Appendix G2
CRSS Modeling Assumptions

Appendix G2 — CRSS Modeling Assumptions

1.0 Background

The Colorado River Simulation System (CRSS), the Bureau of Reclamation's (Reclamation) long-term planning model that covers the entire Colorado River Basin (Basin), is the primary model used in the Colorado River Basin Water Demand and Supply Study (Study) to simulate future conditions. The model framework used for this process is a commercial river modeling software called RiverWare™ (Zagona et al., 2001); a generalized river basin modeling software package developed by the University of Colorado through a cooperative arrangement with Reclamation and the Tennessee Valley Authority. CRSS was originally developed by Reclamation in the early 1970s and was implemented in RiverWare™ in 1996.

CRSS simulates the operation of the major reservoirs on the Colorado River and provides information regarding the projected future state of the system on a monthly basis in terms of output variables including the amount of water in storage, reservoir elevations, releases from the dams, the amount of water flowing at various points throughout the system, and the diversions to and return flows from the water users throughout the system. The basis of the simulation is a mass balance (or water budget) calculation that accounts for water entering the system, water leaving the system (e.g., from consumptive use of water, trans-basin diversions, evaporation), and water moving through the system (i.e., either stored in reservoirs or flowing in river reaches). The model was used to project the future conditions of the Colorado River system on a monthly time-step for the period 2012 through 2060.

The input data for the model includes monthly natural inflows, various physical process parameters such as the evaporation rates for each reservoir, initial reservoir conditions on January 1, 2012, and the future diversion and depletion schedules for entities in the Basin States and for the United Mexican States (Mexico). These future schedules were based on the six demand scenario quantified in the Study (*Technical Report C – Water Demand Assessment)*.

The rules of operation of the Colorado River mainstream reservoirs including Lake Powell and Lake Mead are also provided as input to the model. This set of operating rules describes how water is released and delivered under various hydrologic conditions and aim to reflect actual operations. Rules that guide the portfolio implementation are also input to the model and reflect a "dynamic" implementation that triggers options to be implemented only when needed as determined by the occurrence of a set of pre-defined vulnerability signposts. These signposts consist of combinations of certain Lees Ferry natural flow conditions and Lakes Powell and Mead reservoir elevations that are correlated to the occurrence undesirable conditions (e.g. Lake Mead less than 1,000 feet above mean sea level [msl]) or vulnerabilities.

The future hydrology used as input to the model consisted of sequences that comprise the Study's four water supply scenarios (*Technical Report B – Water Supply Assessment)*. Each sequence (a total of 1,959 when combining all four water supply scenarios) is input as natural flow at 29 individual inflow points (or nodes) on the system. The locations of the hydrologic input sites are shown and the methodologies used to generate future inflow sequences are discussed in *Technical Report B – Water Supply Assessment*.

The following sections describe the CRSS modeling assumptions and configuration associated with the modeling of the system reliability without options and strategies (Baseline system reliability) and those for the modeling of the system reliability with options and strategies.

2.0 System Reliability without Options and Strategies (Baseline) Modeling Assumptions

For the modeling of the Baseline system reliability, the state of the system was simulated from 2012–2060 with all combinations of the supply and demand scenarios. The four supply scenarios are Observed Resampled, Paleo Resampled, Paleo Conditioned, and Downscaled GCM (General Circulation Model) Projected. See *Technical Report B – Water Supply Assessment* for further descriptions of the supply scenarios. The six demand scenarios are Current Projected (A), Slow Growth (B), Rapid Growth (C1 and C2), and Enhanced Environment (D1 and D2). Additional details are available in *Technical Report C – Water Demand Assessment*. Additionally, two assumptions regarding Lakes Powell and Mead operations after the expiration of the *Record of Decision for Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations of Lake Powell and Lake Mead* (2007 Interim Guidelines [U.S. Department of the Interior (DOI), 2007]) in 2026 were considered and are described more in the reservoir operations section below. The combination of all water supply and demand scenarios and two operational assumptions for Lakes Powell and Mead result in 48 Baseline simulations, each with multiple future sequences that reflect water supply uncertainty. For combinations in which a demand scenario is coupled with the downscaled GCM projected hydrology, agriculture, outdoor municipal and industrial (M&I), and phreatophyte demands, along with reservoir evaporation are adjusted to reflect increased water needs under a warmer climate, see Technical Report C for additional details. The following sections detail the assumptions and model configuration for the Baseline simulations.

2.1 Initial Conditions

The model was initialized with observed 2011 end-of-calendar-year (EOCY) reservoir conditions shown in table G2-1.

2.2 Reservoir Operations

2.2.1 Upper Basin Reservoirs above Lake Powell

The Taylor Park, Fontenelle, and Starvation reservoirs are operated in accordance with their existing rule curves (Reclamation, 2007), although Fontenelle's operating rules in CRSS have been updated since the 2007 Interim Guidelines (DOI, 2007). The Aspinall Unit operations do not reflect the *Record of Decision* (ROD) *for the Aspinall Unit Operations Final Environmental Impact Statement* (FEIS) (Reclamation, 2012) because the modeling in the Study began before the signing of the ROD. Instead, Aspinall Unit operations are also operated in accordance with their previous rule curves (*Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations of Lake Powell and Lake Mead Final Environmental Impact Statement* [Reclamation, 2007]).

TABLE G2-1
2011 End-of-Calendar-Year Reservoir Storage Conditions used as Initial Conditions

Reservoir	Elevation (feet msl)	Storage (af)
Fontenelle	6,486.86	207,381
Flaming Gorge	6,031.41	3,403,746
Starvation	5,734.92	255,000
Taylor Park	9,307.93	66,655
Blue Mesa	7,489.07	574,132
Morrow Point	7,154.97	112,986
Crystal	6,750.95	6,359
Navajo	6,057.10	1,311,371
Powell	3,639.74	15,972,410
Mead	1,132.83	14,883,261
Mohave	638.82	1,585,878
Havasu	445.69	537,515

CRSS was modified to reflect the Navajo and Flaming Gorge RODs (Reclamation, 2006a and 2006b, respectively). In general, both RODs contain downstream flow targets that the reservoirs must attempt to meet according to the rules within the RODs. In summary, Flaming Gorge operations are governed by the April through July unregulated inflow into the reservoir, which determines which downstream flow targets should be met—e.g., in a wet year (larger inflow into the reservoir), higher downstream flows are targeted. The flow targets are specified at the sub-monthly time step, which historically could not be reflected within CRSS. In order to capture the sub-monthly component of the flow targets, and thus Flaming Gorge's operations, the model was programmed to determine typical daily operations before summing to a monthly release (Butler, 2011).

Similarly, Navajo's ROD contains multiple downstream flow targets, specified at sub-monthly time intervals. In this case, a September 30th storage target guides Navajo's operations. A release pattern is selected to bring Navajo closest to the September 30th storage target while helping meet the downstream flow targets stated in the ROD (Butler, 2011).

2.2.2 Lake Powell and Lake Mead

For 2012 through 2026, Lake Powell and Lake Mead are operated according to the 2007 Interim Guidelines. For modeling purposes, after the expiration of the 2007 Interim Guidelines in 2026, two operational assumptions, a. and b. below, were considered.

1) the Shortage, Surplus, and Coordinated Operations provisions of the 2007 Interim Guidelines are extended

a. The Equalization Line at Powell from 2027 through 2060 is determined by assuming the slope of the Equalization Line from 2012 through 2026 extends through 2060.

2) *the operating rules revert to the rules of the 2007 Interim Guidelines Final EIS No Action Alternative*. The No Action Alternative assumes the following for Shortage, Surplus and Coordinated Operations. There is no Intentionally Created Surplus (ICS) assumed in the No Action Alternative.

a. Shortage: Stage 1 Shortage is triggered to prevent Mead from declining below 1,050 feet msl. Stage 1 Shortages range in volume from approximately 350 to 500 kaf. If Lake Mead's elevation continues to decline, a Stage 2 Shortage is imposed to keep Mead above 1,000 feet msl. Stage 2 Shortages can be up to 3.0 maf.

b. Surplus: Surplus determinations are per Flood Control Surplus conditions or the 70R Strategy[1].

c. Coordinated Operations: Three factors affecting Lake Powell's release are: 1) the minimum objective release of 8.23 maf, 2) equalization; and 3) spill avoidance. For equalization to occur the 602(a) storage requirement must be met.

In both cases, Lake Mead flood control procedures are in effect. Also, if Lake Mead elevation falls below 1,000 feet msl, deliveries to the Southern Nevada Water Authority (SNWA) are assumed to continue.

If Lake Mead is sufficiently low such that after the maximum shortage (per the 2007 Interim Guidelines or No Action Alternative post 2026) is applied water is still unavailable to meet the remaining deliveries, the remaining deliveries were shorted hydrologically with respect to their physical location on the river.

2.2.3 Lake Mohave and Lake Havasu

Lake Mohave and Lake Havasu are operated in accordance with their existing rule curves.

2.3 Intentionally Created Surplus

Intentionally Created Surplus (ICS) may be created through various mechanisms, including extraordinary conservation, tributary conservation, system efficiency projects, and importation of non-Colorado River water. The 2007 Interim Guidelines detail the different types of ICS and the rules that govern the creation, storage, and use of ICS credits. In addition to contractor-specific creation, several Lower Basin projects have been completed since 2007. In 2010, the Warren H. Brock Reservoir became operational. Based on the funding agreement, the Metropolitan Water District of Southern California (MWD) and the Central Arizona Project (CAP) were credited with 100 kaf, and SNWA with 400 kaf of system efficiency ICS (referred to as Brock ICS to

[1] 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. See appendix A of the 2007 Interim Guidelines Final EIS (Reclamation, 2007) for the full 70R computation.

distinguish from other system efficiency ICS). Additionally, the same three agencies funded an 18-month pilot-run of the Yuma Desalting Plant (YDP). Based on the pilot run, MWD, CAP, and SNWA were credited with 24,397 af; 3,050 af; and 3,050 af of system efficiency ICS (referred to as YDP ICS), respectively. Under the 2007 Interim Guidelines, ICS cannot be created after 2026 and must be used by 2036. Under the modeling assumption that the 2007 Interim Guidelines expire in 2026, ICS is subject to these constraints. However, under the assumption that the 2007 Interim Guidelines are extended through 2060, it is assumed that ICS activity is also extended through 2060. The remaining sections detail the state-specific modeling assumptions for creation and delivery of ICS.

2.3.1 Arizona

Arizona has an initial credit of 100 kaf from Brock and 3,050 af from the YDP pilot project. In CRSS, it is assumed that starting in 2018, the CAP will take delivery of 10 kaf per year (kafy) of the Brock ICS credits in any non-shortage year (Lake Mead > 1,075 feet msl) as defined by the 2007 Interim Guidelines until the credits have been exhausted or the ICS mechanism expires. Additionally, Arizona will use its 3,050 af of YDP credits in the first normal year (Lake Mead > 1,075 feet msl and < 1,145 feet msl) after 2017.

2.3.2 California

California has an initial credit of 66 kaf from Brock, 24,396 af from YDP, and 344,439 af from extraordinary conservation (EC), which are the December 31, 2011 balances. It is assumed that all deliveries of California's ICS credits are made to MWD and that any creation of ICS credits through extraordinary conservation is also made by MWD. Because ICS expires at different times depending on the post-2026 operations assumption, the logic for creation and delivery of ICS differs depending on which policy is in effect.

When it is assumed that the 2007 Interim Guidelines expire in 2026 and operations revert to the FEIS No Action Alternative, ICS must be completely recovered by 2036. Under this operating assumption, the 66 kaf of Brock ICS is recovered at a rate of 20 kafy, beginning in 2026, except during Shortage and Surplus conditions, or when EC-ICS is created. Once all Brock ICS credits are exhausted, the YDP ICS credits are used to bring the total ICS delivery between Brock and YDP to 20 kafy until all YDP credits are also exhausted. Again, the YDP credits are not delivered during Shortage and Surplus conditions or when EC-ICS is created. When the 2007 Interim Guidelines are assumed to extend through 2060, the Brock and YDP ICS is recovered using the same logic, although the initial recovery does not begin until 2041.

The creation and delivery of EC-ICS again depends on the post-2026 operations assumption and also varies with the natural flow conditions at Lees Ferry. EC can be created in Surplus and Shortage conditions and is assumed to not be delivered during Shortage conditions. The provided demand schedules (see Technical Report C) include an assumed creation of 200 kaf of EC-ICS, which is reflected in the model by increasing the initial balance to 544,439 kaf (the 2011 end-of-calendar-year balance plus the assumed creation minus the system assessment). Additionally, it is assumed that another 200 kaf of EC-ICS is created in 2013. For the period 2014 through 2060, the creation and delivery amounts vary with post-2026 operations and the annual Lees Ferry natural flow. The annual natural flow at Lees Ferry is compared with the 1906 through 2008 observed natural flow to determine the quantity of EC-ICS (table G2-2). The maximum amount of EC-ICS that can be stored in Lake Mead is 1.5 million acre-feet (maf), so any creation amount is constrained to not exceed the maximum storage constraint. When the 2007 Interim Guidelines are assumed to expire in 2026, the delivery amounts no longer depend on the natural flow conditions. Beginning in 2031, ICS is delivered in any surplus year that delivery to MWD is less than 1.25 maf. In normal years the EC-ICS delivery is computed as the end of the previous year's ICS balance divided by the number of years before 2037. This amount in constrained to be no larger than the remaining balance nor more than the remaining Colorado River Aqueduct capacity. For example, if the 2030 balance is 1.5 maf, then the 2031 delivery is 250 kaf in Normal conditions.

TABLE G2-2
California Extraordinary Conservation ICS Creation and Delivery Amounts

	2007 Interim Guidelines Expire in 2026		2007 Interim Guidelines Extend through 2060			
			Creation (kaf)		Delivery (kaf)	
Lees Ferry Natural Flow Percentile	Creation (kaf) 2014–2026	Delivery (kaf) 2014–2030[1]	2014–2040	2041–2060	2014–2040	2041–2060
>= 80th	200	0	200	150	0	0
< 80th and >= 60th	200	0	200	75	0	0
< 60th and >= 40th	75	0	75	0	0	100
< 40th and >= 20th	0	0	0	0	0	250
< 20th	0	150	0	0	150	250

[1] ICS deliveries can continue through 2036. For the period 2031–2036, the EC-ICS delivery is computed as the end of the previous year's ICS balance divided by the number of years left before 2037.

2.3.3 Nevada

In the state of Nevada, SNWA accounts for all ICS activity. The 2011 end-of-year balances for Brock and YDP ICS are 400,000 and 3,050 af, respectively. SNWA also had a non-zero 2011 end-of-year balance for EC-ICS; however, for the purposes of modeling, these credits were not considered. In addition to EC, YDP and Brock ICS, SNWA takes advantage of tributary conservation and imported ICS and has access to 1.25 maf of stored water in an Arizona groundwater bank. It is assumed that SNWA has access to 30 kaf of tributary conservation ICS in 2012 through 2015 and 15 kaf in 2015 through 2060 with access to an additional 9 kafy of imported ICS. This section describes the modeled logic for utilizing these multiple resources. Based on the quantification of demands (Technical Report C), SNWA has demands above Nevada's basic apportionment of 300 kaf that increase through time. The logic presented here focuses on using ICS credits to help offset the demands above apportionment. The system conditions, i.e., Normal, Surplus, or Shortage, and the differing constraints on the different types of ICS, necessitate logic that differs with system condition.

The logic describes how all sources would be utilized in priority order; however, if at any stage there is no more remaining demand above apportionment, then the remaining sources are not used. In Normal conditions, SNWA starts by utilizing the tributary conservation and imported

ICS[2]. If there is more tributary and imported ICS than demand above apportionment, then the remaining ICS credits are converted to EC-ICS and are stored in Lake Mead; if the 2007 Interim Guidelines are assumed to expire in 2026, then the remaining credits cannot be stored after 2026. The next source utilized is stored EC-ICS credits in Lake Mead. The withdrawals from EC-ICS can occur 10 years after the 2007 Interim Guidelines expire and cannot exceed 300 kaf in any one year. Next, Brock ICS will be recovered at a rate of up to 40 kafy until the 400 kaf are fully recovered, or 10 years after the 2007 Interim Guidelines expire, whichever occurs first. Finally, the Arizona groundwater credits are recovered at a rate of up to 40 kafy until fully utilized. During a Domestic and Quantified Surplus, the Normal conditions logic is applied, although before doing so, the surplus deliveries are applied to the demand above apportionment. During Flood Control Surplus, no ICS deliveries are made and any EC-ICS credits stored in Lake Mead are lost. The flood control delivery to SNWA contains an additional 30 kaf of water that is assumed to be deposited into a groundwater bank. The use of this water is not modeled; however, the total deposits are recorded.

During Shortage Conditions, the tributary conservation and imported ICS are recovered up to their respective maximum values. Because EC and Brock ICS cannot be recovered during shortage years, the Arizona groundwater bank is the next source available; it is recovered up to 40 kafy.

2.4 Other Key Assumptions

2.4.1 Upper Colorado River Water Rights

Historically, CRSS has not modeled water rights in the Upper Basin. Deliveries were made to all users if there is water in the reach, regardless of whether there was a downstream user with a more senior water right. Although this can affect the modeled deliveries and shortages to various users, it also can skew modeled streamflow. During the Study, an effort was made to improve the Upper Colorado River reach upstream of the confluence with the Gunnison River by incorporating two senior water rights on the Upper Colorado main stem. The reach above the confluence with the Gunnison River is largely governed by two senior rights: the senior right of the Shoshone Power Plant and the senior users from the Grand Valley Irrigation Company. CRSS was modified to ensure that Shoshone Power Plant had access to 1,250 cubic feet per second by shorting users above Shoshone. Then, all users above the Grand Valley Irrigation Company, except for Shoshone Power Plant, are shorted to ensure that the senior users' demands are fully met before meeting any other demands. The existing demand node that represented the Grand Valley Irrigation Company included senior and junior user demands. It was assumed that half of the existing demands were senior demands, which total 106.5 kafy of consumptive demand under the Current Projected (A) demand scenario. Incorporating the simple priority deliveries into CRSS more accurately reflects shortages to Upper Colorado main stem users while improving the modeled flows at the Colorado River near Glenwood Springs and Cameo gages.

[2] Tributary conservation and imported ICS are described together throughout the document; however, in practice and in CRSS, tributary ICS is used before imported ICS.

2.4.2 Lee Ferry Deficit

Logic has been implemented such that when the monthly, 10-year moving aggregate flow volume at Lee Ferry falls below 75 maf, water is injected into the system just above Lake Powell, and then released from Lake Powell during the same month. The magnitude of the injection and subsequent release is computed to bring the 10-year total volume at Lee Ferry to 75 maf. The injected water is reported as Lee Ferry deficit[3] throughout the Study. When water is assumed to be supplied to the system in this manner, the uncertainty regarding metric results increases, particularly in the Upper Basin. However, due to the infrequent occurrence of a Lee Ferry deficit across all traces, these results are not disregarded. This uncertainty, however, should be considered carefully when viewing metric results, particularly in the Upper Basin, that have been impacted by this modeling assumption.

2.4.3 Deliveries to Mexico

For modeling purposes, future water deliveries to Mexico are made as follows:

1. The model accounts for the entire delivery to Mexico at the Northerly International Boundary (NIB).
2. Water deliveries to Mexico are pursuant to the provisions of the 1944 Treaty. This provides annual deliveries of 1.5 maf to Mexico and up to 1.7 maf during Lake Mead flood control release conditions.
3. For modeling purposes it is assumed that during Shortage Conditions, Mexico shares shortage in proportion to U.S. users in the Lower Basin (16.67 percent). This assumption is consistent with that used in the modeling supporting 2007 Interim Guidelines Final EIS (Reclamation, 2007)[4].
4. Neither Minute No. 318 (through 2013) nor Minute No. 319 (through 2017) were modeled in the Study due to their limited duration.

2.4.4 Warren H. Brock Reservoir

Brock reservoir is assumed to operate every year beginning in 2012 and is assumed to conserve approximately 90 percent of non-storable flows. This reduces the average annual volume of non-storable flows delivered to Mexico from 73 kafy (historical average from 1964 through 2010, excluding flood years on the Gila or flood control releases) to 7 kafy.

2.4.5 Welton-Mohawk Return Flows

Bypass of return flows from the Welton-Mohawk Irrigation and Drainage District to the Cienega de Santa Clara in Mexico is assumed to be 109 kafy (historical average from 1990 through 2010) and is not counted as part of the 1944 Treaty delivery to Mexico.

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[3] Article III(d) of the Colorado River Compact stipulates that the Upper Division States will not cause the flow of the river at the Lee Ferry Compact Point to be depleted below an aggregate of 75 maf for any period of 10 consecutive years. For the purpose of the Study, a Lee Ferry deficit is defined as the difference between 75 maf and the 10-year total flow arriving at Lee Ferry.

[4] Allocation of Colorado River water to Mexico is governed by the 1944 Treaty. Reclamation's modeling assumptions are not intended to constitute an interpretation or application of the 1944 Treaty or to represent current United States policy or a determination of future United States policy regarding deliveries to Mexico.

2.4.6 Yuma Desalting Plant

The YDP is not assumed to operate during the Study period.

2.5 Control Run

The control run helps understand current variability of the system and model bias, which informs the development of several indicator metrics (see appendix G3). Demands were held constant for the entire modeling horizon at the 2015, current projected levels for the control run, and the equalization line is held constant at the 2015 level. The conditions were simulated for the 49-year period using the Observed Resampled supply scenario.

3.0 System Reliability with Options and Strategies Modeling Assumptions

3.1 Modeling Representative Options

Each characterized option (see *Technical Report F – Development of Options and Strategies*) that was contained within one of the portfolios was implemented in CRSS. The following sections describe how each representative option was implemented in CRSS and any assumptions that were made in the implementation. In some instances, multiple representative options are modeled identically, with only magnitudes varying—this is noted where applicable.

When options introduce new water into the system, e.g., desalination projects, assumptions were necessary to determine how this water would be used. For example, in the Lower Basin the water could be used to benefit the system, i.e., improve reservoir elevations and help meet demands within basic apportionment. Conversely, the new water could be used to meet the demand above the Lower Division States' basic apportionments. Ultimately, a hybrid approach was used. In the hybrid approach, new water goes towards meeting the demands above the Lower Division States' basic apportionments and offsetting shortages when Lake Mead elevation is greater than 1,050 feet above msl. Once Lake Mead elevations drop below 1,050 feet above msl, the water is assumed to go to the system until the next time Lake Mead is at or above elevation 1,050 feet above msl. The determination of whether the new water goes towards meeting demands above the Lower Division States' basic apportionments or to the system is an annual decision made in January based on the end of the previous year's Lake Mead elevation. Appendix G3 includes a sensitivity analysis which tested several elevations for determining whether the options' yield goes towards the system or demands above the Lower Division States' basic apportionment. Each option in which this approach is used is noted in the following sections.

3.1.1 Importations to the Front Range

Importations to the Front Range are modeled as a reduction in diversions by Front Range exports and the San Juan Chama Project (SJCP) export. The total project amount is split between the Front Range exports and the SJCP by computing the amount going to SJCP and assuming the remainder goes to the Front Range. SJCP's portion of the project is computed as the minimum of one-quarter of the total amount and the current year's SJCP demand. The reduction in the SJCP goes to demands above apportionment, in New Mexico, when they exist; otherwise, the reduction in SJCP's diversion becomes system water.

3.1.2 Southern California Desalination Options

Both the Pacific Ocean desalination and the Southern California groundwater desalination options are modeled as reductions in deliveries to MWD. For these options, it was assumed that MWD would reduce its diversions from the Colorado River to a minimum diversion of 450 kafy so that others could benefit from Southern California desalination options via an exchange with Colorado River water. The Pacific Ocean and the Southern California groundwater desalination options help meet the demands above the Lower Division States' basic apportionments when Lake Mead is greater than 1,050 feet msl; otherwise they go towards a system benefit.

3.1.3 Gulf of California Ocean Desalination

The Gulf of California (Gulf) ocean desalination option is modeled as an injection of water into the system above Imperial Dam. The injected water was assumed to have a salinity concentration of 750 milligrams per liter (mg/L). The Gulf of California ocean desalination helps meet the demands above the Lower Division States' basic apportionments when Lake Mead is greater than 1,050 feet msl; otherwise it goes towards a system benefit.

3.1.4 Yuma Brackish Water Desalination

The Yuma brackish water desalination option is modeled as an injection of water into the system below Imperial Dam. The Yuma brackish water desalination helps meet the demands above the Lower Division States' basic apportionments when Lake Mead is greater than 1,050 feet msl; otherwise it goes towards a system benefit.

3.1.5 Coal Bed Methane-produced Water

Although coal bed methane-produced water would be distributed over large areas in reality, it is modeled as a point injection at four locations in the Upper Basin. Table G2-3 lists the locations and the percent of the total project water that is injected at each location. The percentages were computed using the characterization of this option found in Appendix F6. All injections are assumed to have a salinity concentration of 250 mg/L and the injected water becomes system water.

TABLE G2-3
Coal Bed Methane-Produced Water Injection Locations

Injection Location in CRSS	Percent of Total
San Juan River Below Navajo Reservoir	57
White River above Watson, Utah	2.7
Green River above Green River, Utah	28
Green River at Green River, Wyoming	12.3

3.1.6 Tamarisk Control

Tamarisk control in the Upper Basin is modeled as an injection of water just above Lake Powell. For modeling purposes, the injected water is assumed to have a salinity concentration of 0 mg/L and is considered system water.

Tamarisk control on the Lower Colorado River mainstem is modeled as a reduction in demand of existing phreatophyte nodes. The assumed savings from tamarisk control are proportionally distributed to the three demand objects.

3.1.7 Conversion of Power Plants to Air Cooling

The characterization of the conversion of power plants to air cooling estimated 160 kaf of yield potential (appendix F10). This option is modeled as an 89.5-percent reduction in demand of several Upper Basin energy users. The percentage reduction was computed to yield a savings of approximately 160 kaf in 2015, although this same percentage is applied for every year the option is used.

3.1.8 M&I Conservation

M&I conservation is modeled as a proportional reduction in the consumptive demand of M&I users Basin-wide. This proportional application results in roughly 25 percent of each phase of conservation being applied to Upper Basin M&I users while the remaining 75 percent is applied to Lower Basin M&I users. Appendix F8 describes how the conservation amounts were quantified, including how and why they vary amongst demand scenarios. In the appendix, three levels of conservation are identified. For modeling purposes, these levels were further split into five phases, so that the effects of conservation could be more widely distributed through time and so the phases equate to roughly 200-kaf steps for consistency with other projects. Table G2-4 lists the five phases of M&I conservation by demand scenario. In the Lower Basin, it was assumed that M&I conservation be used to first meet demand above the Lower Division States' basic apportionment.

TABLE G2-4
M&I Conservation Quantities and Timing by Modeling Phase

Conservation Level	Modeling Phase	Year Available	Conservation Magnitudes (kaf)					
			Current Projected (A)	Slow Growth (B)	Rapid Growth (C1)	Rapid Growth (C2)	Enhanced Environment (D1)	Enhanced Environment (D2)
1	1	2016	200	200	200	50	50	50
2	2	2021	200	150	250	200	100	150
	3	2031	200	150	250	200	100	150
3	4	2041	200	200	275	250	200	275
	5	2051	200	200	275	250	200	275
Total Conservation			**1,000**	**900**	**1,250**	**950**	**650**	**900**

3.1.9 M&I Reuse Options

Municipal Wastewater Reuse

Municipal wastewater reuse is modeled as a reduction in diversion of the M&I exports in California, Arizona, New Mexico, Colorado, Wyoming, and Utah. The municipal wastewater reuse consists of both non-potable and indirect potable reuse (see appendix F5 for more information). Table G2-5 lists the reuse amounts by state and 200-kaf phase (fifth phase is only 132 kaf). Phase 1 is solely composed of non-potable reuse, and phases 3 through 5 are only indirect potable reuse. Phase 2 consists of the remaining available yield of non-potable reuse and enough indirect potable reuse in California and Arizona to bring the entire phase to 200 kaf.

In the Lower Basin, it was assumed that municipal reuse be used to first meet demand above the Lower Division States' basic apportionment. When reuse is combined with the M&I conservation option in portfolios the following assumption is made: if enough conservation takes place, then M&I reuse can indeed reduce the diversions from the Colorado River. Municipal reuse in California is modeled by reducing MWD's diversion from the Colorado River; MWD cannot reduce its Colorado River diversion below 450 kafy, which constrains the benefit to California. When MWD's diversion cannot be reduced further, the municipal wastewater reuse option is still implemented in the other states because it is applied to all states at once.

TABLE G2-5
Municipal Wastewater Reuse by State

	Amount of Reuse (af)					
Phase	**California**	**Arizona**	**Colorado**	**Utah**	**New Mexico**	**Wyoming**
1	109,200	45,500	27,600	11,100	5,500	1,100
2	115,300	48,000	22,400	8,900	4,500	900
3	141,000	59,000	0	0	0	0
4	141,000	59,000	0	0	0	0
5	93,500	38,500	0	0	0	0

Industrial Wastewater Reuse

Industrial wastewater reuse is modeled as a reduction in M&I demand for users with self-served industrial (SSI) demand in Colorado, Arizona, California, and Nevada. In Arizona, industrial demands exist in both the Central Arizona and the Mainstem planning areas. Rather than distributing a small savings to every M&I user in the Mainstem planning area, it was assumed that the reduction in demand occurred at the City of Yuma demand node. The total estimated demand reductions from industrial wastewater reuse were distributed between Colorado, Arizona, California, and Nevada as 26, 56, 15, and 3 percent of the total savings, respectively. The percentages were computed from the average SSI demand in each state among all demand scenarios. Within each state, the reduction in demand is proportionally distributed to all SSI users.

3.1.10 Grey Water Recycling

Grey water recycling is modeled by reducing M&I demands for the same users as municipal wastewater reuse. The total quantified yield from grey water recycling is proportionally distributed to the identified M&I exports.

3.2 Agricultural Conservation

Agricultural conservation is modeled as a proportional reduction in agricultural demands Basin-wide. This proportional application results in roughly 40 percent of each phase of conservation being applied to Upper Basin agricultural users while the remaining 60 percent is applied to Lower Basin agricultural users. Five phases of agricultural conservation exist, with savings of 200 kaf at each phase. Phase 1 is available in 2016, phase 2 in 2021, and phases 3 through in 2026.

3.3 Watershed Management

The dust control and weather modification options were modeled as percent increases in April through July natural flow at applicable natural flow nodes. Only April through July were selected because both programs focus on increasing runoff from snow pack. These options are modeled as percent increases instead of static values to help capture some of the uncertainty in these programs in the model. Additionally, weather modification will likely result in higher yields in years that already have above average snow pack; modeling the additional water as a percentage helps capture this characteristic as well. The percent increases were computed to result in the assumed yield from the options characterization when applied to the 1908–2008 average April through July natural flow at the applicable natural flow nodes. Table G2-6 lists the assumed percent increases for each phase of weather modification and dust mitigation.

Weather modification percent increases are applied to the following natural flow nodes: Colorado at Glenwood Springs, Colorado; Colorado at Cameo, Colorado; Taylor above Taylor Park, Colorado; Gunnison at Blue Mesa, Colorado; Gunnison at Grand Junction, Colorado; Dolores at Cisco, Utah; Green above Fontenelle, Wyoming; Green at Green River, Wyoming; Green at Greendale, Utah; Yampa at Maybell, Colorado; Little Snake near Lily, Colorado; Duchesne at Randlett, Utah; White near Watson, Utah; San Rafael near Green River, Utah; San Juan at Archuletta, New Mexico; and San Juan at Bluff, Utah. Dust control percent increases are applied to the following natural flow nodes: Colorado at Cameo, Colorado; Taylor above Taylor Park, Colorado; Gunnison at Blue Mesa, Colorado; Gunnison at Grand Junction, Colorado; Dolores at Cisco, Utah; San Juan at Archuleta, New Mexico; and San Juan at Bluff, Utah.

The natural salt loads will increase at the affected locations by assuming that the salinity concentration does not change due to weather modification or dust control. These options are assumed to be implemented for system benefit.

TABLE G2-6
Watershed Management Options with the Percent Increases to Natural Flow

Representative Option	Percent Increase in Natural Flow
Watershed-Weather Modification (step 1)	1.02
Watershed-Weather Modification (step 2)	2.03
Watershed-Dust (step 1)	6.12
Watershed-Dust (step 2)	2.62

3.4 Upper Basin Banking

This option created an Upper Basin water bank designed to help reduce the magnitude of a Lee Ferry deficit. In conjunction with the water bank, various conservation (M&I, agricultural, and energy) efforts across the Upper Basin would be coordinated for the purpose of yielding water to store in the bank. In order to ensure the conserved water is credited to the bank entirely, the water is routed to the designated storage facility, i.e., downstream users are not allowed to use water generated through upstream conservation. For modeling purposes it was assumed that a program could be in place by 2019, which is two years before the earliest occurrence of a Lee Ferry deficit under any supply/demand scenario combination. The following sections describe the modeling assumptions developed for the purposes of including the banking option in the Study. The provided modeling assumptions were based on the option submission and were further developed through the Modeling Sub-Team.

3.4.1 Bank Details and Administration

The Upper Basin Bank was assumed to be stored in a conceptual off-stream storage location just upstream of Lake Powell. The bank was constrained to a 5-maf storage capacity, and a 3 percent tax was applied to the bank's storage at the end of each year to account for various losses from seepage, transmission, etc.

Regarding the administration of water accumulated in the bank, when the 10-year Lee Ferry flow was less than 75 maf, banked water was released from the off-stream storage facility and passed through Lake Powell in order to ensure a 10-year flow of 75 maf at Lee Ferry. This supplementation continued until the 10-year volume was at or greater than 75 maf without supplementation from the bank or the bank was fully depleted. If the bank was fully depleted and the 10-year volume was still less than 75 maf, then water was injected upstream of Powell and reported as Lee Ferry deficit consistent with the Baseline modeling discussed earlier.

3.4.2 Generation of Water for the Bank

A two-tiered approach was assumed to generate water for use in the bank in order to 1) make annual contributions aimed at growing the balance over time under Tier 1 and 2) yielding additional water for the bank as the 10-year flow at Lee Ferry approaches 75 maf under Tier 2. The generated water was assumed to be from a combination of M&I, agricultural, and energy water conservation. From the quantification of conservation options independent of this specific option, there is the Basin-wide potential for approximately 1 mafy of conservation each in the agricultural and M&I sectors by 2060. A discussion of methods applied to determine the maximum values of conservation are provided in the agriculture and M&I conservation characterization documentation (see *Technical Report F – Development of Options and Strategies*). When benefits of such efforts are assumed to be distributed geographically in proportion to water use for those sectors, there is Upper Basin potential for approximately 250 kafy of M&I conservation and 400 kafy of agricultural conservation by 2060 under the current projected demand scenario. Additionally, according to the option characterization, there is at least 160 kafy of water conservation potential in the energy sector by 2060 within the Upper Basin.

As stated earlier, Tier 1 conservation aimed to build a balance in the bank over time via annual contributions. To accomplish this, conservation efforts to benefit the bank increased from the implementation date, reaching an annual yield of approximately 400 kaf by 2060. Contributions to the bank increased in five steps consistent with the five different phases of M&I conservation, previously discussed. The first increment of M&I conservation begins in 2016, though it is not routed to the bank until 2019. In 2021, the second increment of M&I conservation, and the energy conservation options are implemented and routed to the bank. Increments three through five use the remaining phases of M&I conservation, and begin in 2031, 2041, and 2051, respectively, totaling approximately 400 kaf in 2060 under the current projected demand scenario. With banking, M&I conservation was assumed to always be in effect in the Upper Basin. Tier 2 conservation aimed to produce additional water for the bank when conditions indicated a Lee Ferry deficit was likely to occur in the short term. Specifically, when the Lee Ferry deficit signpost occurred, Tier 2 conservation was triggered. Agricultural conservation, including short-term fallowing, was used for the purpose of Tier 2 water generation. When Tier 2 conservation was necessary, the maximum available agricultural conservation yields were used to generate water for the bank. Given this logic, the maximum annual bank contribution was the combination of Tiers 1 and 2 in 2060, amounting to just over 800 kafy. Once the Lee Ferry deficit signpost was no longer active, Tier 2 is turned off and contributions from Tier 1 continue according to schedule. Once the bank's capacity is reached, Tier 1 conservation measures continue; however, the water is no longer routed to the bank—it simply becomes system water. A further discussion of how the banking option behaves in the dynamic portfolio framework is included in a later section.

3.4.3 Routing of Water

As water was generated for the purpose of benefitting the bank, it was routed to the conceptual off-stream storage location above Lake Powell. Conservation under this option was not for the purpose of meeting downstream shortages or unmet demands within the Upper Basin. To ensure that the water reached Lake Powell and was credited to the bank, logic and rules were built into CRSS to prevent users from diverting and using the conservation yield.

4.0 Modeling Dynamic Portfolios

The final phase of the study evaluates system reliability with options and strategies. In this phase, multiple options were combined together (portfolio) to collectively help address system vulnerabilities. A static set of options were selected and multiple dynamic portfolios were used to select options. In the static portfolio, 36 options were modeled together. Under the static portfolio, it was assumed that each option 'turned on' in the first year that it was available as defined by the options characterization (Technical Report F).

Dynamic portfolios were used to select options to preemptively address water delivery vulnerabilities while attempting to prevent over-investment. In order to address the vulnerabilities before they occurred, system conditions are monitored within CRSS and are described as signposts in the Study (appendix G3 describes the development of signposts). When a signpost is observed, e.g., Lake Powell falls below some elevation, then an option is turned on to prevent a future vulnerability from occurring. Logic was added to CRSS to react to the signposts and select options from a particular portfolio. A priority list of options, i.e., the portfolio, and a list of which vulnerabilities are addressed by each option was necessary model input. Tables G2-7 through G2-10 present the model input used for each of the four portfolios. In several portfolios, certain options are assumed to be implemented in all traces rather than reacting to system conditions. These options are effectively removed from the portfolio list and are statically turned on through other logic in CRSS. Table G2-11 lists which vulnerabilities are addressed by each option. From this input, once a signpost or an actual vulnerability occurs, CRSS selects the first option that is (1) available and (2) addresses the particular vulnerability in accordance with the following logic:

- In a single year, no more than four options total may be implemented Basin-wide. This aims to reduce over-investment while ensuring that enough options could be implemented to address all vulnerabilities in a single year.
- In a single year, additional options are implemented to address the same vulnerability until their total yield equals or exceeds 100 kafy, subject to the limitation described in (1).
- If multiple signposts are triggered in the same year, an option is implemented for the first vulnerability. If the selected option(s) do not address the other vulnerabilities, additional options are implemented until all vulnerabilities are addressed, subject to the limitation in (1).

TABLE G2-7
CRSS Input for Portfolio A[1]

Representative Option	Cost ($/af)[2]	Earliest Year Available	Magnitude (kaf)
Watershed-Weather Mod 1	30	2016	100
Watershed-Weather Mod 2	35	2021	200
Watershed-Dust 1	220	2026	280
Ag Conservation-Transfer 1	250	2016	200
Ag Conservation-Transfer 2	400	2021	200
Watershed-Tamarisk	400	2023	30
Ag Conservation-Transfer 3	500	2026	200
M & I Conservation 1[3]	500	2016	200
Watershed-Dust 2	520	2036	120
Ag Conservation-Transfer 4	600	2026	200
Desal-Yuma Area Groundwater	600	2021	100
M & I Conservation 2[3]	700	2021	200
Ag Conservation-Transfer 5	750	2026	200
Desal-SoCal Groundwater	750	2021	20
M & I Conservation 3[3]	750	2031	200
M & I Conservation 4[3]	900	2041	200
M & I Conservation 5[3]	900	2051	200
Desal-Salton Sea Drainwater 1	1,000	2026	200
Desal-Salton Sea Drainwater 2	1,150	2031	200
Desal-Salton Sea Drainwater 3	1,300	2036	100

TABLE G2-7
CRSS Input for Portfolio A[1]

Representative Option	Cost ($/af)[2]	Earliest Year Available	Magnitude (kaf)
Desal-Pacific Ocean-Mexico	1,500	2026	56
Reuse-Municipal 1	1,500	2021	200
Reuse-Municipal 2	1,600	2031	200
Import-Front Range-Missouri	1,700	2041	600
Reuse-Municipal 3	1,800	2036	200
Reuse-Municipal 4	1,800	2041	200
Reuse-Municipal 5	1,800	2046	132
Desal-Pacific Ocean-CA 1	1,850	2031	200
Desal-Pacific Ocean-CA 2	1,850	2036	200
Energy Water Use Efficiency-Air Cooling[4]	2,000	2021	160
Local-Coalbed Methane	2,000	2021	100
Reuse-Industrial	2,000	2021	40
Desal-Gulf1	2,100	2028	200
Desal-Gulf2	2,100	2033	200
Local-Rain	3,150	2016	75
Reuse-Grey Water	4,200	2021	178

[1] This portfolio also includes the Upper Basin banking option.

[2] Cost is not input into CRSS; however, it is included in this table for clarity because it is the basis for the priority sorting of options.

[3] M&I conservation options are assumed to be on in the Upper Basin in all traces starting in the earliest year available, regardless of system conditions. The conserved amount is typically routed to the bank. M&I conservation in the Lower Basin is still turned on in response to system conditions; therefore, only the Lake Mead pool elevation, Lower Basin shortage, and Lower Basin demand above apportionment vulnerabilities will trigger M&I conservation.

[4] Energy Water Use Efficiency-Air Cooling is assumed to be on in all traces starting in the earliest year available, regardless of system conditions and is typically routed to the bank. Therefore this option is removed from the priority option list before loading into CRSS and is turned on through other logic in CRSS.

Ag – agricultural
Desal – desalination
SoCal –Southern California
Weather Mod - weather modification

TABLE G2-8
CRSS Input for Portfolio B

Representative Option	Cost ($/af)[1]	Earliest Year Available	Magnitude (kaf)
Watershed-Weather Mod 1[2]	30	2016	100
Watershed-Weather Mod 2[2]	35	2021	200
Ag Conservation-Transfer 1[2]	250	2016	200
Ag Conservation-Transfer 2	400	2021	200
Ag Conservation-Transfer 3	500	2026	200
M & I Conservation 1	500	2016	200
Ag Conservation-Transfer 4	600	2026	200
Desal-Yuma Area Groundwater	600	2021	100
M & I Conservation 2	700	2021	200
Ag Conservation-Transfer 5	750	2026	200
Desal-SoCal Groundwater	750	2021	20
M & I Conservation 3	750	2031	200
M & I Conservation 4	900	2041	200
M & I Conservation 5	900	2051	200
Desal-Salton Sea Drainwater 1	1,000	2026	200
Desal-Salton Sea Drainwater 2	1,150	2031	200
Desal-Salton Sea Drainwater 3	1,300	2036	100
Desal-Pacific Ocean-Mexico	1,500	2026	56
Reuse-Municipal 1	1,500	2021	200
Reuse-Municipal 2	1,600	2031	200
Import-Front Range-Missouri	1,700	2041	600
Reuse-Municipal 3	1,800	2036	200
Reuse-Municipal 4	1,800	2041	200
Reuse-Municipal 5	1,800	2046	132
Desal-Pacific Ocean-CA 1	1,850	2031	200
Desal-Pacific Ocean-CA 2	1,850	2036	200
Energy Water Use Efficiency-Air Cooling	2,000	2021	160
Local-Coal Bed Methane	2,000	2021	100
Reuse-Industrial	2,000	2021	40
Desal-Gulf 1	2,100	2028	200
Desal-Gulf 2	2,100	2033	200

[1] Cost is not input into CRSS, however, it is included in this table for clarity because it is the basis for the priority sorting of options.

[2] These options are assumed to be on in all traces regardless of system conditions and are not implemented in response to signposts. Therefore these options are removed from the priority option list before loading into CRSS and are turned on through other logic in CRSS.

TABLE G2-9
CRSS Input for Portfolio C[1]

Representative Option	Cost ($/af)[2]	Earliest Year Available	Magnitude (kaf)
Watershed-Weather Mod 1	30	2016	100
Watershed-Weather Mod 2	35	2021	200
Watershed-Dust 1	220	2026	280
Ag Conservation-Transfer 1	250	2016	200
Ag Conservation-Transfer 2	400	2021	200
Watershed-Tamarisk	400	2023	30
Ag Conservation-Transfer 3	500	2026	200
M & I Conservation 1[3]	500	2016	200
Watershed-Dust 2	520	2036	120
Ag Conservation-Transfer 4	600	2026	200
Desal-Yuma Area Groundwater	600	2021	100
M & I Conservation 2[4]	700	2021	200
Ag Conservation-Transfer 5	750	2026	200
Desal-SoCal Groundwater	750	2021	20
M & I Conservation 3[4]	750	2031	200
M & I Conservation 4[4]	900	2041	200
M & I Conservation 5[4]	900	2051	200
Desal-Salton Sea Drainwater 1	1,000	2026	200
Desal-Salton Sea Drainwater 2	1,150	2031	200
Desal-Salton Sea Drainwater 3	1,300	2036	100
Reuse-Municipal 1	1,500	2021	200
Reuse-Municipal 2	1,600	2031	200
Reuse-Municipal 3	1,800	2036	200
Reuse-Municipal 4	1,800	2041	200
Reuse-Municipal 5	1,800	2046	132
Energy Water Use Efficiency-Air Cooling[5]	2,000	2021	160
Reuse-Industrial	2,000	2021	40
Local-Rainwater Harvesting	3,150	2016	75
Reuse-Grey Water	4,200	2021	178

[1] This portfolio also includes the Upper Basin banking option.

[2] Cost is not input into CRSS; however, it is included in this table for clarity because it is the basis for the priority sorting of options.

[3] M&I conservation step 1 is assumed to be on in all traces, Basin-wide, regardless of system conditions. In the Upper Basin, the conserved amount is typically routed to the bank. Therefore this option is removed from the priority option list before loading into CRSS and is turned on through other logic in CRSS.

[4] The remaining M&I conservation options are assumed to be on in the Upper Basin in all traces starting in the earliest year available, regardless of system conditions, and the conserved amount is typically routed to the bank. M&I conservation in the Lower Basin is still turned on in response to system conditions; therefore, only the Lake Mead pool elevation, Lower Basin shortage, and Lower Basin demand above apportionment vulnerabilities will trigger M&I conservation.

[5] Energy Water Use Efficiency-Air Cooling is assumed to be on in all traces starting in the earliest year available regardless of system conditions and is typically routed to the bank. Therefore this option is removed from the priority option list before loading into CRSS and is turned on through other logic in CRSS.

TABLE G2-10
CRSS Input for Portfolio D

Representative Option	Cost ($/af)[1]	Earliest Year Available	Magnitude (kaf)
Watershed-Weather Mod 1	30	2016	100
Watershed-Weather Mod 2	35	2021	200
Ag Conservation-Transfer 1	250	2016	200
Ag Conservation-Transfer 2	400	2021	200
Ag Conservation-Transfer 3	500	2026	200
M & I Conservation 1	500	2016	200
Ag Conservation-Transfer 4	600	2026	200
Desal-Yuma Area Groundwater	600	2021	100
M & I Conservation 2	700	2021	200
Ag Conservation-Transfer 5	750	2026	200
Desal-SoCal Groundwater	750	2021	20
M & I Conservation 3	750	2031	200
M & I Conservation 4	900	2041	200
M & I Conservation 5	900	2051	200
Desal-Salton Sea Drainwater 1	1,000	2026	200
Desal-Salton Sea Drainwater 2	1,150	2031	200
Desal-Salton Sea Drainwater 3	1,300	2036	100
Reuse-Municipal 1	1,500	2021	200
Reuse-Municipal 2	1,600	2031	200
Reuse-Municipal 3	1,800	2036	200
Reuse-Municipal 4	1,800	2041	200
Reuse-Municipal 5	1,800	2046	132
Energy Water Use Efficiency-Air Cooling	2,000	2021	160
Reuse-Industrial	2,000	2021	40

[1] Cost is not input into CRSS; however, it is included in this table for clarity because it is the basis for the priority sorting of options.

TABLE G2-11
Options that Address Different Vulnerabilities

Representative Option	Year Available	Vulnerability Addressed by Representative Option					
		UB Shortage	Lee Ferry Deficit	Low Lake Mead Pool Elevations	Lower Basin Shortage 1	Lower Basin Shortage 2	Lower Division States' Demand Above Basic Apportionment
Ag Conservation	2016	X	X	X	X	X	X
M & I Conservation	2016	X[1]	X[1]	X	X	X	X
Local-Rainwater Collection	2016	X	X	X	X	X	X
Reuse-Grey Water	2021	X	X	X	X	X	X
Reuse-Industrial	2021	X	X	X	X	X	X
Reuse-Municipal Step 1-2	2021	X	X	X	X	X	X
Reuse-Municipal Step 3-5	2036			X	X	X	X
Desal-Gulf	2028			X	X	X	X
Desal-Pacific Ocean	2031			X	X	X	X
Desal-Pacific Ocean-MX	2026			X	X	X	X
Desal-Tribs	2026			X	X	X	X
Desal-SoCal groundwater	2021			X	X	X	X
Desal-Yuma	2021			X	X	X	X
Import-Front Range-Missouri	2041	X	X	X	X	X	
Energy Conservation	2021	X	X				
Watershed-Dust Management	2026	X	X				
Watershed-Tamarisk	2023		X	X	X	X	
Watershed-Weather Mod	2016	X	X				
Local-Coalbed Methane	2021	X	X				

[1] For Portfolios A and C, only Lower Basin M&I conservation steps are implemented based on signposts. Therefore, the M&I conservation options under these scenarios do not address the Upper Basin shortage and Lee Ferry deficit vulnerabilities.

Options are selected at the beginning of each year based on system conditions at the end of the previous year. When the Upper Basin Banking option is not part of the portfolio, all options are brought online Basin-wide. For example, conservation is applied Basin-wide, and once an option is selected, it is assumed to be on for the remainder of the simulation.

When a portfolio includes banking, there are several exceptions to these rules. The Upper Basin Banking option assumes that M&I conservation is always on in order to generate water for the bank. Because the bank is only applied in the Upper Basin, the Lower Basin M&I conservation portion is split out as a separate option and selected based on signposts monitoring Lower Basin water delivery vulnerabilities. Furthermore, while M&I conservation in the Upper Basin is always in place, the conserved water does not always go to the bank. Once the bank is at its capacity of 5 maf, the water yielded from M&I conservation is assumed to be system water for the given year. Once the bank is significantly below its capacity, the water is again routed to the bank. Analogous logic is applied to energy conservation when banking is used, although it is less nuanced because there is no energy conservation option in the Lower Basin.

Additionally, agricultural fallowing supplies water to the bank during Tier 2 operations, which can be turned on and off as necessary. When banking is in place, agricultural fallowing can still be turned on Basin-wide if necessitated by a signpost. If any phases of agricultural fallowing are already on when Tier 2 banking is needed, then the Upper Basin portion of the fallowing options switch from system benefit to targeted benefit, i.e., it is routed to the bank. Conversely, if any agricultural fallowing phases are not currently on, but are available when Tier 2 banking is needed, then they are turned on, at the maximum yield potential for the current year, for the Upper Basin only and the conservation yield is routed to the bank. In this case, agricultural fallowing phases in the Upper Basin are turned off once Tier 2 banking is no longer necessary.

5.0 References

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