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Long-Term Drought and Glen Canyon Dam: Potential Effects on Water Deliveries and Hydropower

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SUMMARY

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Charles V. Stern
Specialist in Natural Resources Policy

Ashley J. Lawson
Analyst in Energy Policy

Drought and Glen Canyon Dam: Potential Effects on Water Deliveries and Hydropower

The Bureau of Reclamation (Reclamation) owns and operates the Glen Canyon Unit (near Page, AZ) as part of the federal Colorado River Storage Project. The unit includes Glen Canyon Dam, on the Colorado River, and its impounding reservoir, Lake Powell—one of the largest man-made reservoirs in the United States. The reservoir provides for the storage and regulation of water flows in the Colorado River Basin between the Upper Colorado River Basin (Colorado, New Mexico, Utah, and Wyoming) and the Lower Basin (Arizona, California, and Nevada). The dam also allows the Upper Basin to meet its obligations under a 1944 treaty with Mexico and generates low-cost hydropower for Western Area Power Administration (WAPA) customers in the Southwest.

Lake Powell's water storage levels have been declining due to a combination of long-term drought in the basin and demand for water resources that outstrips available supplies in most years. As Lake Powell's storage levels fall, Glen Canyon Dam's ability to generate hydropower also decreases. If the lake were to fall below a certain level (referred to as *minimum power pool*), the dam would be unable to generate hydropower. Decreased reservoir storage at Lake Powell also threatens Reclamation's ability to release flows from the Upper Colorado River Basin to the Lower Basin through the dam and to meet obligations under the 1922 Colorado River Compact and other subsequent agreements. Below a certain level (i.e., *dead pool*), Glen Canyon Dam could *prevent* water from flowing to the Lower Basin.

It is unclear what the legal or practical effects would be if low storage levels in Lake Powell rendered the Upper Basin unable to meet its obligations under the various compacts, laws, and other provisions that govern water allocations (i.e., the *Law of the River*). Reclamation would likely face decisions on whether to ration whatever flows were bypassed to the Lower Basin and Mexico, with delivery priority based on a complex set of factors. Such a scenario also could trigger litigation between the Upper and Lower Basins and/or an international treaty dispute with Mexico.

When federal hydropower is not available (i.e., when generation levels at Glen Canyon Dam are low), WAPA customers experience higher costs. However, these customers have varying levels of dependency on WAPA power, so the relative impact on their costs varies. Low hydropower output at Glen Canyon Dam can affect the wider region, as well. Potential impacts may include higher electricity prices, increased electric reliability risks, and higher greenhouse gas emissions. However, Glen Canyon Dam's relatively small contribution to the regional electricity grid generally limits the magnitude of these effects.

The federal government and states in the Colorado River Basin have engaged in efforts to increase water storage levels in Lake Powell, and precipitation in the winter of 2022-2023 appears likely to increase Lake Powell volumes in the short term. However, Reclamation's projections continue to show a chance of Lake Powell falling to minimum power pool levels in the coming years. As a result, Reclamation is considering structural and operational modifications at Glen Canyon Dam. Basin states and Reclamation also are implementing new and ongoing efforts to improve storage in Lake Powell, and new proposals are under consideration. In addition, some stakeholders have proposed efforts to mitigate the potential effects of Lake Powell's decreasing storage levels (e.g., effects on hydropower customers).

Congress has been involved in approving drought mitigation agreements related to the Colorado River Basin and the Glen Canyon Unit, and additional congressional authorization and/or appropriations would be required for many of the changes under consideration. Issues for Congress may include consideration of which, if any, efforts to support related to drought in the Colorado River Basin in general and Glen Canyon Unit facilities in particular. Congress may consider the costs and benefits of various proposals in the context of long-term drought in the basin, as well as their potential for creating precedents for other drought-prone areas.

Contents

Figures

Contacts

Introduction

The Bureau of Reclamation (Reclamation) owns and operates the Glen Canyon Unit (near Page, AZ) as part of the federal Colorado River Storage Project (CRSP). The unit includes Glen Canyon Dam, on the Colorado River, and its impounding reservoir, Lake Powell—one of the largest man-made reservoirs in the United States. The reservoir provides for the storage and regulation of water flows in the Colorado River Basin between the Upper Colorado River Basin (Colorado, New Mexico, Utah, and Wyoming) and the Lower Basin (Arizona, California, and Nevada). The dam also allows the Upper Basin to meet its obligations under a 1944 treaty with Mexico and generates low-cost hydropower for Western Area Power Administration (WAPA) customers in the Southwest.

Lake Powell's water storage levels have been declining due to a combination of long-term drought in the basin and demand for water resources that outstrips available supplies in most years. As Lake Powell's storage levels drop, Glen Canyon Dam's ability to produce hydropower also decreases. If water storage were to reach a certain level (referred to as *minimum power pool*), the dam would be unable to generate any hydropower. Decreased reservoir storage at Lake Powell also threatens the dam's ability to bypass flows from the Upper Basin to the Lower Basin and to meet Upper Basin obligations under the 1922 Colorado River Compact and other agreements. If Lake Powell storage levels decline past minimum power pool and reach a level referred to as *dead pool*, Glen Canyon Dam could *prevent* water from flowing to the Lower Basin.

The federal government and Colorado River Basin states are implementing new and ongoing efforts to try to increase water storage levels in Lake Powell, and precipitation in the winter of 2022-2023 appears likely to increase Lake Powell storage in the short term. However, projections continue to show a chance of water storage falling to minimum power pool in the coming years. As a result, Reclamation is considering new proposals, including structural and operational modifications at Glen Canyon Dam, some of which would need congressional authorization and appropriations. Some stakeholders also have proposed efforts to mitigate the potential effects of Lake Powell's decreasing storage levels.

This report provides background on management of Colorado River Basin waters, with a focus on Glen Canyon Unit facilities (i.e., Glen Canyon Dam and Power Plant and Lake Powell). It also discusses the potential ramifications of drought and falling water storage levels at these facilities and addresses related issues for Congress. For broader information on federal management of Colorado River and Lower Basin issues, see CRS Report R45546, *Management of the Colorado River: Water Allocations, Drought, and the Federal Role*.

Background on Federal Development of the Colorado River Basin

The Glen Canyon Unit is a significant component of the federal system managing the waters of the Colorado River. This system is collectively governed by the *Law of the River*, a phrase that refers to the multiple compacts, federal laws, court decisions and decrees, contracts, and regulatory guidelines governing Colorado River operations.[1] The seminal Law of the River

[1] For a comprehensive reference to Law of the River documents, see Bureau of Reclamation, Lower Colorado River Basin, "Law of the River," at https://www.usbr.gov/lc/region/pao/lawofrvr.html.

document apportioning the waters of the Colorado River Basin is the Colorado River Compact of 1922. In an effort to resolve basin conflicts and avoid litigation, Congress gave its consent for the states and Reclamation to enter into the Colorado River Compact to apportion Colorado River water supplies.[2] The compact allocated the river's water supplies between the Upper Basin and the Lower Basin, with the dividing line between the two basins located at Lee Ferry, AZ.[3] Signatories to the compact agreed to apportion 7.5 million acre-feet (MAF) annually to both the Upper and Lower Basins for beneficial consumptive use. The Colorado River Compact also required that Upper Basin states "will not cause the flow of the river ... to be depleted below an aggregate of 75,000,000 acre-feet for any period of 10 consecutive years."[4] A subsequent 1944 treaty with Mexico (anticipated in the compact) allocated an additional 1.5 MAF per year of Colorado River flows to Mexico; responsibility for providing this amount is generally understood to be shared equally between the Lower and Upper Basins.[5] As a result, pursuant to the Colorado River Compact and the 1944 treaty, the Upper Basin must bypass (i.e., pass through the dam) an average of at least 8.25 MAF per year to the Lower Basin.

Over time, Congress has authorized Reclamation to construct numerous federal facilities to improve storage and conveyance of Colorado River waters. Most Lower Basin facilities (the largest being Hoover Dam, near the Nevada/Arizona Border) were authorized and constructed decades prior to Upper Basin facilities, which were constructed following congressional enactment of legislation in the 1950s and 1960s (see below section, "Glen Canyon Unit"). Congress did not allow projects authorized for study in the Upper Basin to proceed with federally funded construction until Upper Basin states determined their individual water allocations, which occurred under the Upper Colorado River Basin Compact of 1948 (Upper Basin Compact).[6] Because there was some uncertainty as to the exact amount of water that would remain in the system after meeting Lower Basin obligations, the Upper Basin Compact established state allocations in terms of percentage.[7] **Figure 1** shows Lower and Upper Basin allocations by state following approval of the Upper Basin Compact (i.e., the baseline for allocations under the Law of the River).

[2] Ch. 72, 42 Stat. 171 (1921). In lieu of litigation, interstate compacts historically have been a preferred means of allocating water among competing uses. Pursuant to the U.S. Constitution, Article I, Section 10, clause 3, no such compacts can be entered into without the consent of Congress.

[3] Upper Basin states include Colorado, New Mexico, Utah, Wyoming, and a small portion of Arizona. Lower Basin states include the rest of Arizona, California, and Nevada. *Lee Ferry* (near the Utah Border, at the confluence of the Colorado and Paria Rivers) is the dividing line between the basins in the Compact. *Lees Ferry* (or *Lee's Ferry*), approximately 1 mile upstream from that point, is the location of the U.S. Geological Survey streamgage that has measured flows dating to 1921.

[4] Colorado River Compact, 1922, Article III(d).

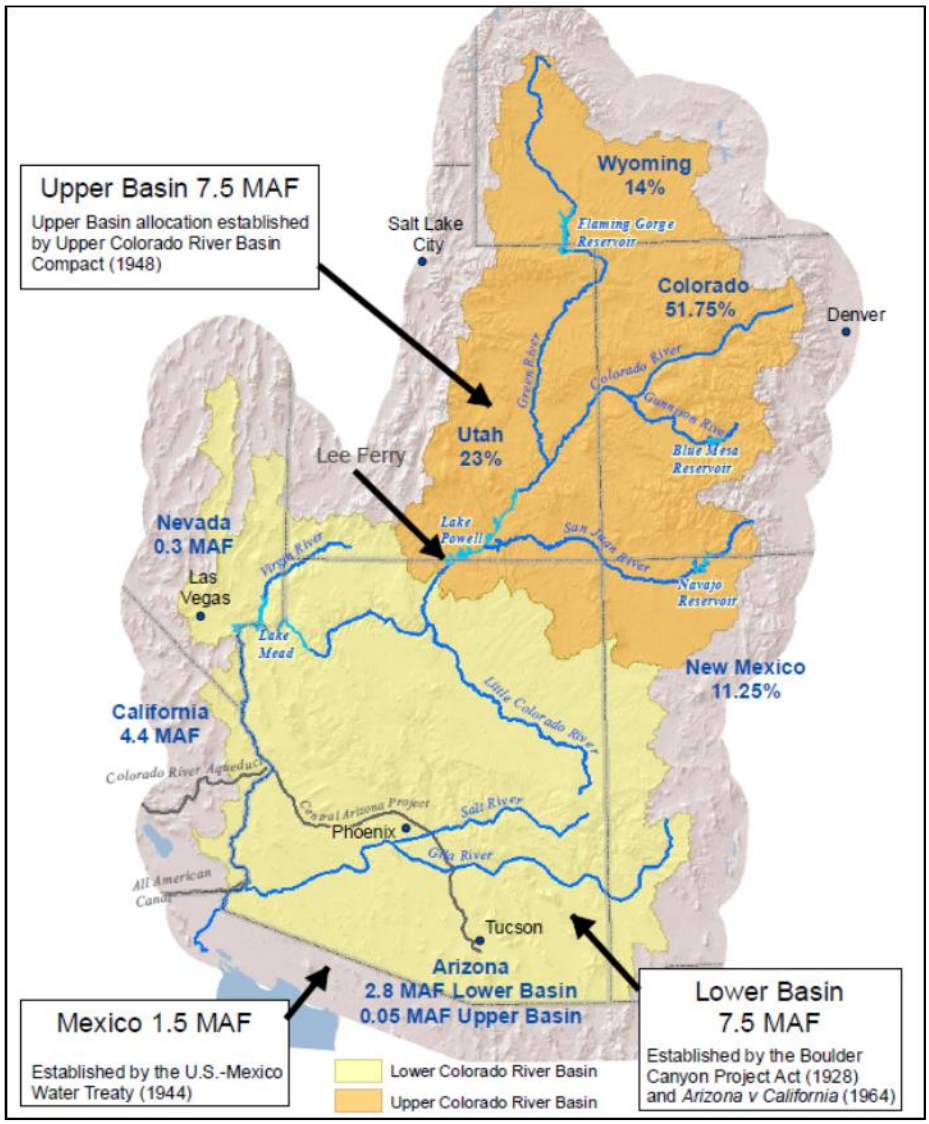
[5] See Treaty Between the United States of America and Mexico Respecting Utilization of Waters of the Colorado and Tijuana Rivers and of the Rio Grande, U.S.-Mex., February 3, 1944, 59 State. 1219. Mexico ratified the treaty on October 16, 1945, and the United States ratified it on November 1, 1945. The treaty became effective on November 8, 1945. Although Article II(c) of the Colorado River Compact anticipated that this water would be made available from unallocated surplus, it provided that any deficiency of water to Mexico must be "equally borne" by the Upper and Lower Basins. The treaty also provided that during periods of extraordinary drought, the amount of water provided to Mexico may be reduced in the same proportion as consumptive uses in the United States are reduced.

[6] Upper Colorado River Basin Compact, 1948.

[7] The exception is 50,000 acre-feet that was allocated to Arizona to account for the state's share of Upper Basin waters.

Figure 1. Colorado River Basin Allocations

(shown as percentage of allocation or million acre-feet [MAF])



Source: Figure by the Congressional Research Service (CRS), using data from the U.S. Geological Survey, ESRI Data & Maps, 2017, Central Arizona Project, and ESRI World Shaded Relief Map.

Notes: Although the Upper and Lower Basins were each allocated 7.5 MAF of water, there was uncertainty about how much water would remain in the Upper Basin after Colorado River Compact obligations to Lower Basin states were fulfilled. Therefore, outside of 50,000 acre-feet provided annually to Arizona, the Upper Basin Compact included apportionments in terms of percentage of the overall Upper Basin allocation.

The remainder of this report focuses on current issues related to long-term drought in the Colorado River Basin and its effects on the Glen Canyon Unit.

Glen Canyon Unit

The Glen Canyon Unit of CRSP was one of four *initial units* authorized by Congress in the Colorado River Storage Project Act of 1956 (CRSPA; P.L. 84-485).[8] The unit includes Glen Canyon Dam and its impounding reservoir, Lake Powell. Glen Canyon Dam is the largest of the CRSP dams in the Upper Basin, and one of the largest dams in the country. Reclamation completed construction on the dam in 1963, and the federal government—through Reclamation—currently operates the dam. Lake Powell, with storage of 26.2 MAF, is the largest-capacity reservoir in the Upper Basin and the second-largest reservoir in the country. Due to the reservoir's large capacity, it took 17 years to fill, reaching its maximum capacity for the first time in June 1980.

Unlike most other *Reclamation projects* constructed by the federal government throughout the West,[9] the Glen Canyon Unit was not meant to be a large-scale irrigation project.[10] Rather, the dam's major purposes were to store water for future use by Lower Basin states and to provide hydroelectric power and the resulting revenues. Some have referred to Glen Canyon Dam as a "cash register" dam, whereby hydropower receipts finance other project construction, including those for smaller "participating" CRSP projects.[11]

Glen Canyon Dam has several means by which water can be passed downstream (**Figure 2**). The dam has eight hydropower penstocks,[12] located on the dam at an elevation of 3,470 feet above sea level (fasl); these penstocks are the primary means by which dam operators release required flows from the Upper Basin to the Lower Basin.[13] Each of the penstocks is approximately 15 feet in diameter, with a total discharge capacity of 31,500 cubic feet per second (cfs).[14] Reclamation estimates that the depth for minimum power pool at Glen Canyon Dam (i.e., the depth below which hydropower cannot be generated) is 20 feet above the penstocks, or 3,490 fasl.[15]

Below the penstocks, four 96-inch diameter pipes at an elevation of 3,374 fasl allow an additional way for water to pass at lower reservoir levels.[16] These pipes—commonly referred to as the *River Outlet Works* (or *River Outlets*)—have a capacity of approximately 15,000 cfs (i.e., considerably less than the penstocks);[17] they have been opened to let additional water to flow through only a

[8] The other four initial units are the Flaming Gorge Unit on the Green River in Wyoming and Utah; the Navajo Unit on the San Juan River in New Mexico and Colorado; and the Curecanti Unit (later renamed the Apsinall Unit), consisting of three dams on the Gunnison River in Colorado. Congress also authorized 11 *participating units* in the Colorado River Storage Project Act of 1956 (CRSPA; P.L. 84-485) and subsequently added several other projects as participating projects.

[9] "Reclamation projects" typically refers to projects constructed by the Bureau of Reclamation, whose goal generally is to "reclaim" arid western lands for irrigated agriculture and other types of development.

[10] Jedediah Rogers, *Glen Canyon Unit*, Bureau of Reclamation, 2006, p. 11.

[11] Ibid., p. 12.

[12] A penstock is an intake structure that controls water flows.

[13] Bureau of Reclamation, *Glen Canyon Dam and Powerplant, Technical Record of Design and Construction*, December 1970. Hereinafter, Reclamation, *Glen Canyon Dam, Record of Design and Construction.*

[14] Ibid.

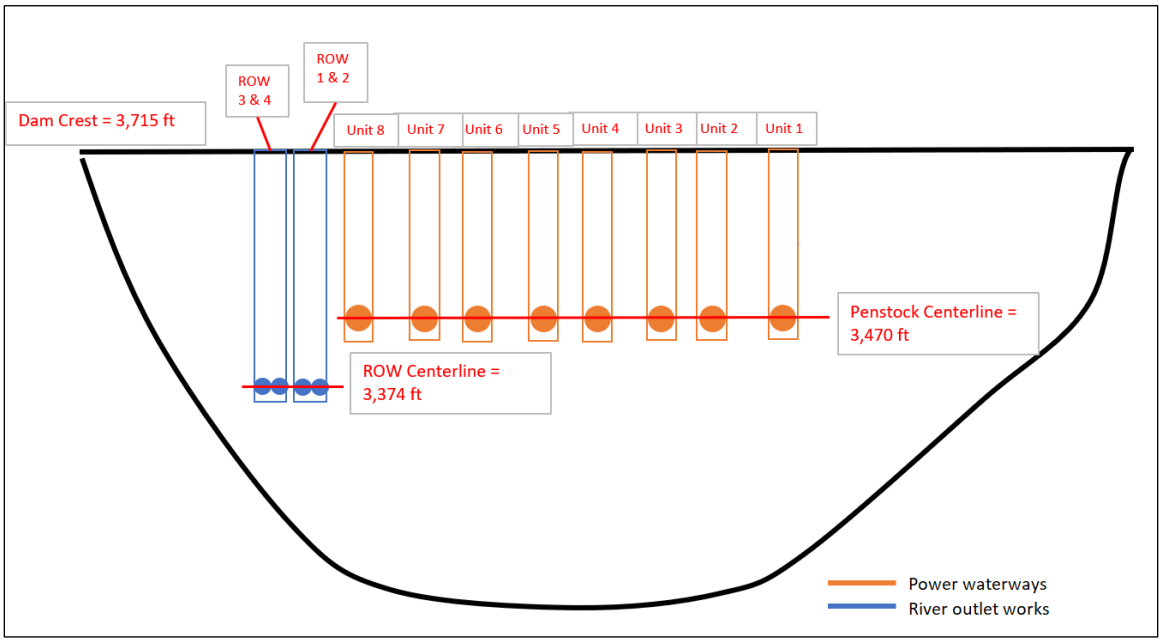
[15] Bureau of Reclamation, "Drought Response Operations Agreement," at https://www.usbr.gov/dcp/droa.html. Below this depth, there is a risk of damage to the dam's infrastructure.

[16] These pipes are connected to the reservoir by two intakes. Ibid.

[17] Ibid.

few times since the dam's completion.[18] At the top of the dam, water also can be released for flood control through two spillways on either side of the top of the dam (located at 3,648 fasl).

Figure 2. Glen Canyon Dam Outlet Elevations: Upstream View



Source: Bureau of Reclamation, "Glen Canyon Dam, Low-Head Hydropower Modifications," presentation, February 7, 2023. Modified by CRS.

Notes: Elevations are in terms of feet (ft) above sea level. ROW= River Outlet Works.

Glen Canyon Dam serves multiple functions in the Colorado River Basin. Its two most prominent uses are impounding Colorado River water to regulate flows from the Upper Basin to the Lower Basin (e.g., meeting the Colorado River Compact's non-depletion requirement and providing for certain environmental flows in Grand Canyon National Park) and generating hydropower for power customers.[19] The sections below discuss each of these uses in more detail.

Regulation of Colorado River Flows

As noted above, the Colorado River Compact required, among other things, that Upper Basin states deplete no more than 75 MAF of Colorado River flows over any 10-year period (i.e., an average of 7.5 MAF per year). The Upper Basin's half of the 1.5 MAF in deliveries pursuant to the 1944 treaty with Mexico (i.e., 750,000 AF per year) is in addition to that amount, resulting in an average flow requirement of 8.25 MAF per year. Glen Canyon Dam helps Upper Basin users regularly meet their obligations to the Lower Basin and Mexico by providing for the flexible regulation of Upper Basin flows. In particular, the dam stores surplus flows to meet these requirements in low flow years. This in turn allows Upper Basin users to divert waters in low flow years that otherwise would be required to meet their Lower Basin delivery obligations.

Reclamation typically operates Glen Canyon Dam so as to pass flows from the Upper Basin to the Lower Basin and Mexico through the hydropower penstocks. If the hydropower penstocks are no

[18] The River Outlet Works were used when the dam was first filled, during short-term high-flow experiments, and for emergency releases during floods in the early 1980s. They have never been used over extended periods.

[19] The dam is also important for other uses, including as a drinking water sources for surrounding areas.

longer available for bypassing flows, the River Outlets are capable of bypassing flows sufficient to meet Law of the River requirements at reservoir elevations between the outlets and the penstocks. However, declining Lake Powell storage levels lead to less pressure (*head*), which in turn means that as storage levels continue to fall, less water can be released through the River Outlets over the same time period. Reclamation's original design documents estimated that below an elevation of 3,440 fasl, the flows bypassed by the River Outlets would fall below 8.3 MAF per year.[20] At an elevation of 3,370 fasl, Lake Powell would reach *dead pool*, or the point below which the outlets would no longer be able to bypass flows. At dead pool, approximately 1.7 MAF of water would be inaccessible using current facilities and the dam could, under some circumstances, become a hindrance in meeting Law of the River flow obligations.[21]

Hydropower Generation and Marketing

Reclamation began installing hydropower facilities at Glen Canyon Dam in 1964, after the dam was constructed. By 1966, Reclamation had installed all eight generators at the dam—one for each penstock—and hydropower facilities were available at full capacity. Glen Canyon Power Plant has a total installed nameplate capacity of 1,320 megawatts (MW).[22] The facility is part of the larger Western power grid, the Western Electricity Coordinating Council (WECC). While Glen Canyon Power Plant contributes most of the hydropower for CRSP (discussed below), the facility is a relatively small component of WECC. In 2021, total installed nameplate capacity in WECC was 286,000 MW.[23]

While Glen Canyon's contribution to total annual electricity generation is relatively small, the facility (like hydropower in general) has certain characteristics that help to maintain reliability and resilience across the region. In particular, hydropower can provide *peaking power* (i.e., power that can be brought online to meet higher demand at short notice) and other grid services such as *ramping* (i.e., quickly changing generation up or down in response to changing output from wind or solar energy). Along with Hoover Dam, Glen Canyon Dam can provide *black start* capability (i.e., the ability to set and maintain key grid operating characteristics [e.g., frequency] in the event of a widespread power outage), which is necessary for regional grid reliability and resilience. Glen Canyon Power Plant has a contract with the Palo Verde Generating Station, the country's largest nuclear power plant, to provide black start and emergency shutdown power.[24]

Glen Canyon Dam's ability to maximize its generation capacity depends on numerous factors, including optimized hydropower operations (e.g., the ability to pass maximum flows through turbines). Lower water storage levels at Lake Powell have decreased Glen Canyon Dam's generating capacity by decreasing head at the dam. In addition, operating restrictions associated with the 1992 Grand Canyon Protection Act (P.L. 102-575) have limited opportunities for

[20] Reclamation, *Glen Canyon Dam, Record of Design and Construction*, p. 164.

[21] Ibid.

[22] *Nameplate capacity* refers to the maximum amount of power a generator is expected to produce under specified conditions set by the manufacturer. Under real-world operating conditions, maximum power output is typically different from nameplate capacity.

[23] Western Electric Coordinating Council, "State of the Interconnection," at https://www.wecc.org/epubs/StateOfTheInterconnection/Pages/capacity.aspx.

[24] Upper Colorado River Commission, *2022 Drought Response Operations Plan*, at http://www.ucrcommission.com/wp-content/uploads/2022/04/2022-DROA-Plan-Executed-Transmittal-April-21-2022.pdf.

maximum flow and peaking power.[25] As a result, Glen Canyon Dam's capacity as of early 2023 was estimated at approximately 59% of its nameplate capacity, or 778 MW.[26]

Congress requires that power produced at federal water resources facilities be offered for sale at cost, without any markup or profit, to *preference customers*.[27] Preference customers include publicly owned utilities and rural electric cooperatives. These utilities typically acquire electricity from a number of sources in addition to federal hydropower and sell electricity to retail customers at cost. Depending on where federal hydropower is generated, it is sold by one of the four federally owned power marketing administrations (PMAs).[28]

Hydropower generated at Glen Canyon Dam is combined with power generated by the 10 other CRSP power plants at Upper Basin units and marketed by WAPA. WAPA, in turn, combines CRSP hydropower with power generated at the Collbran, Seedskadee, Dolores, and Rio Grande projects into its Salt Lake City Area/Integrated Projects (SLCAIP). Glen Canyon Dam's generation capacity accounts for 73% of all SLCAIP generation capacity, and in the past, Glen Canyon hydropower generation has represented approximately 65%-75% of SLCAIP generation and 75%-85% of CRSP's contribution to WAPA SLCAIP hydropower.[29] This power is sold to 130 wholesale customers, which serve approximately 5 million people and 53 Native American tribes in Arizona, Nebraska, New Mexico, Nevada, Colorado, Utah, and Wyoming.[30] These wholesale customers have long-term (20-year) contracts with the United States and include publicly owned electric utilities, Native American tribes, federal agencies, and rural electric cooperatives. In addition to these preference customers, WAPA also provides SLCAIP power to meet minimum Reclamation project power needs (i.e., pumping power) in the Upper Basin. This low-cost power, generally referred to as *project use power*, is important for many agricultural irrigation districts who rely on low-cost support for reclamation project operations.[31]

[25] P.L. 102-575, Title XVIII, §1802(a). Most recently, these operational protections were formalized in the 2016 Long-Term Environmental and Management Program. See Bureau of Reclamation, *2016 Long-Term Experimental and Management Program Environmental Impact Statement*, October 2016. This legislation requires Reclamation to operate Glen Canyon Dam in such a manner as to protect, mitigate adverse impacts to, and improve the values for which Grand Canyon National Park and Glen Canyon National Recreation Area were established. Among other things, it resulted in experimental flow regimes by the Glen Canyon Dam Adaptive Management Program.

[26] CRS calculations based on data in personal correspondence with Bureau of Reclamation, January 19, 2023.

[27] The Flood Control Act of 1944 (16 U.S.C. §825s) directs that the power marketing administrations (PMAs) sell their power, with preference given to publicly or cooperatively owned utilities, "at the lowest possible rates to consumers consistent with sound business practices." The 1937 Bonneville Project Act (16 U.S.C. §832c), the Reclamation Project Act of 1939 (43 U.S.C. §485h(c)), and the Flood Control Act are statutes that stipulate preference to public bodies for the sale of federal power.

[28] The four PMAs, created between 1937 and 1977, are the Southwestern Power Administration, Southeastern Power Administration, Western Area Power Administration (WAPA), and Bonneville Power Administration. The PMAs were transferred from the Department of the Interior to the Department of Energy through the Department of Energy Organization Act of 1977 (P.L. 95-91).

[29] Unlike hydropower capacity, actual generation at individual facilities (and the resulting contribution to WAPA's broader generation totals) is highly variable. For FY2020 and FY2021 (the most recent years for which data were available), Glen Canyon Dam accounted for 72% and 78% of generation, respectively. See WAPA, *2021 Annual Report*, Statistical Appendix (hereinafter, WAPA 2021 Statistical Appendix), p. 10, and WAPA, "Colorado River Storage Project Update," presentation for Glen Canyon Dam Adaptive Management Working Group, August 25, 2016.

[30] WAPA, "Statement on Reclamation's August Projections for Colorado River," press release, August 16, 2021.

[31] Reclamation defines *project use power* as "the electrical capacity, energy, and associated ancillary service components required to provide the minimum electrical service using the most economical methods ('minimum electric service') needed to operate and/or maintain Reclamation Project facilities in conformance with project authorization." See Bureau of Reclamation, "Project Use Power," in *Reclamation Manual FAC 04-06*, December 6, 2018.

SLCAIP sells electricity at roughly $12 per megawatt-hour (MWh) to its customers.[32] Market prices for alternative suppliers are not readily available because WECC does not operate a wholesale electricity market. Instead, market transactions tend to occur between individual electricity suppliers and purchasers with limited publicly available information. One exception is the Palo Verde trading hub, which has relatively transparent prices available from various sources. Palo Verde prices averaged $43/MWh in 2021 and $78/Mwh in 2022.[33]

The ability of Glen Canyon Dam and its power plant to produce hydropower heavily influences the availability of low-cost WAPA hydropower for its customers. Although individual customer reliance on CRSP power varies widely, Reclamation has estimated that CRSP power accounts for about 20% of the total electrical needs for rural customers in Colorado and New Mexico.[34]

Revenues from the sale of hydropower generated by Glen Canyon Dam and other CRSP facilities are deposited into the Upper Colorado River Basin Fund, which was established in Section 5 of CRSPA.[35] The basin fund pays for the operation and maintenance of CRSP facilities. The fund also repays the portion of the federal capital investment in CRSP facilities that is allocated to hydropower, and funds the construction costs of participating projects that are above irrigators' ability to pay, and some fish and wildlife activities.[36] In FY2021, WAPA reported $204 million in total revenues from the sale of SLCAIP hydropower.[37] For that same year (FY2021), Reclamation estimated $102 million for its authorized costs to be drawn from the Colorado River Basin Fund.[38]

In addition to affecting power generation, Lake Powell's storage levels have implications for power revenues and the balance of the Upper Colorado River Basin Fund itself. Traditionally, when less power was available from the SLCAIP than customers had contracted for, WAPA—pursuant to its contracts with its wholesale customers—was obligated to purchase replacement power, which is often more expensive than hydropower.[39] However, due in part to recent concerns about basin fund values associated with these purchases, WAPA made an emergency rate change in late 2021.[40] In this change, WAPA customers agreed to waive WAPA's obligation

[32] Under the current firm power rate, the energy charge is 12.36 mills per kilowatt-hour, equivalent to $12.36 per megawatt-hour (MWh). Department of Energy (DOE), Power Marketing Administration, "Notice of Rate Order Concerning Fixed Firm Power Rates," 86 *Federal Register* 61211, November 5, 2021. SLCAIP customers pay a separate rate for capacity, transmission, and ancillary services, so the total rate customers pay is greater than $12/MWh. However, the energy charge is most analogous to wholesale power rates in the WECC market. This report uses just the energy rate to allow comparison between rates available to WAPA customers.

[33] Annual average of daily average prices for off-peak power at Palo Verde. Data provided by Bloomberg. The 2022 average reflects several periods of abnormally high prices. For example, daily average prices at Palo Verde reached $350/MWh during the late August-early September heat wave affecting California and other areas of the West. Daily average prices at Palo Verde reached $414/MWh in December 2022, driven in part by unusually high natural gas prices in the west. The December price levels drew scrutiny from regulators. See, for example, Kassia Micek, "California Regulators Investigate Natural Gas Price Spikes, Power Market Impacts," S&P Global Commodity Insights, March 16, 2023.

[34] Bureau of Reclamation, Upper Colorado Basin, *Reclamation Power Marketing*, at https://www.usbr.gov/uc/power/.

[35] 43 U.S.C. §620d.

[36] Prior to FY2019, the Upper Colorado River Basin Fund also funded costs associated with the Glen Canyon Dam Adaptive Management Program, as well as cost sharing for the Upper Colorado and San Juan Endangered Fish Recovery Implementation Programs. Since FY2019, these costs have been funded through discretionary appropriations.

[37] WAPA 2021 Statistical Appendix, p. 11. Although exact figures for Glen Canyon Dam's contribution to this total are not available, it is likely similar to the dam's proportion of total CRSP hydropower generation.

[38] Bureau of Reclamation, *Fiscal Year 2021 Budget Justifications,* p. 544.

[39] WAPA, "Statement on Reclamation's August Projections for Colorado River," press release, August 16, 2021.

[40] DOE, Power Marketing Administration, "Notice of Rate Order Concerning Fixed Firm Power Rates," 86 *Federal*

to purchase replacement power. Instead, the rates are to cover costs associated with expected generation levels. Customers can elect to receive replacement power from WAPA, at market rates. Alternatively, customers can procure replacement power or otherwise meet their retail customers' needs in other ways. WAPA previously estimated this change would lead to a rate increase of 11%, compared with an increase of 50% if WAPA had continued supplying all replacement power for its customers.[41]

Ongoing Efforts to Mitigate Long-Term Drought Effects

Storage levels in Lake Powell have been declining since the beginning of the basin's long-term drought in the early 2000s, and several agreements have attempted to alleviate this trend. Reclamation and Colorado River Basin states previously agreed to efforts to "equalize" Lake Powell and Lake Mead storage in a 2007 agreement, the Colorado River Interim Guidelines for Lower Basin Shortages and the Coordinated Operations for Lake Powell and Lake Mead (2007 Interim Guidelines).[42] This agreement provided for, among other things, four operational tiers dictating Lake Powell releases based on various lake elevations (**Figure 3**).

Register 61211, November 5, 2021.

[41] Ibid.

[42] Bureau of Reclamation, *Record of Decision: Colorado River Interim Guidelines for Lower Basin Shortages and the Coordinated Operations for Lake Powell and Lake Mead*, Final Environmental Impact Statement, November 2007.

Figure 3. Lake Powell Operational Tiers in 2007 Interim Guidelines

Lake Powell Operational Tiers (subject to April adjustments or mid-year review modifications)		
Lake Powell Elevation (feet)	**Lake Powell Operational Tier**	**Lake Powell Active Storage** (maf)
3,700		**24.32**
	Equalization Tier equalize, avoid spills or release 8.23 maf	
3,636 – 3,666		**15.54 – 19.29**
	Upper Elevation Balancing Tier release 8.23 maf; if Lake Mead < 1,075 feet, balance contents with a min/max release of 7.0 and 9.0 maf	(2008 – 2026)
3,575		**9.52**
	Mid-Elevation Release Tier release 7.48 maf; if Lake Mead < 1,025 feet, release 8.23 maf	
3,525		**5.93**
	Lower Elevation Balancing Tier balance contents with a min/max release of 7.0 and 9.5 maf	
3,370		**0**

Source: Bureau of Reclamation, *Record of Decision: Colorado River Interim Guidelines for Lower Basin Shortages and the Coordinated Operations for Lake Powell and Lake Mead*, Final Environmental Impact Statement, November 2007, modified by CRS.

Notes: maf = million acre-feet.

Based on widespread consensus that the 2007 agreements alone were insufficient to improve the basin's long-term water supply outlook amid ongoing drought, Reclamation and Colorado River Basin states pursued additional agreements to shore up Lake Mead and Lake Powell storage levels. These negotiations resulted in the 2019 drought contingency plans (DCPs) for the Upper and Lower Colorado River Basins, authorized in P.L. 116-14. Pursuant to the Upper Basin DCP, Reclamation has targeted operational changes under a Drought Response Operations Agreement (DROA) for the Upper Basin, with a goal of "protecting" a Lake Powell water storage elevation of 3,525 fasl (i.e., 35 feet above minimum power pool).[43] Under DROA, the two main mechanisms for protecting this elevation at Lake Powell are (1) reducing releases from Glen Canyon Dam to the Lower Basin and (2) operating initial unit reservoirs on the mainstem of the Colorado River (e.g., Navajo Reservoir, Blue Mesa Reservoir, and Flaming Gorge Reservoir, see **Figure 1**) to protect Lake Powell elevations, potentially through storage drawdown.[44]

[43] Bureau of Reclamation, "Drought Response Operations Agreement," at https://www.usbr.gov/dcp/droa.html.

[44] Operational changes may occur through the Drought Response Operations Agreement's (DROA's) emergency provisions, which allow the Secretary of the Interior to make supplemental water deliveries at his or her discretion (after consultation with basin states). Operational changes also may occur through a planning process establishing formal triggers for Upper Basin water deliveries to Lake Powell, based on agreed-upon hydrological targets, including releases from other initial units to Lake Powell, as well as withholding some Lower Basin releases until later in the

Reclamation used DROA authorities to increase water stored in Lake Powell in 2021 and 2022. In 2021, Reclamation transferred 180,000 AF to Lake Powell from multiple initial unit reservoirs, including Flaming Gorge Reservoir (125,000 AF), Blue Mesa Reservoir (36,000 AF), and Navajo Reservoir (20,000 AF). In 2022, Reclamation reduced Lake Powell releases from 7.48 MAF under the 2007 Interim Guidelines to 7.00 MAF, resulting in an additional 0.48 MAF in Lake Powell storage. That same year, Reclamation also transferred approximately 0.50 MAF from Flaming Gorge Reservoir (on the Utah/Colorado border) to Lake Powell.[45]

Water Year 2023 Status

Lake Powell storage levels fell in 2021 and 2022, despite the most recent changes under DROA. Lake Powell's March 11, 2023, elevation of 3,520 fasl was the lake's lowest level on record, more than 178 feet below its full storage capacity.[46] This level was 31 feet above the minimum power pool elevation of 3,490 fasl, and below Reclamation's target protection volume of 3,525 fasl. Above-average snowpack in 2023 is expected to increase Lake Powell storage in the short term, but the ongoing risk of decreased power generation and for storage levels falling to minimum power pool remains (**Figure 4**).[47]

year.

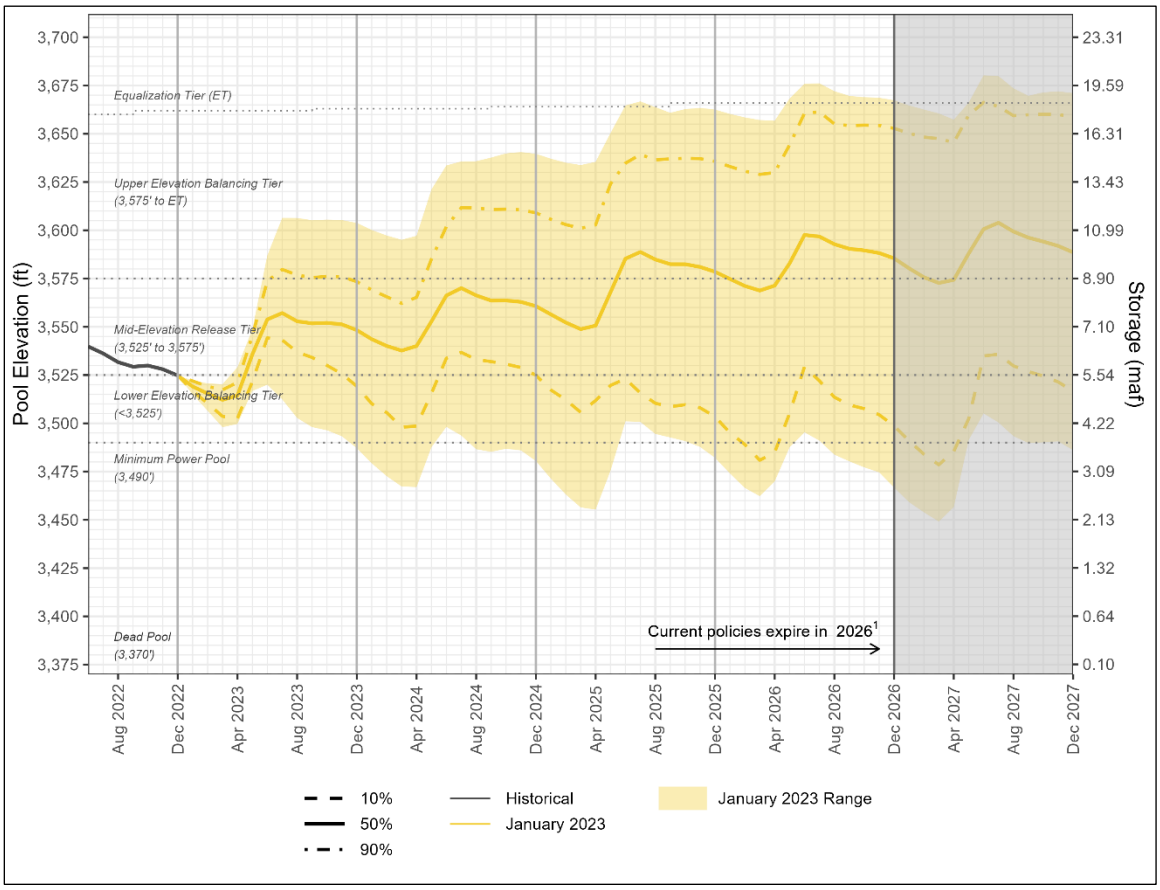
[45] See Bureau of Reclamation, "Previous DROA-Related Actions," at https://www.usbr.gov/dcp/droa.html.

[46] Lake Powell Water Database, March 22, 2023, at https://lakepowell.water-data.com/index2.php?as_of=2023-03-22.

[47] As of January 2023, Reclamation calculated a 10% chance of Lake Powell reaching minimum power pool by the beginning of the 2024 water year (October 2023). This projection was down from a 30% chance of the reservoir reaching minimum power pool calculated in August 2022. See Bureau of Reclamation, "5-Year Probabilistic Projects," January 30, 2023, at https://www.usbr.gov/lc/region/g4000/riverops/crss-5year-projections.html.

Figure 4. Projected Lake Powell End-of-Month Elevations

(projections from January 2023)



Source: Bureau of Reclamation, "5-Year Probabilistic Projections," January 2023, at https://www.usbr.gov/lc/region/g4000/riverops/crss-5year-projections.html.

Notes: ft = feet; maf = million acre-feet.

Decreased storage levels at Lake Powell, coupled with other factors (e.g., flow limitations under the Grand Canyon Protection Act), have impacted hydropower availability and generation at Glen Canyon Dam. Reclamation has reported that every additional 1 foot of decline at Lake Powell equates to a loss of 3 MW of generating capacity.[48] During the 10 years prior to the beginning of the current drought in 2000, the dam's power plant reportedly generated an average of 4,600 GWh annually; from 2000 to 2020, this total declined by 17% to an average of 3,800 GWh.[49] In recent years it has declined further, to 3,351 GWh in 2021 and 2,590 GWh in 2022.[50]

[48] Personal correspondence with Bureau of Reclamation, January 19, 2023.

[49] Statement of Bureau of Reclamation Commissioner Camille Calimlim Touton, in U.S. Congress, Senate Committee on Energy and Natural Resources, Subcommittee on Water and Power, 117th Cong., 2nd sess., May 25, 2022.

[50] U.S. Bureau of Reclamation, *Plant Data, Monthly and Annual Performance Data for Active USBR Facilities*, at https://www.usbr.gov/power/data/Plant_Data_12_2022.xlsx.

Potential Effects of Declining Lake Powell Storage Levels

Declining storage levels at Lake Powell may affect the regulation of Colorado River flows and Glen Canyon Dam hydropower generation. The sections below discuss each of these areas of potential impact.

Colorado River Regulation

If Lake Powell storage fell below minimum power pool, some have estimated the River Outlets operating at their maximum capacity (15,000 cfs) would be able to bypass as much as 10.9 MAF per year in flows (i.e., more than enough to meet Law of the River requirements under most circumstances). However, as with the hydropower penstocks, the maximum discharge of the River Outlets declines with decreasing head. As a result, at a certain storage level, discharge from the dam would no longer be in accordance with the Law of the River. One study estimated that at a Lake Powell elevation of 3,430 feet, the River Outlets would have capacity to discharge 10,200 cfs, or 7.41 MAF/year (i.e., considerably less than the Law of the River's requirement of 8.23 MAF/year).[51] If storage fell below the River Outlets elevation of 3,370 fasl, approximately 1.89 MAF would be left in the reservoir as *dead storage* (i.e., dead pool).[52]

It is unclear what the legal and practical effects would be or what actions would be taken if low storage in Lake Powell rendered the Upper Basin unable to meet its Law of the River requirements. Reclamation would likely face decisions on whether to ration whatever flows were bypassed to the Lower Basin and Mexico, with delivery priority determined based on a complex set of factors. At the same time, some might worry that a *compact call* (i.e., a call on Upper Basin waters by Lower Basin users) could lead to protracted legal action, potentially resulting in reduced water availability for Upper Basin users. In addition to issues associated with Lower Basin deliveries to contractors, some Lower Basin environmental programs, in particular the Glen Canyon Dam Adaptive Management Program,[53] could be affected if high flow releases were not possible due to declining Lake Powell water levels. Such a scenario could jeopardize compliance with statutory mandates in the Grand Canyon Protection Act, which require Glen Canyon Dam to be operated to protect Grand Canyon National Park.

Hydropower

Federal hydropower is typically among the lowest cost options for power. One reason for this is that hydropower has low marginal costs, especially compared to most thermal generation (e.g., natural gas), which must pay for the fuel used. Another reason is that WAPA sells hydropower at its cost-of-service (i.e., without making a profit). When federal hydropower is not available (i.e., when generation levels at Glen Canyon Dam are low), WAPA customers experience higher costs.

Different WAPA customers have different levels of dependency on WAPA power, so the relative impact on their costs varies. For example, Tri-State Generation and Transmission Association

[51] John C. Schmidt, *Fill Mead First: A Technical Assessment,* Department of Watershed Sciences, Utah State University, October 11, 2016, p. 10.

[52] Ibid.

[53] See footnote 25.

(Tri-State) is WAPA's largest customer, accounting for 23% of WAPA's sales in 2021.[54] Tri-State procures electricity from a number of sources, and WAPA power makes up about 8% of Tri-State's total generation supply.[55] In comparison, the Navajo Tribal Utility Authority (NTUA) buys about 7% of WAPA's supply, but this volume represents about 42% of NTUA's total electricity supply.[56] Utilities with a higher share of their supply from WAPA, such as NTUA, may be more strongly affected by lower hydropower generation than utilities like Tri-State that have a lower share.

Low hydropower output at Glen Canyon Dam can affect prices for non-WAPA customers as well, though the magnitude of this effect depends upon other factors. Some factors, such as widespread drought, can affect other hydropower facilities at the same time, magnifying the effect. Other factors, such as deployment of new electricity generators in the region, might reduce the effect. When WAPA has hydropower in excess of its customer obligations, the agency sells this power to other customers, mostly in WECC. These sales put downward pressure on prices in WECC overall, because hydropower outcompetes more expensive generation sources. Conversely, when WAPA has less hydropower than is expected, the supply of low-cost power in the region goes down and more high-cost generation sources are used.

In addition to cost considerations, low hydropower output raises greenhouse gas considerations. When hydropower is not available in WECC, it is typically replaced with fossil fuel-fired electricity generation sources, which emit greenhouse gases. As a result, dry years tend to have higher greenhouse gas emissions than wet years, all else being equal. A number of electric utilities in the West have greenhouse gas reduction targets. Some targets are voluntary and some are mandatory under state law.[57] Increased regional greenhouse gas emissions resulting from low hydropower output at Glen Canyon Dam may complicate efforts to comply with these targets. WAPA customers with greenhouse gas reduction targets may face extra challenges, depending upon the extent to which they depend on WAPA for their electricity supply.

A third potential effect is increased reliability risks in the region. As noted in the section "Hydropower Generation and Marketing," hydropower can provide peaking power and grid services, both of which help to maintain reliability and prevent power outages. When hydropower output is low, other grid resources are typically used for these services. WECC, which oversees reliability in the region, has identified increasing reliability risks over its 10-year planning horizon due in part to the retirement of baseload power plants and the planned addition of wind and solar energy, which cannot always be relied upon for peaking power and grid services.[58] WECC has also noted how drought conditions create uncertainty in reliability planning:

> For example, due to sustained drought at Glen Canyon and Hoover dams, future operation of these hydro resources is uncertain. In 2021 and 2022, these dams, cornerstones of their respective generation fleets, were dangerously close to shutting down due to low water levels. The Bureau of Reclamation took measures in 2021 and 2022 to reduce the water

[54] WAPA 2021 Statistical Appendix.

[55] CRS calculations based on Tri State Generation and Transmission, *2021 Annual Report*, and WAPA 2021 Statistical Appendix.

[56] Bret Walton, "What Happens If Glen Canyon Dam's Power Shuts Off?" *Circle of Blue*, June 6, 2022.

[57] A map of voluntary utility greenhouse reduction targets and state requirements for 100% carbon-free electricity is at https://sepapower.org/utility-transformation-challenge/utility-carbon-reduction-tracker/.

[58] Western Electricity Coordinating Council, *2022 Western Assessment of Resource Adequacy*. For discussion of why changing energy resources pose reliability risks, see CRS Report R45764, *Maintaining Electric Reliability with Wind and Solar Sources: Background and Issues for Congress*, by Ashley J. Lawson, and CRS In Focus IF11257, *Variable Renewable Energy: An Introduction*, by Ashley J. Lawson.

> output of Lakes Powell and Mead, which temporarily prevented the shutdown of both power facilities. However, given the West's intensifying drought, it is unclear whether or when these resources will become inoperable due to low water levels.[59]

In addition to effects on electricity customers, the loss of hydropower generation at Glen Canyon Dam would negatively affect Upper Colorado River Basin Fund balances, and could result in reductions to fund-related expenditures or consideration of whether to supplement the fund with rate increases or appropriations. These effects would potentially be felt by project irrigators, who, in addition to relying on Glen Canyon Dam for low-cost project use power for irrigation, also rely on the basin fund to cover other project-related expenses.[60] While Glen Canyon is not the only source of revenues accruing to the fund, and other CRSP facilities would continue to provide some level of funding, its relative contribution in terms of receipts would be difficult to replace without significant new revenue-generating facilities or funding from another source.

Issues for Congress

Issues and potential options for Congress related to Glen Canyon Dam and declining storage in Lake Powell may include the following:

- How much, if any, financial relief to provide to power and water users and others affected by declining dam storage levels;
- What, if any, modifications to the dam's water and power facilities are warranted to respond to low storage levels; and
- Whether to support or add to ongoing activities to encourage conservation of Upper Basin waters or whether to authorize new strategies to increase Lake Powell storage.

The options under consideration for Glen Canyon Dam could have implications beyond CRSP and the Colorado River Basin. As increasingly arid conditions combine with escalating demand for water and energy resources throughout the West, other areas may face similar tradeoffs and consider related options. A 2023 report by the Government Accountability Office (GAO) noted Glen Canyon as a prominent example of the effects of climate change on PMA operations. GAO noted that nationwide, the effects of climate change could result in costs to utilities and customers in the billions of dollars, including costs from power outages and infrastructure damage.[61]

Financial Relief for Power Customers and Others

One set of concerns is how to provide targeted relief to WAPA contractors and their customers affected by Glen Canyon Dam's declining hydropower generation. Congressional responses to the potential full or partial loss of low-cost WAPA hydropower could include subsides for replacement power purchases or other price relief. In the 117th Congress, legislation was introduced that would have barred the Secretary of the Interior from collecting hydropower

[59] Western Electricity Coordinating Council, *2022 Western Assessment of Resource Adequacy*, p. 14.

[60] For instance, among other things the Upper Colorado River Basin Fund covers irrigation assistance in the Upper Basin, which is the amount of Reclamation project construction costs allocated to irrigation that are calculated to be beyond irrigation contractors' ability to pay. For more information, see Bureau of Reclamation, *Irrigation Ability-to-Pay Analyses*, Reclamation Manual PEC 11-01, August 26, 2019.

[61] U.S. Government Accountability Office, *Power Marketing Administrations: Additional Steps Are Needed to Better Manage* , 23-106224, March 29, 2023, p. 31.

operations and maintenance and construction costs from customers during years in which drought renders Colorado River Basin facilities unable to generate hydropower.[62] Other legislation would have provided billing credits for WAPA customers losing access to firm power due to hydropower generation shortfalls.[63] These approaches could offset some expected cost increases for WAPA customers resulting from low hydropower availability, and they could raise questions about when and how customers (or the federal government) would ultimately pay for these costs. In addition to customer relief, falling generation may lead to proposals to add funding to the Upper Colorado River Basin Fund or to supplement activities that traditionally rely on the fund with appropriations from other sources.

Apart from direct price relief, Congress could address price concerns by adopting policies that could increase the availability of lower-cost replacement power to WAPA customers. One such option is promoting energy efficiency and conservation among end users of Glen Canyon Dam hydropower. Efficiency and conservation both lower total electricity demand. Lower total demand could, in theory, reduce the need for replacement power even with continued low output from Glen Canyon Dam.[64] Another option is to strengthen WAPA's ability to exchange power with other utilities, potentially expanding WAPA's access to lower-cost electricity than it currently can purchase when needed (e.g., for customers opting in to purchase power under the 2021 emergency rate change). For example, WAPA has evaluated having several of its regions, including CRSP, participate in a regional transmission organization (RTO) proposed by Southwest Power Pool (SPP).[65] According to a study commissioned by WAPA and other prospective RTO participants, RTO participation is projected to lower overall costs for customers by promoting sales of any excess power and increasing access to low-cost electricity supplies when needed. The study projected greater savings in drought years compared with average hydrologic years.[66] Congress could consider providing policy direction regarding WAPA's participation in any future Western RTO.

Facility Construction or Alterations

Reclamation is exploring what, if any, physical alterations or operational changes to Glen Canyon Dam could adjust for low reservoir storage at Lake Powell. This approach could also potentially improve the dam's ability to generate hydropower and/or pass through flows sufficient to meet Lower Basin obligations under the Colorado River Compact at lower storage levels. Using additional funding for drought in the West that was made available by Congress in FY2022 (P.L. 117-43), Reclamation is currently conducting appraisal studies related to the operation of the

[62] See H.R. 9249 and S. 4232 in the 117th Congress.

[63] For example, H.R. 9563 in the 117th Congress would have provided contractors with pro rata credits to make up for reduced generation by the SLCAIP below 4,900 gigawatt-hours.

[64] Congress adopted a similar policy for the Bonneville Power Administration. For more information, see Northwest Power and Conservation Council, *Northwest Power Act*, at https://www.nwcouncil.org/reports/columbia-river-history/northwestpoweract/.

[65] A regional transmission organization (RTO) is an independent, non-profit entity that manages a regional transmission system and encourages competition for electricity generation and other grid services. RTOs have similar roles to independent system operators (ISOs). The Southwest Power Pool (SPP) currently administers an RTO in the central United States, one of seven RTOs/ISOs in the United States. SPP is considering expanding its RTO to serve western areas. WAPA's Upper Great Plain-East region currently participates in the existing SPP RTO. More information about SPP's proposal is available at https://www.spp.org/western-services/rto-west/. Information about RTOs and ISOs in general is on FERC's website at https://www.ferc.gov/power-sales-and-markets/rtos-and-isos.

[66] Brattle Group, *Benefits of the SPP RTO Expansion Into the WEIS Footprint*, September 20, 2022, at https://www.wapa.gov/About/keytopics/Documents/2022-spp-rto-brattle-study.pdf.

Glen Canyon Unit during drought. As part of these studies, Reclamation is considering new mid- and/or low-level power intakes on the dam (i.e., intakes that would connect to existing penstocks), connecting some of the River Outlets to the hydropower penstocks, or adding a new underground tunnel and power plant on one of the dam's abutments.[67] Reclamation's technical studies also reportedly are considering other nonstructural options, such as adjusting basin operations to maximize Glen Canyon Dam releases, refining the minimum power pool operating limit,[68] or investing in replacement power (specifically in the form of solar and/or wind generation).[69] To date, Reclamation has provided only scoping information on options under consideration; most of these changes likely would entail significant costs and would need congressional authorization.

Although Reclamation's active studies appear to be limited to those changes discussed above, some groups have advocated for a more fundamental change to Upper Basin operations and Glen Canyon Dam in the form of potential dam removal and/or draining of Lake Powell. One plan, referred to as the "Fill Mead First" plan, argues that Lake Powell should be drained and Glen Canyon Dam should be modified to operate on a "run of the river" basis. These groups argue that although such an effort would have costs (specifically in the form of reduced hydropower generation and some lost recreational opportunities and operational flexibility), it would enable better use of Lake Mead's storage capacity, would open new river miles in what was Lake Powell, and could result in a net decrease in evaporation in the two reservoirs.[70] An analysis of the electricity implications of a Fill Mead First policy concluded that average electricity cost increases per year would be $0.96 for residential customers, $7.04 for commercial customers, and $75.77 for industrial customers.[71] The results are based on electricity price data for 2010-2014 and do not reflect recent conditions, including the fact that WAPA customers are currently receiving less generation from Glen Canyon Dam than was studied (meaning the cost impact of losing all generation from Glen Canyon Dam might be less than estimated).

Other Efforts to Increase Lake Powell Storage

There are numerous other ongoing efforts to improve the hydrologic outlook at Lake Powell beyond efforts undertaken in the 2007 Interim Guidelines and the Upper Basin DCP/DROA. For example, the System Conservation Pilot Program, formally authorized by Congress in 2014, is an effort to make available additional *system water* in Lake Powell and Lake Mead through conservation projects and other reductions to consumptive water use.[72] Whereas most system conservation projects to date have been employed in the Lower Basin (i.e., to benefit Lake Mead elevations), projects reportedly also were carried out under this authority through 2018 in the

[67] Bureau of Reclamation, "Glen Canyon Dam, Low-Head Hydropower Modifications," presentation, February 7, 2023.

[68] Preliminary presentations by Reclamation have noted that the 20-foot difference between the hydropower penstocks and minimum power pool is largely to avoid vortex formations, which could potentially be avoided (and minimum power pool reduced) with vortex-suppressing structures. Ibid.

[69] Ibid.

[70] For more information, see Glen Canyon Institute, "Fill Mead First," at https://www.glencanyon.org/fill-mead-first/.

[71] Thomas Power, Donovan Power, and Joel Brown, *The Impact of the Loss of Electric Generation at Glen Canyon Dam, Phase II: Financial Impacts on Existing Electric Consumers*, February 22, 2016.

[72] *System water* refers to water that is provided to increase water supplies as a whole, without being directed toward additional consumptive use for specific contractors or water users. For example, a conservation project that reduces consumptive use and achieves water savings would have that savings directed toward the broader Colorado River system.

Upper Basin and resulted in some water savings in Lake Powell.[73] Congress recently reauthorized the system conservation authority through FY2024 in the Consolidated Appropriations Act, 2023 (P.L. 117-328).[74] Congress also included $50 million in funding for Upper Basin activities from FY2022 to FY2026 in the Infrastructure Investment and Jobs Act (P.L. 117-58), and Reclamation's initial allocations of this funding have indicated its intent to, among other things, fund water demand management activities in the Upper Basin that could further benefit Lake Powell. Similarly, in the law commonly referred to as the Inflation Reduce Act (P.L. 117-169), Congress appropriated $4.0 billion to Reclamation for long-term drought efforts, with a focus on activities in the Colorado River Basin.[75] Reclamation has indicated its intent to use at least $500 million of this funding on Upper Basin activities that will result in additional conservation for the entire Upper Basin system.[76]

Concluding Observations

Issues associated with Glen Canyon Dam and declining storage levels at Lake Powell have gained widespread attention. This attention is largely driven by potential effects on Upper Basin operational flexibility and hydropower generation, and the prospect that low water levels could eventually disrupt federal management of the Colorado River. Numerous efforts have been undertaken in the past several decades to improve the hydrologic outlook at Lake Powell; these efforts are ongoing, but many stakeholders remain concerned that lake levels will reach minimum power pool (or lower) in the coming years. As a result, Reclamation and basin interests are exploring additional options, including structural and operational changes at Glen Canyon Dam and other facilities, to account for low reservoir elevations, as well as increased water conservation in the Upper Basin. Some of these efforts would need congressional action. At the same time, some in Congress have proposed potential mitigation for power users and others who would be affected by low storage levels. Congress may consider the costs and benefits of these proposals in the context of long-term drought in the Colorado River Basin, as well as their potential precedent for other areas.

Author Information

Charles V. Stern
Specialist in Natural Resources Policy

Ashley J. Lawson
Analyst in Energy Policy

[73] For more information, see Upper Colorado River Commission, "System Conservation Pilot Program," at http://www.ucrcommission.com/system-conservation-pilot-program/.

[74] Division CC of the Consolidated Appropriations Act, FY2023 (P.L. 117-328).

[75] P.L. 117-169, §50233.

[76] Bureau of Reclamation, "Biden-Harris Administration Announces New Steps for Drought Mitigation Funding from Inflation Reduction Act," press release, October 12, 2022.

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