Technical Appendix 15

Dams and Electrical Power Resources

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Acronyms and Abbreviations

Acronym or Abbreviation	Full Phrase
2007 Final EIS	2007 Interim Guidelines Final Environmental Impact Statement
2007 Interim Guidelines	Colorado River Interim Guidelines for Lower Basin Shortages and the Coordinated Operations for Lake Powell and Lake Mead
Basin	Colorado River Basin
BCP	Boulder Canyon Project
CCS	Continued Current Strategies
cfs	cubic feet per second
CRiSPPy	Colorado River Storage Project Python-based model
CRSP	Colorado River Storage Project
CRSPA	Colorado River Storage Project Act of 1956
CRSS	Colorado River Simulation System
DMDU	decision making under deep uncertainty
DSPR	Dam Safety Priority Rating
EIS	environmental impact statement
GCDAMP	Glen Canyon Dam Adaptive Management Program
GCPA	Grand Canyon Protection Act
GWh	gigawatt hour
HFE	High-Flow Experiments
kW	kilowatt
LB Priority	Lower Basin Priority
LB Pro Rata	Lower Basin Pro Rata
maf	million acre-feet
MW	megawatts
MWh	megawatt hours
NERC	North American Electric Reliability Corporation
Reclamation	Bureau of Reclamation
ROD	Record of Decision
SIB	Southerly International Boundary
SLCA/IP	Salt Lake City Area Integrated Projects
U.S.	United States
WAPA	Western Area Power Administration
WECC	Western Electricity Coordinating Council

TA 15. Dams and Electrical Power Resources

TA 15.1 Affected Environment

This section provides an overview of the four primary dams and reservoirs in the analysis area of the Colorado River corridor from the full pool elevation of Lake Powell to the Southerly International Boundary (SIB): Glen Canyon Dam/Lake Powell, Hoover Dam/Lake Mead, Davis Dam/Lake Mohave, and Parker Dam/Lake Havasu. This section provides the context for analyzing the effects of the alternatives on the electrical power capacity, spillway condition, and life safety of Glen Canyon Dam and Hoover Dam, and the power generation at all four dams. This section also provides the context for analyzing the effects of the alternatives on electricity rates and the market value of the electricity.

Other, smaller dams and hydroelectric facilities in the analysis area include Headgate Rock, Senator Wash, Siphon Drop, and Pilot Knob. Changes to these smaller dams and their associated reservoirs are not being proposed in any of the alternatives, and due to the nature of their operations, there are no anticipated substantial effects on the electrical power capacity, generation, spillway, or safety of these dams nor are there any anticipated substantial effects relative to their electricity rates nor the economic value of the power they produce from the alternatives.

The Bureau of Reclamation (Reclamation) operates and maintains the Glen Canyon, Hoover, Davis, and Parker Dams. The Western Area Power Administration (WAPA) is responsible for marketing and transmitting the power generated at these facilities across the Upper and Lower Colorado River Basins (Basin; Reclamation 2007a). As established in the 1922 Colorado River Compact, the Upper Basin consists of the states of Colorado, New Mexico, Utah, and Wyoming; the Lower Basin consists of the states of Arizona, California, and Nevada; and Lee Ferry is considered the dividing point between the two basins. Lee Ferry is located one mile below the mouth of the Paria River in Arizona. The Colorado River Compact established that each basin would receive 7.5 million acre-feet (maf) of water annually. In 1956, the Colorado River Storage Project Act of 1956 (CRSPA) outlined Upper Basin water storage and management processes to facilitate the apportionment of water in the Upper Basin and the delivery of water to the Lower Basin. This water storage system called for the building of four dams, with Glen Canyon Dam and Lake Powell reservoir serving as the primary water storage infrastructure for the Upper Basin.

TA 15.1.1 Hydropower Generation and Capacity Overview

Hydropower generation occurs when water stored in a reservoir passes through a turbine, which converts the energy of the falling water to mechanical energy, which is then converted to electricity as the turbine turns the rotors in the generating units. The amount of electrical power generated is directly related to the amount of water passing through the turbines and the force, or "head," of the water as it moves through the turbines. The pressure difference between the lake reservoir elevation and the generators influences the head of the water. The higher the reservoir elevation, the more head the water can exert when passing through the turbines. Capacity is mainly affected by the depth of the reservoir and the number of generators.

Power generation has two main measurable components: power and energy. Power is the rate at which energy is transferred or consumed, or the amount of electricity produced at a specific time and is measured in megawatts (MW). Energy is the amount of power generated over time and is measured in megawatt hours (MWh). Capacity is the maximum power that can be produced at a specific moment. The physical capacity of a powerplant is the maximum power that results from generator and turbine capacity and reservoir levels. Firm capacity is the reliable, guaranteed amount of power output from a powerplant that accounts for operational constraints such as water releases and ramp rates[1]. Physical and firm capacity are measured in MW. This affected environment portion of this technical appendix describes the physical capacity of the Glen Canyon Dam and Hoover Dam powerplants, and the environmental consequences portion analyzes the effects of the alternatives on the firm capacity of these powerplants as firm capacity takes into account all of the conditions that WAPA and Reclamation use for operational decisions.

Additional information on power generation, control, regulation, reserves, and ramping can be found in the Colorado River Interim Guidelines for Lower Basin Shortages and the Coordinated Operations for Lake Powell and Lake Mead Final Environmental Impact Statement (2007 Final EIS) Section 3.11.1.1 (Reclamation 2007a); and that information is incorporated here by reference.

TA 15.1.2 Hydropower Marketing and Administration Overview

WAPA markets power and administers power contracts for electricity generated from the dams that are specific to each of the hydropower projects. WAPA sets power rates annually for each hydropower project. The rates cover the operating costs of WAPA and those of the hydropower project (WAPA 2025a). WAPA power sales and transmission operations are organized by region with Glen Canyon Dam powerplant operating within the Colorado River Storage Project (CRSP) Management Center and Hoover, Parker, and Davis Powerplants operating within the Desert Southwest Region. WAPA bundles and markets power to a variety of entities including: small and medium-sized municipalities that operate publicly owned utilities; irrigation cooperatives and water conservation districts; rural electrical associations; generation and transmission co-operatives; federal facilities; universities; state agencies; and tribes (Reclamation 2016a) that, in total, serve approximately 40 million people across the following states: Nebraska, Wyoming, Utah, Nevada, Colorado, Arizona, and New Mexico.

WAPA distributes the power through four types of contracts that are classified as: long-term firm power and other long-term sales; non-firm energy and short-term sales and purchases; seasonal power sales; and purchase power (WAPA 2025a). Firm power contracts guarantee the capacity and energy that will be available 24 hours a day and non-firm contracts come without a guarantee of continuous availability (WAPA 2025a). Firm and non-firm contracts can be short or long term.

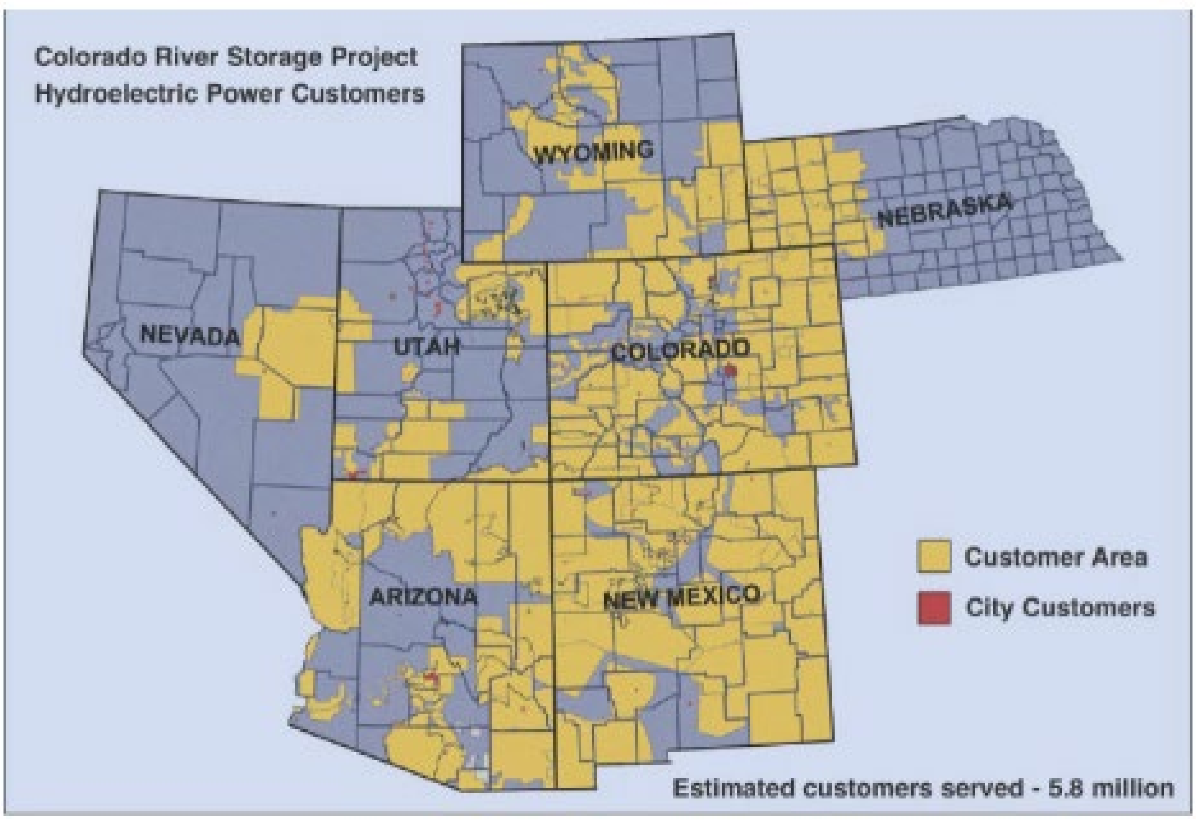
The contracts for Glen Canyon Dam power are effective 2024 through 2057 (WAPA 2023). There are more than 100 customers for Glen Canyon Dam power and they provide electricity within the

[1] The ramp rate is the rate of change in instantaneous output from a powerplant. The ramp rate is established to prevent undesirable effects due to rapid changes in loading or discharge.

states of Wyoming, Utah, Colorado, New Mexico, Arizona, Nevada, and Nebraska. WAPA markets Hoover Dam generated power to 46 customers and Parker Dam and Davis Dam generated power to 36 customers within southern Nevada, Arizona, and southern California. Hoover Dam power is marketed as a long-term contingent capacity contract with associated energy. This means that WAPA is obligated to deliver the energy that can be generated from the available capacity. The new contracts for Hoover Dam took effect on October 1, 2017, and expire on September 30, 2067. The Parker Dam and Davis Dam power is marketed as long-term, firm contracts. Contracts for the Parker Dam and Davis Dam were signed prior to 2007 and terminate in 2028. WAPA anticipates signing new contracts that will replace the expiring contracts.

The Basin is within what is referred to as the Western Interconnection region of the Western Electricity Coordinating Council (WECC), see **Figure TA 15-1**. The WECC is a regional, non-profit corporation that oversees bulk electrical system reliability planning and assessment. The Western Interconnection area includes two Canadian provinces, 14 western states, and the northern United Mexican States (WECC 2025). The Glen Canyon, Hoover, Parker, and Davis Dam powerplants account for approximately 2.2 percent of the total electrical capacity within the Western Interconnection region.

Figure TA 15-1
Colorado River Storage Project Hydroelectric Power Customers



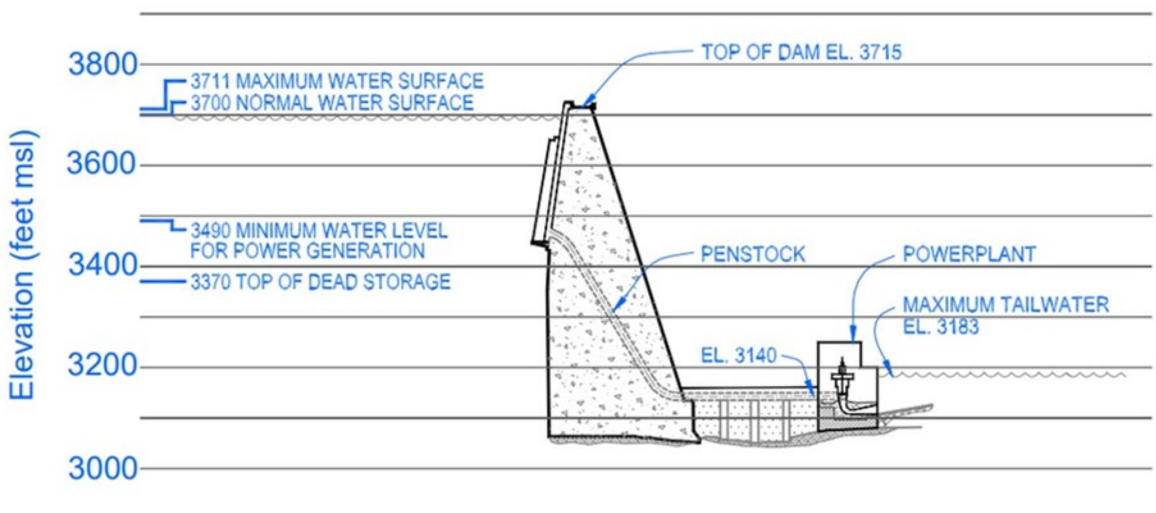
TA 15.1.3 Hydroelectric Power - Infrastructure Conditions and Hydroelectric Power Generation and Capacity

This section provides an overview of the infrastructure conditions of the Glen Canyon Dam/Lake Powell reservoir, the Hoover Dam/Lake Mead reservoir, Davis Dam/Lake Mohave reservoir, and Parker Dam/Lake Havasu reservoir, and their hydropower capacity and generation.

Glen Canyon Dam/Lake Powell

Glen Canyon Dam is located in Page, Arizona and is a concrete arch dam rising 710 feet with a 35-foot-wide roadway connecting the dam's spillways, see **Figure TA 15-2**. The dam's reservoir, Lake Powell, has a water storage capacity of 25.16 maf and a maximum reservoir elevation of 3,711 feet. The dam and reservoir are operated and maintained by Reclamation's Glen Canyon Field Division in Page, Arizona.

Figure TA 15-2
Lake Powell and Glen Canyon Dam Important Operating Elevations



Water Releases and Operational Considerations

During normal operating conditions, water is released from Glen Canyon Dam through the Glen Canyon powerplant through intakes on the upstream face of the dam. Eight, 15-foot steel penstocks convey water to the powerplant turbines through an elevation drop of 330 feet to a centerline elevation of 3,140 feet. Water cannot be released from the penstocks below a Lake Powell elevation of 3,490 feet (which is known as the minimum power pool and is 20 feet above the penstock intake centerline). At an elevation of 3,490 feet, it is estimated that vortex formation would begin to occur at the powerplant. Releases in excess of powerplant capacity are made when flood conditions are caused by high runoff in the Upper Basin or when High-Flow Experiments (HFEs) are triggered downstream. Historically, these releases are well above 3,490 feet. However, HFEs can be conducted down to an elevation of 3,500 feet.

Four, 96-inch steel pipes comprise the river outlet works at a centerline elevation of 3,374 feet. The outlets have a maximum combined capacity of 15,000 cubic feet per second (cfs) at elevation 3,500 feet. Below 3,500 feet the capacity deceases. Below minimum power pool, the outlet works are the sole means of releasing water. An annual release of 8.23 maf equates to a continuous flow of up to 11,368 cfs. With all four outlets operational, this release can be maintained down to approximately elevation 3,440 feet, however, operations and maintenance constraints may limit these releases or the elevation. Since the construction of Glen Canyon Dam, the river outlet works are typically reserved for flood control, HFEs, augmenting powerplant and spillway discharges, or for periods when the powerplant is not operating.

Reservoir operations are managed to maintain the water surface elevation near or below 3,700 feet, which is the normal operating level. Operational preference is to maintain a water surface elevation below the top of active conservation, 3,700 feet, to minimize the occurrence of flood operations and the need for additional monitoring. Glen Canyon Dam is designed to safely accommodate the probable maximum flood including operating up to the maximum water surface elevation of 3,711 feet.

Another important operational consideration is maintaining adequate vacant storage around elevation 3,684 feet on January 1, which provides necessary capacity for managing inflows from spring runoff.

In 1983, heavy late-winter mountain snow accumulation within the Basin created runoff 150 percent of normal, causing the first real use of the Glen Canyon spillway. High, extended releases through the spillways (up to 27,000 cfs from the right spillway and 32,000 cfs from the left) caused serious cavitation damage within the tunnel, particularly in the vertical bends. Cavitation is the formation of vapor cavities in a liquid. As the vapor cavities move into a zone of higher pressure, they collapse, sending out destructive high pressure shock waves (Reclamation 2019). The 1983 damage led to the installation of four-by-four-foot air slots in the spillways to prevent future cavitation damage by introducing air into the water flow.

Current Condition

Reclamation, utilizing the Dam Safety Priority Rating (DSPR) system, evaluated Glen Canyon Dam and gave it a DSPR 5 category rating. This is Reclamation's lowest-priority rating from a dam-safety risk standpoint, indicating the facility poses the lowest risk to the public. The total mean annualized failure probability of static, hydrologic, and seismic risks to the dam is 3 orders of magnitude below Reclamation's Public Protection Guideline.

Maintenance tasks for the river outlet works include lining repairs and hollow-jet valve maintenance. The interior of the river outlet works was originally lined with coal tar enamel. Relining of the river outlet works with solvent borne epoxy began in the fall of 2024. The fabrication of the river outlet works hollow-jet valves dates back to the original construction of the dam, with no rehabilitation since that time. In 2023, an inspection of the outlet works found that to continue long-term operation of the outlet works, major repairs or replacement of the hollow-jet valves should be considered, as well as increasing the frequency of regular operation and maintenance tasks. River outlet works conduits were relined between 2024 and 2025. Refurbishment or replacement of the hollow jet valves is in the planning stages.

Operations

The operating criteria for Glen Canyon Dam were published in 1997. The Glen Canyon Dam Powerplant operating regime was modified with the 2016 Glen Canyon Dam Long-Term Experimental and Management Plan Record of Decision (2016 LTEMP ROD), which continued with a minimum water release rate of 8,000 cfs or more between 7:00 a.m. and 7:00 p.m., and at least 5,000 cfs between 7:00 p.m. and 7:00 a.m.; the maximum hourly increase (that is, the up-ramp rate) of 4,000 cfs per hour; a daily fluctuation limit of 8,000 cfs per 24-hour period; and a water maximum release rate of 25,000 cfs (Reclamation 2016b). The 2016 LTEMP ROD modified the daily fluctuation limit, so it is calculated as a function of the monthly volume and it increased the down-ramp rate to no greater than 2,500 cfs per hour (Reclamation 2016b).

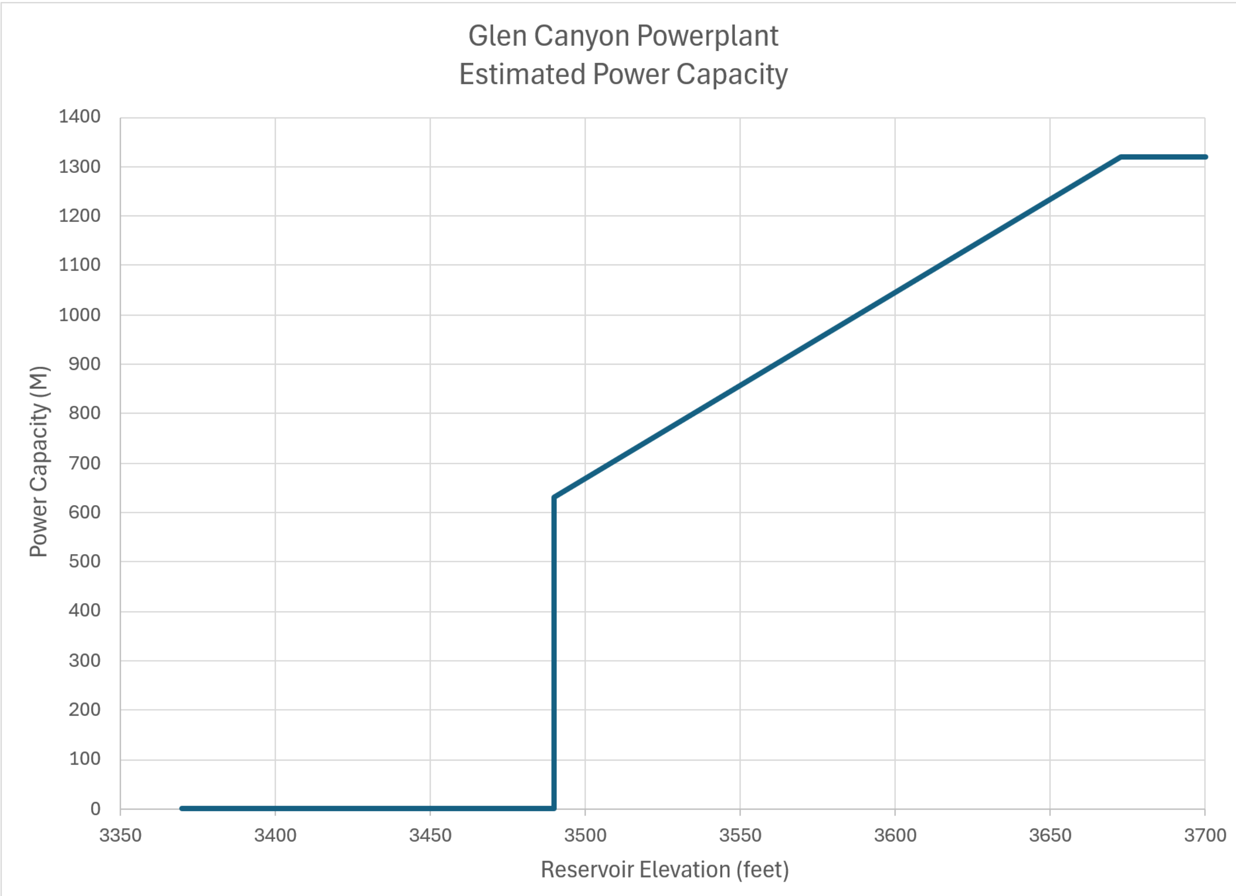
Hydropower Generation and Physical Capacity

Glen Canyon Dam powerplant has eight generators with a maximum combined physical capacity of 1,320 MW at a reservoir elevation of 3,700 feet (Reclamation 2016a). At minimum power pool, the powerplant has an estimated physical capacity of 630 MW.

Since 2007, the powerplant has undergone updates to improve efficiency, including: replacement of all eight turbines, four generator rewinds, replacement of all step-up transformers, optimization of software within the facility; and continued operations and maintenance (Reclamation 2024).

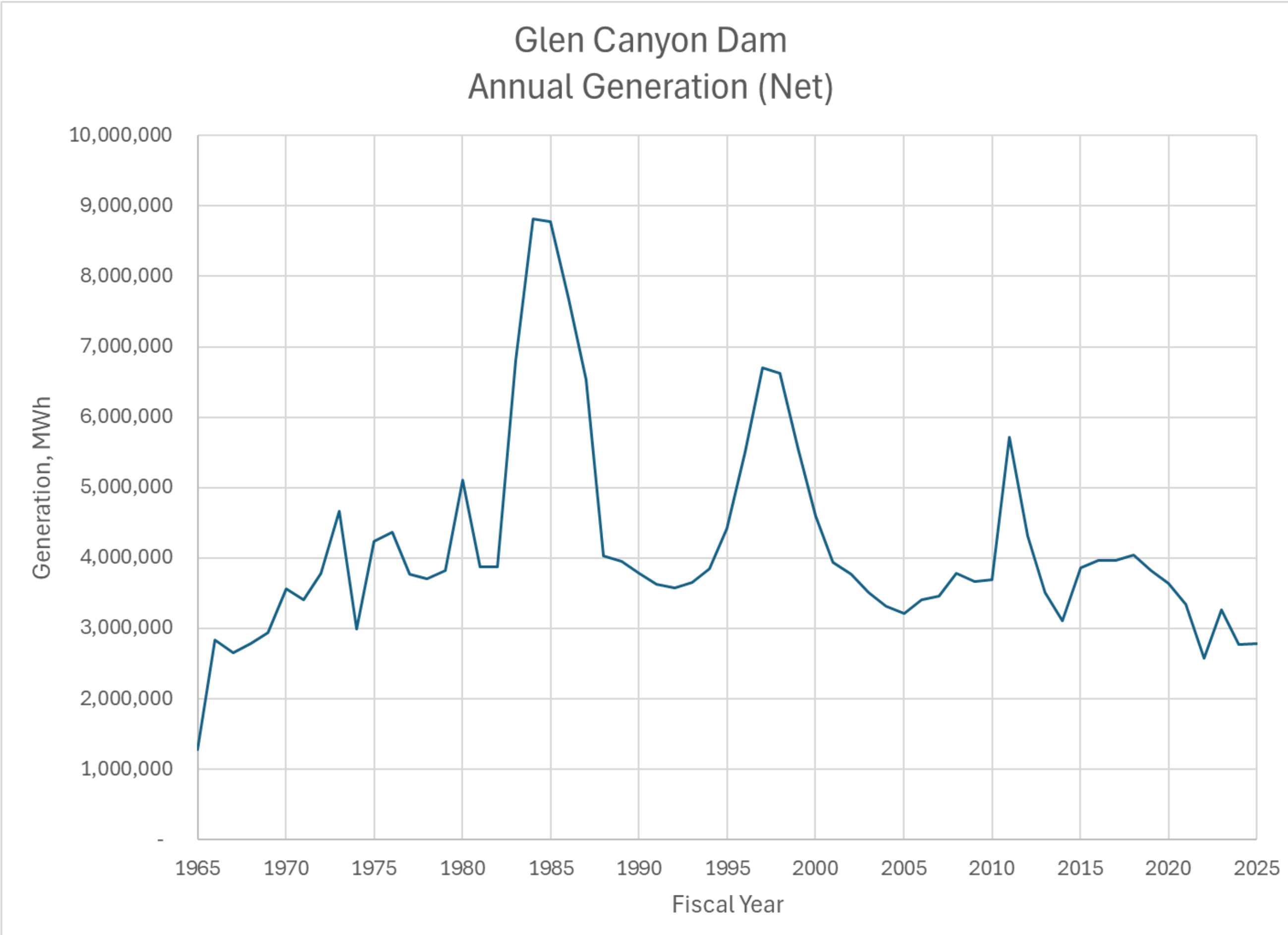
Despite the improved efficiencies, the powerplant's physical capacity to generate power has been affected by drought conditions and the resulting decreases in Lake Powell reservoir elevations. The decreases in elevation and, therefore, head, combined with reduced annual releases, have reduced power generation since 2007. **Figure TA 15-3** below shows the estimated physical capacity at a range of lake elevations. **Figure TA 15-4** displays the historical annual power generation from 1990 to present.

Figure TA 15-3
Power Capacity Estimates for Glen Canyon Powerplant at Varying Lake Powell Elevations



Source: Reclamation 2025a

Figure TA 15-4
Annual Glen Canyon Powerplant Generation from 1965 to Present

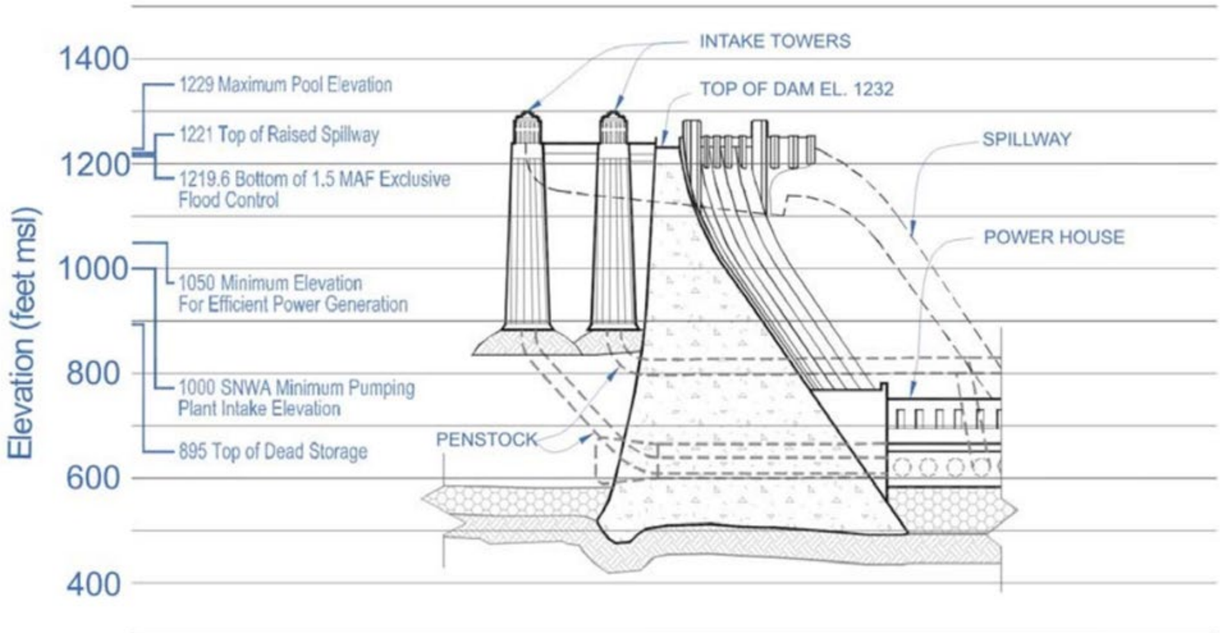


Source: Reclamation 2025a

Hoover Dam/Lake Mead

Hoover Dam is located in Black Canyon on the Arizona-Nevada state line, approximately 35 miles southeast of Las Vegas, Nevada. The dam and its reservoir, Lake Mead, are operated and maintained by Reclamation's Lower Colorado River Region. Hoover Dam is a concrete gravity-arch structure standing 726 feet high with a crest length of 1,244 feet, see **Figure TA 15-5**. Lake Mead has a water storage capacity of 30.2 maf and a maximum reservoir elevation of 1,232 feet.

Figure TA 15-5
Lake Mead and Hoover Dam Important Operating Elevations



Note: The minimum power pool elevation at Hoover Dam was lowered from 1,050 feet to 950 feet above mean sea level following a major turbine upgrade completed between 2011 and 2016.

Water Releases and Operational Considerations

Effective power generation currently requires a minimum water elevation of 950 feet in Lake Mead (Reclamation 2024). Water levels between 895 and 950 feet constitute the inactive pool, where releases can occur but do not generate hydropower. Below 895 feet, water reaches dead pool elevation, at which point releases are no longer possible.

Water is released from Lake Mead to the river through four intake towers. These 395-foot-high towers are positioned two on each side of the canyon and are regulated by two 32-foot diameter, 11-foot-tall cylindrical gates—one near the bottom and another at mid-height. The two upstream intake towers release water to the lower main penstocks. Water can enter the penstocks at elevations between 1,045 and 895 feet. Within the lower main penstocks, four 13-foot-diamter steel penstocks bifurcate from the main penstock and supply water to four generator turbines. With eight of the original twelve lower outlet works available, the discharge capacities for the lower outlet works are 15,300 cfs and 15,400 cfs at a reservoir water surface elevation of 1219.6 feet, which is the bottom of the exclusive flood control space. The two downstream intake towers supply water to the upper main penstocks. Four 13-foot-diameter steel penstocks bifurcate from each upper main penstock and lead to nine generator turbines. Each upper main penstock then branches into six pipes. Four of the branches are closed with blind flanges. With four of the original twelve upper outlet works presently available, the discharge capacities for the upper outlet works are 10,800 cfs and 10,700 cfs at elevation 1,219.6 feet. The combined discharge capacity of all generator turbines is estimated at 49,000 cfs.

There are two spillways at Hoover Dam, each consisting of a concrete overflow crest structure and basin with four spillway drum gates each, and a concrete-lined tunnel that discharges directly into the Colorado River. The original discharge capacity of both spillways was 400,000 cfs, but the maximum safe discharge capacity for each spillway was reduced to approximately 135,000 cfs due to the formation of a hydraulic jump inside the tunnels at those flows or greater.

Under normal conditions, nearly all Colorado River flow passes through the turbines, with the spillways and outlet works used only in exceptional circumstances. The maximum safe channel capacity is estimated to be 40,000 cfs. The largest release from Hoover Dam (excluding test releases) occurred in July 1983, with 24,700 cfs discharged through the spillways and 26,100 cfs through the powerplant penstocks. Maximum combined powerplant and river outlet works releases were 74,405 cfs in June 1998 during testing of the outlet works gates. Current operations aim to keep Lake Mead below 1,219.6 feet as much as possible. While limited operation above this level has occurred historically, it is preferred to minimize time spent in the flood control space. The bottom of the spillway drum gate is 1,205.4 feet. Operating below this elevation is desired as elevations above this point rely on mechanical gate function, where risk of failure increases. The most critical elevation threshold is 1,226.9 feet. This elevation corresponds to a spillway discharge exceeding 40,000 cfs and represents an imminent emergency.

Current Condition

The DSPR system evaluated Hoover Dam to be in the DSPR 5 (low priority, normal urgency of action) category. The total mean annualized failure probability for static, hydrologic, and seismic risks remains three orders of magnitude below Reclamation's Public Protection Guideline threshold.

Water conveyance systems at Hoover Dam are generally in good condition. The intake towers and penstocks are more than 85 years old and part of the original construction of Hoover Dam. The intake towers and penstocks cannot be replaced, and routine maintenance is required to maintain structural integrity. As part of the routine maintenance program, the penstocks are drained, inspected, and the coating is repaired as needed.

In August 1941, Lake Mead's water level was within one foot of the spillway crest when the spillway gates were lowered, allowing flows for the first time. Relatively modest flows, never exceeding 13,000 cfs, were passed through both spillways for four months. Velocities reached up to 175 feet-per-second in the Hoover Dam spillway elbow. When halted in early December 1941, an inspection of the Arizona spillway tunnel revealed a 38- by 112-foot eroded section of tunnel lining due to flow cavitation that required repairs. The 1941 damage was attributed to a slight misalignment of the tunnel invert. In response to this finding, the tunnels were patched with special heavy-duty concrete and the surface of the concrete was polished smooth. The spillways were subsequently modified in 1947 by adding flip buckets to eliminate conditions thought to have contributed to the 1941 damage.

Operations

The Hoover Dam water releases are highest in the spring and summer with daily fluctuations made to meet water demands downstream as well as meet hydropower demand. The total range of flood control releases from Hoover Dam are from Step 1 - 0 cfs to Step 6 - 73,000 cfs (Reclamation 2007b). Hoover Dam releases are managed on an hourly basis to maximize the value of generated power by providing peaks during high-demand periods. Releases from Hoover Dam are also based on flood control regulations that are operated by the United States (U.S.) Army Corps of Engineers. Approximately 1.5 maf of space must be reserved at all times exclusively for flood control purposes.

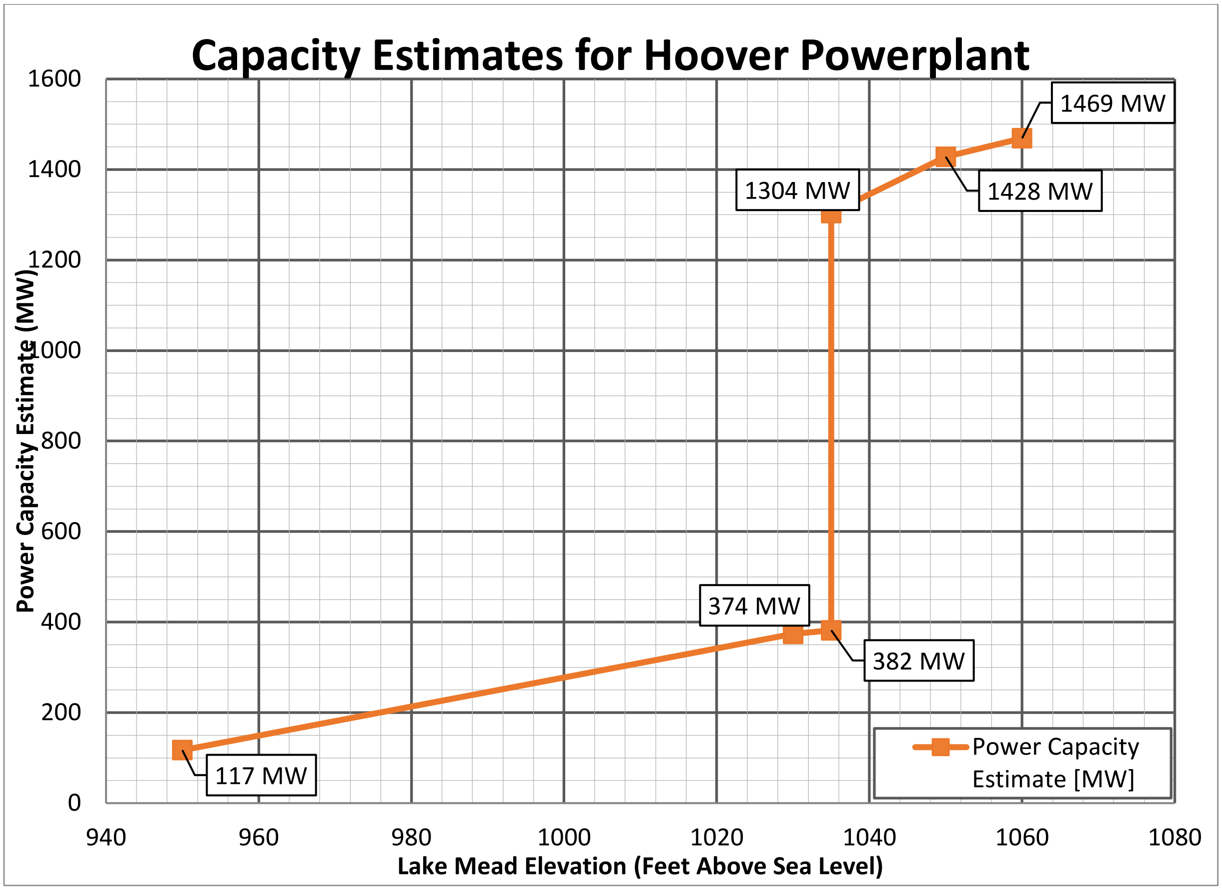
Hydropower Generation and Physical Capacity

The Hoover Dam powerplant is the largest hydropower-generation facility in the Basin. The Hoover Dam powerplant has seventeen commercial generators with a maximum combined capacity of 2,074 MW. The powerplant requires a minimum Lake Mead elevation of 950 feet to produce power. At minimum power pool, the powerplant has an estimated physical capacity of 117 MW. The optimal elevation for hydropower production at Lake Mead is 1,035 feet. At this elevation or greater, hydropower can be produced at or above market value. With current generators, if the elevation drops below 1,035 feet, operation costs will be higher than the value of the hydropower produced.

Since the 2007, Reclamation has replaced five existing turbines at the powerplant with "wide-head" turbines, upgraded wicket gates, modernized unit controls, and conducted typical operations and maintenance of the facility. The upgraded turbines have increased efficiency. The wicket gates open and close to allow or stop water from entering the turbines and the upgraded controls, combined with the other facility upgrades contribute to increased efficiency. However, at elevation 1,035 feet Hoover Dam would only be able to use its five wide head turbines. The 12 older turbines are expected to get excessive cavitation damage and would not be used.

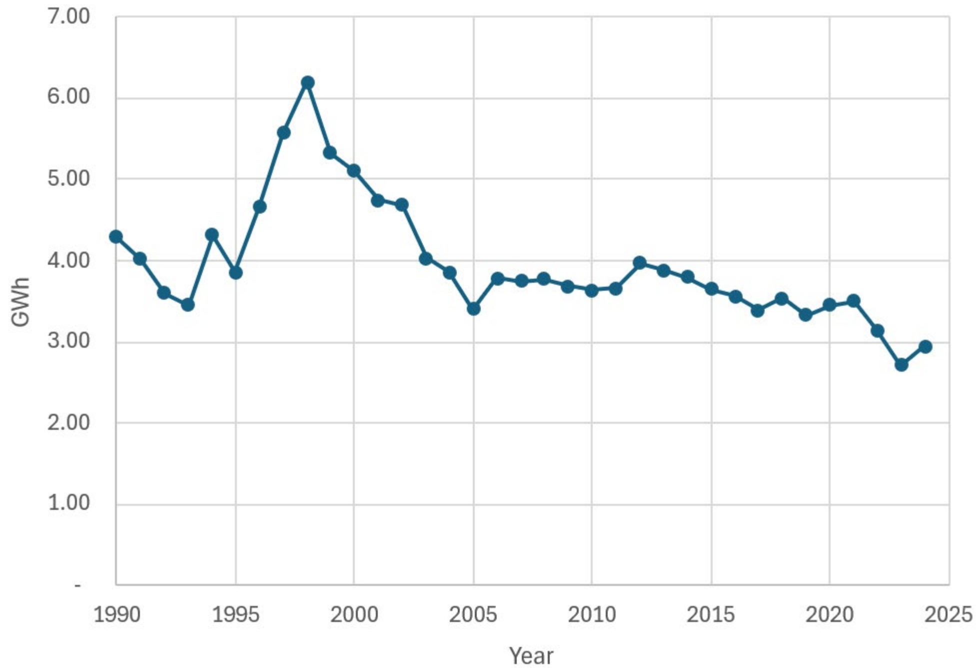
Despite the increased efficiencies, the power generating capacity of Hoover Dam has been affected by drought conditions. **Figure TA 15-6** below shows the estimated electric power capacity at a range of Lake Mead elevations. **Figure TA 15-7** displays the historical annual power generation from 1990 to present. The decrease in the elevation of the Lake Mead reservoir has led to a decrease in head, which has resulted in a decrease in electric power output.

Figure TA 15-6
Power Capacity Estimates for Hoover Powerplant at Varying Lake Mead Elevations



Source: Reclamation 2025b

Figure TA 15-7
Annual Hoover Powerplant Net Generation from 1990 to 2024



Source: Reclamation 2025b

Davis Dam/Lake Mohave and Parker Dam/Lake Havasu

Davis Dam is a 320-foot-tall rock and earth-fill gravity dam, rising 140-feet above the Colorado River. The dam spans the border of Arizona and Nevada in Pyramid Canyon and is 67 miles downstream from Hoover Dam. Its dam crest is 1,600-feet long and 50-feet wide. Its reservoir, Lake Mohave has a water storage capacity of 1.8 maf and a maximum reservoir elevation of 647 feet. Davis Dam is operated and maintained by Reclamation's Davis Dam Field Division which is part of the Lower Colorado Basin Dams Office.

Parker Dam, commonly known as the "deepest dam in the world," is a concrete arch structure, 320 feet tall, with 73 percent of its height below the original stream bed elevation of the Colorado River. The dam is on the Arizona and California border and 88 miles downstream from Davis Dam. The dam has a crest length of 856 feet and a width of 39 feet. The dam's reservoir, Lake Havasu, has a storage capacity of 646,200 acre feet and a maximum reservoir elevation of 450 feet. Parker Dam is operated and maintained by Reclamation's Parker Dam Field Division of the Lower Colorado Basin Dams Office.

Water Releases and Operational Considerations

Davis Dam has a rectangular concrete forebay at its eastern end. At the end of the forebay is a spillway that consists of three 50-foot x 50-foot fixed wheel gates and a spillway crest elevation of 597 feet. The river outlet works consist of 22-foot x 19-foot radial gates with a crest elevation of 542 feet. From the forebay, water enters the powerplant through five 22-foot diameter steel lined penstocks to five hydroelectric generators. The powerplant can release up to 26,000 cfs at 120 feet of head and 31,000 at 136 feet of head. Normal releases from Davis Dam are made through the powerplant turbines with the spillway and outlet works in the closed position. The safe downstream channel capacity on the river is 40,000 cfs. Normal operating elevations for the Lake Mohave reservoir are between 630 and 646 feet.

Parker Dam has a forebay on the right downstream abutment. In the center of the dam is a spillway that consists of five 50-foot wide overflow gate bays at the dam center with a crest elevation of 400 feet. From the forebay water enters the powerplant through four 22-foot diameter steel lined penstocks that convey water to four hydroelectric generators. Their combined discharge capacity is 22,000 cfs. The safe downstream channel capacity on the river is 40,000 cfs. The normal operating elevations for the Lake Havasu reservoir are between 445 and 450 feet.

Current Condition

The DSPR system evaluated Davis and Parker Dams to be in the DSPR 4 (low urgency of action) category, as the total mean annualized failure probability of static and seismic risks to the dams is one-half order of magnitude below Reclamation's Public Protection Guideline threshold value. The dams were determined to be in good condition and performed adequately, and responses of the dams to reservoir loading are predictable, with conditions not appearing to change.

Operations

The Davis Dam fluctuates releases between 4,200 cfs and 23,000 cfs, while Parker Dam fluctuates between 1,800 cfs and 19,000 cfs. The maximum releases for the Parker Dam powerplant and Davis Dam powerplant are 19,000 cfs and 23,000 cfs, respectively. The exact release depends on downstream water demands and tends to be lowest during the winter and highest in spring and summer. Parker Dam is operated under the same rule curve that determines end-of-month target elevations as prior to the Colorado River Interim Guidelines for Lower Basin Shortages and the Coordinated Operations for Lake Powell and Lake Mead (2007 Interim Guidelines), maintaining Lake Havasu's water surface elevation between 445 and 450 feet. Seasonal adjustments to the reservoir's water surface elevation allow for flood control in the fall and higher water levels in the spring. The average annual elevation was 447.5 feet from 1996 to 2007, and approximately 447.7 feet from 2008 to 2022, remaining consistent for the last several decades. Current minimum releases of the Parker Dam are 1,600 cfs daily, 1,400 cfs hourly, and 95,000 acre feet during a 30-day month. The 2007 Final EIS stated Parker Dam releases from Lake Havasu ranged from 6.19 maf to 10.3 maf (averaged 7.4 maf) from 1996 to 2007 (Reclamation 2007a). Since 2008, annual dam releases ranged from 6.2 maf to 6.7 maf (averaged 6.4 maf) through 2022. The average annual Parker Dam releases have decreased by 1.0 maf since the issuance of the 2007 Interim Guidelines.

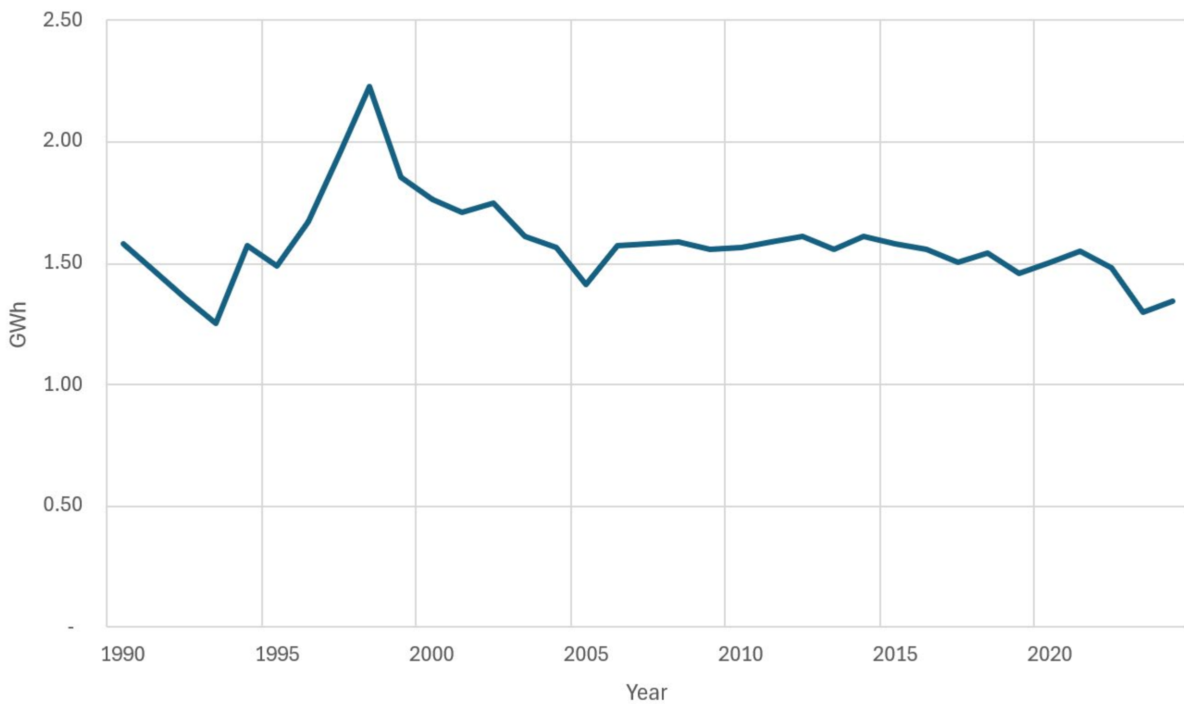
Hydropower Generation and Physical Capacity

The Davis Dam powerplant has four 51.75 MW generators and one 48 MW generator for a total of 255 MW of capacity. The Parker Dam powerplant has four 30 MW generators, totaling 120 MW, with a discharge capacity of 22,000 cfs (Reclamation 2023).

Since 2007, both the Davis and Parker Dam facilities have undergone typical operations and maintenance. All four turbines at the Parker Dam powerplant were replaced between 2004 and 2010. Drought conditions have had less impact on the capacity at Davis and Parker powerplant than the

Hoover and Glen Canyon powerplants because the elevations of Lake Mohave and Lake Havasu reservoirs have remained relatively constant. Both dams are what is referred to as "run of the river", with some flexibility to control releases. **Figure TA 15-8** shows the historical combined annual power generation at the Parker and Davis powerplants. The slight drought induced reduction in river flow has led to a decline in electric power generation.

Figure TA 15-8
Annual Parker and Davis Powerplant Generation from 1990 to Present



Source: Reclamation 2025a

TA 15.1.4 Hydroelectrical Power Distribution

Hydroelectric power generation can be adjusted operationally through a coordinated effort between WAPA and Reclamation. This operational flexibility allows WAPA to quickly and efficiently increase or decrease generation in response to customer demand, generating unit or transmission line outages (contingency reserves), unscheduled customer deviations from internally scheduled contracted power usage (regulation and load/generation following) within a specific metered load area known as a balancing authority, integrated power system requirements, and requests for emergency assistance from interconnected utilities. Power operations are the physical operations of an electric power system, including hydropower generation and control, operational flexibility, scheduling, power generation load following, regulation, transmission, and emergency operations. These are discussed in the sections below. Additional information on power generation, control, regulation, reserves, and ramping can be found in the 2007 Final EIS Section 3.11.1.1 (Reclamation 2007a); and that information is incorporated here by reference.

Scheduling[2]

Power scheduling occurs by matching available power generation to seasonal, daily, and hourly system energy and capacity needs. Power scheduling is affected by the temporal distribution of monthly water release volumes, restrictions in water release patterns, availability of generator units (due to maintenance), availability of other regional hydropower units, power allocations, and peak and off-peak power demand period. Glen Canyon Dam scheduling by WAPA to meet power requirements typically results in higher water releases via the powerplants in the peak power demand months of December, January, July, and August. In the Lower Colorado River dams, scheduling is driven by water orders. There is high degree of flexibility in the releases within a month for Hoover Dam but the amount of power delivered is constrained by monthly water orders. For Parker Dam and Davis Dam the scheduling occurs daily for power based on water orders.

Load Following[3]*, Ancillary Services, Generation, and Regulation*[4]

Hoover Dam and Glen Canyon Dam can change in response to changes in the load (demand) or unanticipated changes in the power generation resources within the operating region. This ability to respond to rapidly changing load conditions is called load or generation following (Reclamation 2016a). Load following creates large fluctuations in water releases, which can have impacts on some downstream environmental resources (Reclamation 2016a). The 1996 Operation of Glen Canyon Dam: CRSP ROD (Reclamation 1996) narrowed the range of operation for Grand Canyon Protection Act (GCPA) and CRSPA purposes, thereby reducing the ability of power generation at Glen Canyon Dam to respond to customer load.

Changes in WAPA's scheduling guidelines for Glen Canyon Dam typically occur over a period of months, not only because of the operational constraints originally imposed by the 1996 Glen Canyon Dam ROD (Reclamation 1996) but also due to changing market conditions. Operational conditions for Glen Canyon Dam are further affected by the frequency, season, and time-of-day limitations that may be in effect; physical and environmental operating restrictions at other CRSP generating facilities and within the interconnected electric system; and the availability and price of replacement power (Reclamation 2016a).

National Regional Reliability Standards[5]

To ensure interconnected system reliability, WAPA follows mandatory reliability standards enforced by the North American Electric Reliability Corporation (NERC) and the WECC. In addition, WAPA follows operational criteria, guidelines, and procedures set in place by the WECC and the contingency Reserve Sharing Group applicable to each balancing authority. Each WECC utility is located within such a load control area, and one utility within the balancing authority serves as the balancing authority operator. WAPA is the balancing authority operator for the Western Area Lower Colorado Region balancing authority, the Western Area Colorado-Missouri Region balancing

[2] Scheduling information is provided for context. The alternatives do not address scheduling and there are no anticipated impacts on scheduling from the alternatives.
[3] Load following are adjustments to power output as demand for electricity fluctuates throughout the day.
[4] Load following, ancillary services, generation, and regulation information is provided for context. The alternatives do not address load following, generation, or regulations and there are no anticipated impacts on them from the alternatives.
[5] National/Regional Reliability Standard information is provided for context. The alternatives do not address these standards and there is no anticipated impacts on them from the alternatives.

authority, and the Western Area Upper Great Plains West Region balancing authority and is responsible for ensuring that each load-serving utility within each balancing authority serves its own internal load while meeting its power and reserve obligations. Operating as a balancing authority, WAPA is the provider of last resort should a load-serving entity not be able to fulfill its obligation to the balancing authority, and it carries all compliance responsibility for the balancing authority function. All CRSP powerplants are within the Western Area Colorado-Missouri Region balancing authority, and the flexibility and load/generation following capability of CRSP hydroelectric powerplants, particularly Glen Canyon Powerplant, are important in meeting NERC/WECC reliability standards and criteria.

Colorado River Storage Project Basin Fund[6]

The CRSPA established the Basin Fund (43 U.S. Code 620d), which remains available until the funds are expended to carry out the purposes and operations. Maintaining a sufficient Basin Fund balance is critical to operating and maintaining the reliability of CRSP facilities in delivering water to water users and generating and transmitting power to power customers. Reclamation and WAPA use this fund to repay the federal CRSP investment (with interest), operate CRSP facilities and maintain CRSP facilities' expenses, provide power for WAPA customers, provide funding under a Basin States' memorandum of agreement, support environmental and salinity programs, and provide irrigation assistance. The Basin Fund also has historically funded environmental programs like the Glen Canyon Dam Adaptive Management Program (GCDAMP) and the San Juan River Basin Endangered Fish Recovery Programs and other related experiments. In recent years, however, appropriations—instead of the Basin Fund—have funded environmental programs like the GCDAMP and the Upper Colorado and San Juan River Basin Endangered Fish Recovery Programs and other related experiments.

WAPA provides wholesale power to preference customers, including public utilities, municipalities, and tribes, which fold this power into the rest of their portfolio to fulfill their load requirements. Under WAPA's current rate structure, WAPA provides its long-term firm power customers with a set amount of power on a quarterly basis. The amount of power is based on the amount of water Reclamation forecasts to release from the CRSP units during that quarter. If the CRSP units do not generate enough power to fulfill these contractual and rate obligations based on the quarterly set amount, WAPA and its customers purchase power and transmission on the energy market to make up the difference. WAPA uses cash from the Basin Fund to make those purchases.

Under the GCPA of 1992 (Public Law 102-575), WAPA records the financial costs of environmental experiments at Glen Canyon Dam as a non-reimbursable expense by accounting for such costs as a constructive return to the U.S. Treasury rather than an operations and maintenance expense to be recovered through WAPA's cost-based power rates. Experimental releases that bypass the electrical generators at Glen Canyon Dam reduce hydropower generation. Accordingly, WAPA purchases replacement power to fulfill contractual delivery obligations.

[6] Basin Funds are discussed for context. The Basin Fund will not be impacted by the alternatives because it is a reimbursable fund. Any changes in generation would be offset by changes in rates.

Boulder Canyon Project Fund

Under 43 U.S. Code Section 620d-1, the Boulder Canyon Project (BCP) Fund, formally the Colorado River Dam Fund, is a special fund established by the BCP Act of 1928 to pay for the construction and operation of the BCP, including Hoover Dam. All revenues generated by the project, primarily from power sales, are deposited into this fund, which is then used to repay the U.S. Treasury for the construction costs, cover operation and maintenance, and fund other beneficial purposes like flood control, water delivery for reclamation, and payments to Arizona and Nevada.

Disturbances and Emergencies and Outage Assistance[7]

In the event of a widespread sudden loss of generation resource power outage, or an imbalance in the transmission system element causing a load/resource imbalance requiring an immediate response (i.e. disturbance), NERC contingency reserve standards require that available generation capacity be utilized to return the electric generation and transmission system to normal operating conditions within load/generation balance within 10 minutes following the disturbance. Generally, emergency operations contingency reserves are needed only for periods of an hour or less but can and frequently are activated several times a day.

WAPA also has existing contractual agreements to use capacity at Glen Canyon Dam to restart traditional thermal powerplants and provide emergency shutdown power to nuclear powerplants. It is especially important for generation resources at Glen Canyon Dam to be available for safe startup of nuclear facilities in the area in the unlikely event of a widespread power outage. WAPA's ability to supply emergency assistance is limited by available transmission capacity and available generation capability, while the ability to deliver emergency assistance varies on an hourly basis, depending on firm load obligations and available generation from project resources. With a full reservoir and average loads, the Glen Canyon Dam powerplant has been able to provide emergency assistance beyond its required reserves by utilizing its remaining unloaded capacity after serving load, regulation, frequency response, and contingency reserve obligations.

Transmission System[8]

The Hoover Dam, Glen Canyon Dam, Parker Dam, and Davis Dam powerplants are connected to a transmission system. Each facility's generation can affect transmission limitations when lines do not have enough capacity to transmit electricity from the point of generation to the point of demand. Actual transmission refers to the measured flow of power on the line. WAPA operates 17,000 circuit miles of transmission lines.

Power Marketing

WAPA markets long-term firm capacity and energy, short-term, firm capacity and energy, and non-firm energy. Firm power is capacity and energy that are guaranteed to be available to the customer. Loads are made up of firm load, non-firm sales, and interchanges out of the control area. Firm load

[7] Disturbance and emergencies and outage assistance are discussed for context. The alternatives in the EIS do not address disturbance, emergencies, or outage assistance and there are no anticipated impacts on these from the alternatives.

[8] Transmission is discussed for context. The alternatives in the EIS do not address transmission and there are no anticipated impacts on transmission from the alternatives.

and capacity obligations include long- and short-term firm sales, Reclamation project use loads, system losses, balancing authority control area regulation, firm load contingency reserves, and scheduled outage assistance. Capacity is reserved to provide regulation, contingency reserves, frequency support and response, meet contractual obligations, and participating project capacity. For Glen Canyon Dam, capacity is also reserved to serve Reclamation's irrigation and drainage pumping plant loads before being marketed as long-term firm capacity.

Colorado River Storage Project

WAPA markets about 5,300 gigawatt hours (GWh) of wholesale CRSP power to 150 entities serving retail customers in Arizona, Colorado, Nevada, New Mexico, Utah, and Wyoming (WAPA 2025b). Customers are small and medium-sized municipalities that operate publicly owned electrical systems; irrigation cooperatives and water conservation districts; rural electrical associations or generation and transmission co-operatives who often act as wholesalers to these associations; federal facilities such as Air Force bases, universities, and other state agencies; and tribes (Reclamation 2016a).

Capacity and energy from Glen Canyon Dam are bundled and marketed by WAPA as the Salt Lake City Area Integrated Projects (SLCA/IP) to consumers across Arizona, Colorado, Nebraska, New Mexico, Nevada, Utah, and Wyoming. Electricity generated at SLCA/IP facilities in the Upper Colorado Region is marketed by WAPA under statutory criteria in the Reclamation Project Act of 1939, the Flood Control Act of 1944, CRSPA, and the Department of Energy Organization Act of 1977, along with associated marketing plans and contractual obligations.

The majority of CRSP power is sold under long-term firm electric service contracts. If WAPA is unable to supply contracted amounts of firm capacity or energy from Reclamation hydroelectric resources, it must purchase the deficit from other (primarily non-hydropower) resources for delivery. The expense for this purchased power is shared by all SLCA/IP customers.

For WAPA's eight largest customers in 2013, the SLCA/IP provided 6.1 percent of energy and 4.7 percent of capacity requirements; the remaining 93.9 percent of energy and 95.3 percent of capacity being provided by customer utility-owned generation facilities or purchased from investor-owned or other utility systems, as well as other federal hydropower projects marketed by WAPA. Reliance on SLCA/IP capacity and energy varies considerably among customers; Navajo Tribal Utility Authority (27.4 percent) and Utah Municipal Power Agency (25.7 percent) received more than 25 percent of their energy from SLCA/IP in 2009, while three utilities, Navajo Tribal Utility Authority (19.1 percent), Utah Municipal Power Agency (17.8 percent), and Deseret Generation and Transmission Cooperative (17.8 percent), relied on WAPA for more than 15 percent of their capacity. Other utilities, such as Tri-State G&T (1,537 GWh and 235 MW), received larger energy and capacity allocations but relied on WAPA for only a small portion of their total capacity and energy requirements.

Desert Southwest Region

WAPA markets 10,600 GWh of wholesale Desert Southwest Region power to 80 entities in Arizona, southern California, and southwest Nevada. Capacity and energy from Hoover Dam are bundled and marketed by WAPA as the BCP and capacity and energy from Parker and Davis Dams are bundled and marketed by WAPA as the Parker Davis Project to consumers in Nevada, Arizona, and California.

The BCP has delivered power to customers for over 80 years. The BCP Post-2017 remarketing effort was created in 2014 to determine power allocations for the Hoover powerplant that expired in September 2017 (WAPA 2017). The new BCP contracts were signed in October 2016 and now run from 2017-2067. The existing contract delivers power to 46 direct and 74 total allocations including allocations through state agencies in Arizona, Nevada, and Southern California.

Davis Dam provides all 255,000 kilowatt (kW) of operating capacity to the Parker Davis Project and Parker Dam provides 60,000 kW of operating capacity to the Parker Davis Project and 60,000 kW to the Metropolitan Water District of Southern California (WAPA 2024). The existing Parker Davis Project sales contract expires in 2028 and planning for a future remarketing in underway. At present, there are 36 contractors receiving power allocations from the Parker Davis Project. The electricity produced by the Parker Davis Project provides electricity to approximately 300,000 people (WAPA 2025c).

Rates

WAPA sets rates for firm electric service from Federal hydropower projects in its marketing territory based on Department of Energy regulations and applicable Federal statutes. Customers pay rates that align specifically with the project they buy power from.

WAPA has a public rate-setting process that includes collaborative planning, a public comment period, and information and comment forums. A *Federal Register* notice announces proposed rates before the comment periods and then another notice is issued with final rates at the end of the process.

Wholesale Rates

WAPA has various wholesale customers including municipal utilities, federal and state public power facilities, and rural electric cooperatives as well as tribal entities. Power rates are established in order for revenues to be sufficient to pay all costs assigned to power within required time periods. Power revenues also pay annual power operation and maintenance, purchased power, transmission service, and interest expenses on Treasury loans used to finance construction of power and transmission projects, and irrigation assistance beyond the ability of the irrigators to repay. CRSP and Lower Colorado Dam's power revenues also must contribute toward salinity control costs under the Basin Salinity Control Act. CRSP power revenue also contributes to construction costs (with interest) of CRSP participating projects, as well as certain environmental costs as provided under the GCPA. Arizona power customers pay a surcharge for Central Arizona Project construction projects and Multispecies Conservation Program costs. Remaining annual revenues are used to pay off investment costs assigned to power, so that each investment can be paid within the time allowed (Reclamation 1995).

Retail Rates

Retail rates are those paid by end users (residential, commercial, and industrial customers of WAPA's wholesale customers). The retail rates charged by not-for-profit entities normally are set to cover system operation and capital costs. As costs of these individual components change, the retail rates are adjusted to ensure enough revenue is collected to meet the utility's financial obligations.

TA 15.2 Environmental Consequences

This environmental consequences section analyzes the effects of the alternatives on: the minimum power pool for Lake Powell and Lake Mead; the power capacity of the Glen Canyon Dam and Hoover Dam powerplants; the power generation of the Glen Canyon Dam, Hoover Dam, Davis Dam, and Parker Dam powerplants; the spillway condition and life safety of Glen Canyon Dam and Hoover Dam; and electricity rates and the market value of the electricity.

The spillway condition, life safety, and hydropower capacity of the Davis Dam and Parker Dam are not analyzed because Lake Mohave and Lake Havasu reservoirs have historically remained relatively constant, and their elevations are expected to remain so under all alternatives. Both Lake Mohave and Lake Havasu would continue to be operated under a rule curve that provides specific target elevations at the end of each month (refer to **TA 3.1.8**, *Davis Dam to Lake Havasu,* in **TA-3**, Hydrologic Resources).

TA 15.2.1 Methodology

WAPA's Colorado River Storage Project Python-based model (CRiSPPy) and Reclamation's Colorado River Simulation System (CRSS) model and decision making under deep uncertainty (DMDU) analysis framework inform the basis for the effects analysis. Refer to **Chapter 3**, **Section 3.2.6**, *Decision Making under Deep Uncertainty* for additional details on the DMDU framework. The CRSS model models: potential water releases from the dams; reservoir elevations; and power generation for each of the alternatives and the Continued Current Strategies Comparative Baseline (CCS Comparative Baseline). Additional information on CRSS model and model assumptions can be found in **Appendix A**, CRSS Model Documentation. The CRiSPPy model was updated to specifically address the scope of this Post-2026 Environmental Impact Statement (EIS). The model covers 34 years of monthly operations (2027–2060) across 1,200 hydrology conditions with each alternative representing 489,600 model runs. The CRiSPPy model is a hydropower scheduling tool that combines optimization algorithms, data management, and graphical user interface. CRiSPPY model assumptions can be found in the technical report *CRiSPPy: An advanced hydropower scheduling tool for the Colorado River Storage Project* (Ploussard et al. 2025). The analysis of the impacts of the alternatives on electricity rates and the market value of the electricity for Glen Canyon Dam is based on analysis WAPA and Argonne National Laboratories prepared in the *Post-2026 Environmental Impact Statement Rate Analysis for the Colorado River Storage Project* (Yu et al. 2025).

TA 15.2.2 Impact Analysis Area

The analysis area for Issues 1-4 encompasses the four primary dams in the Colorado River corridor from the full pool elevation of Lake Powell to the SIB: Glen Canyon Dam/Lake Powell reservoir, the Hoover Dam/Lake Mead reservoir, Davis Dam/Lake Mohave reservoir, and Parker Dam/Lake Havasu reservoir. The analysis area for Issue 5 consists of the WAPA retail power customers of Glen Canyon Dam power that are in the states of Arizona, Colorado, Nevada, New Mexico, Texas, Utah, and Wyoming.

Assumptions

All action alternatives except for the Basic Coordination Alternative incorporate mechanisms related to the storage and delivery of conserved water in Lake Powell and/or Lake Mead (refer to **Chapter 2, Sections 2.6–2.8**). Unless otherwise specified, impacts reflect modeling assumptions about voluntary conservation behavior.

The Lower Basin electrical generation and firm capacity modeling results are direct outputs from the CRSS model. Refer to **Appendix A**, CRSS Model Documentation, for more details related to model assumptions and documentation. The Glen Canyon Dam electrical generation and firm capacity modeling results are direct outputs from the CRiSPPy model. For additional information and modeling assumptions, please refer to *CRiSPPy: An advanced hydropower scheduling tool for the Colorado River Storage Project* (Ploussard et al. 2025). The Glen Canyon Dam rates analysis data was developed by Argonne National Laboratory. Information and modeling assumptions for the rates analysis can be found in the *Post-2026 Environmental Impact Statement Rate Analysis for the Colorado River Storage Project* (Yu et al. 2025)

Impact Indicators

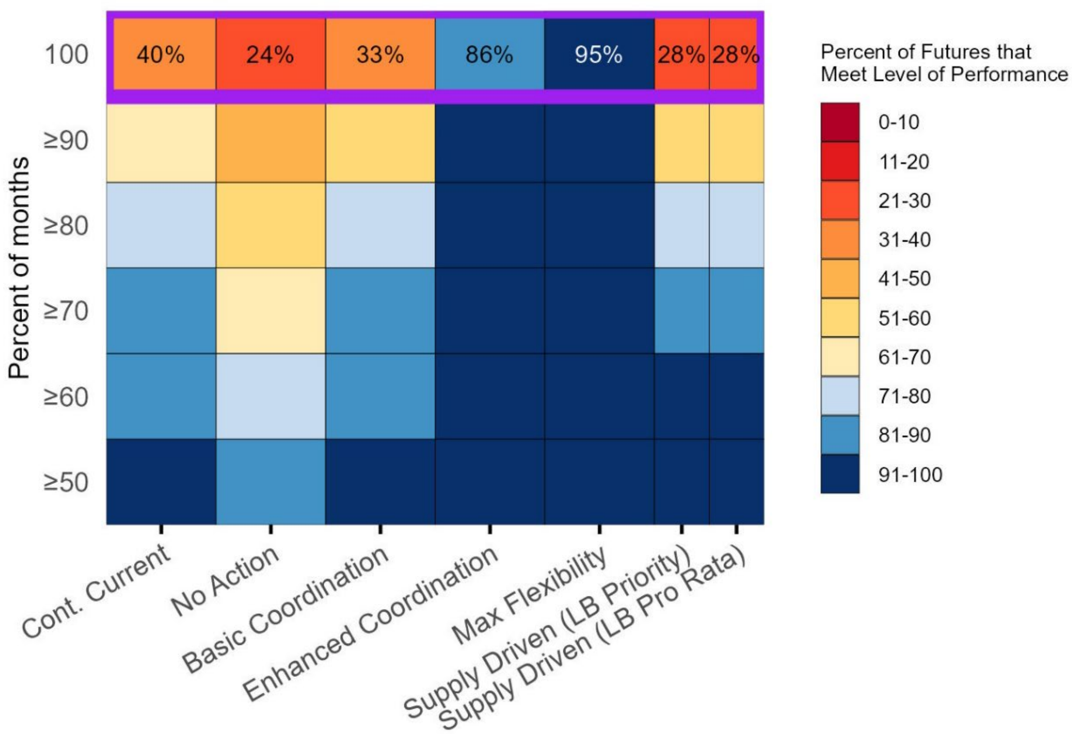
- *Lake Powell and Lake Mead Reservoir elevations* – Reservoir elevations were evaluated in relation to the minimum power pool elevations for Lake Powell and Lake Mead and in relation to Glen Canyon Dam and Hoover Dam infrastructure and safety.
- *Firm capacity (MW)* – Firm capacity is the reliable, guaranteed amount of power output from a powerplant that accounts for operational constraints such as water releases and ramp rates. Firm capacity is measured in MW. This analysis utilizes firm capacity as an indicator rather than physical capacity because it more accurately reflects the actual conditions WAPA and Reclamation use for operational decisions.
- *Energy generation (MWh)* – The amount of energy created over a certain period, measured in MWh. Energy generation is dependent on reservoir head and water release volume.
- *Spillway releases* –spillway releases due to operational activities.
- *Electricity rates* – The minimum average rate increase amount per major rate increase measured in $/MWh for customers of Glen Canyon Dam power.
- *Market value of electricity* – The future market value of electricity generated at Glen Canyon Dam measured in millions of dollars per year.

TA 15.2.3 Issue 1: How do the alternatives impact the frequency at which reservoir elevations drop below minimum power pool at Lake Powell and Lake Mead?

Minimum power pool is the lowest reservoir elevation level at which a hydropower plant can produce power. The frequency at which reservoir elevations drop below minimum power pool for Glen Canyon Dam and Lake Mead were measured by calculating the percent of futures in which the elevations of the reservoirs achieve desirable elevations of at least 3,490 feet and 950 feet respectively (refer to **Figure TA 15-9** and **Figure TA 15-10**); and by using vulnerability figures that display conditions that could cause Lake Powell and Lake Mead to drop below the desirable elevations of 3,450 feet and 950 feet respectively (refer to **Figure TA 15-11** and **Figure TA 15-12**).

Figure TA 15-9 below shows the percentage of futures in which Lake Powell elevation is at least 3,490 feet for all months of the year. Under the Maximum Operational Flexibility Alternative, 95 percent of futures meet this level of performance over the next 30 years, signifying that this alternative has a very high robustness. The Enhanced Coordination Alternative also has a fairly high robustness of 86 percent while the No Action (24 percent) and the Supply Driven Alternatives (both Lower Basin Priority [LB Priority] and Lower Basin Pro Rata [LB Pro Rata] approaches; 28 percent) are the least robust.

Figure TA 15-9
Lake Powell Power Pool: Robustness.
Percent of futures in which Lake Powell elevation is at least 3,490 feet in the percent of months specified in each row



The vulnerability figure below, **Figure TA 15-10**, shows the distribution of the driest 20-year averages in the reference ensemble with a 20-year average Lees Ferry flow of around 11.6 maf. Also included in the reference hydrology box plot are the 20-year averages for 2002–2021 (12.5 maf) and 2005 to 2024 (13.1 maf), shown as dashed lines, for comparison. All alternatives except for the Enhanced Coordination and Maximum Operational Flexibility Alternatives are vulnerable to about 75 percent of traces in the reference hydrology. **Figure TA 15-10** shows that under dry conditions, the Maximum Operational Flexibility and Enhanced Coordination Alternatives have the lowest vulnerability and many preferred outcomes. Conversely, all other alternatives have relatively high vulnerability and more not preferred outcomes.

Figure TA 15-10
Lake Powell Power Pool: Vulnerability.
Conditions that Could Cause Lake Powell Elevation Below 3,490 Feet in any Month

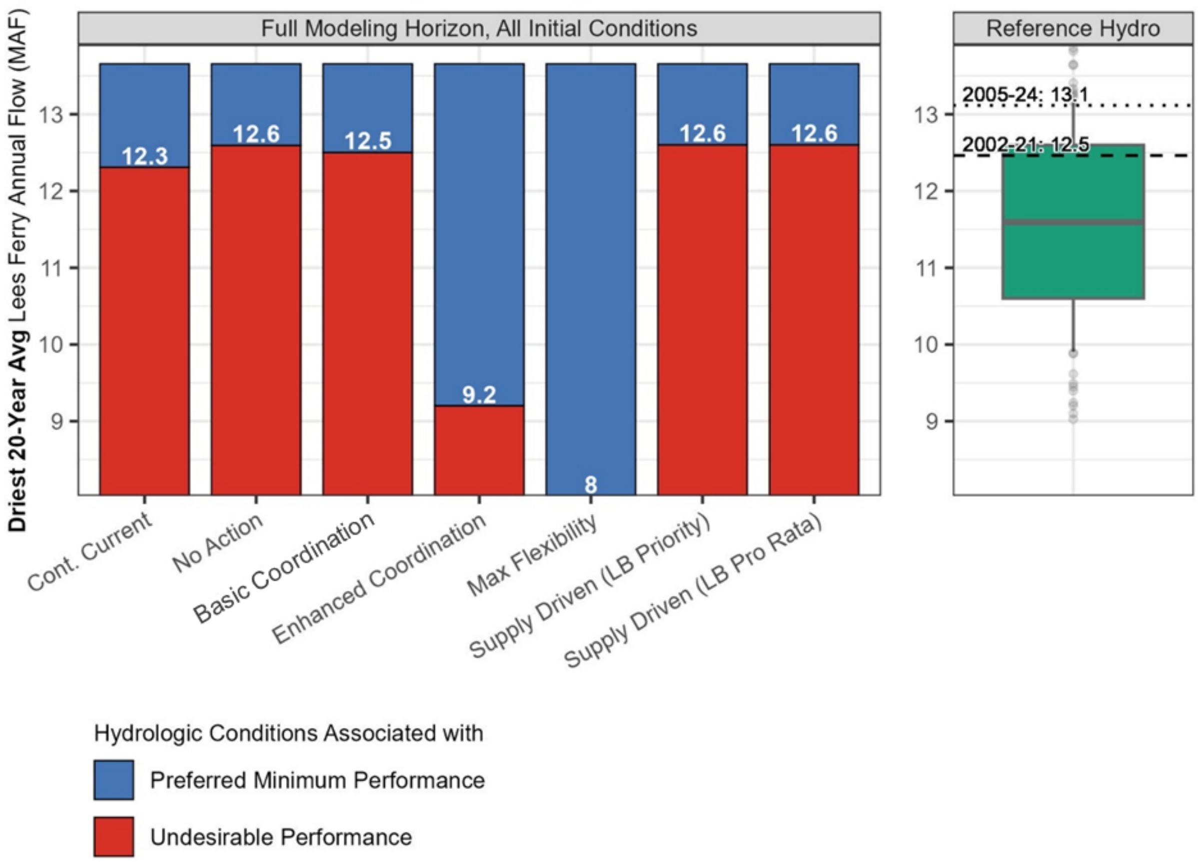
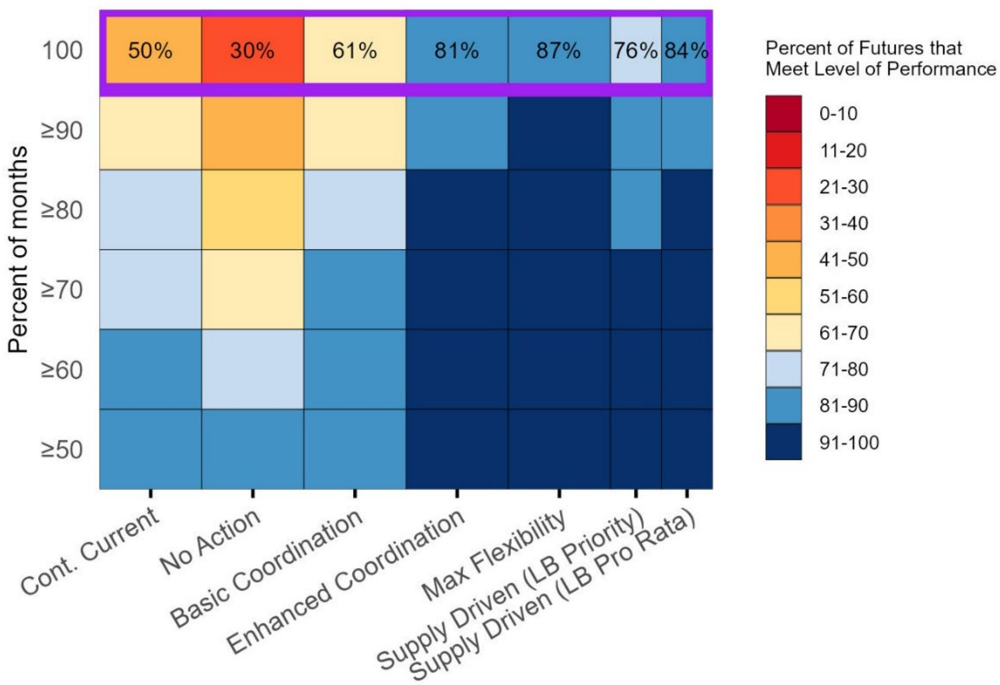


Figure TA 15-11 below shows the percentage of futures in which Lake Mead elevation is at least 950 feet for all months of the year. The figure shows that the Maximum Operational Flexibility Alternative is the most robust, with 87 percent of futures over all months having a Lake Mead elevation of at least 950 feet. The Supply Driven Alternative (LB Pro Rata approach) (84 percent) and the Enhanced Coordination Alternative (81 percent) also provide a relatively high level of robustness. The No Action Alternative has the lowest robustness, with 30 percent of futures achieving the required elevation in all 12 months, followed by the CCS Comparative Baseline with 50 percent.

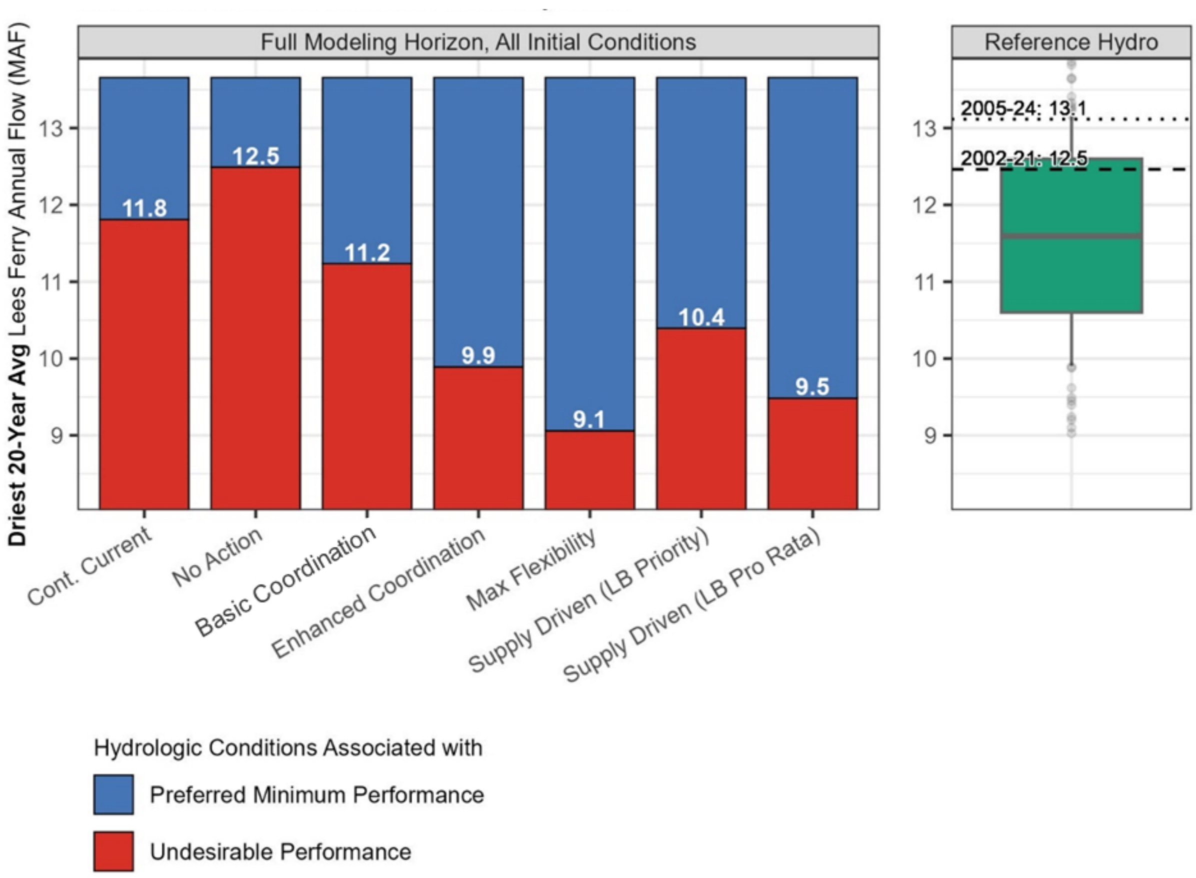
Figure TA 15-11
Lake Mead Power Pool: Robustness.
Percent of futures in which Lake Mead elevation is at least 950 feet in the percent of months specified in each row



Note: Supply Driven LB Priority and Supply Driven LB Pro Rata results differ primarily because of how the two shortage-distribution approaches interact with the modeled assumptions governing the storage and delivery of conserved water (see **Appendix B**, Modeling Assumptions: Lake Powell and Lake Mead Storage and Delivery of Conserved Water)

The vulnerability figure below, **Figure TA 15-12**, shows the distribution of the driest 20-year averages in the reference ensemble with a median 20-year average Lees Ferry flow of around 11.6 maf. Also included in the reference hydrology box plot are the 20-year averages for 2002–2021 (12.5 maf) and 2005 to 2024 (13.1 maf), shown as dashed lines, for comparison. All alternatives except for the Maximum Operational Flexibility, Supply Driven Alternative (LB Pro Rata approach), and the Enhanced Coordination Alternatives are vulnerable to about 25% or more of traces in the reference hydrology. **Figure TA 15-12** shows that the Maximum Operational Flexibility, Supply Driven (LB Pro Rata Approach), and Enhanced Coordination Alternatives are the least vulnerable to Lake Mead elevations falling below 950 feet. The No Action Alternative and CCS Comparative Baseline are the most vulnerable.

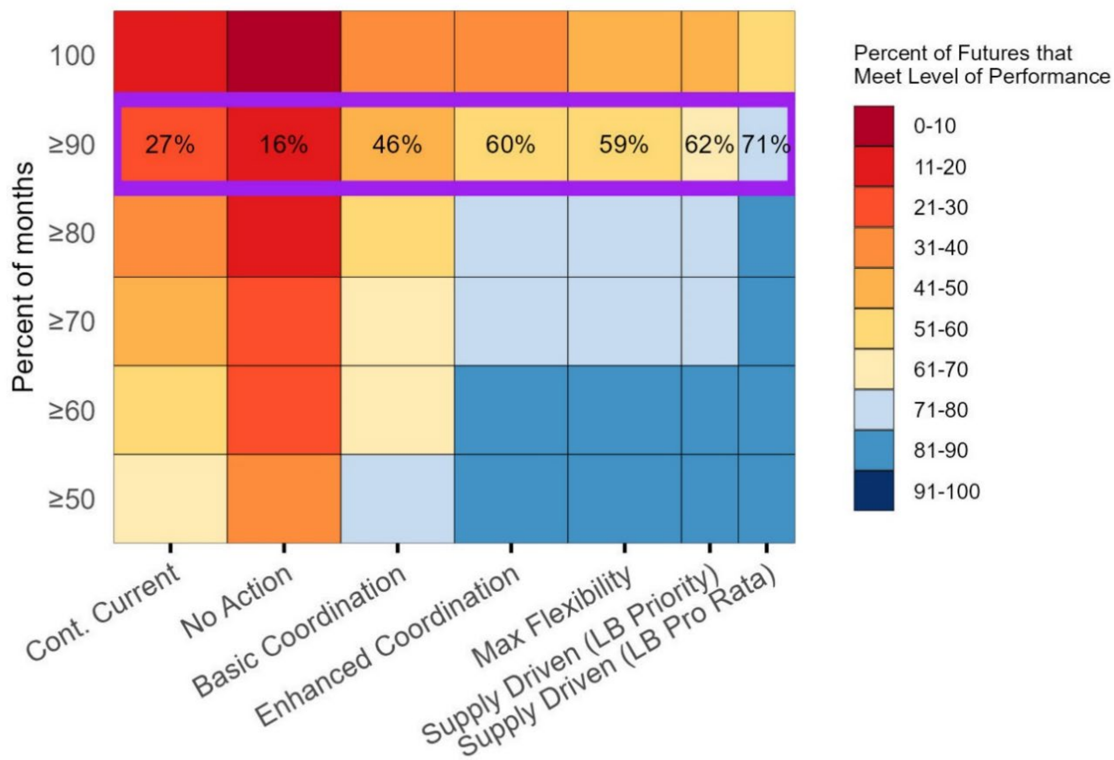
Figure TA 15-12
Lake Mead Power Pool: Vulnerability.
Conditions that Could Cause Lake Mead Elevation Below 950 Feet in any Month



Note: Supply Driven LB Priority and Supply Driven LB Pro Rata results differ primarily because of how the two shortage-distribution approaches interact with the modeled assumptions governing the storage and delivery of conserved water (see **Appendix B**, Modeling Assumptions: Lake Powell and Lake Mead Storage and Delivery of Conserved Water)

Figure TA 15-13 below shows the power pool robustness of Lake Mead for when elevations of at least 1,035 feet are achieved. This elevation or higher allows for the high head turbines to achieve their maximum capacity. The percentage of futures reaching this desired elevation in 90 percent of months is the highest under the Supply Driven Alternative (LB Pro Rata approach) (71 percent), followed by the Supply Driven Alternative (LB Priority approach) (62 percent), the Enhanced Coordination Alternative (60 percent), and the Maximum Operational Flexibility Alternative (59 percent). The No Action Alternative (16 percent) and the CCS Comparative Baseline (27 percent) are the least robust alternatives.

Figure TA 15-13
Lake Mead High-Head Turbines: Robustness.
Percent of futures in which Lake Mead elevation is at least 1,035 feet in the percent of months specified in each row



Note: Supply Driven LB Priority and Supply Driven LB Pro Rata results differ primarily because of how the two shortage-distribution approaches interact with the modeled assumptions governing the storage and delivery of conserved water (see **Appendix B**, Modeling Assumptions: Lake Powell and Lake Mead Storage and Delivery of Conserved Water)

Summary of Issue 1

The Maximum Operational Flexibility Alternative provides the greatest degree of power pool robustness for both Lake Powell and Lake Mead. For Lake Powell, the second highest level of robustness occurs under the Enhanced Coordination Alternative, and the least amount of robustness is provided by the Supply Driven Alternatives (both LB Priority and LB Pro Rata approaches). Conversely, for Lake Mead, the second highest level of robustness is provided by the

Supply Driven (LB Pro Rata approach), followed by the Enhanced Coordination Alternative. For Lake Mead elevation robustness, the least robust alternative is the No Action Alternative. From the perspective of keeping the elevations of both reservoirs above a preferred threshold during the driest of conditions, the Maximum Operational Flexibility and Enhanced Coordination Alternatives provide the most preferred outcomes for Lake Powell and the Supply Driven Alternatives (both LB Priority and LB Pro Rata approaches) and the No Action Alternative provide the least number of preferred outcomes. For Lake Mead, the Maximum Operational Flexibility, Supply Driven (LB Pro Rata approach), and Enhanced Coordination Alternatives provide the most preferred outcomes, and the No Action Alternative provides the least preferred outcomes.

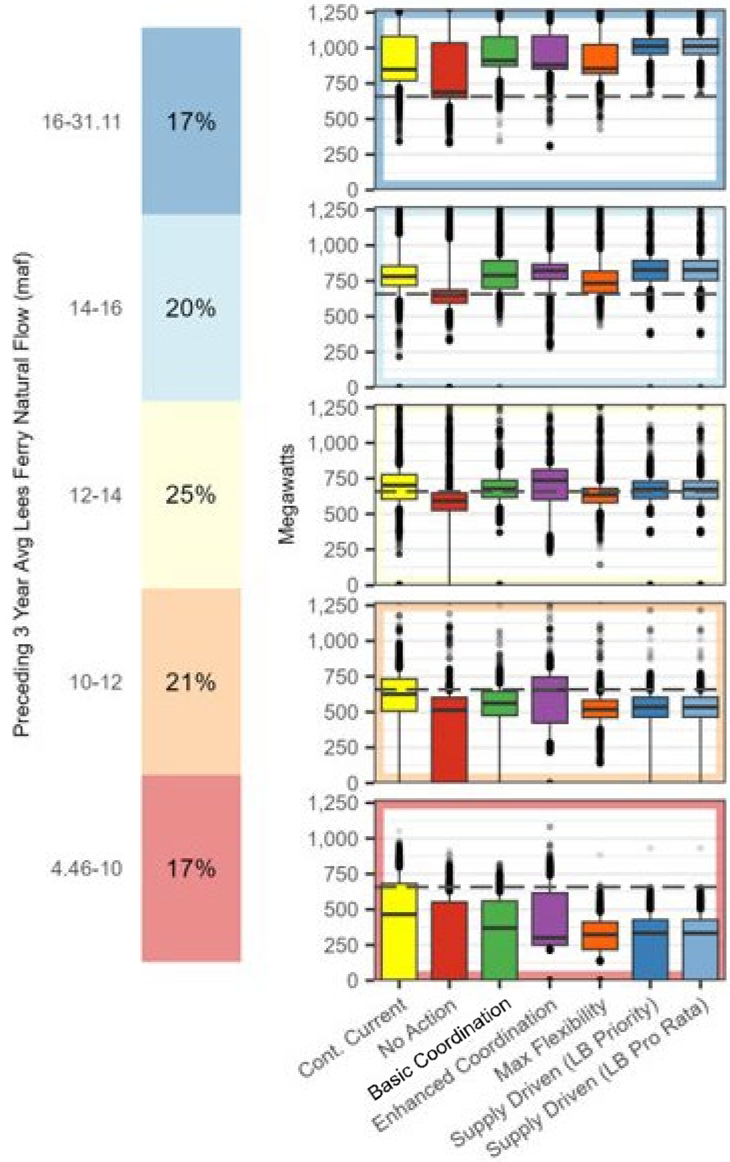
TA 15.2.4 Issue 2: How would the alternatives impact the firm capacity of the Glen Canyon Dam and Hoover Dam powerplants?

Firm capacity is the reliable, guaranteed amount of power output from a powerplant that accounts for operational constraints such as water releases and ramp rates. Firm capacity is measured in MW. This section will consider how the different alternatives impact the firm capacities of the hydropower plants at the Glen Canyon Dam and Hoover Dam.

The boxplot below, **Figure TA 15-14**, shows the firm capacity of Glen Canyon Dam for a three-year period across five different potential flows at Lees Ferry using August as the flow month. The dashed line on the boxplot is the modeled historical median (658.3 MW which is the average total power capacity between August 2016 and August 2025 based on historical data). Reclamation used the estimated capacity for the month of August as a yearly representation due to the peak energy demands and available capacity during that month. The bold center line of each box represents the median value, the top and bottom of each box captures the 25th to 75th percentile of the modeled results, the lines extend to the 10th and 90th percentiles, and the outliers are represented as dots beyond these lines.

As shown in **Figure TA 15-14**, firm capacity is the greatest under all alternatives under the Wet Flow Category (16.0–31.11 maf). Under the Wet and Moderately Wet Flow Categories, the Enhanced Coordination, Basic Coordination, and the Supply Driven Alternatives (both LB Priority and LB Pro Rata approaches) provide the highest capacity and the Maximum Operational Flexibility and No Action Alternatives provide the lowest. Under the Average Flow Category (12.0–14.0 maf), the Enhanced Coordination Alternative (600–800 MW), followed by CCS Comparative Baseline (600–775 MW), provides the highest capacity and the No Action Alternative (525–625 MW) provides the lowest capacity. The other action alternatives under the Average Flow Category all have similar levels of capacity and achieve between 675 and 750 MW of capacity. Under the Dry Flow Category (4.46–10.0 maf), the No Action, Basic Coordination, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives, and the CCS Comparative Baseline show a wide range of interquartile values with all having the potential to drop to 0 MW of capacity. Under the Dry Flow Category, the highest level of capacity occurs under the CCS Comparative Baseline followed by the Enhanced Coordination and Maximum Operational Flexibility Alternatives.

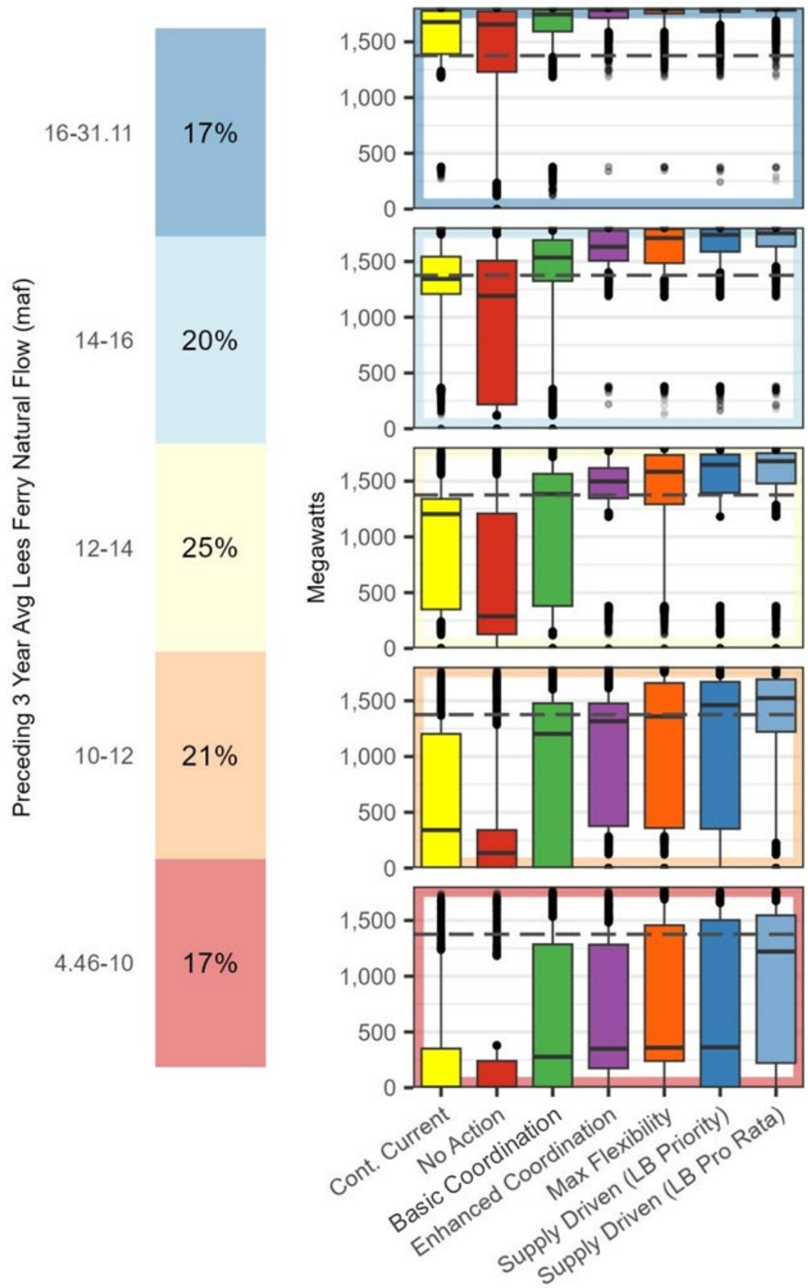
Figure TA 15-14
Glen Canyon August Power Capacity Box Plots



The boxplot below, **Figure TA 15-15** shows the power capacity of Hoover Dam for a three-year period across five different potential flows at Lees Ferry using August as the flow month. The dashed line on the boxplot is the modeled historical median (1,376 MW, the average power capacity between August 2016 to August 2025 based on historical data). Reclamation used the estimated capacity for the month of August as a yearly representation due to the peak energy demands and available capacity during that month. The bold center line of each box represents the median value, the top and bottom of each box captures the 25th to 75th percentile of the modeled results, the lines extend to the 10th and 90th percentiles, and the outliers are represented as dots beyond these lines.

Under the Wet Flow Category (16–31.11 maf) all alternatives and the CCS Comparative Baseline provide a high level of capacity. For the Average Flow Category, between 12.0–16.0 maf, the Supply Driven (both LB Priority and LB Pro Rata approaches), Enhanced Coordination, and Maximum Operational Flexibility Alternatives provide the highest levels of capacity. The CCS Comparative Baseline and the No Action and Basic Coordination Alternatives all have wide interquartile ranges. In the Dry Flow Category, the Supply Driven (LB Pro Rata approach) provides the highest level of capacity and the lowest interquartile range. All of the other action alternatives have wide interquartile ranges and the CCS Comparative Baseline and No Action and Basic Coordination Alternatives have the potential to drop to 0 MW of capacity. Under the Critically Dry Flow Category, 10.0-12.0 maf, the Supply Driven Alternatives (both LB Pro Rata and LB Priority approaches) produce a high capacity. However, the Supply Driven (LB Priority approach) has the potential to drop to 0 MW of capacity. Under the Critically Dry Flow Category, the action alternatives have a high interquartile ranges and the Basic Coordination like the Supply Driven (LB Priority approach) has the potential to drop to 0 MW of capacity. The Maximum Operational Flexibility and Enhanced Coordination Alternatives produce the third and fourth highest levels of capacity after the Supply Driven Alternatives (both LB Priority and LB Pro Rata approaches) and while they have a wide interquartile range, they do not drop to 0 MW of capacity. The CCS Comparative Baseline and the No Action and Basic Coordination Alternatives produce the lowest levels of capacity in the Critically Dry Flow Category and they both have the potential to drop to 0 MW of capacity. Under all flow categories, the Supply Driven Alternative (LB Pro Rata approach) provides the highest capacity followed by the Supply Driven Alternative (LB Priority approach) and the Maximum Operational Flexibility Alternative. Under all flow categories, the No Action Alternative produces the lowest amount of capacity followed by the CCS Comparative Baseline.

Figure TA 15-15
Hoover August Power Capacity Box Plots



Note: Supply Driven LB Priority and Supply Driven LB Pro Rata results differ primarily because of how the two shortage-distribution approaches interact with the modeled assumptions governing the storage and delivery of conserved water (see **Appendix B**, Modeling Assumptions: Lake Powell and Lake Mead Storage and Delivery of Conserved Water)

Summary of Issue 2 Impacts

The firm capacity at Glen Canyon Dam during a Wet Flow Category is the highest under the Supply Driven Alternatives (both LB Priority and LB Pro Rata approaches). In an Average Flow Category, the Enhanced Coordination Alternative provides the highest level of capacity. Under a Critically Dry Flow Category, the CCS Comparative Baseline, Enhanced Coordination, and Maximum Operational Flexibility Alternatives provide Glen Canyon Dam powerplant with the highest capacity.

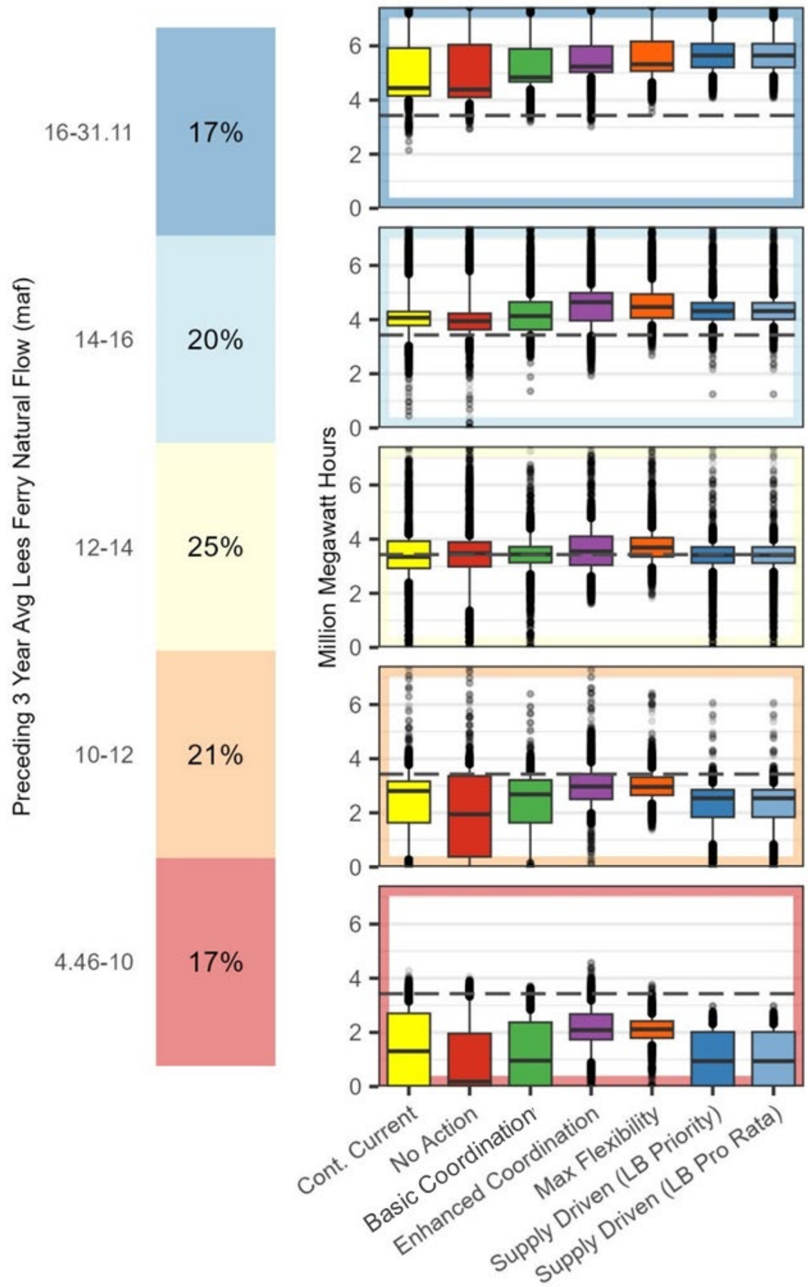
For the Hoover Dam powerplant, the Supply Driven Alternatives (both LB Priority and LB Pro Rata approaches) provide high levels of capacity across all flow categories. Considered collectively, the Maximum Operational Flexibility Alternative leads to relatively high firm capacity for both the Glen Canyon Dam powerplant and the Hoover Dam powerplant. Although the Supply Driven Alternatives (both LB Priority and LB Pro Rata approaches) provide high firm capacity for the Hoover Dam powerplant, they have a wide interquartile variability and lower levels of capacity for the Glen Canyon Dam powerplant under dry conditions.

TA 15.2.5 Issue 3: How would the alternatives impact the energy generation of the Glen Canyon Dam, Hoover Dam, Davis Dam, and Parker Dam powerplants?

Energy generation is the amount of energy created over a certain period, measured in MWh. Energy generation is dependent on reservoir head and water release volume. The model inputs used to develop the figures in this analysis simulated releases and lake reservoir elevations to calculate estimated energy generation. **Figure TA 15-15**, **Figure TA 15-16**, **Figure TA 15-17**, and **Figure TA 15-18** illustrate the power generation response of Glen Canyon Dam, Hoover Dam, Davis Dam, and Parker Dam powerplants respectively. The boxplots illustrate how the alternatives respond during different hydrologic conditions that are based on the preceding three-year average of Lees Ferry natural flow. The bold center line of each box represents the median value, the top and bottom of each box captures the 25th to 75th percentile of the modeled results, the lines extend to the 10th and 90th percentiles, and the outliers are represented as dots beyond these lines.

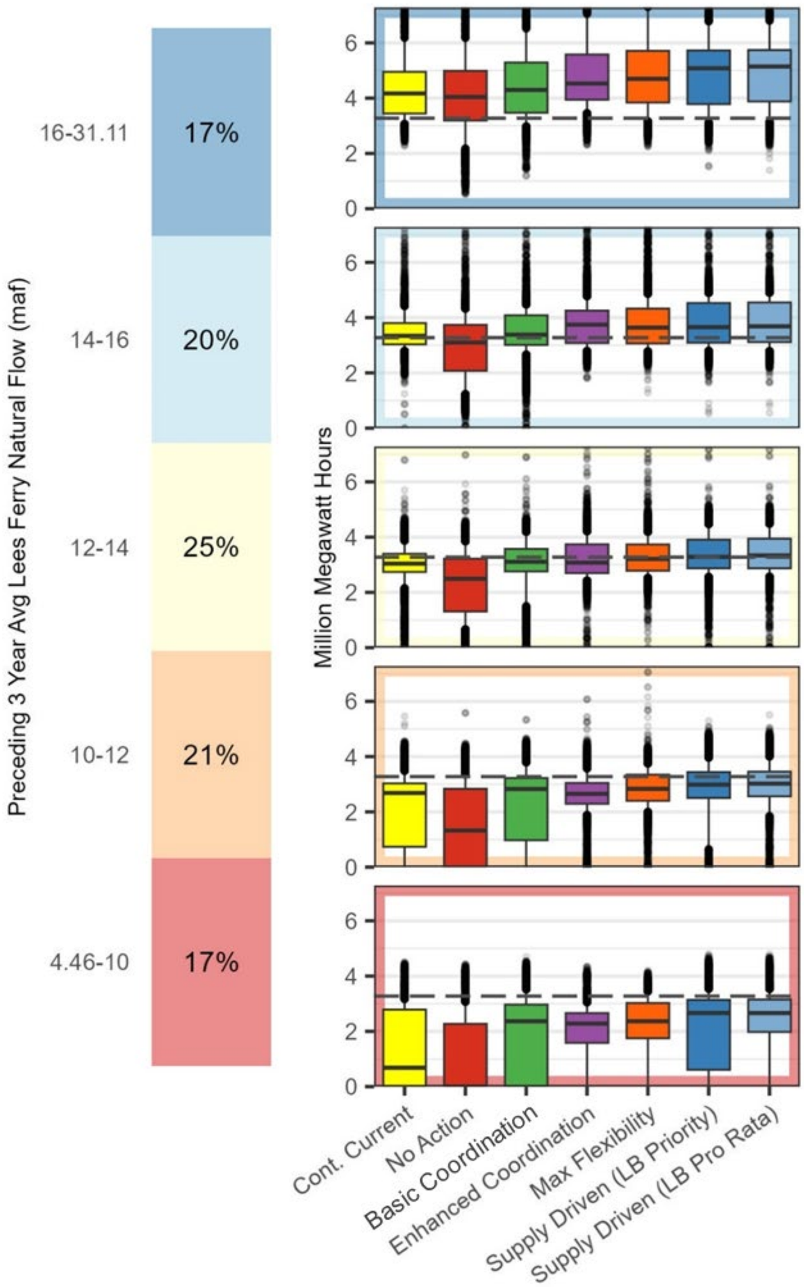
As described in **Figure TA 15-16**, Glen Canyon Dam powerplant, under the Wet and Moderately Wet Flow Categories of 16.0-31.11 maf and 14.0-16.0 maf generate the highest amount of power under the Supply Driven (both LB Priority and LB Pro Rata approaches), Maximum Operational Flexibility, and Enhanced Coordination Alternatives. The CCS Comparative Baseline and No Action Alternative produce the least amount of power. Under the Average Flow Category (12.0–14.0 maf), the Maximum Operational Flexibility and Enhanced Coordination Alternatives produce the highest amounts of power. Under the Critically Dry Flow Category (4.46–10.0 maf), the Enhanced Coordination and Maximum Operational Flexibility Alternatives have the highest level of power generation, and the No Action Alternative has the lowest. Under the Critically Dry Flow Category, all alternatives but the Enhanced Coordination and Maximum Operation Flexibility Alternatives have the potential to fall to 0 MWh.

Figure TA 15-16
Water Year Glen Canyon Generation Box Plots



For the Hoover Dam powerplant, as shown in **Figure TA 15-17** below, under the Wet and Moderately Wet Flow Categories, the Maximum Operational Flexibility, Supply Driven (both LB Priority and LB Pro Rata approaches), and Enhanced Coordination Alternatives produce the highest amount of power. Under the Average Flow Category, energy generation is similar across all of the action alternatives, with relatively small interquartile ranges. The No Action Alternative has the greatest interquartile variability and produces the least amount of power. In the Moderately Dry and Dry Flow Categories (4.46–12.0 maf), the Supply Driven Alternatives (both LB Priority and LB Pro Rata approaches) produce the highest amount of power followed by the Maximum Operational Flexibility and the Enhanced Coordination Alternatives. The Supply Driven Alternative (LB Pro Rata approach), Maximum Operational Flexibility, and Enhanced Coordination Alternatives provide relatively high amounts of power while having low interquartile ranges that do not drop to 0 MWh. The CCS Comparative Baseline and Basic Coordination Alternatives have the potential to produce as much energy as the Maximum Operational Flexibility Alternative but they have a high interquartile range and have the potential to fall to 0 MWh. Under the Critically Dry Flow Category, the No Action Alternative produces the lowest level of power and has the potential to fall to 0 MWh.

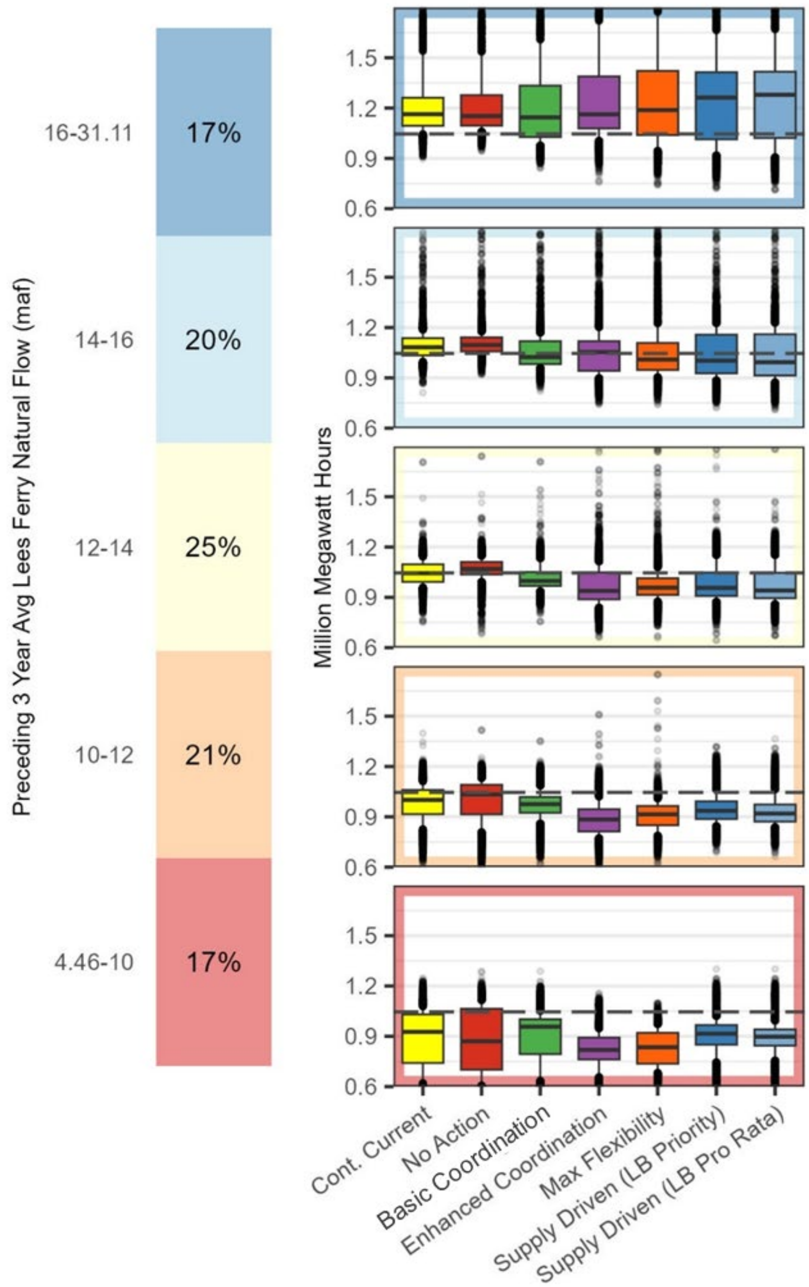
Figure TA 15-17
Water Year Hoover Generation Box Plots



Note: Supply Driven LB Priority and Supply Driven LB Pro Rata results differ primarily because of how the two shortage-distribution approaches interact with the modeled assumptions governing the storage and delivery of conserved water (see **Appendix B**, Modeling Assumptions: Lake Powell and Lake Mead Storage and Delivery of Conserved Water)

For the Davis Dam powerplant, as shown in **Figure TA 15-18** below, in the Wet Flow Category (16.0–31.11 maf), the Supply Driven (both LB Priority and LB Pro Rata approaches), Maximum Operation Flexibility, and Enhanced Coordination Alternatives produce the most power and the CCS Comparative Baseline and No Action Alternative produce the least amount. In the Moderately Wet Flow Category (14.0–16.0 maf), the No Action Alternative, CCS Comparative Baseline, and Supply Driven Alternatives (both LB Priority and LB Pro Rata approaches) have the highest levels of power generation. Under the Average Flow Category (12.0–14.0 maf), the No Action Alternative and the CCS Comparative Baseline have the highest power production with the action alternatives providing slightly lower, comparable levels of power. Under the Dry Flow Category, the second-lowest flow scenario (10.0–12.0 maf), the CCS Comparative Baseline and the No Action and Basic Coordination Alternatives produce the most amount of power and the Enhanced Coordination Alternative produces the least. Under the Critically Dry Flow Category, these three alternatives continue to produce the most power, but the CCS Comparative Baseline and No Action Alternative have high interquartile variability and have the potential to produce the lowest levels of power of all the alternatives. Under the Critically Dry Flow Category, the action alternatives that produce the most power are the Basic Coordination and the Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives.

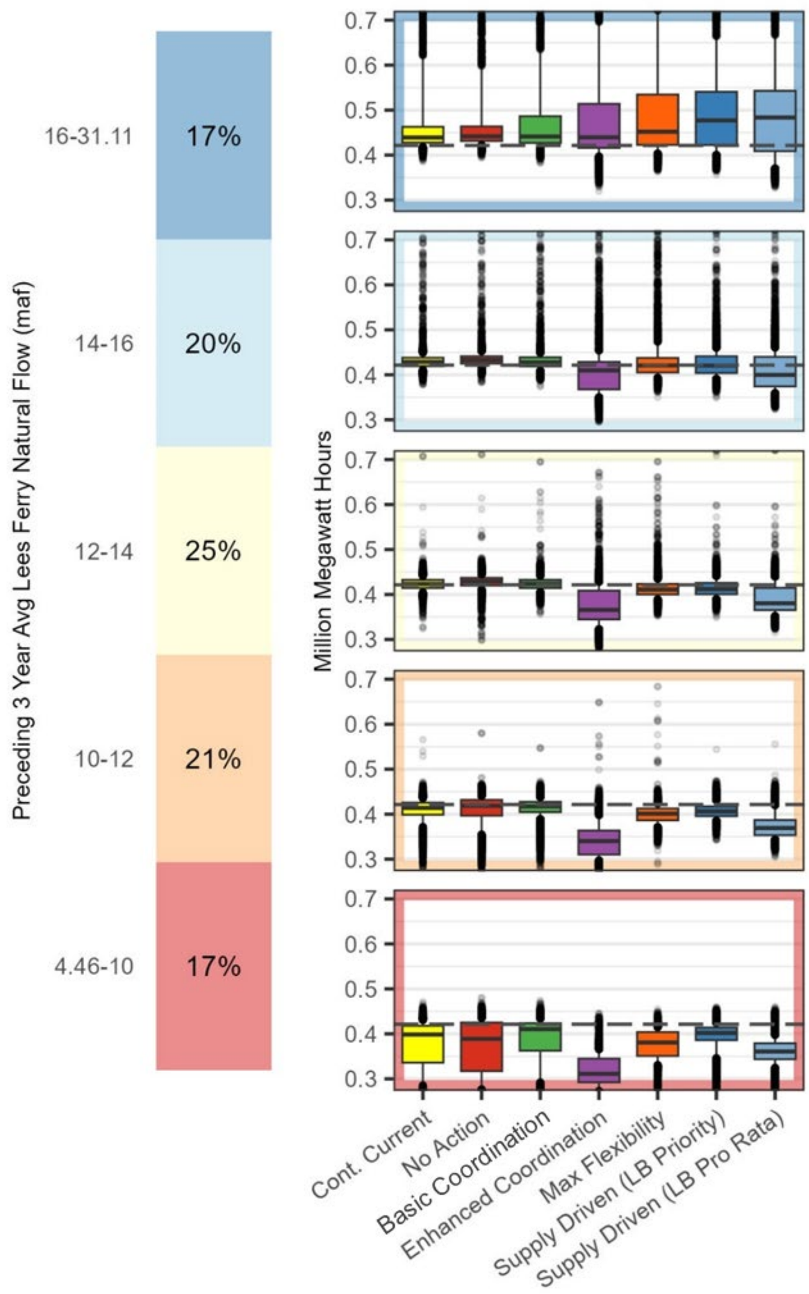
Figure TA 15-18
Water Year Davis Generation Box Plots



Note: Supply Driven LB Priority and Supply Driven LB Pro Rata results differ primarily because of how the two shortage-distribution approaches interact with the modeled assumptions governing the storage and delivery of conserved water (see **Appendix B**, Modeling Assumptions: Lake Powell and Lake Mead Storage and Delivery of Conserved Water)

For the Parker Dam powerplant, as shown in **Figure TA 15-19**, under the Wet Flow Category the Supply Driven Alternative (both LB Priority and LB Pro Rata approaches) and the Maximum Operational Flexibility Alternative produce the most power and the No Action Alternative and CCS Comparative baseline produce the least. Under the Moderately Wet and Mid Flow Categories (12.0–16.0 maf), all the alternatives produce similar amounts of power with the Enhanced Coordination and Supply Driven (LB Pro Rata approach) Alternatives having relatively higher interquartile ranges and the potential to produce the least amount of energy. Under the Moderately Dry Flow Categories (10.0–12.0 maf), the CCS Comparative Baseline and No Action, Basic Coordination, Maximum Operational Flexibility, and Supply Driven (LB Priority approach) Alternatives provide similar levels of power and the Enhanced Coordination and the Supply Driven (LB Pro Rata approach) Alternatives provide the lowest levels. Similar results occur under the Critically Dry Flow Category but under this flow category the interquartile range for the No Action Alternative and the CCS Comparative Baseline are large and result in both having the potential to produce low levels of power.

Figure TA 15-19
Water Year Parker Generation Box Plots



Note: Supply Driven LB Priority and Supply Driven LB Pro Rata results differ primarily because of how the two shortage-distribution approaches interact with the modeled assumptions governing the storage and delivery of conserved water (see **Appendix B**, Modeling Assumptions: Lake Powell and Lake Mead Storage and Delivery of Conserved Water)

Summary of Issue 3 Impacts

Energy generation at each of the powerplants responds differently under each of the alternatives. The Glen Canyon Dam powerplant would have the highest power production under the Maximum Operational Flexibility and Enhanced Coordination Alternatives under all flow categories except the Wet Flow Category where the Supply Driven Alternatives (both LB Priority and LB Pro Rata approaches) have the highest power production. The Hoover Dam powerplant would produce the highest amounts of energy under the Supply Driven Alternatives (both LB Priority and LB Pro Rata approaches) under all flow categories. The Davis Dam powerplant would have the highest power production under the Supply Driven Alternatives (both LB Priority and LB Pro Rata approaches) under the Wet Flow Category. Under the Moderately Wet Category, the No Action Alternative has the highest median power production. Under the mid and lower two flow categories, the No Action Alternative, followed by the CCS Comparative Baseline, provides the highest amount of power. The Parker Dam powerplant would produce the highest amount of power under the Supply Driven Alternatives (both LB Priority and LB Pro Rata approaches) under the Wet Flow Category, but as the flow categories decrease, the alternatives produce similar results, with the Enhanced Coordination Alternative producing the lowest amount of power.

TA 15.2.6 Issue 4: How would the alternatives impact spillway infrastructure and life safety?

Spillway infrastructure and life safety are affected by reservoir elevation, particularly high elevations, which vary greatly between alternatives. High reservoir elevations, for extended durations, pose a risk to spillway infrastructure. This analysis compares the various action alternatives to the No Action Alternative and the CCS Comparative Baseline for the following metrics:

- Lake Powell pool elevations
- Lake Mead pool elevations

Lake Powell

Critical high elevations at Lake Powell are listed in **Table TA 15-1** below. Reclamation minimizes controlled discharge over the spillway, as these discharges are not intended for frequent or extended operation. One way to reduce these controlled discharges is to maintain a vacant space requirement in the reservoir, which serves as a buffer of unused storage capacity to absorb large runoff inflows without causing controlled discharge.

Table TA 15-1
Critical Elevations at Lake Powell

Critical Condition	Associated Elevation	Description of Critical Elevation
Spillway	3,700 feet	Glen Canyon Dam spillway
Vacant Space Requirement	3,684 feet	Target reservoir elevation on January 1. Allows for 1.9 maf of flood control storage up to the top of the spillway

Figure TA 15-20 depicts the performance of each alternative with regard to keeping Lake Powell below elevation 3,684 feet on January 1. Rows of the heat map show different frequency ranges for keeping Lake Powell below this elevation; higher rows require this level of performance more often. The highlighted row represents the percentage of futures that an alternative successfully achieves this result in 90 percent of the months. Keeping Lake Powell below 3,684 feet ensures that sufficient reservoir volume is reserved to accommodate spring runoff.

The Supply Driven Alternatives (both LB Priority and LB Pro Rata approaches) are the most robust at staying below elevation 3,684 feet 90 percent of the time, doing so in 82 percent of futures. The Basic Coordination Alternative, Maximum Operational Flexibility Alternative, and the CCS Comparative Baseline perform similarly, ranging in success between 66 percent to 70 percent of futures. The No Action Alternative has the worst performance at a 60 percent success rate. All alternatives, except the No Action Alternative, show increasing robustness to the darkest shade of blue as the specified frequency is relaxed.

Figure TA 15-20
Lake Powell Preservation of Spring Runoff Space 3,684 Feet: Robustness.
Percent of futures in which the January 1 Lake Powell elevation does not exceed 3,684 feet in the percent of years specified in each row

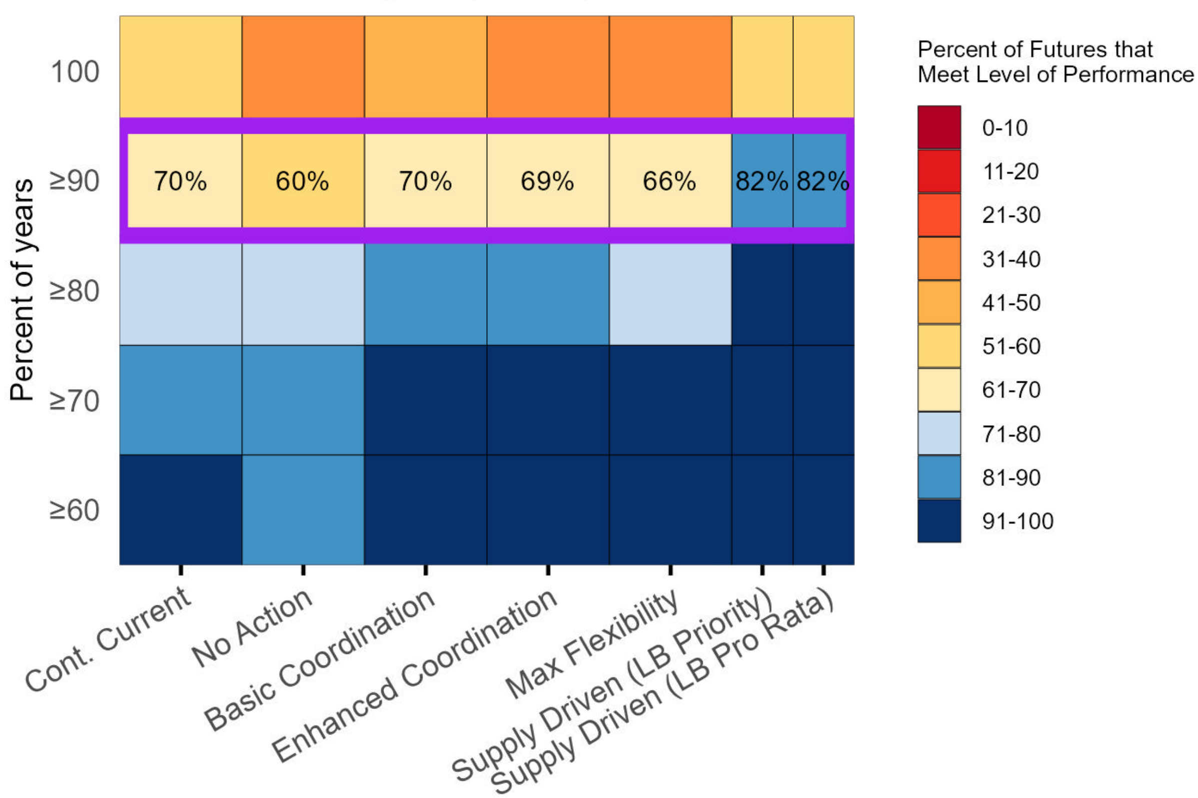


Figure TA 15-21 looks at conditions that could cause Lake Powell elevation to be above 3,684 feet more than 10 percent of years. This definition of undesirable performance is based on the highlighted row in **Figure TA 15-20**, which determined a future as successful when an alternative kept Lake Powell below this buffer elevation at least 90 percent of the time.

For this vulnerability analysis, the wettest 20-year average of Lees Ferry Annual Flow was identified as a skillful streamflow statistic. The reference hydrology shows the historical averages for the 2005–2024 and 1911–1930 periods for comparison. The Supply Driven Alternatives (both LB Priority and LB Pro Rata approaches) become vulnerable to elevations above 3,684 feet at 17.0 maf and perform the best of all alternatives. The No Action, Enhanced Coordination, and Maximum Operational Flexibility Alternatives are the most vulnerable to undesirable performance, but all alternatives are expected to satisfy the preferred minimum performance under the driest 50 percent of traces in the reference hydrology, which includes the recent 20-year average of 2005–2024 (13.1 maf).

Figure TA 15-21
Lake Powell Preservation of Spring Runoff Space : Vulnerability.
Conditions that could cause Lake Powell elevation above 3,684 in more than 10 percent years

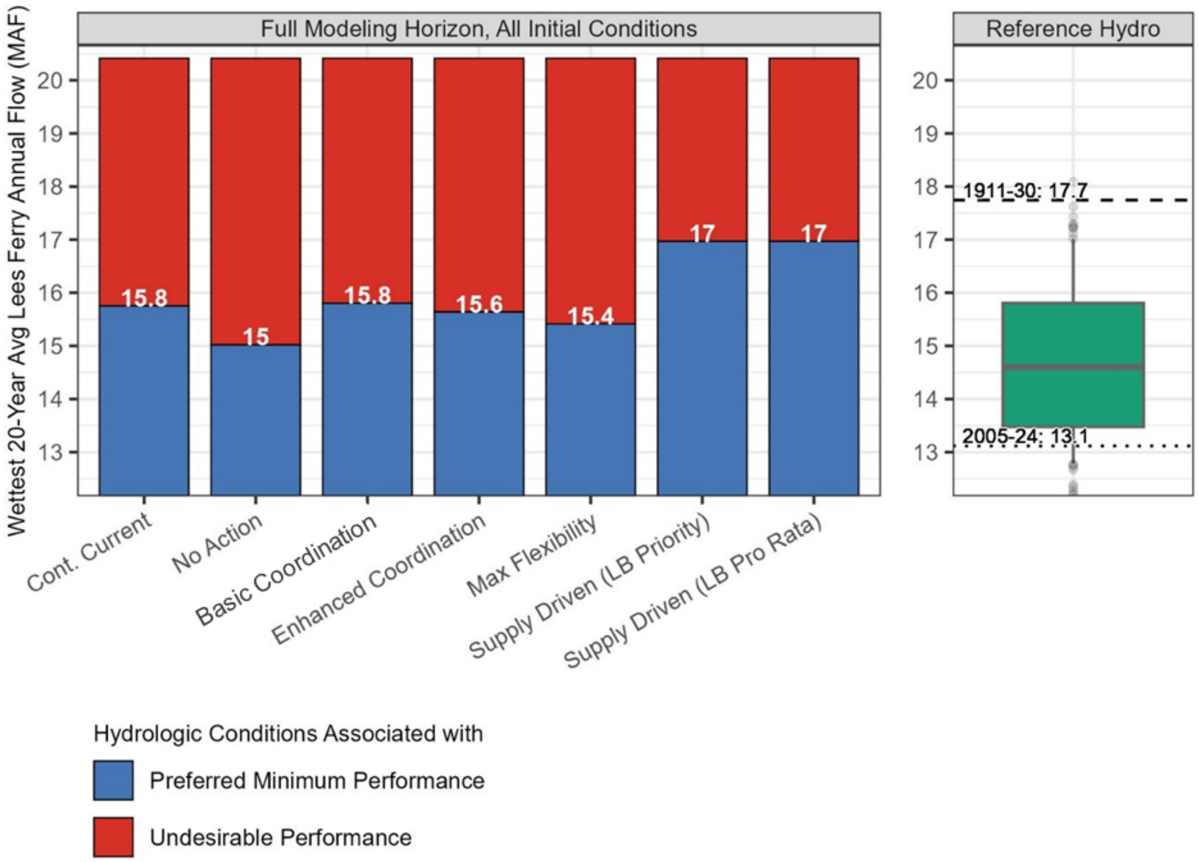


Figure TA 15-22 shows how each alternative performs with respect to keeping Lake Powell's elevation below 3,700 feet in 100 percent of months, which is an important buffer elevation to protect dam infrastructure and minimize large magnitude spillway releases. Rows of the heat map show different frequency specifications for keeping Lake Powell below this elevation, with higher rows requiring this level of performance more often. The Supply Driven Alternatives (both LB Priority and LB Pro Rata approaches) are the most successful at keeping Lake Powell below 3,700 feet 100 percent of the time in 64 percent of the futures. All other alternatives are less robust: the Basic Coordination Alternative and CCS Comparative Baseline perform slightly better than the No Action, Enhanced Coordination, and Maximum Operational Flexibility Alternatives, succeeding in 58 percent and 56 percent of futures, respectively. All actions show increasing robustness to darker shades of blue as the specified frequency is lessened to keep Lake Powell below 3,700 feet in 94 percent of months.

Figure TA 15-22
Glen Canyon Dam Spillway Avoidance: Robustness.
Percent of futures in which Lake Powell elevation is below 3,700 feet in the percent of months specified in each row

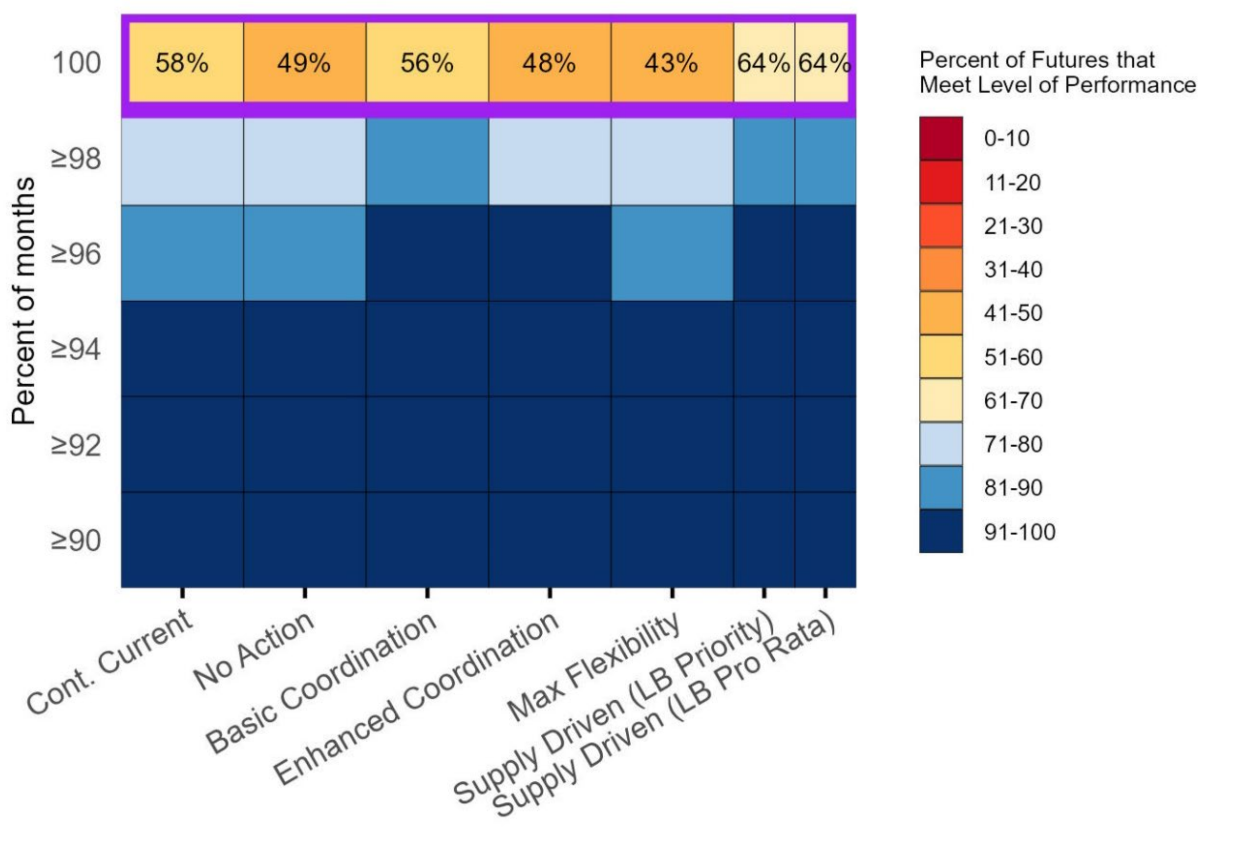


Figure TA 15-23 shows what conditions are likely to cause Lake Powell's monthly elevation to rise above elevation 3,700 feet in at least one month across a 34-year future. This definition of undesirable performance is based on the highlighted row in **Figure TA 15-21**, which specifies that a future was successful if Lake Powell stayed below 3,700 feet in 100 percent of months. For this vulnerability analysis, the wettest 10-year average of Lees Ferry Annual Flow was used to identify conditions of concern. The reference hydrology panel shows the distribution of the wettest 10-year averages in the reference ensemble, along with the notably wet 1914–1923 10-year average and the most recent observed 10-year average from 2015 to 2024 for comparison. The Supply Driven Alternatives (both LB Priority and LB Pro Rata approaches) are least vulnerable to Lake Powell's elevation exceeding 3,700 feet, where undesirable performance is reached when 10-year average flows exceed 16.5 maf. The No Action, Enhanced Coordination, and Maximum Operational Flexibility Alternatives show the most vulnerability at 15.2, 15.1, and 15.0 maf, respectively. These conditions are slightly below the 50th percentile of the reference hydrology ensemble of approximately 15.4 maf.

Figure TA 15-23
Glen Canyon Dam Spillway Avoidance: Vulnerability.
Conditions that could cause Lake Powell elevation above 3,700 feet in one or more months

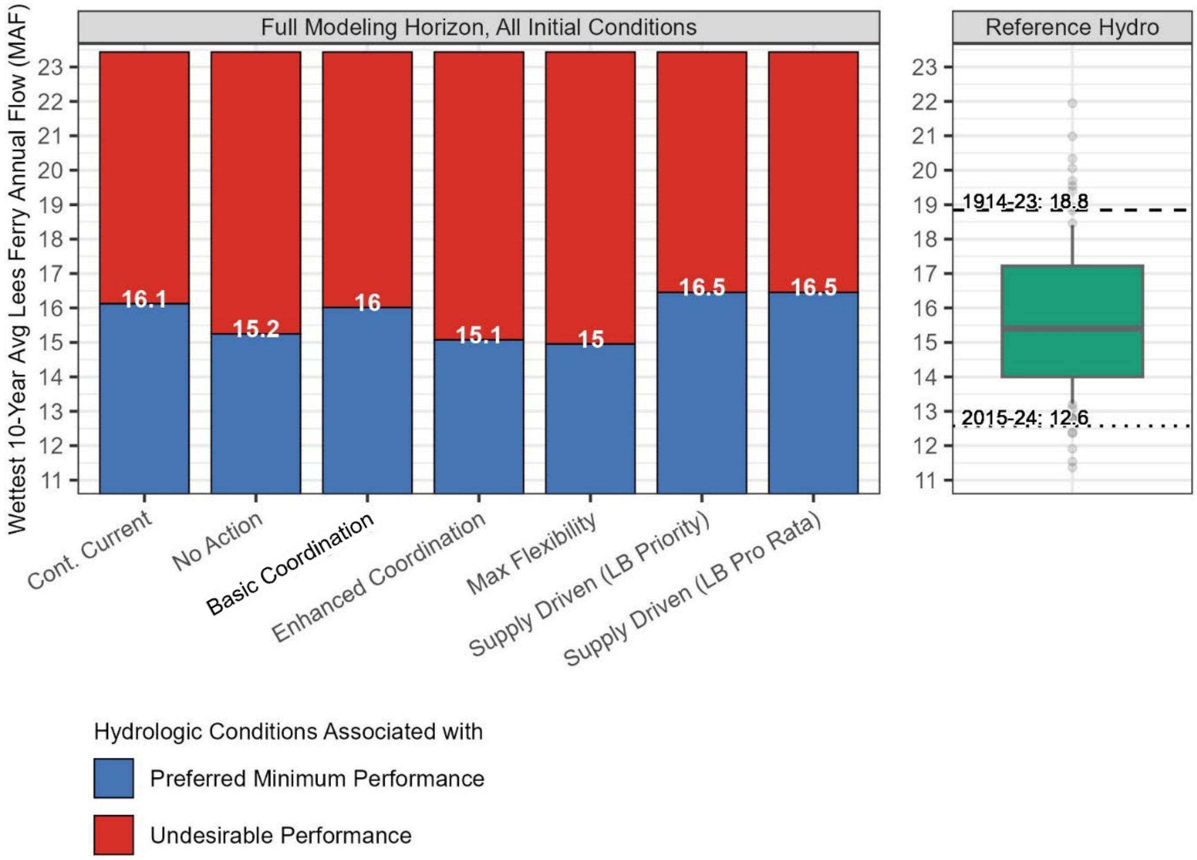


Figure TA 15-24 depicts the performance of each alternative with regard to monthly spillway volume released from Glen Canyon Dam. Rows of the heat map show different frequency ranges for keeping the Glen Canyon Dam spillway releases below a specified volume; higher rows require a stricter cap on spillway releases. The highlighted row represents the percentage of futures that an alternative successfully achieves this result in 100 percent of the months. Minimizing spillway releases maximizes water supply and power generation while reducing wear and tear to the spillway structure.

The Supply Driven Alternatives (both LB Priority and LB Pro Rata approaches) are the most robust at maintaining zero releases from the Glen Canyon Dam spillway for 100 percent of months, succeeding in 76 percent of futures. The Basic Coordination Alternative and the CCS Comparative Baseline perform similarly at 70 percent. The Maximum Operational Flexibility Alternative has the lowest level of performance, succeeding in 63 percent of futures.

Figure TA 15-24
Glen Canyon Dam Spillway Releases: Robustness.
Percent of futures in which spillway releases are avoided in the percent of months specified in each row

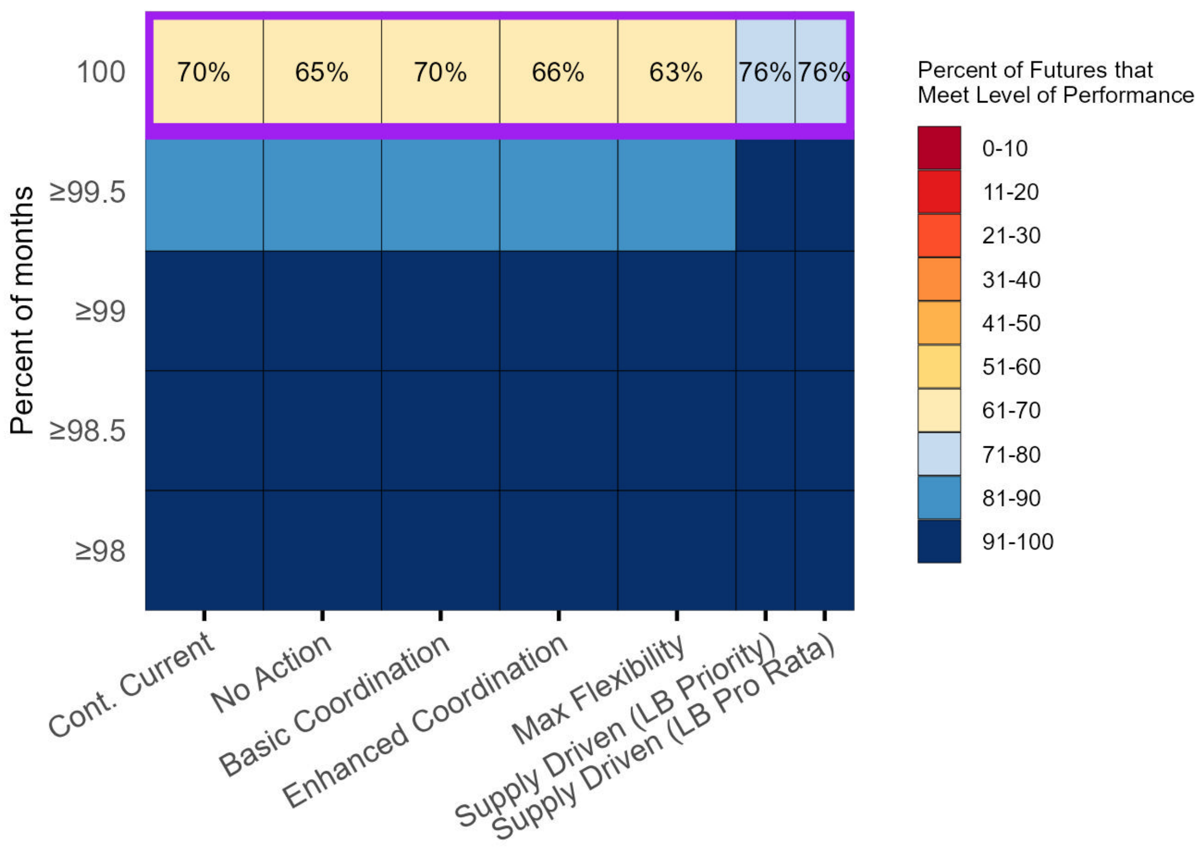
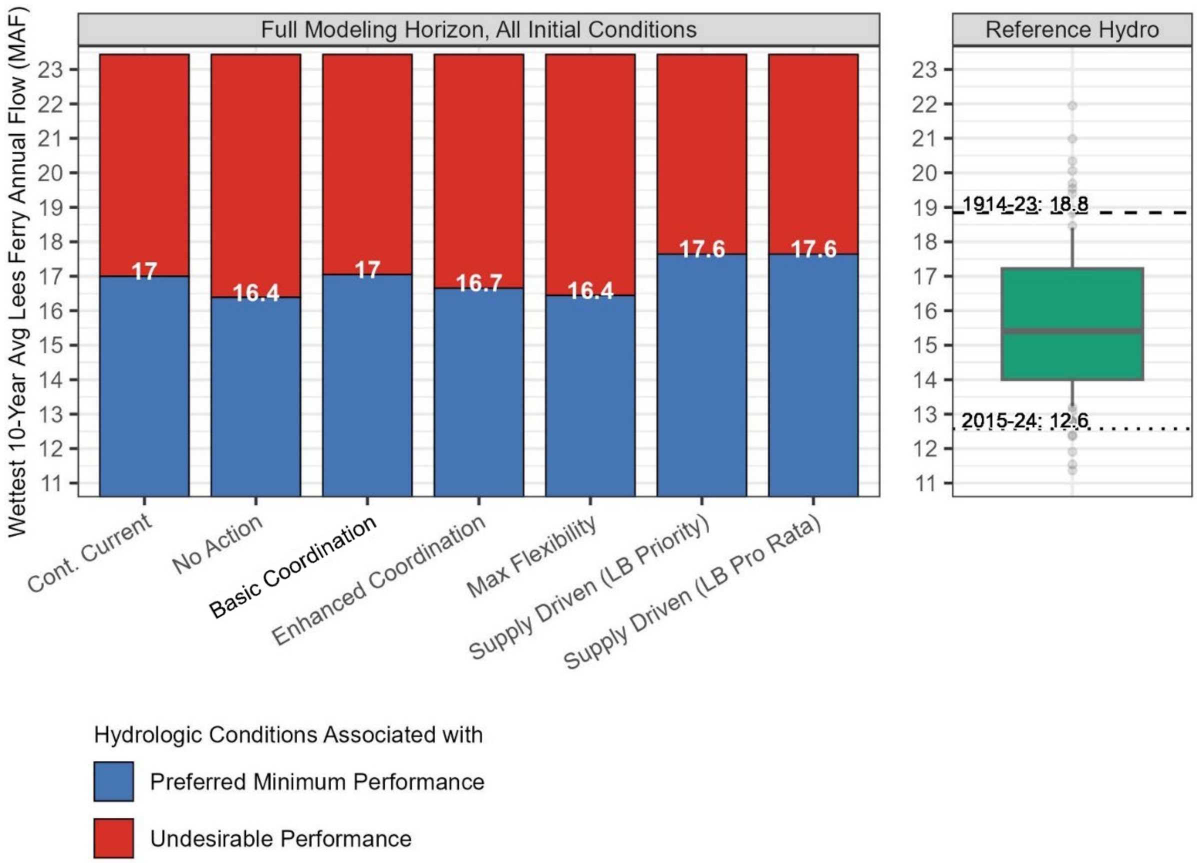


Figure TA 15-25 looks at flow conditions that could cause a Glen Canyon Dam spillway release in at least one month in any year. The figure is based on an analysis that includes all three sets of initial condition scenarios (including a high scenario where Lake Powell starts at 3,629 feet). This definition of undesirable performance is based on the highlighted row in **Figure TA 15-23**, which determined a future as successful when an alternative kept the spillway volume release at 0.0 maf in 100 percent of months. For this vulnerability analysis, the wettest 10-year average of Lees Ferry Annual Flow was identified as a skillful streamflow statistic. The reference hydrology shows a median 10-year average of around 15.4 maf. It also includes the averages for the 1914–1923 and 2015–2024 periods for comparison. None of the alternatives are vulnerable to the median 10-year average flow of 15.4 maf. Undesirable performance for the Supply Driven Alternatives (both LB Priority and LB Pro Rata approaches) are not likely to occur until above the highest 25 percent of the traces in the reference hydrology ensemble at 17.6 maf. All alternatives are vulnerable to spilling under the wettest 10-year average in the historical record (18.8 maf), which occurred from 1914–1923.

Figure TA 15-25
Glen Canyon Dam Spillway Releases: Vulnerability.
Conditions that could cause a spillway release from Glen Canyon Dam in one or more months



Lake Mead

Critical high elevations at Lake Mead are listed in **Table TA 15-2** below. Reclamation minimizes uncontrolled discharge over the spillway as they are not intended for frequent or extended operation. One way to reduce these uncontrolled discharges is to maintain a vacant space requirement in the reservoir to absorb large runoff inflows without causing uncontrolled discharge.

Table TA 15-2
Critical Elevations at Lake Mead

Critical Condition	Associated Elevation	Description of Critical Elevation
Spillway	1,205.4 feet	Hoover Dam spillway crest
Maximum Operating Elevation	1,219.6 feet	Allows for 1.5 maf of flood control storage up to the top of the spillway
Maximum Spillway Discharge	1,226.9 feet	Spillway discharge at this elevation is 40,000 cfs, which triggers a "Imminent Life-Threatening Emergency" response

Figure TA 15-26 depicts the performance of each alternative with regard to keeping Lake Mead below elevation 1,205.4 feet. Rows of the heat map show different frequency ranges for keeping Lake Mead below this elevation; higher rows require staying below 1,205.4 feet more often. This elevation is the invert of the spillway drum gates for Hoover Dam, and operating above the spillway drum gates level increases the likelihood for mechanical failure. The highlighted row represents the percentage of futures that an alternative is successful at keeping Lake Mead below elevation 1,205.4 feet in 90 percent of the months. The greater than or equal to 90 percent row was chosen because it provides a reasonable amount of flexibility to go below 1,205.4 feet occasionally in very wet hydrology.

The CCS Comparative Baseline and the No Action Alternative are most robust at staying below elevation 1,205.4 feet 90 percent of the time, doing so in 83 percent and 82 percent of the futures respectively. Over the full modeling period, the Supply Driven Alternatives (both LB Priority and LB Pro Rata approaches) are the least robust, and only meets the preferred minimum performance in 43 percent and 40 percent of futures. All alternatives, particularly the Supply Driven (both LB Priority and LB Pro Rata approaches) and Maximum Operational Flexibility Alternatives, show better performance (greater than 50 percent of futures remain below 1,205.4 feet) if the frequency is relaxed to the 80 percent row.

Figure TA 15-26
Hoover Dam Spillway Crest Avoidance: Robustness.
Percent of futures in which Lake Mead elevation does not exceed 1,205.4 feet in the percent of months specified in each row

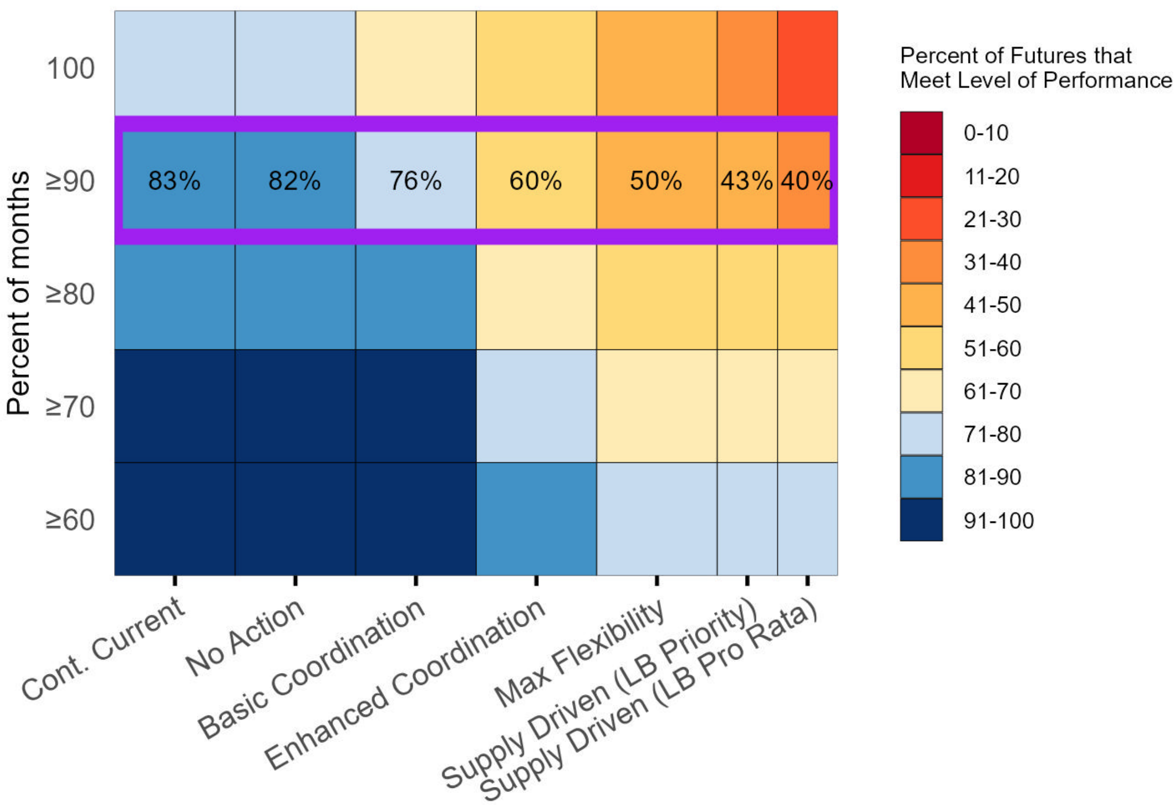


Figure TA 15-27 shows what conditions are likely to cause Lake Mead's monthly elevation to rise above elevation 1,205.4 feet in more than 10 percent of months across a 34-year future. This definition of undesirable performance is based on the highlighted row in **Figure TA 15-25**, which specified that a future was successful if Lake Mead stayed below 1,205.4 feet in at least 90 percent of months. For this vulnerability analysis, the wettest 20-year average of Lees Ferry Annual Flow was used to identify conditions of concern. The reference hydrology panel shows the distribution of wettest 20-year averages in the reference ensemble along with an exceedingly wet 20-year average period (1911–1930) and the most recent observed 20-year average (2005–2024) for comparison. The Supply Driven (both LB Priority and LB Pro Rata approaches) and Maximum Operational Flexibility Alternatives are most vulnerable to similar conditions: 20-year average flows of 13.6 maf and 14.1 maf, respectively. These conditions are near the 25th percentile of the reference hydrology ensemble, so are vulnerable to 75 percent of traces that are wetter in this reference ensemble. The No Action Alternative and the CCS Comparative Baseline are the least vulnerable; under the No Action Alternative and CCS Comparative Baseline, Lake Mead is likely to go above 1,205.4 feet elevation in less than 10 percent of months in 90 percent of traces. From 1911 to 1930, the 20-year average was 17.7 maf, so all alternatives are vulnerable to conditions that have already occurred. From 2005 to 2024, the 20-year average was 13.1 maf. At this drier average annual flow, none of the alternatives are likely to cause undesirable performance.

Figure TA 15-27
Hoover Dam Spillway Crest Avoidance: Vulnerability.
Conditions that could cause Lake Mead elevation above 1,205.4 feet in more than 10% of Months

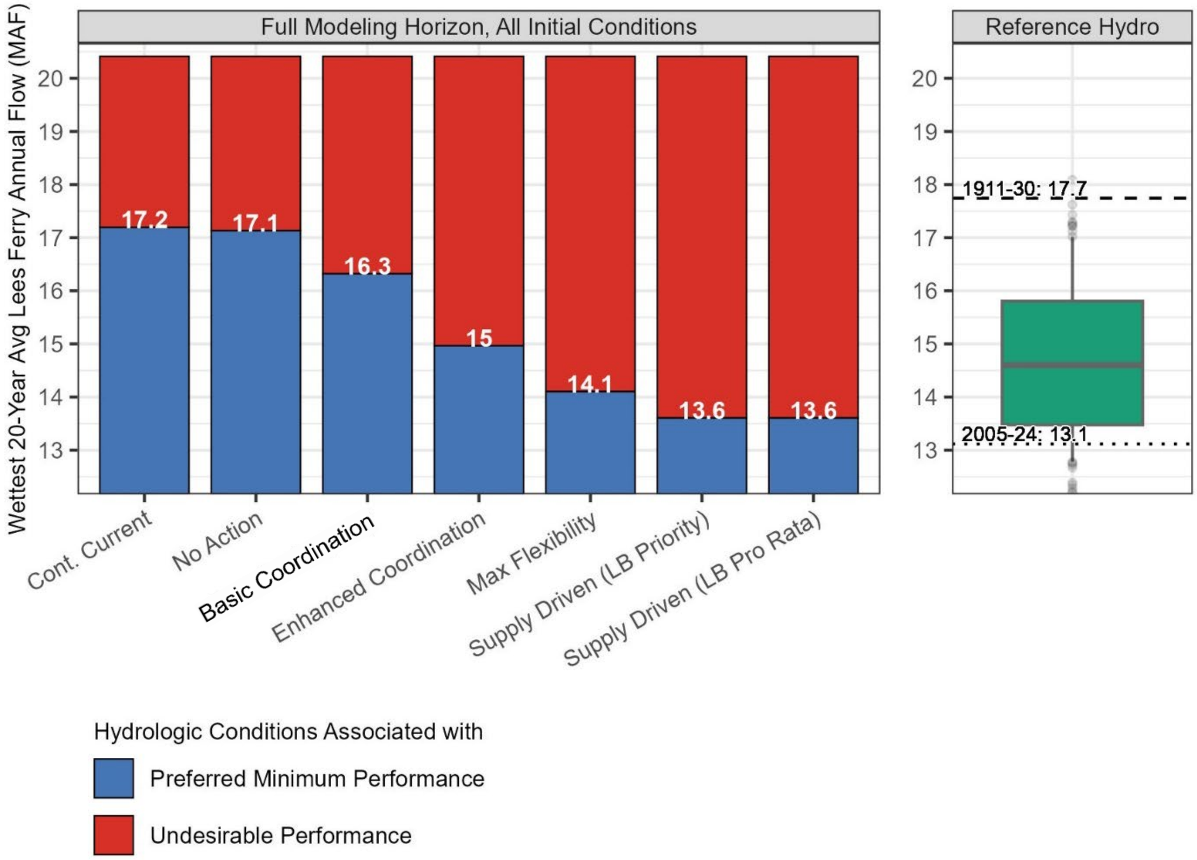
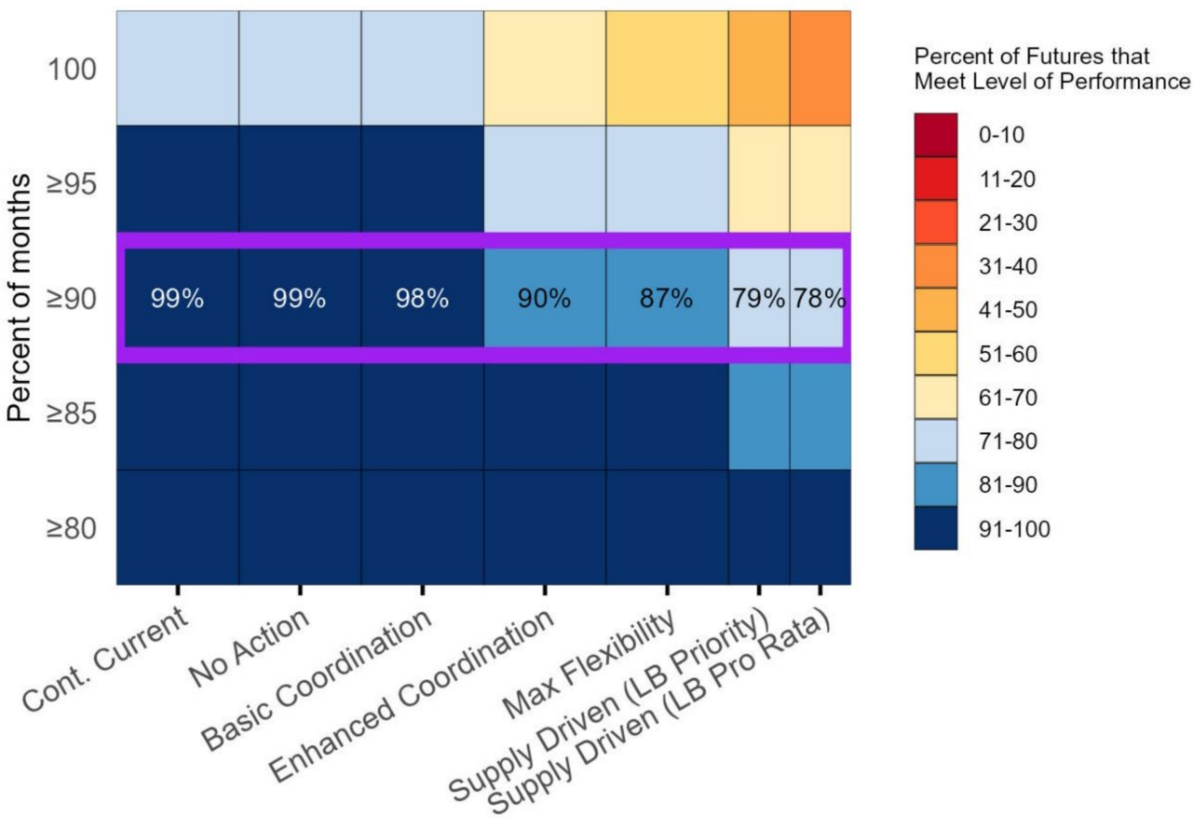


Figure TA 15-28 shows how each alternative performs with respect to keeping Lake Mead's elevation below 1,219.6 feet, which is an important flood buffer elevation. Rows of the heat map show different frequency specifications for keeping Lake Mead below this elevation, with higher rows requiring this level of performance more of the time. The greater than or equal to 90 percent row was chosen because it provides a reasonable amount of flexibility to go above 1,219.6 feet occasionally in very wet hydrology. The CCS Comparative Baseline and the No Action Alternative are successful at keeping Lake Mead below 1,219.6 feet 90 percent of the time in 99 percent of futures. The Basic Coordination Alternative is similarly as robust at 98 percent. The Supply Driven Alternatives (both LB Priority and LB Pro Rata approaches) succeed in 79 percent of futures and is the most vulnerable to rising above 1,219.6 feet in 90 percent of months. All alternatives show increasing robustness to darker shades of blue as the specified frequency is relaxed, succeeding in 100 percent of futures in the lowest row, or greater than or equal to 80 percent of months.

Figure TA 15-28
Avoidance of Lake Mead Maximum Operating Elevation: Robustness.
Percent of futures in which Lake Mead elevation does not exceed 1,219.6 feet in the percent of months specified in each row



For this vulnerability analysis shown in **Figure TA 15-29**, the median 5-year average of Lees Ferry Annual Flow was identified as a skillful streamflow statistic. The reference hydrology shows the range of median 5-year averages included in the reference ensemble as well as the volumes for the historical median 5-year average (2008–2012) and the average volume for 2020–2024 for comparison.

The Supply Driven Alternatives (both LB Priority and LB Pro Rata approaches) are the most vulnerable, being vulnerable to futures with median 5-year averages greater than 15.1 maf and 14.9 maf, respectively. The Supply Driven Alternative is vulnerable to less than 25 percent of traces in the reference hydrology, shown by the 75th percentile being about 14 maf. None of these alternatives are vulnerable to the median 5-year average flow of 12.6 maf. The CCS Comparative Baseline and the No Action, Basic Coordination, and Enhanced Coordination Alternatives demonstrated no vulnerability for the full range of reference hydrology traces, indicating a low likelihood that the Lake Mead elevation would rise above 1,219.6 feet in more than 10 percent of months.

Figure TA 15-29
Avoidance of Lake Mead Maximum Operating Elevation : Vulnerability. Conditions that could cause Lake Mead elevation to exceed 1,219 feet in more than 10% of months

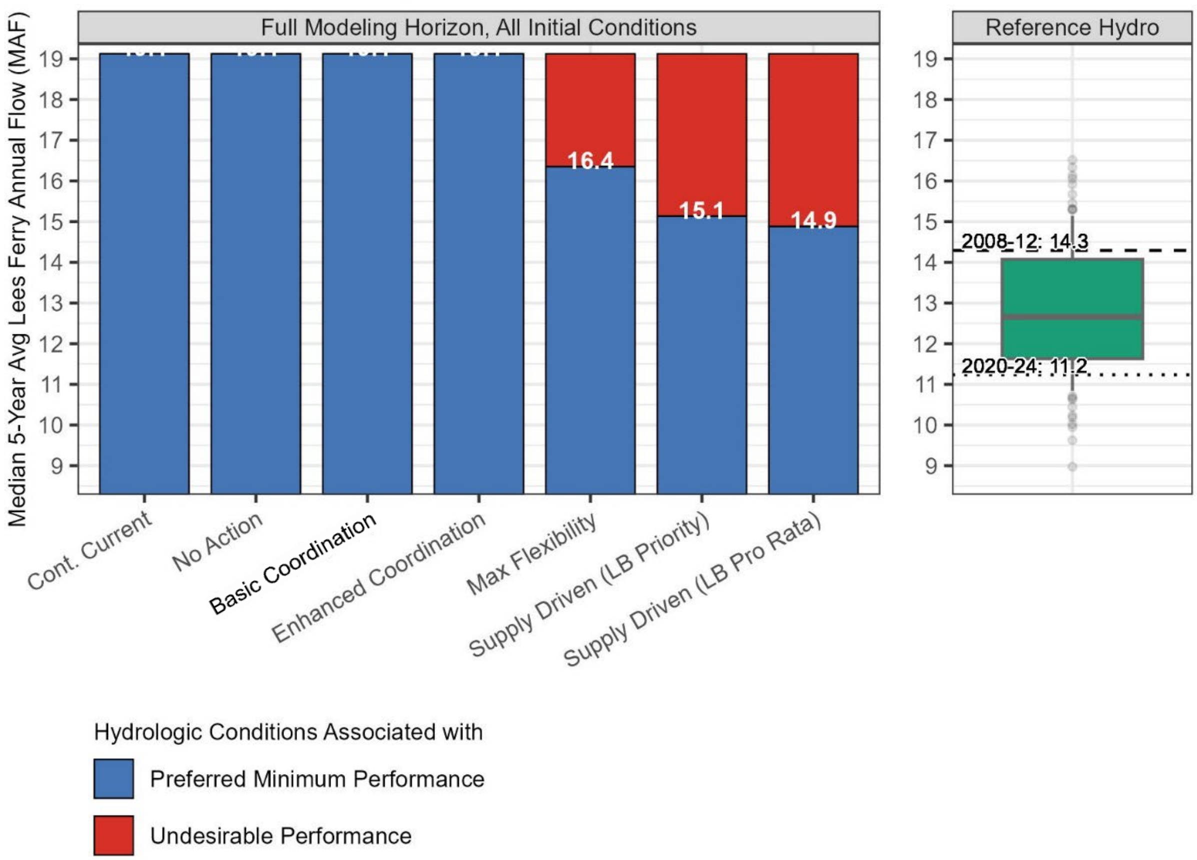


Figure TA 15-30 below depicts the performance of each alternative with regard to keeping Lake Mead below elevation 1,226.9 feet. Rows of the heatmap show different frequency ranges for keeping Lake Mead below this elevation; higher rows require staying below 1,226.9 feet more often. The highlighted row represents the percentage of futures that an alternative is successful at keeping Lake Mead below this elevation feet in 100 percent of the months. At this elevation spillway releases exceed 40,000 cfs which is considered to be a life-threatening emergency downstream.

Over the full modeling period, the Supply Driven Alternative (LB Priority approach [71 percent] and Pro Rata approach [69 percent]) is the least robust Alternative. The Maximum Operational Flexibility Alternative (81 percent) performs similarly to Enhanced Coordination Alternative (83 percent). The No Action and Basic Coordination Alternatives and the CCS Comparative Baseline all are most robust; Lake Mead remains below the critical level of 1,226,9 feet in 100 percent of months for more than 90 percent of futures. If the requirement relaxes to staying below 1,226.9 feet at Lake Mead in 98 percent of months, all alternatives increase robustness to the darkest shades of blue.

Figure TA 15-30
Avoidance of Lake Mead Maximum Spillway Discharge: Robustness.
Percent of futures in which Lake Mead elevation does not exceed 1,226.9 feet in the percent of months specified in each row

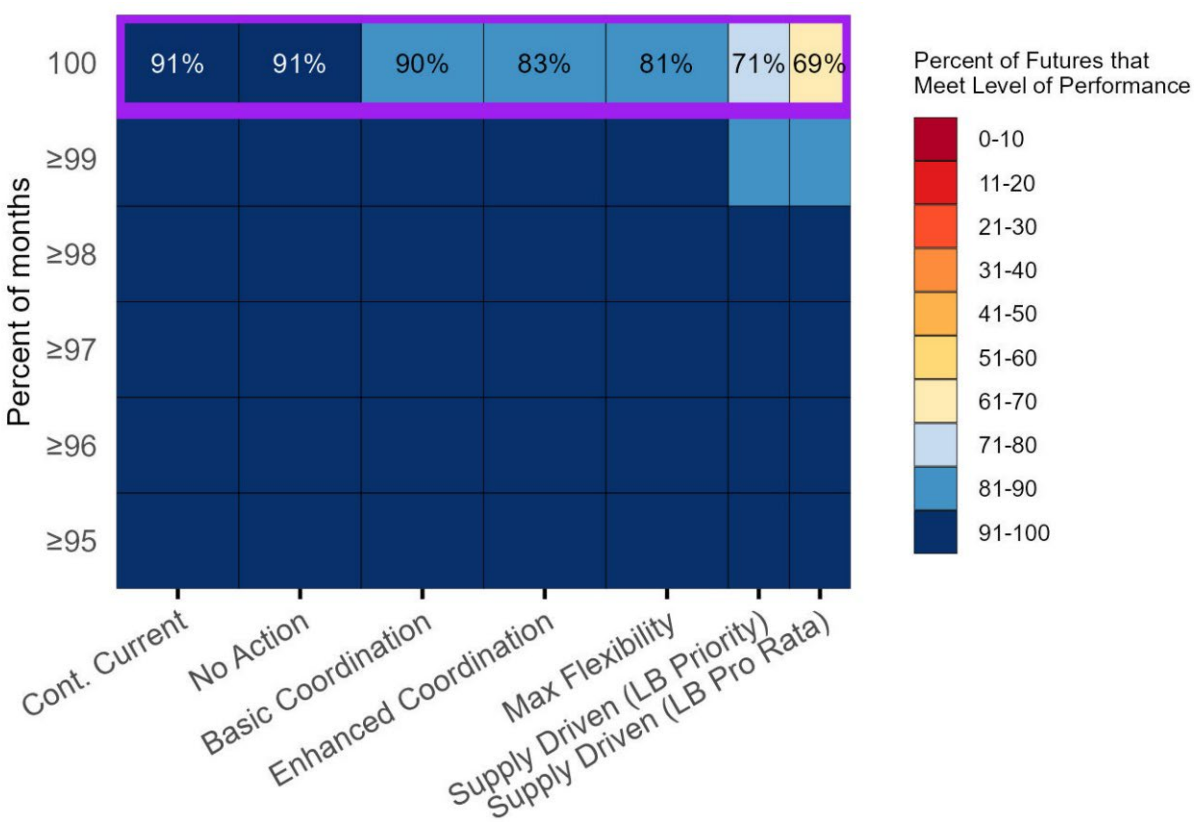
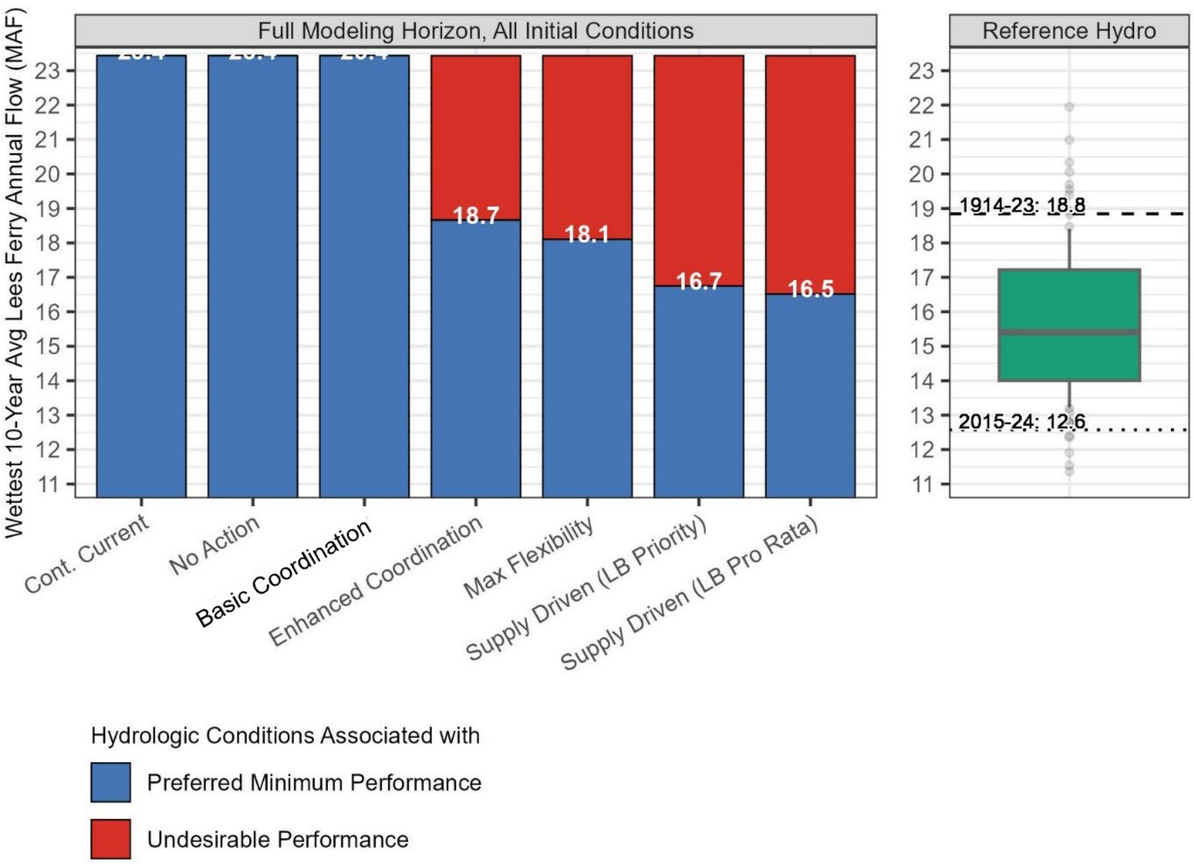


Figure TA 15-31 shows what conditions are likely to cause Lake Mead's monthly elevation to rise above elevation 1,226.9 feet in one or more months across a 34-year future. This definition of undesirable performance is based on the highlighted row in **Figure TA 15-29**, which specified that a future was successful if Lake Mead stayed below 1,226.9 feet in 100 percent of months. For this vulnerability analysis, the wettest 10-year average of Lees Ferry Annual Flow was used to identify conditions of concern.

Figure TA 15-31
Avoidance of Lake Mead Maximum Spillway Discharge: Vulnerability. Conditions that could cause Lake Mead elevation to exceed 1,226.9 feet in one or more months



The reference hydrology panel shows the distribution of wettest 10-year averages in the reference ensemble along with the wettest observed 10-year average (1914–1923) and the most recent observed 10-year average from 2015 to 2024. The Supply Driven Alternatives (both LB Priority and LB Pro Rata approaches) are most vulnerable to 10-year averages of 16.7 maf (LB Priority) and 16.5 maf (LB Pro Rata). The Enhanced Coordination and Maximum Operational Flexibility Alternatives are vulnerable to similar conditions: 10-year average flows of 18.7 maf and 18.1 maf, respectively. These conditions are near the 75th percentile of the reference hydrology ensemble, so only about 25 percent of the traces include periods this wet or wetter. The Basic Coordination and No Action Alternatives and the CCS Comparative Baseline are the least vulnerable; Lake Mead is not likely to go above 1,226.9 feet elevation in one or more months for 100 percent of traces. All alternatives show preferred minimum performance under the median 10-year average annual flow of 15.6 maf.

Summary of Issue 4 Impacts

From a spillway condition and life safety perspective, keeping the reservoir water level below the spillway crest is essential for dam and public safety. Minimizing spillway use preserves the water supply, maintains flood storage capacity, and reduces wear and tear on spillway infrastructure. Maintaining lower reservoir levels allows inflow to be routed through controlled outlets, respond to spring runoff, and protect life safety downstream. The alternatives generally perform similarly under wet hydrologic flow conditions, apart from the Supply Driven Alternatives (both LB Priority and LB Pro Rata approaches) performing best for Lake Powell and the No Action Alternative and the CCS Comparative Baseline performing best for Lake Mead.

High elevation reservoir infrastructure and critical flood storage buffers for Glen Canyon Dam and Lake Powell are better protected under the Supply Driven Alternatives (both LB Priority and LB Pro Rata approaches) during wetter hydrological conditions. Conversely, at Hoover Dam and Lake Mead, the Supply Driven Alternatives (both LB Priority and LB Pro Rata approaches) have the least preferred performance in terms of keeping Lake Mead below critical high elevations. For Lake Mead, the duration spent above these high-water thresholds is minimized under the No Action and Basic Coordination Alternatives and the CCS Comparative Baseline. Under the Basic Coordination Alternative, both Glen Canyon Dam and Hoover Dam achieve preferred minimum performance and high-water thresholds are minimized. The Enhanced Coordination and Maximum Operational Flexibility Alternatives provide the second and third most preferred performance when considering Glen Canyon Dam and Hoover Dam collectively.

TA 15.2.7 Issue 5: How would changes in firm capacity and energy generation impact the electricity rates and the market value of the electricity?

Glen Canyon Dam

Argonne National Laboratories and WAPA analyzed the impacts of the alternatives on the projected electricity rates and the market value of electricity from Glen Canyon Dam in their report *Post-2026 Environmental Impact Statement Rate Analysis for the Colorado River Storage Project*[9] (Yu et al. 2025). The report documents the modeling framework and key methodologies used to identify these findings (Yu et al. 2025). The report, which is incorporated here by reference, found that Enhanced Coordination, Maximum Operational Flexibility, and Supply Driven (both the LB Priority and LB Pro Rata approaches) Alternatives are associated with higher electricity production, lower projected rate trajectories, and reduced long-term market values. The report found that under wet or average hydrologic conditions, the Enhanced Coordination, Maximum Operational Flexibility, and Supply Driven (both the LB Priority and LB Pro Rata approaches) Alternatives lead to similar or slightly better results than those under the other alternatives. The analysis also found that, under dry hydrologic conditions, the Enhanced Coordination, Maximum Operational Flexibility, and Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives result in substantially smaller

[9]Please note that the alternative names reflected in the report do not match

rate increases and less frequent rate adjustments. The report also found that under favorable hydrologic conditions, the alternatives resulted in similar market values. The analysis shows that under conditions of water scarcity, the Enhanced Coordination, Maximum Operational Flexibility, and the Supply Driven (both LB Priority and LB Pro Rata approaches) Alternatives result in substantially higher values of electricity generated at Glen Canyon Dam (Yu et al. 2025).

TA 15.3 References

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