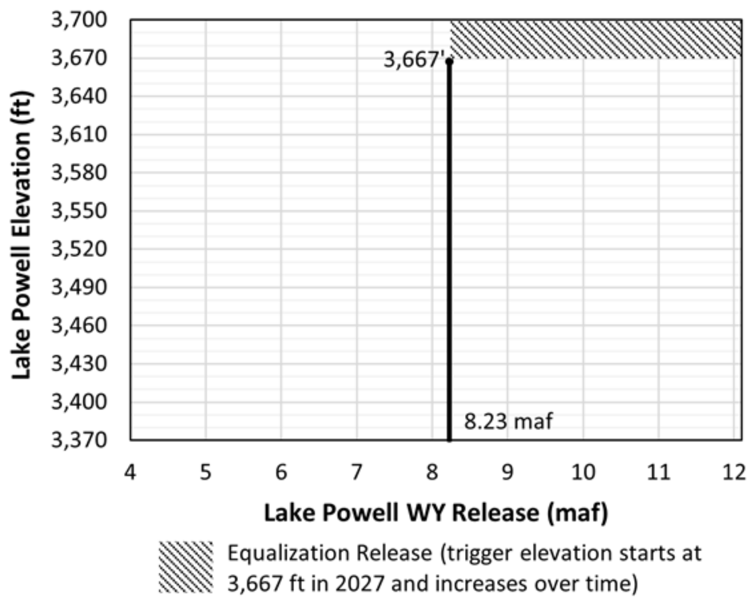
A.6.3 No Action Alternative

In the No Action Alternative, Lake Powell annual operations are assumed to be based on the EOCY pool elevation at Lake Powell (**Figure A-1**). For October through December, 2.0 maf is released consistent with 8.23 maf monthly release pattern (**Table Attachment A1-1**) unless Lake Powell is in Safe Operating Capacity Operations (**Section A.6.1**, *Safe Operating Capacity Operations*). In January, CRSS sets the Lake Powell operations using the EOCY pool elevation:

- If the Lake Powell EOCY pool elevation is greater than or equal to the Equalization Level (**Table A-6**), the equalization operations govern the operating year releases. For modeling purposes, the Equalization Level used in the No Action Alternative extends the 2007 Interim Guidelines Equalization Level through 2060, using the same calculation and parameters that were used to develop the 2007 Interim Guidelines Equalization Level. **Appendix J** describes the 602(a) storage calculation, which forms the basis for the Equalization Level under the 2007 Interim Guidelines. It documents the parameters used in the 2007 calculation, which are also used in this extension through 2060. **Appendix J** also presents a comparison illustrating how different parameter assumptions would influence the resulting 602(a) storage values.
- If the Lake Powell EOCY pool elevation is less than the Equalization Level, the operating year release is set to 8.23 maf.

[5] The Secretary reserves the right to operate Reclamation facilities to protect the Colorado River system if hydrologic conditions require such action as described in Sections 6 and 7(D) in the 2007 Interim Guidelines ROD.

Figure A-1
Lake Powell Operations, No Action Alternative



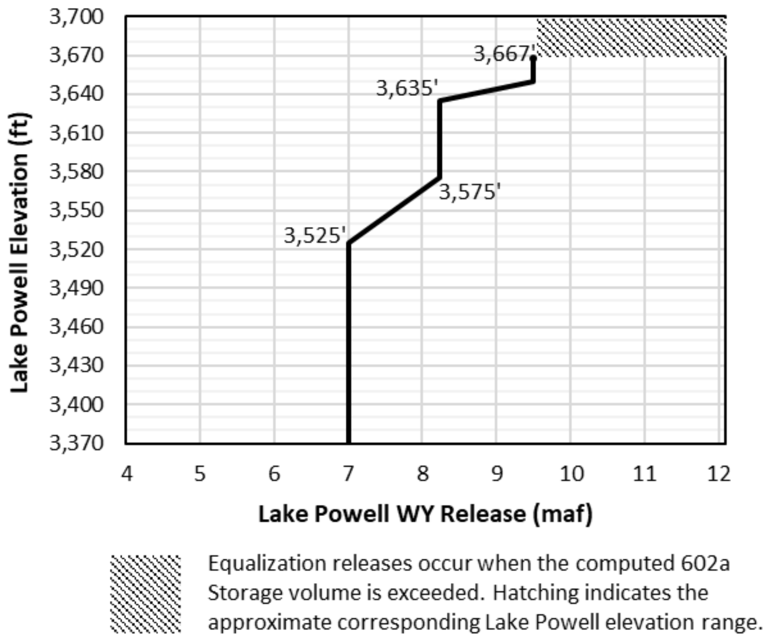
Coordination at High Elevations
Under the No Action Alternative, equalization releases are made from January to September. The operating year release is computed as the release required to balance the contents of Lake Powell and Lake Mead by the end of the water year with a minimum release of 8.23 maf and constrained such that the release does not cause Lake Powell to decline below the Equalization Level (**Table A-6**). The monthly release from Lake Powell is then calculated using the method described in **Section A.6.1**, *Disaggregation from Annual to Monthly Release*.

Primary Operations
Minimum objective release operations set operating year release to 8.23 maf. The monthly release from Lake Powell is then calculated using the method described in **Section A.6.1**, *Disaggregation from Annual to Monthly Release*.

A.6.4 Basic Coordination Alternative
The Lake Powell operating year release is determined in October based on the previous EOWY Lake Powell storage/pool elevation (September 30).

- If the Lake Powell previous EOWY storage is greater than or equal to the 602(a) storage volume, the equalization operations govern the operating year releases.
- If the Lake Powell previous EOWY storage is less than the 602(a) storage volume, the operating year release is set based on the EOWY pool elevation as shown in **Figure A-2**.

Figure A-2
Lake Powell Operations Diagram, Basic Coordination Alternative



Coordination at High Elevations

If the combined Colorado River Storage Project (CRSP) storage is above the 602(a) storage volume at the previous EOWY, equalization operations determine the operating year release. A detailed description of the 602(a) storage volume calculation and parameters used in the calculation is found in **Appendix J**. For modeling purposes, the same parameters that were used to compute the 602(a) storage volume for the 2007 Interim Guidelines Equalization line are used for the Basic Coordination Alternative. In this alternative, the 602(a) storage volume is not converted to a Powell elevation. The operating year release is set to the minimum of the volume needed to bring the CRSP storage down to the calculated 602(a) storage volume[6] or to balance the Lake Powell and Lake Mead projected EOWY storage, but no lower than 9.5 maf (the maximum release in primary operations). The modeled 602(a) storage volume grows over time; in 2027, the volume is 25,082,344 af and in 2060 it reaches 29,647,144 af. Equalization may only be triggered at the start of the water year, and once an equalization determination is made Lake Powell operates in the Equalization Tier for the remainder of the operating year. **Appendix J** also presents a comparison illustrating how different parameter assumptions would influence the resulting 602(a) storage values.

[6] The modeled logic erroneously referenced the Continued Current Strategies and No Action Alternative Equalization Level, rather than the intended 602(a) storage volume.

Primary Operations

The operating year release when Lake Powel is not in equalization is calculated as follows:

- If the previous EOWY Lake Powell elevation is above elevation 3,650 feet and an equalization determination has not been made, the operating year release is 9.5 maf.
- If the previous EOWY Lake Powell elevation is between 3,635 feet and 3,650 feet, the operating year release volume linearly increases from 8.23 maf at elevation 3,635 feet to 9.5 maf at elevation 3,650 feet.
- If the previous EOWY Lake Powell elevation is between 3,575 feet and 3,635 feet, the operating year release is 8.23 maf.
- If the previous EOWY Lake Powell elevation is between 3,525 feet and 3,575 feet, the operating year release volume linearly increases from 7.0 maf at elevation 3,525 feet to 8.23 maf at elevation 3,575 feet.
- If the previous EOWY Lake Powell elevation is below 3,525 feet, the operating year release is 7.0 maf.

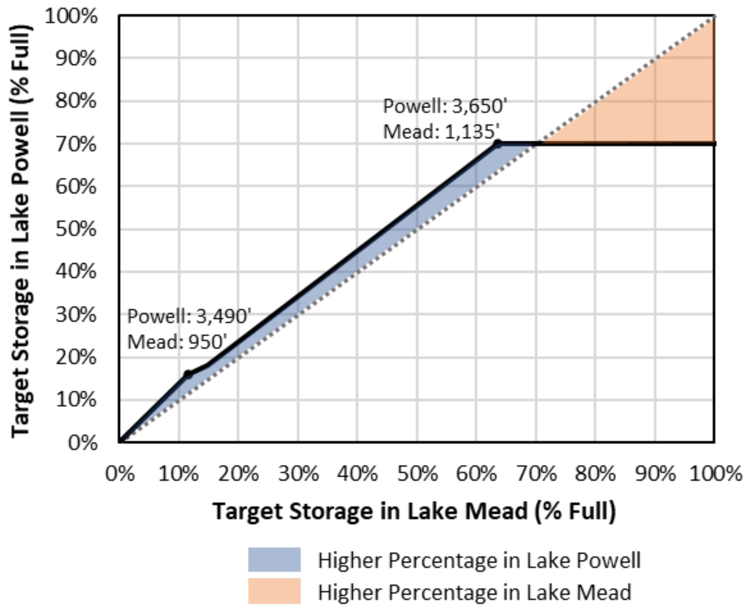
The monthly release from Lake Powell is then calculated using the method described in **Section A.6.1**, *Disaggregation from Annual to Monthly Release*.

A.6.5 Enhanced Coordination Alternative

Lake Powell operations target a specific distribution of storage across Lake Powell and Lake Mead for any given total volume of water as shown in **Figure A-3**. The dotted diagonal line marks a 50/50 split for reference, and the target storage curve is variable across that line, indicating the portion where Lake Powell is at higher percent capacity than Lake Mead (emphasized with blue shading) and the portion where Lake Mead is at higher percent capacity than Lake Powell (emphasized with orange shading).

- From 0 percent to 63 percent combined storage, operations would target keeping more water in Lake Powell.
- Above 63 percent full, a greater portion of water would be proactively sent to Lake Mead to prevent unplanned spill-avoidance releases and protect Glen Canyon Dam at high elevations.

Figure A-3
Coordinated Operations of Lake Powell and Lake Mead, Enhanced Coordination Alternative



The targets for coordinated operations can also be represented in a tabular format as shown in **Table A-7**.

Table A-7
Target Storages for Coordination Operations of Lake Powell and Lake Mead, Enhanced Coordination Alternative

Mead Storage acre-ft	Powell Storage acre-ft	Combined Storage acre-ft
0	0	0
2,005,585	3,742,714	5,748,299
3,156,353	4,215,805	7,372,158
4,475,301	5,544,923	10,020,224
15,107,119	16,309,410	31,416,529
23,143,714	16,321,726	39,465,440

Primary Operations

In October, an initial operating year release is determined; in April, a one-time mid-year adjustment can be made to the operating year release. The Lake Powell initial operating year release is calculated based on the following factors:

- Previous EOWY physical storage of Lake Powell and Lake Mead ($V_{EOWY}^{Powell}, V_{EOWY}^{Mead}$, respectively)
- Target storage distribution (from **Figure A-3**)
- Preceding 10-year running average inflow to Lake Powell ($\bar{I}_{10}$)
- Lower Basin shortage for upcoming calendar year (S; see **Section A.7.5**)

CRSS first calculates the EOWY Lake Powell Target Storage (V_{target}^{Powell}) by linearly interpolating values in **Table A-7** based on the combined previous EOWY storage of Lake Powell and Lake Mead (i.e., $V_{EOWY}^{Powell} + V_{EOWY}^{Mead}$). The initial operating year release (R) is then calculated as:

$$R = \left(V_{EOWY}^{Powell} - V_{target}^{Powell}\right) + \bar{I}_{10} - S$$

The operating year release volume must be greater than or equal to 4.72 maf, which is LTEMP daily minimum release converted to an operating year volume, and less than or equal to 10.8 maf, which is the operating year volume consistent with the monthly flow of 900 kaf to prevent large release volumes causing sand evacuation below Glen Canyon Dam. The monthly release from Lake Powell is then calculated using the method described in **Section A.6.1**, *Disaggregation from Annual to Monthly Release*.

In April, a mid-year adjustment to the operating year release can be made if the Lake Powell projected storage is too far off target. A new V_{target}^{Powell} is calculated using the method summarized above, but the forecasted EOWY combined Lake Powell and Lake Mead storage (i.e., $V_{EOWY}^{Powell} + V_{EOWY}^{Mead}$) is used instead of the previous year's values. The adjustment volume is then calculated as the difference between the forecasted EOWY Lake Powell storage and V_{target}^{Powell}.

There is no adjustment to the operating year release if any of the following conditions are met:

- The absolute value of adjustment volume is less than 1.0 maf.
- If the projected EOWY or end-of-March Lake Powell storage are less than or equal to 3,525 feet and the release adjustment is greater than zero.
- If the projected EOWY or end-of-March Lake Powell storage are greater than 3,650 feet and the release adjustment is less than zero.

An adjusted operating year volume is determined by adding the adjustment volume to the initial operating year release, and is still subject to the minimum and maximum operating year release volumes of 4.72 and 10.8 maf, respectively.

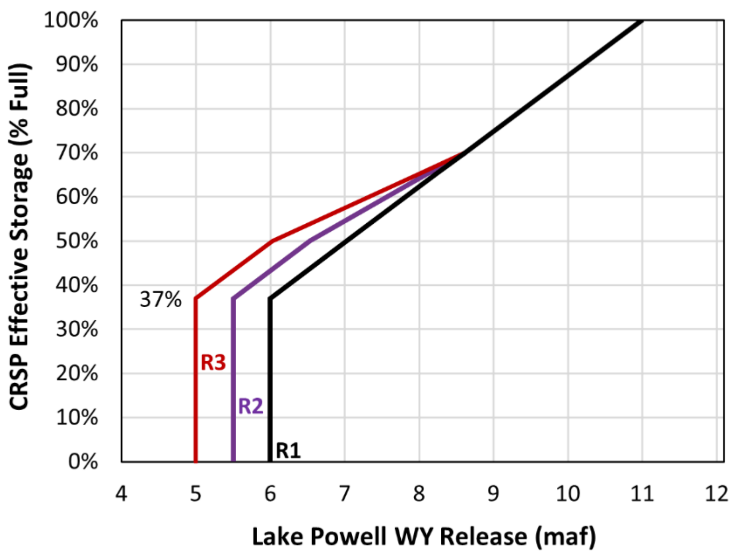
A.6.6 Maximum Operational Flexibilities Alternative

The Lake Powell operating year release is set in October using the previous EOWY effective[7] storage of CRSP reservoirs (Lake Powell, Flaming Gorge, Blue Mesa, and Navajo) and a climate response indicator[8], as described below. The Conservation Reserve, which is a storage mechanism for conserved water in Lake Powell and/or Lake Mead, is assumed to be subtracted from the physical storage so that it does not affect Lake Powell operations. The Conservation Reserve modeling assumptions are described in **Appendix B**.

Lake Powell operations are shown in **Figure A-4** and are determined based on the following release regimes:

- If the CRSP effective storage is less than or equal to 100 percent and greater than 37 percent, releases range from 11 maf to 6 maf.
- If the CRSP effective storage is less than 37 percent, the operating year release is set to 6 maf unless run-of-river operations are triggered.
- Releases can be adjusted by up to one maf, depending on the previous 3-year average Lees Ferry natural flow, as described in the following section

Figure A-4
Lake Powell Operations Diagram, Maximum Operational Flexibility Alternative



[7] "Effective" elevation or storage is calculated as physical elevation (storage) minus any conserved volume that is held in the respective reservoir(s).
[8] For modeling purposes, the previous 3-year average Lees Ferry natural flow is used.

Primary Operations

The Lake Powell operating year release is based on CRSP effective storage and the previous 3-year average natural flow at Lees Ferry, Arizona. Base operating year releases are decreased by up to 1.0 maf consistent with **Table A-8**, and are summarized below.

- When the CRSP effective storage is at or below 100 percent of capacity and at or above 70 percent of capacity, a release volume would be determined for that year based on a function of storage, with 11.0 maf release at 100 percent of capacity decreasing linearly to 8.6 maf at 70 percent of capacity.
- When the CRSP effective storage is at or below 70 percent of capacity and at or above 50 percent of capacity, the release volume depends on the previous 3-year average Lees Ferry natural flow :
    - If the previous 3-year average Lees Ferry natural flow is greater than or equal to 10.0 maf, a release volume would be determined for that year based on a function of storage, with a release of 8.6 maf at 70 percent of capacity decreasing linearly to 7.0 maf at 50 percent of capacity (R1 curve in **Figure A-4**).
    - If the previous 3-year average Lees Ferry natural flow is less than 10.0 maf and greater than or equal to 8.0 maf, a release volume would be determined for that year based on a function of storage, with a release of 8.6 maf at 70 percent of capacity decreasing linearly to 6.5 maf at 50 percent of capacity (R2 curve in **Figure A-4**).
    - If the previous 3-year average Lees Ferry natural flow is less than 8.0 maf, a release volume would be determined for that year based on a function of storage, with a release of 8.6 maf at 70 percent of capacity decreasing linearly to 6.0 maf at 50 percent of capacity (R3 curve in **Figure A-4**).
- When the CRSP effective storage is at or below 50 percent of capacity, the release volume depends on the previous 3-year average Lees Ferry natural flow :
    - If the previous 3-year average Lees Ferry natural flow is greater than or equal to 10.0 maf, a release volume would be determined for that year based on a function of storage, with a release of 7 maf at 50 percent of capacity decreasing linearly to 6.0 maf at 37 percent of capacity (R1 curve in **Figure A-4**). Below 37 percent of capacity, the determined release would be 6.0 maf.
    - If the previous 3-year average Lees Ferry natural flow is less than 10.0 maf and greater than or equal to 8.0 maf, a release volume would be determined for that year based on a function of storage, with a release of 6.5 maf at 50 percent of capacity decreasing linearly to 5.5 maf at 37 percent of capacity (R2 curve in **Figure A-4**). Below 37 percent of capacity, the determined release would be 5.5 maf.
    - If the previous 3-year average Lees Ferry natural flow is less than 8.0 maf, a release volume would be determined for that year based on a function of storage, with a release of 6.0 maf at 50 percent of capacity decreasing linearly to 5.0 maf at 37 percent of capacity (R3 curve in **Figure A-4**). Below 37 percent of capacity, the determined release would be 5.0 maf.

Table A-8
Release Curves and Relevant Conditions, Cooperative Conservation Alternative

Lake Powell Release Curve	Previous 3-Year Average Lees Ferry Natural Flow (maf)	Release Decrease Compared to R1 Curve at 50% Full (kaf)
R1	≥ 10	N/A
R2	< 10 to ≥ 8	500
R3	< 8	1,000

The monthly release from Lake Powell is then calculated using the method described in **Section A.6.1**, *Disaggregation from Annual to Monthly Release*.

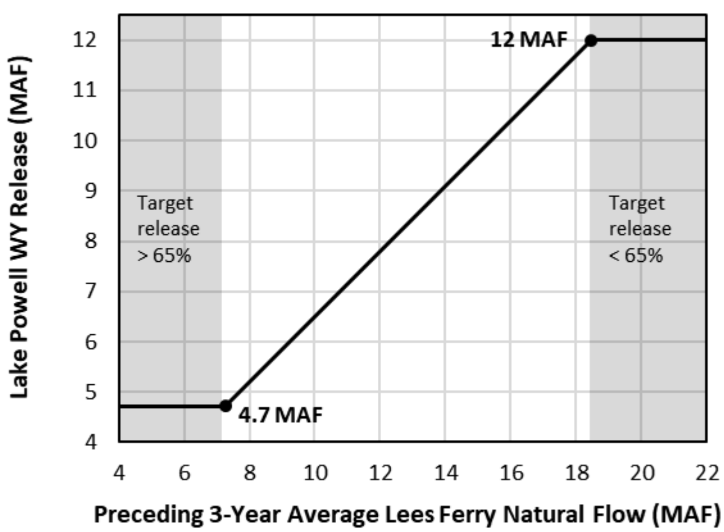
Run-of-River Operations

In any month, if the Lake Powell elevation is projected to be below 3,510 feet under primary operations, Lake Powell will operate in run-of-river operations to protect infrastructure. Lake Powell monthly releases would be calculated as the minimum of Powell's inflow minus gains and losses and the calculated release to achieve the operating year release determined in the previous section. The minimum monthly release is assumed to be 5,000 cfs.

A.6.7 Supply-Driven Alternative

The Lake Powell operating year release is calculated in October based on the preceding 3-year natural flow and is depicted in **Figure A-5**.

Figure A-5
Lake Powell Operations Diagram, Supply-Driven Alternative



Primary Operations

The Lake Powell operating year release is calculated using the following equation:

$$Release = NF\% \; x \; 3 \; Year \; Avg \; NF$$

where:

NF% = 65%

Appendix D explores the implications of using different natural flow percentages.

The release is constrained to between 4.72 maf and 12.0 maf. The monthly release from Lake Powell is then calculated using the method described in **Section A.6.1**, *Disaggregation from Annual to Monthly Release*.

Gap Water

In years when Lake Powell cannot meet its required water year release because of low elevation infrastructure constraints, additional water is introduced into the system to (partially) make up the shortfall. For modeling purposes, this supplemental volume is termed "gap water." In CRSS, this volume is computed monthly, when the monthly release is reduced based on the low elevation infrastructure constraints (**Section A.6.1**, *Infrastructure Constraints at Low Elevations*). If this occurs, gap water is injected above Lake Powell with limits on the annual volume based on the following calculation:

$$G_i = max\left(min\left(O_{i,u} - O_{i,c} \,,\, G_{max} - \sum_{n=j}^{i} G_n\right), 0 \; af\right)$$

where:

i = month
G = gap water injected in a given month
$O_{i,u}$ = monthly release volume before constrained by infrastructure
$O_{i,c}$ = monthly release volume after constrained by infrastructure
j = October

The maximum water year gap water volume is assumed to be:

$$G_{max} = 23\% * Annual \; WY \; Estimated \; UB \; Depletion - UB \; Conservation$$

where:

23% = Lower Basin maximum shortage in this alternative divided by the total Lower Basin apportionment to the U.S. and Mexico (2.1/9 maf)

Annual WY Estimated UB Depletion = sum of the current year's projected Upper Basin depletion (estimated using the logistic regression described in **Section A.6.2**, *Lake Powell Inflow Forecast*) and the previous year's Upper Basin CRSS reservoir evaporation.

UB Conservation = water year Upper Basin conservation defined in **Appendix B**.

If the operating year release volume cannot be released due to infrastructure constraints, the volume not released is tracked as 'Carryover'. The maximum carryover is constrained by the annual gap water volume. The model will try to release the Carryover volume in the following year(s) within the maximum release constraint of 12 maf.

A.7 Lake Mead Operation

Lake Mead is the uppermost reservoir in the Lower Basin. Located 35 miles southeast of Las Vegas, the 726-foot-high Hoover Dam impounds Lake Mead. In CRSS, Lake Mead operations are modeled by solving for the Lower Basin condition, Lower Basin and Mexico diversions including the conservation, storage, and delivery of conserved system and non-system water, and then setting Lake Mead's outflow to meet all downstream diversions.

Section A.7.1 describes the CRSS modeling assumptions common to all alternatives. **Sections A.7.2** through **A.7.7** describe assumptions for Lake Mead operating strategies for each alternative. The assumptions for the Lake Mead mechanism for storage and delivery of conserved system and non-system water are summarized in **Appendix B**.

A.7.1 Assumptions Common to All Alternatives

CRSS solves for the Lower Basin operating condition for the calendar year in January using a specified system condition that varies between alternatives. Each month, the rule computes downstream depletions based on scheduled inputs that are adjusted as necessary for shortage, surplus, conservation storage, and conservation delivery, as well as the volume of water needed to meet storage targets at Lake Mohave and Lake Havasu and to offset evaporation losses at those lakes. The rule then determines the total monthly release required from Lake Mead to satisfy downstream demand, taking into account gains and losses below Lake Mead.

Water User Depletions

The depletions from Lake Mead and downstream of Hoover Dam are affected by the determination of the water supply conditions (Normal, Surplus, or Shortage) as described below in each alternative's section. Individual water users' monthly depletions are adjusted using the following equation:

$$Depletion = Schedule - Shortage + Surplus - Conservation\ Creation + Conservation\ Delivery$$

Annual volumes of shortage, surplus, and conservation activities are disaggregated to monthly volumes proportionally to a user's monthly and annual scheduled water use:

$$MonthlyVolume = AnnualVolume * \left(\frac{Monthly\ WaterUseSchedule}{AnnualWaterUseSchedule}\right)$$

Lake Mead/Hoover Dam Flood Control

Under certain conditions, Lake Mead may release water in addition to downstream demand. This condition is termed "flood control" and is guided by the United States Army Corps of Engineers' (USACE) flood control regulations as contained in the USACE's Water Control Manual for Flood Control, Hoover Dam and Lake Mead, Colorado River, Nevada and Arizona (Water Control Manual) dated December 1982.

In CRSS, there are three flood control procedures currently in effect for different times of the year. These procedures were developed in the original CRSS and are based on the Field Working Agreement between Reclamation and the USACE (United States Army Corps of Engineers 1982). The first procedure is in effect throughout the year. Its objective is to maintain a minimum space of 1.5 maf in Lake Mead, primarily for extreme rain events. This space is referred to as the exclusive flood control space and is represented by the space above elevation 1,219.64 feet. The second procedure is used during the period from January through July. The objective during this period is to route the maximum inflow forecast through the reservoir system using specific rates of Hoover Dam discharge, assuming that Lake Mead will fill to elevation 1,219.64 feet at the end of July. The third procedure is used during the space building or drawdown period (August through December). The objective during this period is to gradually draw down the reservoir system to meet the total system space requirements in each month in anticipation of the next year's runoff.

Exclusive Flood Control Space Requirement

This requirement states that there must be a minimum space of 1.5 maf in Lake Mead at all times. If the release computed to meet downstream demand results in a Lake Mead storage that would violate this space requirement, the rule computes the additional release necessary to maintain that space.

January through July Operation

The flood control policy requires that the maximum forecast be used where that forecast is defined as the estimated inflow volume that, on average, will not be exceeded 19 times out of 20 (a 95 percent non-exceedance). The rule first computes the inflow forecast to Lake Mead by taking the Lake Powell forecast (**Section A.6.2**, *Lake Powell Inflow Forecast*) and adds the long-term, average tributary inflows between Lake Powell and Lake Mead. The maximum forecast is then estimated by adding an additional volume (the "forecast error term") to that inflow forecast. The forecast error term (in maf) is provided in **Table A-9**, taken from the original CRSS data.

Table A-9
Lake Mead January through July Forecast Error Forecast

Forecast Period	Forecast Error Term (maf)
January – July	4.980
February – July	4.260
March – July	3.600
April – July	2.970
May – July	2.525
June – July	2.130
July – July	0.750

The Field Working Agreement defines an iterative algorithm by which the current month's release (in cfs) is determined. Certain release levels are specified, as listed in **Table A-10**.

Table A-10
Lake Mead Flood Control Release Levels

Release Level	Release (cfs)	Description
1	19,000	Parker Powerplant capacity
2	28,000	Davis Powerplant capacity
3	35,000	Hoover Powerplant capacity (in 1987)
4	40,000	Approximate maximum flow non-damaging to streambed
5	73,000	Hoover Dam controlled discharge capacity

The flood control release needed for the current month is determined by:

$$\begin{aligned}
&release\ needed\ for\ the\ current\ month\\
&= maximum\ forecast\ inflow\\
&- current\ storage\ space\ in\ Lake\ Powell\ (below\ the\ live\ capacity\ of\ 23{,}313{,}829\ af)\\
&- current\ storage\ space\ in\ Lake\ Mead\ (below\ the\ live\ capacity\ of\ 27{,}620{,}000\ af)\\
&+ 1.5\ maf\ (exclusive\ space)\\
&- evaporation\ and\ bank\ storage\ losses\ from\ Lake\ Powell\ and\ Lake\ Mead\\
&- Southern\ Nevada\ depletion\ -\ V_{t-July})
\end{aligned}$$

where V_{t-July} is the future volume of water released, assuming a release level from **Table A-10** for the current month through July.

If the computed release for the current month is greater than that assumed for the future months, the future level is increased, and the current month release is re-computed. The computation stops once the computed release for the current month is less than or equal to that assumed for the future months. If the computed release is greater than the previously assumed level, that release is used for the current month; otherwise, the previously assumed level is used. The rule sets Lake Mead's release to the flood control release if it is greater than the release previously computed to meet downstream demands.

Space Building (August to December)

The flood control policy states the flood control storage space (in maf) in Lake Mead (storage below elevation 1,229 feet msl) required at the beginning of each month from August through January, as listed in **Table A-11**.

Table A-11
Lake Mead Flood Control Required Storage Space

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

However, these targets may be reduced to the minimum of 1.5 maf in each month if additional space is available upstream in live storage. Certain upstream reservoirs are specified with a maximum creditable space (in maf) that can be applied towards the total required flood control space. The creditable storage space allowed for each of these reservoirs is listed in **Table A-12**.

Table A-12
Lake Mead Flood Control Maximum Creditable Storage Space

Reservoir	Maximum Creditable Storage Space (maf)
Powell	3.8500
Navajo	1.0359
Blue Mesa	0.7485
Flaming Gorge plus Fontenelle	1.5072

In each month (July through December), if the release computed to meet downstream demands results in an end-of-month Lake Mead storage that would violate the space requirement adjusted for upstream storage, the rule computes the additional release necessary to maintain that space. However, these releases are constrained to be less than or equal to 28,000 cfs.

Flood Control Surplus

If the modeled January 1 system volumes projects Hoover Dam flood control releases based on the Field Working Agreement between Reclamation and the USACE for the flood control operation of Hoover Dam and Lake Mead (USACE 1982), the model assigns the Full Surplus schedules to Metropolitan Water District (MWD), Southern Nevada Water Authority (SNWA), Central Arizona Project (CAP), Imperial Irrigation District (IID), and Coachella Valley Water District (CVWD). In addition, the model assigns an additional delivery of up to 200 kaf to Mexico. All other diversion points remain at Normal schedules.

Infrastructure Constraints at Low Elevations

Lake Mead monthly releases can be constrained due to physical limitations at Hoover Dam. If Lake Mead is below approximately 950 feet in any month, releases are assumed to be constrained to the capacity of the two outlet works.

The capacity of the outlet works varies with the elevation of Lake Mead; the higher the pool elevation, the higher the potential release through the outlet works. CRSS computes the maximum monthly release based on the Lake Mead elevation using **Table A-13** and interpolates for the capacity between elevations.

Table A-13
Mead Outlet Capacity

Pool elevation (feet)	Capacity per Outlet Work (cfs)	Capacity for 2 Outlet Works (cfs)
895	0	0
900	4,800	9,600
925	5,400	10,800
950	6,000	12,000
975	6,600	13,200

Dead Pool-Related Reductions

Dead pool-related reductions occur when Lake Mead is unable to release the volume of water needed to satisfy all downstream demands due to infrastructure or water availability constraints. Dead pool-related reductions are modeled on a monthly basis and are assumed to be distributed using the priority-based shortage scheme. The following sections describe the assumptions and implementation of the priority-based shortage scheme in CRSS. The implementation was designed to reflect the method described in **Appendix C**. Dead pool-related reductions also follow the **Appendix C** method; however, these reductions are applied at the monthly level because the associated reduction volumes are not known at the beginning of the year, unlike the shortage volumes in alternatives triggered by Lake Mead or other system conditions.

Conservation Activity

All ongoing conservation activities are assumed to be cancelled from the month of the first occurrence of a dead pool-related reduction throughout the remainder of the calendar year. In Nevada, Tributary Conservation creation, which occurs in the reaches above Lake Mead, is assumed to be delivered to SNWA for the remainder of the calendar year.

Dead Pool-Related Reductions Volume Computation

After the cancellation of all conservation activity, the dead pool-related reduction volume is computed as the desired release from Lake Mead, i.e., the release that would be made if there were no infrastructure or water availability constraints, minus the volume of water Lake Mead is able to release.

The desired release aims to satisfy all demands that cannot be satisfied via Lower Basin inflows and the releases made from Lake Mohave and Lake Havasu and are calculated as:

$$Desired\ Release = \sum DesiredLBDepl + \sum \Delta LBStorage + \sum \Delta LBEvap - \sum LB\ Inflows$$

where:

DesiredLBDepl = Current month's desired depletions for all water users in the Lower Division States and Mexico, including miscellaneous uses and losses, after adjustments have been made for shortages

Δ*Storage* = Sum of the current month's change in storage for Lake Mohave and Lake Havasu

Δ*Evap* = Sum of the current month's evaporation for Lake Mohave and Lake Havasu

LB Inflows = Sum of the current month's Lower Basin inflows from the Davis, Alamo, Parker, and Imperial natural flow sites and the Arizona forebeared return flows

Dead Pool-Related Reduction Distribution

Dead pool-related reductions are dynamically applied to water users in the Lower Division States and Mexico based on the current month's desired depletions after adjustments have been made for shortage and existing other assumptions (e.g., shortage, system conservation, fallowing, etc.). Although it draws directly from Lake Mead, SNWA is assumed to be included in the group of water users that dead pool-related reductions are distributed to. CRSS water users that represent other system losses, e.g., excess flows to Mexico are represented as a water user, are assumed to not be in the users that dead pool-related reductions are distributed to.

Dead pool-related reductions are assumed to use the Lower Basin-wide priority scheme (see **Appendix C** for details), which follows an approximation of the Lower Basin priority system. This scheme is implemented in CRSS using three stages, described in detail below. The assumed CRSS water users' priorities[9] are shown in **Attachment A2**. All water users' desired depletion in each stage is shorted to zero before progressing to the next stage. The three stages are:

Stage 1: Arizona Priority 4 water users and Nevada Stage 1

Stage 2: All remaining water users who do not hold Present Perfected Rights (PPR), which includes Arizona Priorities 4, 3, and 2, California Priorities 4, 3b, 3a, 2, and 1, and Nevada Priorities 8, 7, 4, and 2.

Stage 3: All PPR water users, shorted by priority date (junior to senior)

Mexico is not included in the stages but does is assumed to be included in the distribution of dead pool-related reductions[10]. The portion of the total dead pool-related reduction applied to Mexico is assumed to be proportional to their desired depletions compared to total Lower Basin depletions in each month and is calculated as:

[9] There are several CRSS "water users" that aggregate multiple real-world users. In those cases, the assumed priority used in CRSS may not match the priority of all users; the assumed priority is chosen as a modeling simplification. The shortage allocation model provides more detail on the distribution of shortages (**Appendix C**).

[10] Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current United States policy or a determination of future United States policy regarding deliveries to Mexico. The United States will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

$$MXDeadPoolReduc\% = \frac{Desired\ Depletion_{MX}}{Desired\ Depletion_{MX} + \sum Desired\ Depletions_{LDS\ Contractors}}$$

where:

Desired Depletion$_{MX}$ = Desired depletion of the Mexico water user

Desired Depletions$_{LDS\ Contractors}$ = Desired depletions of the Lower Division State contractor water users

When distributing the dead pool-related reductions, CRSS first calculates Mexico's assumed portion of dead pool-related reduction by multiplying *MXDeadPoolReduc%* by the total dead pool-related reduction volume. The remaining dead pool-related reduction is then assigned to the Lower Division States and distributed through each stage of reductions until the full volume has been met.

To distribute dead pool-related reductions within the Lower Division States, CRSS computes the water available in each stage and determines the maximum stage that will be impacted by the dead pool-related reduction. For example, if there were 100 kaf of desired depletions in Stage 1, 500 kaf of desired depletions in Stage 2, and 200 kaf of desired depletions in Stage 3, and the dead pool-related reduction was 300 kaf, the maximum stage impacted would be Stage 2. In this example, Stage 1 would satisfy 100 kaf of the dead pool-related reduction and Stage 2 would satisfy the remaining 200 kaf of dead pool shortage, with 300 kaf still available for use to users in the Stage 2 group.

When CRSS has determined the maximum stage that the dead pool-related reduction will impact, all water users with water use in the prior stages have their depletion set to 0 (i.e., fully reduced to meet the dead pool-related reduction). The remaining Lower Division State dead pool-related reduction is computed by subtracting off the total desired depletions for all stages up to the maximum stage, e.g., total desired depletions for Stage 1 and Stage 2 water users for a dead pool-related reduction that is computed to affect Stage 3 water users.

Theis remaining dead pool-related reduction is then applied to the water users with use included in the maximum stage. The following sections describe how the dead pool-related reduction is divided among water users in each stage. In each stage, all water of equal priority is divided proportionally using the following formula:

$$Proportion\ \%_{Specific\ Water\ User/Group} = \frac{\sum Desired\ Depletion_{Specific\ Water\ User/Group}}{\sum Desired\ Depletion_{All\ Applicable\ Water\ Users}}$$

Stage 1 Dead Pool-Related Reductions

Stage 1 dead pool-related reductions are applied to the Arizona Priority 4 water users and Nevada water users. Stage 1 dead pool-related reduction ends when Arizona Priority 4 uses are reduced to zero. Nevada's maximum stage 1 dead pool related reductions is calculated as:

$$NV_{Stage\ 1\ max} = AZ_{P4}\left(\frac{\sum NV_{non-PPR}}{\sum AZ_{non-PPR} + \sum CA_{non-PPR} + \sum NV_{non-PPR}}\right)$$

where:

$NV_{Stage\ 1\ max}$ is Nevada's maximum stage 1 dead pool-related reduction
AZ_{P4} = Desired depletions from all Arizona Priority 4 water users and Arizona's maximum stage 1 dead pool-related reduction
$AZ_{non\text{-}PPR}$ = Desired depletions from all Arizona water users who do not have PPR
$CA_{non\text{-}PPR}$ = Desired depletions from all California water users who do not have PPR
$NV_{non\text{-}PPR}$ = Desired depletions from all Nevada water users who do not have PPR

The ratio between the Nevada and Lower Division State non-PPR water for the shortage allocation model is roughly 7%; however, for modeled dead pool-related reductions this ratio does not always hold. Policy actions prior to the determination of dead pool-related reduction may have already shorted some non-PPR water users, changing the distribution of non-PPR desired depletions between Nevada and the rest of the Lower Division States. Additionally, dead pool-related reduction is a monthly computation, not an annual computation, so different monthly distributions can change the ratio between the Nevada non-PPR water users and the Lower Division State non-PPR water users.

The Stage 1 dead pool-related reduction is distributed to Arizona and Nevada proportional to their maximum stage 1 reduction volume, where Arizona's maximum stage 1 dead pool-related reduction is their total P4 desired depletion. The volume of dead pool-related reductions for Arizona and Nevada are:

$$AZ_{Stage\ 1} = DPRR * \frac{AZ_{P4}}{AZ_{P4} + NV_{Stage\ 1\ max}}$$

$$NV_{Stage\ 1} = DPRR * \frac{NV_{Stage\ 1\ max}}{AZ_{P4} + NV_{Stage\ 1\ max}}$$

where:

$AZ_{Stage\ 1}$= Arizona's portion of the Stage 1dead pool-related reduction
$NV_{Stage\ 1}$ = Nevada's portion of the Stage 1 dead pool-related reduction
$DPRR$ = the dead pool-related reduction volume

Nevada's Stage 1 dead pool-related reduction ($NV_{Stage\ 1}$) is distributed as per the state priority system from junior to senior priority, excluding the PPR water users. The shortages are first applied to the Priority 8 water users until either the Nevada portion of dead pool-related reduction is satisfied, or all Nevada Priority 8 water users have been completely shorted. If all Priority 8 water users are fully shorted and there is still a portion of the Stage 1 dead pool-related reduction remaining, then Priority 7 water users are reduced, continuing in this manner until Nevada's Stage 1 dead pool-related reduction volume has been distributed. When there are multiple users with the same priority, the dead pool-related reduction is distributed proportionally to users with the same priority.

Arizona's Stage 1 dead pool-related reduction ($AZ_{Stage\ 1}$) is distributed proportionally between all Arizona Priority 4 water users.

Stage 2 Dead Pool-Related Reductions
Stage 2 dead pool-related reductions are applied to all remaining non-PPR water users. The dead pool-related reduction is distributed to each state proportional to their remaining non-PPR desired depletions after the Stage 1 dead pool related-reductions have been applied.

Within each state, dead pool-related reductions are distributed from the most junior to the most senior priority water users excluding PPR water users. Dead pool-related reductions are first applied to the most junior priority group (Arizona Priority 3[11], California Priority 4, and Nevada Priority 8) until either the state's assigned dead pool-related reduction volume is met or all users within the priority group have been fully reduced. If the priority group is fully reduced and there is remaining dead pool-related reduction, then reductions are distributed to the next most junior priority group continuing sequentially until the state's total dead pool-related reduction obligation has been satisfied. Within each priority group, the dead pool-related reduction is applied proportionally among all water users in that group.

Stage 3 Dead Pool-Related Reductions
Dead pool-related reductions in Stage 3 are applied to PPR water users using a priority list organized by priority date such that the junior water users are fully shorted before the senior water users are impacted. CRSS does not have a water user to represent each Lower Basin PPR contract and has 8 water users that represent the aggregate of several PPR contracts. When PPR contracts are aggregated to one water user, the water user is placed on the PPR list as the priority date of the PPR contract with the highest volume diversion entitlement.

Remaining Dead Pool-Related Reductions
There are very few instances when the dead pool-related reduction volume is greater than the sum of the desired use from all contract water users in the Lower Division States and Mexico. When this occurs, all water users in the Lower Basin and Mexico are fully shorted (i.e., 0 af of depletions that month), and so CRSS must short the water users that represent other uses and losses in the Lower Basin, such as the assumed excess flows to Mexico.

A.7.2 Continued Current Strategies

The Continued Current Strategies comparative baseline assumes that existing agreements, including the 2007 Interim Guidelines, 2017 Minute 323, and 2019 DCP continue through the analysis period (2027-2060). Lake Mead operations and Lower Basin conditions are set based on previous EOCY pool elevation at Lake Mead. This is a modeling simplification, rather than using an August based projection of December 31 conditions, as specified in the 2007 Interim Guidelines.

Surplus

The Lower Basin is assumed to operate in a Surplus Condition if the Lake Mead elevation starts the year above 1,145 feet or if it exceeds an elevation that would trigger space-building or flood control releases pursuant to the 1984 Field Working Agreement between Reclamation and the US Army Corps of Engineers (Flood Control surplus; described in **Section A.7.1**, *Lake Mead/Hoover Dam Flood Control*) anytime in the year. There are two additional levels of Surplus in Continued Current

[11] Arizona Priority 2 and 3 are modeled as co-equal in the Shortage Allocation Model, and should be modeled as such in CRSS to be consistent with the Shortage Allocation Model.

Strategies: Domestic and Quantified. Increased deliveries to Mexico due to high reservoir conditions are assumed to occur and are consistent with volumes prescribed in Minute 323 Section II.

Domestic Surplus

A Domestic Surplus is determined if the Lake Mead elevation is above 1,145 feet and below the elevation that triggers a Quantified Surplus. Under a Domestic Surplus, depletion schedules are modified in the Lower Division States by the surplus volume as follows:

- For use by MWD, 250,000 af per year in addition to the amount of California's basic apportionment available to MWD.
- For use by SNWA, up to 100,000 af per year in addition to the amount of Nevada's basic apportionment available to SNWA.
    - SNWA is assumed to only take delivery of the volume of surplus water needed to satisfy their demands that exceed apportionment (see Appendix B)
- For use in Arizona, 100,000 af per year in addition to the amount of Arizona's basic apportionment available to Arizona Contractors.

These volumes are reduced by the same volume that Mexico's delivery is increased as described in a subsequent section. The reduction volume is split proportionally among these three users.

Quantified Surplus

A Quantified Surplus is assumed to occur when water needs to be delivered to reduce the risk of potential reservoir spills based on the 70R Strategy (described below). Under a Quantified Surplus, depletion schedules are modified in the Lower Division States consistent with the 2007 Interim Guidelines Section 2.B.3.

Under the 70R Strategy, a surplus condition is based on the system space requirement at the beginning of each year. Based on the 70th percentile historical runoff, a normal 7.5 maf delivery to the Lower Division States, the Upper Basin scheduled use, and Lake Powell and Lake Mead volumes 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. The quantity of the surplus volume (SurVol) is computed as follows:

$$SurVol = (PowellStorage + MeadStorage - maxStorage + ConsMechVol) * (1 + aveBankStorCoef) + runoff - UBDemand - LBDemand$$

where:

Powell Storage = Lake Powell storage at the beginning of the year
Mead Storage = Lake Mead storage at the beginning of the year
maxStorage = maximum combined storage of Lake Powell and Lake 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 Lake Powell (computed as live capacity of Lake Powell and Lake Mead – 70% * Lake Mead space requirement at the beginning of the year)
ConsMechVol = previous year's conservation mechanism volume

aveBankStorCoef = average of Lake Powell and Lake Mead bank storage coefficients
runoff = assumed percentile runoff (70%) based on the historical record of 1931 through the previous year
UBDemand = Upper Basin depletion scheduled for the year (estimated using the logistic regression described in **Section A.6.2** + the estimated evaporation loss in the Upper Basin. The estimated evaporation is the sum of the previous year's evaporation at Lake Powell and calculated evaporation based on target storage at all other Upper Basin reservoirs except McPhee and the TMD reservoir which take the average of the previous 5 years of evaporation.
LBDemand = sum of depletions below Lake Powell + the evaporation losses in the Lower Basin (previous year's evaporation at Lake Mead and calculated evaporation at Lake Mohave and Lake Havasu, based on target storage) – average of the last 5-years of gains between Lake Powell and Lake Mead – average gains below Lake Mead

Once the quantity of surplus volume is known, the model computes each state's share (50 percent to California, 46 percent to Arizona, and 4 percent to Nevada). The model then assigns the Full Domestic Surplus schedules to MWD and SNWA. Arizona's share of the surplus is assigned to CAP, up to their Full Surplus schedule. If surplus water is still available for California, up to 300 kaf is made available to IID and CVWD.

Minute 323 Distribution of Flows Under High Elevation Reservoir Conditions

Distribution of flows to Mexico under high-elevation reservoir conditions are modeled based on the volumes in Minute 323 Section II, when the Lake Mead EOCY pool elevation is at or above 1,145 feet. Mexico's annual delivery is increased by the volumes shown in **Table A-14**.

Table A-14
Minute 323 Annual Increased Delivery To Mexico

Mead Elevation (ft)	Volume (af)
<1,145	
1,145 to 1,170	40,000
1,170 to 1,200	55,000
>1,200	80,000

Normal Conditions

The Lower Basin operates in a Normal Condition if the Lake Mead elevation is above 1,075 feet and below 1,145 feet. Drought Contingency Plan (DCP) contributions are assumed to continue when Lake Mead is less than or equal to 1,090 feet. The modeled DCP contributions are described in the following section.

Shortage Conditions and Contributions

2007 Interim Guidelines Shortages

A 2007 Interim Guidelines Lower Basin Shortage Condition is modeled if the Lake Mead pool elevation is less than or equal to 1,075 feet. A rule solves for the Shortage Condition in January by comparing Lake Mead's previous EOCY pool elevation to defined pool elevations, as shown in **Table A-15**. The annual shortage volumes are distributed between states as shown in **Table A-15**.

Table A-15
2007 Interim Guidelines Lower Division State Shortage Volumes

Lake Mead Elevation (feet)	Arizona Shortage (af)	Nevada Shortage (af)	Total Shortage (af)
>1,075	0	0	0
1,075 to 1,050	320,000	13,000	333,000
<1,050 to 1,025	400,000	17,000	417,000
<1,025	480,000	20,000	500,000

Minute 323 Distribution of Flows Under Low Elevation Reservoir Conditions

Minute 323 defines annual reductions to Mexico under low-elevation reservoir conditions based on the Lake Mead EOCY pool elevation. **Table A-16** shows the modeled reductions to Mexico.

Table A-16
Mexico Minute 323 Reductions

Lake Mead Elevation (feet)	Mexico Reduction (af)
>1,075	0
1,075 to 1,050	50,000
<1,050 to 1,025	70,000
<1,025	125,000

2019 Drought Contingency Plan and Binational Water Scarcity Contingency Plan

CRSS models the 2019 DCP contributions in accordance with Exhibit 1 to the Lower Basin DCP agreement and the Binational Water Scarcity Contingency Plan (BWSCP) contributions in accordance with Minute 323. The contribution volumes (**Table A-17**) are based on the Lake Mead previous EOCY pool elevation. For modeling purposes, DCP contributions can be made through conversion of existing Intentionally Created Surplus (ICS), simultaneous ICS creation and conversion to DCP-ICS, and/or reducing depletions to create system water. CRSS ICS assumptions for Continued Current Strategies are described in **Appendix B**.

Table A-17
2019 DCP and Minute 323 BWSCP Contribution Volumes

Lake Mead Elevation (feet)	DCP (1,000 af) Arizona	DCP (1,000 af) Nevada	DCP (1,000 af) California	Minute 323 BWSCP (1,000 af)
>1,090	0	0	0	0
1,090 – 1,075	192	8	0	41
1,075 – 1,050	192	8	0	30
<1,050 – >1,045	192	8	0	34
1,045 – >1,040	240	10	200	76
1,040 – >1,035	240	10	250	84
1,035 – >1,030	240	10	300	92
1,030 – 1,025	240	10	350	101
<1,025	240	10	350	150

Shortage Distribution

The shortage and DCP contributions are distributed to the Lower Division States as shown in **Table A-15** and **Table A-17**. In Nevada, the Southern Nevada Water Providers (SNWP) water user incurs the entire shortage volume and DCP contribution. The Nevada state apportionment is reduced by the shortage volume, so the SNWP depletion requested is not affected by the shortage volume until their demand is closer to the state apportionment (see **Appendix N** for assumed depletion schedules). In California, the DCP contribution is split such that 93% is applied to MWD and 7% to CVWD. In Arizona, the shortage volume is distributed proportionally between Priority 4 water users and DCP contribution volumes are made by the CAP water user.

A.7.3 No Action Alternative

The Lake Mead operations and Lower Basin conditions for the No Action Alternative are assumed to be determined based on the previous EOCY pool elevation at Lake Mead.

Surplus

The No Action Alternative models two levels of surplus for the Lower Basin: Quantified Surplus and Flood Control Surplus. The Quantified Surplus modeling assumptions under the No Action Alterative are identical to Continued Current Strategies (**Section A.7.2**). Flood Control Surplus is described in **Section A.7.1**, *Flood Control Surplus*.

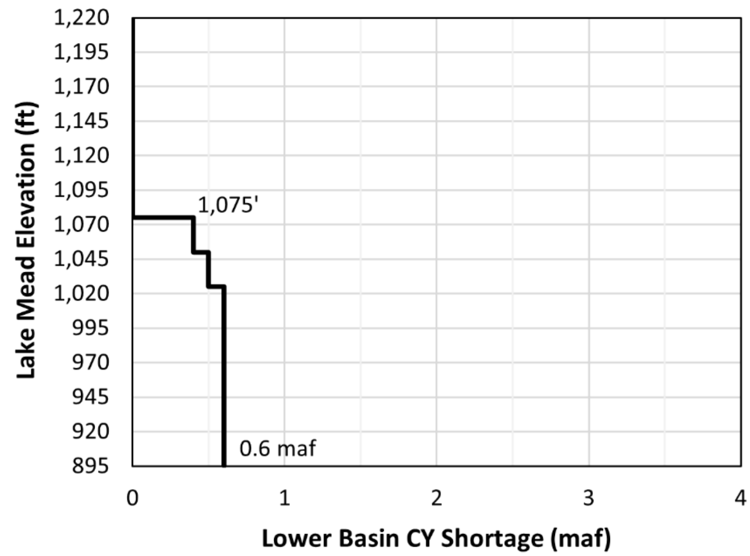
Normal Conditions

The Lower Basin operates in a Normal Condition if the Lake Mead elevation is above 1,075 feet and not in a surplus condition.

Shortage Condition

A Shortage Condition is modeled in the Lower Basin under the No Action Alternative when Lake Mead ended the previous year below 1,075 feet. The shortage volumes by Lake Mead elevation are shown in **Figure A-6** and are the same as the total Lower Basin volume under the 2007 Interim Guidelines Shortages, not including DCP and BWSCP contributions, in Continued Current Strategies.

Figure A-6
Shortage Guidelines to Reduce Deliveries from Lake Mead, No Action Alternative



Note: Shortage volumes include modeling assumptions for reductions in water deliveries to Mexico. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current United States policy or a determination of future United States policy regarding deliveries to Mexico. The United States will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

Shortage Distribution

The No Action Alternative distributes shortages using the priority system. In CRSS, the modeling estimation of the priority system is the same as the method used to distribute dead pool-related reductions (**Section A.7.1**, *Dead Pool-Related Reductions*), except that the shortages are distributed at an annual scale and are based off of the input depletion schedules/state apportionments whereas dead pool-related reductions are distributed monthly and rely on desired use.

First, Mexico's assumed portion of the total Lower Basin shortage is computed. Mexico's portion of the shortage is assumed to be 16.67%, which is proportional to their annual apportionment with respect to the Lower Division States and Mexico apportionments[12]. The remainder of the shortage is then distributed to the Lower Division States, using the modeled priority system, in three stages (described in **Section A.7.1**, *Dead Pool-Related Reductions*).

[12] Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current United States policy or a determination of future United States policy regarding deliveries to Mexico.

A.7.4 Basic Coordination Alternative

The Lake Mead operations and Lower Basin conditions for the Basic Coordination Alternative are assumed to be based on the previous EOWY pool elevation at Lake Mead.

Surplus

The Surplus method under the Basic Coordination Alternative is modeled identical to that of the No Action Alternative.

Normal Conditions

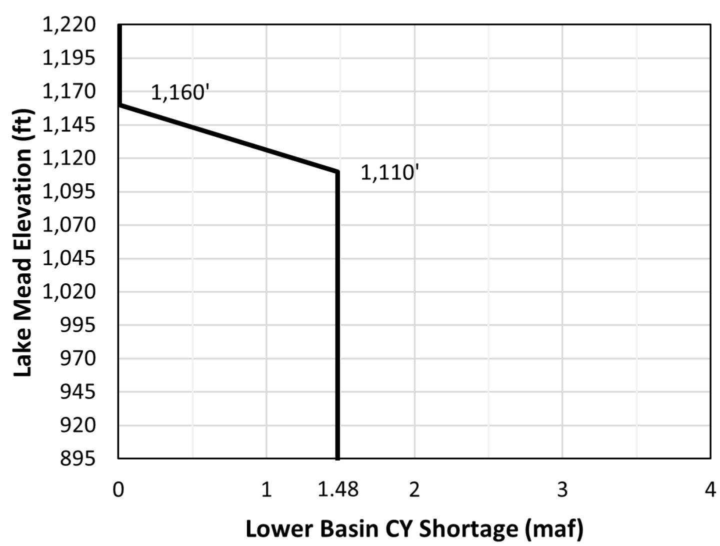
The Lower Basin operates in a Normal Condition if the Lake Mead elevation is above 1,160 feet and not in a surplus condition.

Shortage Condition

A Shortage Condition is modeled in the Lower Basin under the Basic Coordination Alternative when Lake Mead ended the previous water year below 1,160 feet. The shortage zones are summarized below and shown in **Figure A-7**.

- When Lake Mead is at or below elevation 1,160 feet and at or above 1,110 feet, a shortage volume would be imposed for that year based on a function of elevation, with 0.0 maf of shortage at 1,160 feet increasing linearly to 1.48 maf at 1,110 feet.
- When Lake Mead is below elevation 1,110 feet, a shortage of 1.48 maf would be imposed for that year.

Figure A-7
Shortage Guidelines to Reduce Deliveries from Lake Mead, Basic Coordination Alternative



Note: Shortage volumes include modeling assumptions for reductions in water deliveries to Mexico. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current United States policy or a determination of future United States policy regarding deliveries to

Mexico. The United States will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

Shortage Distribution

Shortages in the Basic Coordination Alternative are distributed among the Lower Basin based on the priority system, identical to the No Action Alternative.

A.7.5 Enhanced Coordination Alternative

The Lake Mead operations and Lower Basin conditions for the Enhanced Coordination Alternative are assumed to be based on the previous EOWY sum of effective storage[13] in Lake Powell and physical storage in Lake Mead. The combined storage percentage is computed as:

$$S_{eff} = \frac{P_{EOWY} - C_{UB} + M_{EOWY}}{P_{max} + M_{max}}$$

where:

S_{eff} = the total Lake Powell effective storage and Lake Mead physical storage as a percentage of capacity
P_{EOWY} = Lake Powell physical storage at the end of the previous water year
C_{UB} = the total volume of conserved water in Lake Powell
M_{EOWY} = Lake Mead physical storage at the end of the previous water year
P_{max} = Lake Powell live capacity (23.31 maf)
M_{max} = the Lake Mead live capacity excluding exclusive flood control space (26.12 maf)

Surplus

The Surplus method under the Enhanced Coordination Alternative is modeled identical to that of the No Action Alternative.

Normal Conditions

The Lower Basin operates in a Normal Condition if the sum of Lake Powell effective storage and Lake Mead physical storage at the end of the previous water year is above 60 percent and not in a Surplus Condition.

Shortage Condition

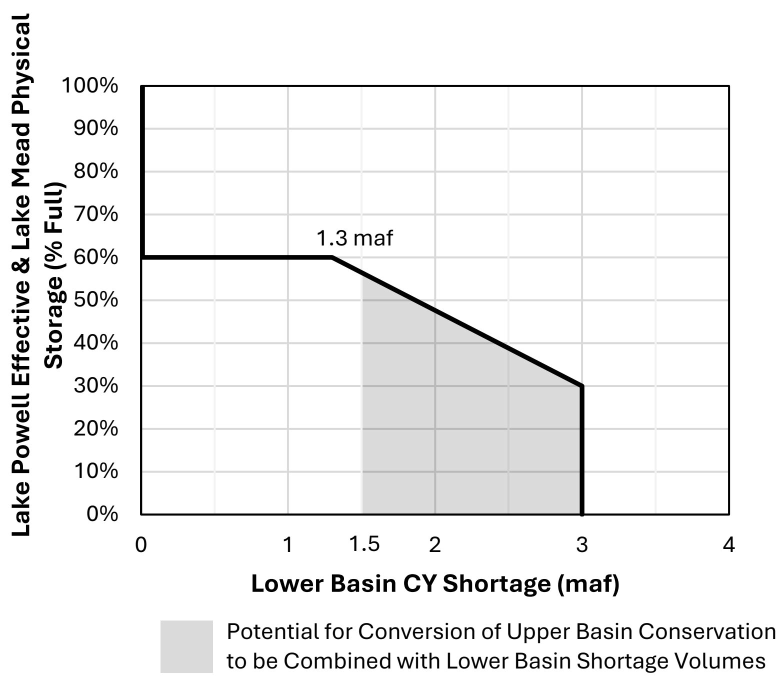
A Shortage Condition is modeled in the Lower Basin under the Enhanced Coordination Alternative when sum of Lake Powell effective storage and Lake Mead physical storage at the end of the previous water year is below 60 percent.

[13] "Effective" storage is calculated as physical storage minus any conserved volume that is held in the respective reservoir(s).

Required shortages could be partially or fully offset by converting previously conserved Upper Basin water, subject to provisions described below. The shortage zones are summarized below and shown in **Figure A-8.**

- When the sum of Lake Powell effective storage and Lake Mead physical storage is equal to or less than 60 percent of combined capacity and greater than or equal to 30 percent combined capacity, a shortage volume would be imposed for that year based on a function of storage, with 1.3 maf of shortage at 60 percent of capacity increasing linearly to 3.0 maf at 30 percent of capacity.
- When the sum of Lake Powell effective storage and Lake Mead physical storage is less than 30 percent of combined capacity, a shortage volume of 3.0 maf would be imposed for that year.

Figure A-8
Shortage Guidelines to Reduce Deliveries from Lake Mead, Enhanced Coordination Alternative



Shortage volumes include modeling assumptions for reductions in water deliveries to Mexico. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current United States policy or a determination of future United States policy regarding deliveries to Mexico. The United States will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

When Lower Basin shortages are greater than 1.5 maf, a volume equal to one-third of the volume above 1.5 maf would be converted from the Lake Powell conservation pool into system water such that the total of Lower Basin shortages and conversion of Upper Basin water equal the required total shortage volume (i.e., above 1.5 maf, there is a 2-to-1 Lower Basin shortage-to-Upper Basin conversion ratio.) If the prescribed 2-to-1 volume is not available in the Lake Powell conservation pool, 100 percent of the available volume would be converted, and the Lower Basin would take the balance of shortages. The Upper Basin conservation pool modeling assumptions are described in **Appendix B**.

Shortage Distribution

Shortages in the Enhanced Coordination Alternative are assumed to be distributed pro rata among Lower Basin water users independent of state. The CRSS implementation of the pro rata shortage approach distributes the shortage volume proportionally to all Lower Division State water users and Mexico[14] using the equation:

$$Water\ User\ Proportion\ \% = \frac{Annual\ Depletion\ Schedule_{\ Water\ User}}{\sum Annual\ Depletion\ Schedule_{\ All\ Applicable\ Water\ Users}}$$

where:

Annual Depletion Schedule$_{Water\ User}$ = Annual depletion schedule volume for the water user being shorted

$\sum$*Annual Depletion Schedule*$_{All\ Applicable\ Water\ Users}$ = Sum of the annual depletion schedules for all contract water users in the Lower Basin and Mexico (i.e., 9.0 maf)

A.7.6 Maximum Operational Flexibilities Alternative

The Lake Mead operations and Lower Basin conditions for the Maximum Operational Flexibilities Alternative are assumed to be based on the previous EOWY total system effective storage (Lake Powell, Flaming Gorge, Blue Mesa, and Navajo, Lake Mead, Lake Mohave, and Lake Havasu) and a climate response indicator[15]. The Conservation Reserve, which is a storage mechanism for conserved water in Lake Powell and/or Lake Mead, is assumed to be subtracted from the physical storage so that it does not affect Lake Mead operations. The Conservation Reserve modeling assumptions are described in **Appendix B**. The EOWY total system effective storage as a percentage is computed as:

$$S_{eff} = \frac{(\sum_{r\in R} r_{EOWY}) - C_{CR}}{\sum_{r\in R} r_{max})}$$

where:

[14] Shortage distributions include modeling assumptions for reductions in water deliveries to Mexico. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current United States policy or a determination of future United States policy regarding deliveries to Mexico. The United States will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

[15] For modeling purposes, the previous 3-year average Lees Ferry natural flow is used.

S_{eff} = the total system effective storage as a percentage of capacity
R = the set of system reservoirs: Lake Powell, Flaming Gorge, Blue Mesa, and Navajo, Lake Mead, Lake Mohave, and Lake Havasu
r_{EOWY} = the EOWY physical storage at the reservoir
r_{max} = the assumed maximum capacity of the reservoir from **Table A-2**
C_{CR} = the total volume of conserved water in the Conservation Reserve

Surplus

The Maximum Operational Flexibilities Alternative assumes that Surplus Conditions only occur during Flood Control Surplus. Flood Control Surplus is described in **Section A.7.1**, *Flood Control Surplus*.

Normal Conditions

The Lower Basin operates in a Normal Condition if the total system effective storage is greater than 60 percent and Lake Mead is not in a Flood Control Surplus Condition.

Shortage Condition

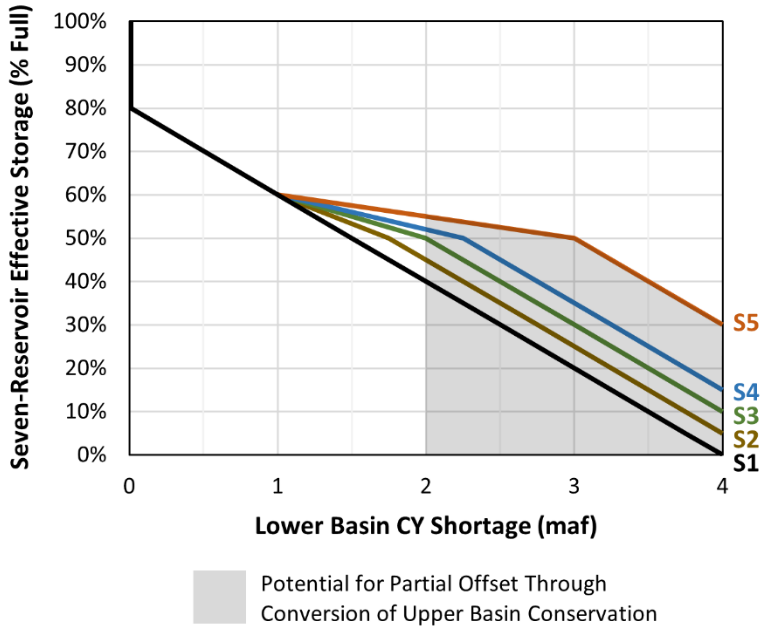
A Shortage Condition is modeled in the Lower Basin under the Maximum Operational Flexibilities Alternative when the total system effective storage is less than 60 percent at the end of the previous water year. The shortage zones and previous 3-year average Lees Ferry natural flow values are summarized below and shown in **Figure A-9** and **Table A-18**.

- When total system effective storage is at or below 80 percent of capacity and at or above 60 percent of capacity, a shortage volume would be imposed for that year based on a function of storage, with 0.0 maf of shortage at 80 percent of capacity increasing linearly to 1.0 maf at 60 percent of capacity.
- When total system effective storage is at or below 60 percent of capacity and at or above 50 percent of capacity, the shortage volume depends on the previous 3-year average Lees Ferry natural flow:
    - If the previous 3-year average Lees Ferry natural flow is greater than 14.0 maf, a shortage volume would be imposed for that year based on a function of storage, with 1.0 maf of shortage at 60 percent of capacity increasing linearly to 1.5 maf at 50 percent of capacity (S1 curve in **Figure A-9**).
    - If the previous 3-year average Lees Ferry natural flow is less than 14.0 maf and greater than or equal to 12.0 maf, a shortage volume would be imposed for that year based on a function of storage, with 1.0 maf of shortage at 60 percent of capacity increasing linearly to 1.75 maf at 50 percent of capacity (S2 curve in **Figure A-9**).
    - If the previous 3-year average Lees Ferry natural flow is less than 12.0 maf and greater than or equal to 10.0 maf, a shortage volume would be imposed for that year based on a function of storage, with 1.0 maf of shortage at 60 percent of capacity increasing linearly to 2.0 maf at 50 percent of capacity (S3 curve in **Figure A-9**).
    - If the previous 3-year average Lees Ferry natural flow is less than 10.0 maf and greater than or equal to 8.0 maf, a shortage volume would be imposed for that year

based on a function of storage, with 1.0 maf of shortage at 60 percent of capacity increasing linearly to 2.25 maf at 50 percent of capacity (S4 curve in **Figure A-9**).
    - If the previous 3-year average Lees Ferry natural flow is less than 8.0 maf, a shortage volume would be imposed for that year based on a function of storage, with 1.0 maf of shortage at 60 percent of capacity increasing linearly to 3.0 maf at 50 percent of capacity (S5 curve in **Figure A-9**).
- When total system effective storage is 50 percent of capacity or less, the shortage volume depends on the previous 3-year average Lees Ferry natural flow:
    - If the previous 3-year average Lees Ferry natural flow is greater than 14.0 maf, a shortage volume would be imposed for that year based on a function of storage, with 1.5 maf of shortage at 50 percent of capacity increasing linearly to 4.0 maf at 0 percent of capacity (S1 curve in **Figure A-9**).
    - If the previous 3-year average Lees Ferry natural flow is less than 14 maf and greater than or equal to 12.0 maf, a shortage volume would be imposed for that year based on a function of storage, with 1.75 maf of shortage at 50 percent of capacity increasing linearly to 4.0 maf at 5 percent of capacity (S2 curve in **Figure A-9**). Below 5 percent of capacity, a shortage of 4.0 maf would be imposed for that year.
    - If the previous 3-year average Lees Ferry natural flow is less than 12.0 maf and greater than or equal to 10.0 maf, a shortage volume would be imposed for that year based on a function of storage, with 2.0 maf of shortage at 50 percent of capacity increasing linearly to 4.0 maf at 10 percent of capacity (S3 curve in **Figure A-9**). Below 10 percent of capacity, a shortage of 4.0 maf would be imposed for that year.
    - If the previous 3-year average Lees Ferry natural flow is less than 10.0 maf and greater than or equal to 8.0 maf, a shortage volume would be imposed for that year based on a function of storage, with 2.25 maf of shortage at 50 percent of capacity increasing linearly to 4.0 maf at 15 percent of capacity (S4 curve in **Figure A-9**). Below 15 percent of capacity, a shortage of 4.0 maf would be imposed for that year.
    - If the previous 3-year average Lees Ferry natural flow is less than 8.0 maf, a shortage volume would be imposed for that year based on a function of storage, with 3.0 maf of shortage at 50 percent of capacity increasing linearly to 4.0 maf at 30 percent of capacity (S5 curve in **Figure A-9**). Below 30 percent of capacity, a shortage of 4.0 maf would be imposed for that year.

Upper Basin users' conserved water is assumed to be converted to system water based on the shortage curve in **Figure A-9**. When Lower Basin shortages are greater than 2.0 maf, the volume above 2.0 maf would be converted from Upper Basin users' Conservation Reserve water to system water, subject to availability in the Reserve. The required Lower Basin shortage volume would be reduced by whatever volume of previously conserved Upper Basin water is converted. The Upper Basin Conservation Reserve modeling assumptions are described in **Appendix B**.

Figure A-9
Shortage Guidelines to Reduce Deliveries from Lake Mead, Maximum Operational Flexibility Alternative



Note: Shortage volumes include modeling assumptions for reductions in water deliveries to Mexico. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current United States policy or a determination of future United States policy regarding deliveries to Mexico. The United States will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

Table A-18
Shortage Curves and Relevant Conditions, Maximum Operational Flexibility Alternative

Shortage Curve	Previous 3-Year Average Lees Ferry Natural Flow (maf)	Shortage Increase Compared to S1 Curve at 50% Full (kaf)
S1	≥ 14	N/A
S2	< 14 to ≥ 12	250
S3	< 12 to ≥ 10	500
S4	< 10 to ≥ 8	750
S5	< 8	1,500

Shortage Distribution

Shortages in the Maximum Operational Flexibilities Alternative are assumed to be based on priority as described in Approach 1 of the Supply-Driven Alternative (refer to **Section A.7.7,** *Shortage Condition*).

A.7.7 Supply-Driven Alternative

The Lake Mead operations and Lower Basin conditions for the Supply-Driven Alternative are assumed to be based on the July 31 effective pool elevation at Lake Mead.

Surplus

The Supply-Driven Alternative assumes three levels of surplus for the Lower Basin: Domestic Surplus, Quantified Surplus and Flood Control Surplus. Flood Control Surplus is described in **Section A.7.1**, *Flood Control Surplus*.

Domestic Surplus

Domestic Surplus is assumed to occur anytime the July 31 Lake Mead effective elevation is at or above 1,165 feet and not in a Quantified or Flood Control Surplus Condition. Surplus volumes are assumed to be distributed as shown in **Table A-19**, with Arizona's volume delivered to CAP, California's volume delivered MWD, and Nevada's volume delivered SNWA in CRSS.

Table A-19
Lower Basin Domestic Surplus Assumptions

Mead Pool Elevation (feet)	Arizona Surplus (af)	California Surplus (af)	Nevada Surplus (af)	Total US Surplus (af)	Mexico Surplus* (af)	Total (af)
<1,165	0	0	0	0	0	0
1,165	80,000	0	3,333	83,333	16,667	100,000
1,170	160,000	0	6,667	166,667	33,333	200,000
1,175	240,000	0	10,000	250,000	50,000	300,000
1,180	240,000	80,000	13,334	333,334	66,666	400,000
1,185+	240,000	160,000	16,667	416,667	83,333	500,000

*Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current United States policy or a determination of future United States policy regarding deliveries to Mexico.

Quantified Surplus

The Quantified Surplus model assumptions are identical to the Continued Current Strategies (**Section A.7.2**, *Surplus*, *Quantified Surplus*), except the quantity of surplus volume is assumed to be distributed among states as follows: 41.6 percent to California, 38.33 percent to Arizona, 3.33 percent to Nevada, and 16.67 percent to Mexico.

Normal Conditions

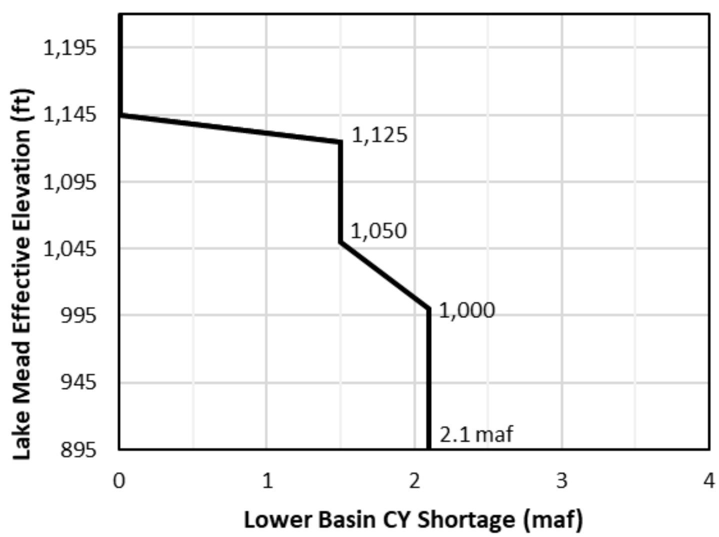
The Lower Basin operates in a Normal Condition if the Lake Mead effective elevation is above 1,145 feet and below 1,165 feet.

Shortage Condition

A Shortage Condition is modeled in the Lower Basin under the Supply-Driven Alternative when the Lake Mead effective elevation on July 31 is below 1,145 feet. The shortage zones are summarized below and shown in **Figure A-10**.

- When Lake Mead effective elevation is at or below 1,145 feet and at or above 1,125 feet, a shortage volume would be imposed for that year based on a function of elevation, with 0.0 maf of shortage at 1,145 feet increasing linearly to 1.5 maf at 1,125 feet.
- When Lake Mead effective elevation is at or below 1,125 feet and at or above 1,050 feet, a shortage volume of 1.5 maf would be imposed for that year.
- When Lake Mead effective elevation is at or below 1,050 feet and at or above 1,000 feet, a shortage volume would be imposed for that year based on a function of elevation, with 1.5 maf of shortage at 1,050 feet increasing linearly to 2.1 maf at 1,000 feet.
- When Lake Mead effective elevation is below 1,000 feet a shortage volume of 2.1 maf would be imposed for that year.

Figure A-10
Shortage Guidelines to Reduce Deliveries from Lake Mead, Supply-Driven Alternative



Shortage volumes include modeling assumptions for reductions in water deliveries to Mexico. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current United States policy or a determination of future United States policy regarding deliveries to Mexico. The United States will conduct all necessary and appropriate discussions regarding the proposed federal action and implementation of the 1944 Water Treaty with Mexico through the IBWC in consultation with the Department of State.

Shortage Distribution

Shortage volumes in this alternative are modeled using two different approaches to the distribution of shortages among mainstream Lower Colorado River users:

1. LB Priority: up to 1.5 maf, intra-state priority using state distributions submitted by Lower Division States; above 1.5 maf, intra-state priority using state distribution based on the CRSS model implementation of priority as described in the No Action Alternative (**Section A.7.3**, *Shortage Condition*, *Shortage Distribution*).

2. LB Pro Rata: up to 1.5 maf, intra-state pro rata using state distributions submitted by Lower Division States; above 1.5 maf, intra-state pro rata distributed to states proportionally based on unreduced apportionments as described in the Enhanced Coordination Alternative (**Section A.7.5**, *Shortage Condition*, *Shortage Distribution*).

"State distributions" refers to how total shortage volumes up to 1.5 maf are assumed to be distributed in the Lower Basin. **Table A-20** reports the assumed distributions of shortage volumes up to 1.5 maf.

Table A-20
Supply-Driven Shortage Distribution Assumptions Submitted by the Lower Division State

Total Shortage (af)	Arizona (af)	California (af)	Nevada (af)	Mexico* (af)
1,500,000	760,000	440,000	50,000	250,000
300,000	240,000	0	9,990	50,010
0	0	0	0	0

*Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Water Treaty or to represent current United States policy or a determination of future United States policy regarding deliveries to Mexico.

A.8 Lake Mohave and Lake Havasu Operations

Lake Mohave and Lake Havasu are operated to meet user-specified storage targets at the end of each month. These operations remain consistent for all alternatives. The storage targets and the corresponding elevations for Lake Mohave and Lake Havasu are provided in the following sections.

A.8.1 Lake Mohave/Davis Dam

Lake Mohave is operated to meet monthly elevation targets (**Table A-21**). These elevation targets are based on storage space targets set by the US Army Corps of Engineers for Lower Basin flood control purposes, as well as for endangered species operations developed in conjunction with the U.S. Fish and Wildlife Service.

Table A-21
Lake Mohave Monthly Elevation and Storage Targets

Month	Lake Mohave Target Elevation (feet)	Lake Mohave Target Storage (1,000 af)
January	641.8	1,666
February	641.8	1,666
March	642.5	1,685
April	643.0	1,699
May	643.0	1,699
June	643.0	1,671
July	642.0	1,658
August	642.0	1,658
September	640.0	1,617
October	630.5	1,371
November	635.0	1,486
December	638.7	1,583

A.8.2 Lake Havasu/Parker Dam

Lake Havasu is operated to meet monthly elevation targets (**Table A-22**). These elevation targets are based on storage space targets set by the US Army Corps of Engineers for Lower Basin flood control purposes, as well as for seasonal needs to meet downstream water demands.

Table A-22
Lake Havasu Monthly Elevation and Storage Targets

Month	Lake Havasu Target Elevation (feet)	Lake Havasu Target Storage (1,000 af)
January	446.5	552
February	446.5	552
March	446.7	555
April	448.7	593
May	448.7	593
June	448.7	593
July	448.0	580
August	447.5	571
September	447.5	571
October	447.5	571
November	447.5	571
December	446.5	552

A.9 Energy Generation

RiverWare™ includes a variety of methods that can be chosen to compute electrical power generation and estimate generation capacity. All methods compute power and energy on a monthly basis. In addition to power and energy, these results can be used to estimate revenue and total economic value of hydropower. The following sections describe the methods used to compute power at Glen Canyon Dam, Hoover Dam, Davis Dam, and Parker Dam.

A.9.1 Glen Canyon Dam

While CRSS includes a RiverWare™ method to compute electrical power generated from Glen Canyon Dam, the power generation data used in **Section 3.15** are computed using Generation Transmission Maximization Model (GTMax) Lite.

If the previous month's elevation is less than 3,490 feet, there is no power or energy generated for the current month. This elevation reflects the minimum power pool elevation at Lake Powell.

A.9.2 Hoover Dam

The method that computes power and energy generated at Hoover Dam assumes two levels of power generation. The lower level of generation occurs at base flow, while the upper level occurs at peak flow. The method computes the fraction of the month that the powerplant is operated at peak flow and base flow. The peak flow is the most efficient flow through the turbines for the current operating head, while the base flow represents the minimum flow through the turbines to produce energy.

The base flow and corresponding power generation are based on the outflow for the current month. The peak flow must be computed through an iterative procedure using operating head, tailwater elevation, and turbine release. The initial turbine release is assumed to be that corresponding to maximum power production. Tailwater elevation at Hoover Dam is computed as a function of Lake Mohave elevation and Hoover Dam release.

The monthly Hoover Dam release volume at the base flow is computed by applying the base flow over the month. The monthly release volume at the peak flow is computed as:

$$PeakFlowVolume = TurbineReleaseVolume - BaseFlowVolume$$

Next, the number of hours required for operation at base and peak flows are computed as:

$$PeakHours = \frac{PeakFlowVolume}{(PeakFlow - BaseFlow) * 3600}$$

$$BaseHours = \frac{SecondsInMonth}{3600} - PeakHours$$

where 3,600 is the amount of seconds per hour.

If the peak hours are greater than the length of the month, the peak hours' value is set equal to the length of the month, and the base hours value is set to zero. The peak and base hours are then multiplied by the power plant capacity at each level and added together to obtain the total energy produced for the month. Power is computed as the energy divided by the length of the month in hours.

The algorithm described above allows power generation at elevations below approximately 950 feet, which is the minimum power pool at Lake Mead. According to the algorithm, power is generated as long as the minimum operating head of 305 feet is available, corresponding to an elevation of about 950 feet. Because there is no operating experience at these elevations, it is impossible to verify whether CRSS mimics the actual turbine performance at such low heads. It is, therefore, critical to interpret energy results from CRSS in a relative, comparative manner rather than as absolute quantities.

Power capacity is the power that could be generated if the flow is directed through the penstock turbine(s) with a given operating head. This is computed to distinguish between actual power production and the power that could be produced.

A.9.3 Davis Dam

The method that computes power and energy generation at Davis Dam uses an empirical relationship as a function of flow, operating head, plant efficiency, and user-specified power coefficients. This empirical relationship is estimated by Reclamation and was last updated in 2019 using January 2012–September 2018 historical data. Energy is computed using this empirical relationship as:

$$Energy\ (MWH) = \left(C_1 * \frac{62.4}{737.5} * Outflow\ (1000\ cfs) * HoursInMonth * \frac{OperatingHead\ (ft)}{1000} - C_2\right) * eff * 1000$$

where 62.4 is the unit weight of water in pounds per cubic foot; 737.5 represents foot-pounds per second per kilowatt; C_1 is estimated to be 0.88 based on historical data; C_2 is estimated to be 0; and eff is set to 1.0. C_1 and eff are representations of the efficiency of the powerplant, where C_1 must be a static value through the entire simulation; eff can vary (by month and/or year). C_2 represents any energy consumed within the powerplant and is set to 0 because Reclamation does not have necessary data to determine C_2.

This energy method is different from the method used in CRSS for the 2007 FEIS; this is because the analysis of energy methods in RiverWare indicated the new method simulates historical energy generation better than the method previously used in CRSS. This new method does not currently estimate the power capacity at Davis Dam, which was computed by the method used for the 2007 FEIS.

A.9.4 Parker Dam

The method that computes power and energy generation at Parker Dam is the same method used for Davis Dam, except C_1 is set to 1.0; C_2 is estimated to be 0; and eff varies by month, as shown in **Table A-23**. The monthly efficiency coefficients are based on an analysis of historical data from Power, Operations, and Maintenance reports (January 2000–April 2021).

Table A-23
Parker Dam Monthly Efficiency Coefficients

Month	Coefficient
January	0.8192
February	0.8583
March	0.8645
April	0.8732
May	0.8705
June	0.8703
July	0.8658
August	0.8631
September	0.8588
October	0.8636
November	0.8369
December	0.7710

A.10 Salinity Method

The salinity module within CRSS is designed for long-term simulation over a horizon of 15 years and beyond and is the same for all alternatives. Results are particularly sensitive to initial conditions during the first 10 to 12 years. The method treats salinity as a conservative water quality parameter, and reservoirs are represented as fully mixed systems. Inputs include salinity associated with hydrologic inflows, initial reservoir salinity concentrations, estimates of salt loading from agricultural return flows, and salt removed by salinity control projects or trans-basin exports out of the basin[16]. Using these inputs, the CRSS produces annual average salinity concentrations at key numeric criteria stations located below Hoover Dam, below Parker Dam, and at Imperial Dam and at 17 locations above Hoover Dam. Salinity concentrations at Hoover Dam and above are computed using RiverWare's water quality module, while concentrations at Parker Dam, Imperial Dam, and at the Northerly International Boundary with Mexico (NIB) are based on the calculations described below.

Salinity concentrations below Parker Dam and at Imperial Dam are projected as functions of concentrations below Hoover Dam using USGS-developed equations (Anning, et al. 2018). Below Parker Dam, concentrations are estimated using a simple linear regression informed by Hoover Dam values, while concentrations at Imperial Dam are determined using a numerical model that

[16] The Yuma Desalting Plant is assumed to remain non-operational for the duration of the simulation.

incorporates tributary inflows and diversions. These equations were identified as the best available representation of downstream salinity concentrations relative to Hoover Dam concentrations.

The concentration below Parker Dam, C_{Parker} is calculated as:

$$C_{Parker} = 1.019 * C_{Hoover}$$

The following equation and **Table A-24** are used to calculate concentration at Imperial Dam, $C_{Imperial}$:

$$C_{Imperial} = \frac{c_{12}c_{13}C_{Hoover}Q_{Main\ stem} + c_3 C_{Parker} c_2 Q_{Diversions} + c_6 c_5 (c_4 - Q_{Main\ stem}) + c_9 c_8 (P - c_7)}{c_1 Q_{Main\ stem} + c_2 Q_{Diversions} + c_5 (c_4 - Q_{Main\ stem})} - c_{10}\frac{dc}{dt}$$

where:

$c_{1\text{-}13}$ = defined in **Table A-24**
C_{Hoover}, = salinity concentration at Hoover
C_{Parker} = 627 mg/L
$Q_{Main\ stem}$ = flow below parker minus Palo Verde Irrigation District and Colorado River Indian Reserve diversions
$Q_{Diversions}$ = sum of Palo Verde Irrigation District and Colorado River Indian Reserve diversions
dC/dt = change in Hoover salinity from the previous timestep

Table A-24
Estimated numerical model coefficients for the Parker Dam to Imperial Dam model and for the Hoover Dam to Imperial Dam model

Coefficient	Estimated value for the Parker Dam to Imperial Dam model	Estimated value for the Hoover Dam to Imperial Dam model	Units
c1	0.95	0.95	Dimensionless
c2	0.7	0.7	Dimensionless
c3	1.187	1.187	Dimensionless
c4	16,860	16,860	ft^3/s
c5	0.088	0.088	Dimensionless
c6	1,140	1,140	mg/L
c7	0	0	inches
c8	0	0	(ft^3/s)/inch
c9	0	0	mg/L
c10	0.5	0.55	Months
c11	5 through April 2008, and 0 thereafter	20 through April 2008, and 0 thereafter	mg/L
c12	NA	1.019	Dimensionless
c13[17]	NA	0.81	Dimensionless

[17] If discharge from Bill Williams River is <1,000 ft^3/s, c_{13} = 1.0.

Salinity concentration at the NIB is projected as a function of simulated salinity at Imperial Dam and base flows accruing to the river between Imperial Dam and the NIB. This logic does not simulate operations by Reclamation's Yuma Area Office to ensure compliance with the Minute No. 242 salinity differential. Rather, this logic assumes constant monthly base flows accruing to the Colorado River between Imperial Dam and the NIB to estimate the salinity at the NIB.

The salinity at the NIB is a function of the estimated volume of Colorado River water originating upstream from Imperial Dam, which is delivered to the NIB. This NIB volume is estimated as the total delivery to Mexico determined by CRSS, minus estimated deliveries to Mexico from sources downstream from Imperial Dam. These include deliveries from pumped groundwater and irrigation return flows to the Southerly International Boundary with Mexico (SIB); and pumped groundwater, base flow, irrigation return flows, and canal wasteway flows which accrue to the Colorado River between Imperial Dam and the NIB. Base flow and salinity concentration from these sources are represented between Imperial Dam and NIB as other measured flows, unmeasured flows, and pumped groundwater returned to the river. Flow and concentration values from these sources were estimated using available historical data from the period of 2018 through 2022. The salinity at the NIB is calculated via a simple monthly mass balance using the volume of Colorado River water delivered to Mexico through Imperial Dam (with the associated Imperial Dam salinity value) plus the base flows and their associated salinity values. These base flow values and salinity concentrations vary for each month but do not vary each year or across traces or alternatives.

Salinity concentration below Hoover Dam and at 17 locations represented in CRSS above Hoover Dam are determined with a basin-wide salinity modeling framework described in Prairie and Rajagopalan (2007), which is implemented within RiverWare's water quality module. Natural flow and salt mass data for an observed period is first developed using Reclamation's RiverWare Natural Flow & Salt model (NFSM). Future salinity concentrations throughout the Colorado River watershed are generated using Reclamation's nonparametric natural salt model. This model relies on annual total flow–salt mass (Upper Basin) and intervening flow–salt mass (Lower Basin) regressions presently developed from 1991–2020 natural flow and salt mass data. The natural salt model provides salt mass estimates based on flows, from which salt concentrations are then calculated that align with natural hydrologic inflows input into CRSS. Present level agricultural salt loading is assumed to remain constant throughout the simulation period while projected increases in agricultural consumptive use are assigned a salinity pickup concentration that determines salt loading as a function of agricultural return flows. Variations in salt mass driven by extreme flow conditions are not explicitly represented; as a result, negative natural salt values can arise during computation.

To maintain realistic behavior at modeled stream gage locations, salt concentrations on river reaches are constrained within their historical minimum and maximum ranges, with any excess stored for later release when concentrations return to historical concentration ranges.

A.11 References

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Attachment A1

CRSS Lake Powell Assumed Monthly Releases

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Attachment A1. CRSS Lake Powell Assumed Monthly Releases

Table Attachment A1-1
CRSS Lake Powell Assumed Monthly Releases (Values in af)

Annual Total	October	November	December	January	February	March	April	May	June	July	August	September
5,000,000	403,000	397,000	425,000	438,000	392,000	429,000	406,000	416,000	412,000	436,000	444,000	402,000
6,000,000	410,000	430,000	510,000	570,000	500,000	530,000	470,000	470,000	500,000	560,000	600,000	450,000
7,000,000	480,000	500,000	600,000	664,000	587,000	620,000	552,000	550,000	577,000	652,000	696,000	522,000
7,480,000	480,000	500,000	600,000	723,000	639,000	675,000	601,000	599,000	628,000	709,000	758,000	568,000
8,230,000	643,000	642,000	715,000	763,000	675,000	713,000	635,000	632,000	663,000	749,000	800,000	600,000
9,000,000	643,000	642,000	715,000	857,000	758,000	801,000	713,000	710,000	745,000	842,000	900,000	674,000
9,500,000	643,000	642,000	715,000	919,000	813,000	858,000	764,000	761,000	798,000	902,000	963,000	722,000
10,000,000	643,000	642,000	715,000	980,000	870,000	920,000	810,000	810,000	850,000	960,000	1,030,000	770,000
10,500,000	643,000	642,000	715,000	1,041,000	921,000	973,000	866,000	862,000	905,000	1,022,000	1,091,000	819,000
11,000,000	643,000	642,000	715,000	1,102,000	975,000	1,030,000	917,000	913,000	958,000	1,082,000	1,156,000	867,000
11,500,000	643,000	642,000	715,000	1,160,000	1,030,000	1,090,000	970,000	960,000	1,010,000	1,140,000	1,220,000	920,000
12,000,000	643,000	642,000	715,000	1,225,000	1,083,000	1,145,000	1,020,000	1,014,000	1,064,000	1,202,000	1,284,000	963,000
12,500,000	643,000	642,000	715,000	1,290,000	1,140,000	1,200,000	1,070,000	1,060,000	1,120,000	1,260,000	1,350,000	1,010,000
13,000,000	643,000	642,000	715,000	1,347,000	1,192,000	1,259,000	1,121,000	1,116,000	1,171,000	1,322,000	1,413,000	1,059,000
13,500,000	643,000	642,000	715,000	1,410,000	1,250,000	1,320,000	1,170,000	1,170,000	1,220,000	1,380,000	1,480,000	1,100,000
14,000,000	643,000	642,000	715,000	1,470,000	1,300,000	1,373,000	1,223,000	1,217,000	1,277,000	1,443,000	1,537,000	1,160,000
14,500,000	643,000	642,000	715,000	1,530,000	1,350,000	1,430,000	1,270,000	1,270,000	1,330,000	1,500,000	1,600,000	1,220,000
15,000,000	643,000	642,000	715,000	1,590,000	1,410,000	1,490,000	1,320,000	1,320,000	1,380,000	1,560,000	1,670,000	1,260,000
15,500,000	650,000	650,000	750,000	1,650,000	1,450,000	1,540,000	1,370,000	1,370,000	1,420,000	1,620,000	1,730,000	1,300,000
16,000,000	650,000	650,000	800,000	1,720,000	1,490,000	1,590,000	1,410,000	1,420,000	1,480,000	1,670,000	1,780,000	1,340,000
16,500,000	650,000	650,000	800,000	1,770,000	1,550,000	1,650,000	1,470,000	1,460,000	1,530,000	1,730,000	1,850,000	1,390,000
17,000,000	650,000	650,000	800,000	1,840,000	1,600,000	1,700,000	1,510,000	1,510,000	1,590,000	1,790,000	1,920,000	1,440,000
17,500,000	650,000	650,000	800,000	1,900,000	1,650,000	1,760,000	1,560,000	1,570,000	1,640,000	1,850,000	1,980,000	1,490,000
18,000,000	650,000	650,000	800,000	1,960,000	1,710,000	1,820,000	1,620,000	1,620,000	1,690,000	1,910,000	2,040,000	1,530,000
20,000,000	800,000	800,000	1,000,000	2,000,000	1,760,000	1,880,000	1,980,000	2,040,000	1,980,000	2,040,000	2,040,000	1,680,000
30,000,000	1,600,000	1,600,000	1,900,000	2,500,000	1,900,000	2,500,000	2,500,000	2,800,000	3,100,000	3,400,000	3,400,000	2,800,000
50,000,000	2,666,667	2,666,667	3,166,667	4,166,667	3,166,667	4,166,667	4,166,667	4,666,667	5,166,667	5,666,667	5,666,667	4,666,667
75,000,000	4,000,000	4,000,000	4,750,000	6,250,000	4,750,000	6,250,000	6,250,000	7,000,000	7,750,000	8,500,000	8,500,000	7,000,000

Footnote:
Releases from 7.0 to 14.0 maf are from LTEMP; Monthly releases for the 5.0 maf annual volume are estimated for modeling purposes to maintain monthly releases above the LTEMP minimum daily volume. Releases outside this range are interpolated from LTEMP patterns for modeling purposes.

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Attachment A2

CRSS Lower Division States Water User Priorities

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Attachment A2. CRSS Lower Division State Water User Priorities

Water user names in the table reflect the water user names in CRSS and will differ from the Shortage Allocation Model. There are several CRSS "water users" that aggregate multiple real-world users. In those cases, the assumed priority used in CRSS may not match the priority of all users; the assumed priority is chosen as a modeling simplification. The shortage allocation model provides more detail on the distribution of shortages (**Appendix C**).

Table Attachment A2-1
CRSS Input Lower Division State Water User Priorities

State	Water User	Priority
Arizona	LakeMeadMohaveNRA	2
	TVMarbleCanyonAZ	4
	McAlisterFamilyTrust	4
	FortMojaveIndResAZ	1
	MohaveValleyIDD	1
	MohaveValleyIDDAgPortion	4
	MohaveValleyIDDMandIPortion	4
	MohaveCoWASubcontract	4
	HavasuNWRAZ	2
	MohaveCountyWA	4
	MohaveWaterConsDist	4
	MohaveWaterConsDist-MohaveCoWASubcontract	4
	AzStateLandDeptMI	4
	AzStateParksWindsorBeach	4
	BullheadCity-MohaveCoWASubcontract	4
	BullheadCity	4
	BureauLandMgmt	4
	CrystalBeachWCD	4
	GoldenShoresWCD	4
	LakeHavasuCity-MohaveCoWASubcontract	4
	LakeHavasuCity	4
	UnallocatedPriority4	4
	SpringsDelSol	4
	GoldDomeMiningCo	4
	DavisDamProject	2
	CAPDiversion	4
	AkChinTribe	3

State	Water User	Priority
Arizona	SaltRiverTribe	3
	IndianWaterRightsSettlementsPriority4	4
	Parker	1
	EPCOR	1
	HopiTribe	4
	NorthBajaLLC	4
	GMGabrychFamily	4
	EPCOR	4
	EhrenbergImprDist	4
	FisherLanding	4
	HillcrestWaterCo	4
	Parker	4
	Quartzsite	4
	ShepardWaterCo	4
	FrontierCommWestCoast	4
	MartinezLakeSites	4
	BFInvestments	4
	LaPazCounty	4
	ImperialNWRAZ	2
	CibolaNWR	2
	CibolaValleyIDD	4
	AZGameAndFishCom	4
	GSCFarm	4
	RedRiverLandCo	4
	WesternWater	4
	BishopFamilyTrust	4
	Cathcarts	4
	CibolaSportsmansClub	4
	CRIRAZ	1
	NorthGilaValleyIDD	1
	YumaCountyWUA	1
	CityOfYuma	1
	UnitBIDD	1
	ArmyYumaProvingGround	3
	NavyMarineCorpsYumaAirStation	3
	UnivOfArizona	3
	YumaMesaFruitGrowersAssn	3
	YumaUnionHighSchool	3
	YumaCemetery	3
	CityOfYuma	3

State	Water User	Priority
Arizona	YumaIrrDist	3
	UnitBIDD	3
	YumaMesaIDD	3
	WelltonMohawkIDD	3
	KamanInc	3
	NorthGilaValleyIDD	3
	YumaCountyWUA	3
	CocopahIndRes	1
	GilaMonsterFarms	1
	Powers	1
	Molina	1
	GilaMonsterFarms	3
	DesertLawnMemorialPark	3
	AlecCamille	3
	HaroldSturges	3
	IrmaSturges	3
	UnionPacificCo	3
	GilaMonsterFarms	4
	DesertLawnMemorialPark	4
	CocopahIndRes	4
	FtYumaReservation	1
	PhillipsMiltonAndJean	1
	CurtisArmon	4
	ChaCha	4
	JRJPartners	4
	OgramBoysEnterprises	4
	OttFamily	4
	PhillipsMiltonAndJean	4
	BeattieFarmsSouthwest	4
	PasquinelliGaryAndBarbara	4
	EdwardRoy	4
	Somerton	4
	AzStateLandDeptAg	4
California	FortMojaveIndResCA	PPR
	CityOfNeedlesBernardinoCounty	PPR
	ChemehueviIndRes	PPR
	OthersAndMiscPresPerfRights	PPR
	QSAIIDtoMWDP3a	3(a)
	QSACVIDtoMWDP3a	3(a)
	MWDDiversion	4

State	Water User	Priority
California	CRIRCA	PPR
	PVIDDiversionPPR	PPR
	PVIDP1	1
	PVIDP3b	3(b)
	IIDDiversionPPR	PPR
	IIDDiversionP3a	3(a)
	QSAIIDtoCoachellaP3a	3(a)
	CoachellaDiversion3a	3(a)
	BardUnitPPR	PPR
	BardUnitP2	2
	QuechanResUnitA	PPR
Nevada	SNWPDiversion	8
	SNWPAdditionalDemand	8
	LaughlinAreaNevadaMI	8
	FortMojaveIndResNV	1 (PPR)
	NVDOW	7
	LakeMeadNRAP2	2
	LakeMeadNRAP1	1 (PPR)