

# An Historical Perspective on the Accounting for Evaporation and System Losses in the Lower Colorado River Basin.

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**Abstract:** Water management of the Lower Colorado River has long sidestepped the questions of how to account for and assess the impact of reservoir evaporation and system losses. To date, the preferred strategy has been to ignore those losses. The hydrologic gap left by this approach, which leaves an imbalance between the water flowing into Lake Mead and the amount released for downstream users, has been covered by simply releasing water stored in Lake Mead from the wet decade of the 1990s ensuring that no user bears the brunt of a legal interpretation that might reduce their supply. This disconnect between the river's allocation framework and hydrologic reality is the result of longstanding governance failures by the U.S. and the Lower Basin states – Arizona, California, and Nevada – including failure of the U.S. to factor in reservoir and system losses in the 1944 Treaty with Mexico and failure of the states to negotiate a Lower Basin compact to apportion their share of the river.

**Introduction:** The accounting and assessment of Lower Basin mainstem reservoir evaporation and system losses has evolved into a major unresolved dispute between California and the six other Colorado River Basin States.

Each presented competing proposals to the Bureau of Reclamation (Reclamation) for modeling analysis under the Supplemental Environmental Impact statement the agency is preparing to revise the 2007 Interim Guideline rules. The six-state proposal would assess a pro-rata share of the estimated 1.5 million acre-feet per year of evaporation and system losses to each Lake Mead user based on the amount of water each uses and their proximity to Hoover Dam. If Lake Mead is projected to drop below elevation 1145', this pro-rata share would be considered a part of each user's annual water order. The six-state approach benefits the junior water users, to the detriment of California's water users and present perfected (pre-compact) mainstream rights in Arizona. The California proposal would maintain the traditional approach of considering these losses to be a limitation on the total water supply available from Lake Mead which under current operation of

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the Law of the River<sup>2</sup> puts the burden on the junior users, primarily the Central Arizona Project (CAP).

While expert analysts have long called for the assessment of evaporation and system losses as a way of bringing the Colorado River water management system into balance<sup>3</sup>, the dueling proposals submitted to the Department of Interior in January 2023 marks the first formal effort in 70 years to specify how the calculation might be made, and how the resulting change in available water supply might be allocated.

The dueling proposals may appear to be an argument about the proper way to measure evaporation and system losses and to then allocate those across the various users of Colorado River water. A broader perspective, however, suggests they are a proxy battle over the reallocation of the water available for use in the Lower Colorado River in response to systemwide overallocation and the reduction of flows due to climate change. Put simply, it is a stalking horse for an underlying question that must be resolved regardless – the imbalance between Colorado River Basin supply and use.

Since the turn of the century, total storage in Lake Mead and Lake Powell has declined by an average of about 1.5 million acre-feet per year. Presuming a continuation of 21st century hydrology and the current Upper Basin use, the Lower Basin would need to reduce its use by 1.5 million acre-feet a year merely to stabilize the system at its current low levels. If there is to be any hope to recover reservoir levels, or to prepare for a future hydrology that might be drier, the cuts need to be deeper. Whether those reductions are attributed to evaporation and system losses or not, the cuts must be made.

Given the river system's supply and use imbalance, it's inevitable that the unresolved and disputed 1922 Compact issues that have been ignored or finessed for decades will resurface. The assessment of evaporation and river losses on the lower river may be the first, but lingering not far below are more challenging disputes. One example is the major differences of opinion

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<sup>2</sup> Paragraph II. (B).(3) of the decree in *Arizona v California* (57 US 150) states "If insufficient mainstream water is available for release, as determined by the Secretary of the Interior, to satisfy annual consumptive use of 7,500,000 acre-feet in the aforesaid three States then the Secretary of the Interior, after providing for satisfaction of present perfected rights in the order of their priority dates without regard to state lines and after consultation with the parties to major delivery contracts and such representatives as the respective States may designate, may apportion the amount remaining available for consumptive use in such manner as is consistent with the Boulder Canyon Project Act as interpreted by the opinion of this Court herein, and with other applicable federal statutes, but in no event shall more than 4,400,000 acre-feet be apportioned for use in California including all present perfected rights." The 1968 Colorado River Basin Projects Act made California's full 4.4 million acre-feet annual entitlement senior to the Central Arizona Project. The 2007 Interim Guidelines and the 2019 Lower Basin Drought Contingency Plan formalize and implement how the Secretary will determine shortages under II. (B).(3).

<sup>3</sup> See for example Fleck, John, and Anne Castle. "Green light for adaptive policies on the Colorado River." *Water* 14.1 (2021): 2.

between the Upper and Lower Division States concerning the obligations of the States of Upper Division to Mexico under Article III(c).<sup>4</sup>

The current argument over the appropriateness of allocating evaporation and system losses, and if so how, thus runs the risk of becoming a distraction from the underlying governance problems on the Colorado River

**Assessing Evaporation and System Losses.** Reclamation estimates and reports evaporation from Lakes Mead, Mojave, and Havasu. The evaporation data are available from the 24-month studies and the Consumptive Uses and Losses Reports (C U & L Reports) prepared by Reclamation.<sup>5</sup> The C U & L Reports do not show river channel losses, evaporation from the surface of the flowing river segments and water consumption by the riparian vegetation on the riverbanks, however, over the years, Reclamation and others have estimated these losses. Most recently, the Southern Nevada Water Authority (SNWA) estimated that total reservoir evaporation and system losses from Lee's Ferry to the Northern International Boundary with Mexico average about 1.5 million acre-feet per year.<sup>6</sup> Approximately 900,000 acre-feet is evaporation from Lakes Mead, Mojave, and Havasu, the remaining 600,000 acre-feet are losses on river stretches.<sup>7</sup>

In contrast to the Upper Basin, where pursuant to Articles V and VI of the Upper Colorado River Basin Compact (1948 Compact) the annual net evaporation from Lake Powell, Flaming Gorge Reservoir, and the Aspinall Unit<sup>8</sup> is divided and assessed to the individual Upper Division States in the same percentage as their 1948 Compact apportionments, there is no similar assessment of

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<sup>4</sup> In their comment letter to Reclamation concerning Supplemental EIS, the State of Arizona and the Central Arizona Project state "Article III(d) and (c) prohibits the Upper Division States from depleting the flow of the river at Lee Ferry below a rolling 10-year aggregate of 75 maf plus one-half of the Mexico delivery obligation. With reduced releases from Glen Canyon Dam potentially analyzed under the SEIS, if the 10-year rolling aggregate falls below the required aggregate volume, (footnote 1) the Upper Division States could be subject to a "Compact call" that would require a reduction in consumptive use in the Upper Basin." Footnote 1 states "A "surplus" currently does not exist because natural flows in the Colorado River have not exceeded 16 maf in the past ten years." This is in stark contrast to numerous statements by representatives of the Upper Division States who have stated that the current "normal" delivery of 8.25 maf/year under the 2007 Interim Guidelines is a luxury, not a legal necessity.

<sup>5</sup> The latest Consumptive Uses and Losses Report data available for the Lower Colorado River Basin covers the five-year period of 2001-2005.

<sup>6</sup> See Attachment 2 to the December 20, 2022, joint letter from the Southern Nevada Water Authority and the Colorado River Commission of Nevada to Assistant Secretary Tonya Trujillo concerning the Notice of Intent to Prepare a Supplemental Environmental Impact Statement.

<sup>7</sup> For its analysis SNWA assumed that Lake Mead would be at elevation 1100'. Obviously, when Lake Mead is above 1100' total evaporation is higher and at lower elevations, total evaporation is less. In contrast, there is little annual variability in evaporation from Lakes Mojave and Havasu. In recent years the USGS has conducted detailed studies of evaporation from the surfaces of Lakes Mead and Mojave. For more technical information see <https://www.usbr.gov/lc/riverops/evaporation/Mead-Mohave%20Evap%20Study.pdf>

<sup>8</sup> Under the 1948 Compact, the annual net evaporation from what are considered common benefit reservoirs (used primarily to meet the joint obligations of the Upper Division States at Lee Ferry) is divided up among the four states. Navajo Reservoir, which like Lake Powell and Flaming Gorge, is an initial storage unit authorized by the 1956 Colorado River Storage Project Act is not considered a common benefit reservoir because the Upper Colorado River Commission has determined that its primary use is to deliver water to users in the State of New Mexico, therefore, the entire annual evaporation from Navajo Reservoir is assigned to New Mexico.

annual reservoir evaporation to the individual Lower Division States. One of the primary reasons for the difference is that the five states with Lower Basin interests have never negotiated a Lower Colorado River Basin Compact.<sup>9</sup>

The historical record seems clear, the 1922 Compact authors considered evaporation from man-made reservoirs a consumptive use that should be assessed against each basin's apportionment, but as to the attribution of these losses to individual states or water agencies, since the 1922 Compact only apportioned the use of water between two basins, they left those details to the future Lower and Upper Basin subcompacts. The same is true for evaporation and seepage losses from canals and delivery systems. As for river channel losses, the issues are more complicated. Losses from the natural flow of the river were not considered a consumptive use, but the Colorado River below Hoover Dam is used as a delivery system and as such, some portion of these losses could be considered a "man-made" consumptive use, and thus, charged to the basin's apportioned waters.

The development of a comprehensive method to assess Lower Basin reservoir evaporation and, if appropriate, conveyance system losses is long overdue. The current practice of not assessing evaporation and system losses on the lower river to the individual states is an oddity borne from the water contracting process under the 1928 Boulder Canyon Project Act (1928 Act) and the Supreme Court's interpretation of that act. In theory the 1928 Act and the Hoover Dam water contracts are subject to the 1922 Compact and would be subject to a Lower Basin compact. But without such a compact, critical allocation and management questions such as the definition of consumptive use, the status and meaning of article III(b) of the 1922 Compact, and the assessment of evaporation and system losses remain unanswered and subject to dispute.

**The Colorado River Compact.** The compact does not specifically address reservoir evaporation, nor does it define "beneficial consumptive use," but there is little doubt that the Colorado River Compact Commissioners considered reservoir evaporation and losses and evaporation from conveyance systems (canals, laterals, ditches, pipelines, etc.) as uses that would be assessed to the apportionment made to the basin in which the reservoirs or conveyance systems were located. During the 15th Compact Commission meeting, Arizona Commissioner Winfield Norviel noted that the location of a reservoir mattered because the basin where the reservoir was located would be charged for the evaporation.<sup>10</sup> In his report to the Utah Governor and Legislature, Commissioner R. E. Caldwell writes "out of the apportionment of 16,000,000 acre-feet, as now made by provision of the compact, each of the basins is required to stand its own losses due to evaporation from the surfaces of large reservoirs, etc."<sup>11</sup> Comments made during the negotiations, as well as the Compact Commissioner's reports to their home states, remain a crucial tool for identifying the intent of the Compact's authors in areas where there remains ambiguity in the Compact text itself.

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<sup>9</sup> The five states are the three Lower Division States of Arizona, California, and Nevada plus Utah and New Mexico. In Utah the Virgin River and Kanab Creek Basins are Lower Basin tributaries and in New Mexico the upper reaches of the Gila River are in the Lower Basin.

<sup>10</sup> See: <https://uttcncenter.unm.edu/resources/colorado-river-compact-centennial/episode-11.html>

<sup>11</sup> R. L. Wilbur and N. Ely, *The Hoover Dam Documents*, U.S. Department of the Interior, 1948, Appendix 213.

The minutes suggest that the commissioners did not consider natural river channel losses as uses that would be assessed to each basin's apportionment since the purpose of the compact was to apportion beneficial consumptive uses.<sup>12</sup> The Commission understood these natural losses were very significant. Reclamation Service Director Arthur Powell Davis told the commission that the channel losses between Lee's Ferry and Laguna Dam (a few miles upstream of Yuma) averaged more than one million acre-feet per year and were nearly identical to the inflows from Lower Basin tributaries in that same stretch. This was a critical assumption because the available flow data at Laguna Dam could be used to estimate flow at Lee's Ferry.<sup>13</sup> Many of the commissioners and their technical advisors, including Arthur Powell Davis, also made the case that by developing the river, natural system losses would be reduced because the channel would become narrower and there would be less overbank flooding. This concept became known as "salvage by use."<sup>14</sup>

The commission minutes provide little information as to how the commissioners would have considered channel losses associated with the use of a river channel to deliver reservoir water downstream to end users. But using the definition of beneficial use by Colorado's Delph Carpenter; "the amount of water consumed and lost to the river during the uses of water diverted. Generally speaking, it is the difference between the aggregate diverted and the aggregate return flow. It is the net loss occurring through beneficial uses," it is possible they would have considered some portion of these losses as chargeable to each basin's apportionment.<sup>15</sup>

**The 1928 Boulder Canyon Project Act.** The Boulder Canyon Project Act, passed by Congress and signed by President Coolidge in December 1928 (1928 Act), authorized the construction of Boulder Dam (now Hoover Dam), the All-American Canal, and made a contingent approval of the Colorado River Compact. The contingencies were met on June 25<sup>th</sup>, 1929, and on that day, President Hoover proclaimed the 1928 Act effective.

In the event Arizona did not ratify the compact within the six-month window provided (which happened), the 1928 Act approved a six-state compact<sup>16</sup> but California had to limit itself to 4.4

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<sup>12</sup> In his December 15, 1922, report to the Colorado Governor and General Assembly, Carpenter defines beneficial consumptive use as "uses caused by the activities of man."

<sup>13</sup> The first river gage at Lee's Ferry was not installed until the summer of 1921. However, in the February 1922 Fall-Davis Report, prepared by the Reclamation Service includes a table that showed annual flows at Laguna Dam from 1899-1920. This table was used to estimate the flow at Lee Ferry, the dividing point between the two basins. Two later hydrologic studies prepared by the Bureau of Reclamation, one in 1934 and the other in 1946, confirmed the accuracy of the assumption that the river gains and river losses between Lee's Ferry and Laguna Dam were nearly identical. Both studies concluded that the natural flow at Lee's Ferry was about 99.2% of the natural flow at Laguna Dam.

<sup>14</sup> The concept of "salvage by use" became a major issue on the river in the 1940s and 1950s. It led to two different and competing theories on how compact apportionments are measured. For more information see *Science Be Dammed* Chapter 14.

<sup>15</sup> Hoover Dam Documents, Appendix 210. Page A80.

<sup>16</sup> The 1928 Act provided two paths for approval of the Colorado River Compact. It gave the states six months to meet with Arizona and try to negotiate an agreement where Arizona would ratify the compact (seven-state path). If Arizona refused to do so, it set requirements for a six-state compact path. Under the six-state path, Utah still needed to waive Article XI of the compact (the other five states had already done so) and California needed to agree to limit itself to 4.4 million acre-feet of III(a) water plus one half of the unappropriated surplus.

million acre-feet of III(a) water plus one half of any excess or surplus waters unapportioned by the compact. The exact language included the phrase “the aggregate annual consumptive use (diversions less return flows) of water of and from the Colorado River for use in the State of California.”<sup>17</sup> It also preauthorized a three-state compact, suggesting an apportionment of the 7.5 million acre-feet of III(a) water with 2.8 million acre-feet for Arizona and 300,000 acre-feet for Nevada, thus by implication 4.4 million for California.<sup>18</sup>

The insertion of the language in the parentheses has had major consequences for the Lower Colorado River. In its 1963 landmark decision, the U.S. Supreme Court largely upheld a ruling by Special Master Simon Rifkind that the 1928 Act was a Congressional apportionment of the mainstream waters of the Colorado River in and below Lake Mead.<sup>19</sup> Rifkind concluded that the 1928 Act limitation on California’s use was based on diversions less return flows. It did not include mainstem reservoir evaporation or delivery losses to the points of diversion. Rifkind considered these losses as limitations on supply, not limitations on uses apportioned by the 1928 Act. The 1964 decree which implements the decision defines “consumptive use” as the amount of water diverted from the river less the return flows to the mainstem of the Colorado River.

**The Hoover Dam Water Contracts.** Before Reclamation could begin construction of Hoover Dam, the Secretary of the Interior needed to enter sufficient water and power contracts to guarantee the federal government would be repaid for the Congressional appropriations necessary to build the project. Before Interior officials could begin the negotiations with the water agencies that would contract for Hoover Dam water and power (all of them were in California), the secretary needed to know how much of each was available for contracting. Erdman Bruno (E.B.) Debler, Reclamation’s chief hydrologist prepared a detailed report. Debler concluded that with phased-in full development in the Upper Basin (6.6 million acre-feet per year), by 1988 the inflow to Lake Mead would average 11.9 million acre-feet per year. Subtracting 1.4 million acre-feet for reservoir evaporation and losses left about 10.5 million acre-feet per year that could be delivered from Hoover Dam. This was enough for the Secretary to safely contract for the full amount of water being requested by the California agencies, 5.362 million acre-feet, 2.8 million acre-feet for Arizona, 300,000 acre-feet for Nevada and it would leave a surplus of almost 2 million acre-feet for Mexico and future contracts.<sup>20</sup>

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<sup>17</sup> 1928 Act, Section 4(a).

<sup>18</sup> We used the word “suggesting” because the amendment’s author, Senator Key Pitman of Nevada always insisted that the language was a suggestion. Obviously, if the three Lower Division States negotiated a different arrangement, they would have submitted it to Congress for approval and, once approved, it would have become the law. The intent of the Pitman split is that such a division would have been preapproved by Congress. There were several other preapproved conditions, including a provision giving Arizona exclusive use of the Gila River within its boundaries.

<sup>19</sup> The Court did not completely agree with the Special Master. The major exception was that Rifkind concluded that shortages should be shared on a pro-rata basis based on each state’s main stem apportionment. The Court disagreed giving that discretion to the Secretary of the Interior.

<sup>20</sup> A chart summarizing Debler’s findings can be found on page 103 of the 1948 Hoover Dam Documents prepared for the Department of the Interior by Ray Lyman Wilbur and Northcut Ely. A synopsis of Debler’s report is included as Appendix 29 of the 1933 version of the Hoover Dam Documents.

Debler did not ignore reservoir evaporation and system losses. In fact, his estimated losses are nearly the same as the recent estimate made by the SNWA. Unfortunately, Debler based his conclusion on the extraordinarily wet hydrology from the early 20<sup>th</sup> Century Pluvial.<sup>21</sup> His basic assumption was that the natural inflow into Lake Mead was about 18.5 million acre-feet per year. With 18.5 million acre-feet of natural inflow, he had the luxury of both allowing the Upper Basin to grow its consumptive use to 6.6 million acre-feet per year and to treat Lower Basin evaporation and losses as a limitation on supply.

In the early 1930s, Interior signed water contracts with California water agencies totaling 5.362 million acre-feet. The contracts were structured in accordance with the language in the 1928 Act and the Debler study. Contract water use was measured as diversions less return flows from the Colorado River mainstem. The United States absorbed all reservoir evaporation and transit losses from Hoover Dam to the points of diversion.<sup>22</sup>

In the 1940s, Interior signed contracts with Nevada totaling 300,000 acre-feet and with Arizona for 2.8 million acre-feet per year. The Arizona Contract included a provision that the Secretary could reduce deliveries to Arizona to less than 2.8 million acre-feet per year to account for depletions within Arizona upstream of Lake Mead and to account for reservoir evaporation and system losses, but this provision was later determined to be illegal by the 1963 Supreme Court decision.<sup>23</sup> In 1944 the United States signed a treaty with Mexico providing Mexico with 1.5 million acre-feet per year, as measured at the international border. Again, the United States absorbed all transit and evaporation losses.

Debler's optimistic inflow assumption was partially offset by his assumption about Upper Basin growth, which was about 2 million acre-feet per year greater than has been the case. Clearly, his study, the diversions less return flows language of the 1928 Act, and the language of the 1930s Hoover Dam water contracts are all partially responsible for today's structural deficit on the Lower Colorado River.<sup>24</sup>

Using the natural flow data available for Lee's Ferry and assuming about 800,000 acre-feet per year of actual inflow from the Paria River,<sup>25</sup> the Little Colorado River, and springs and spring-fed tributaries in the Grand Canyon, since the advent of the "Millennium Drought" in 2000, the

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<sup>21</sup> Based on Colorado River Natural Flow Data, the natural flow at Lee Ferry from 1906-1929 averaged 17.6 million acre-feet per year. The 1906 - 2022 average is 14.7 million acre-feet per year.

<sup>22</sup> Under the first water contract signed between the U.S. and MWD on April 24, 1930, water was delivered at a point immediately below Hoover Dam. Under the amended contract, September 28, 1931, the delivery language was changed to "at a point in the Colorado River immediately above the district's point of diversion."

<sup>23</sup> The court did not totally agree with Rifkind, the decision prohibited the Secretary from subtracting upstream tributary use, but allowed a deduction for uses on the mainstream between Lee's Ferry and Lake Mead. There are no such existing consumptive uses in this segment.

<sup>24</sup> By "structural deficit", we mean the approximate 1.2 million acre-feet per year average annual shortage of mainstream water to the three Lower Division States assuming the States of the Upper Division are delivering an average of 8.25 million acre-feet per year at Lee Ferry.

<sup>25</sup> The Paria River is an Upper Basin stream that enters the Colorado River below the Lees Ferry gage and a mile upstream of Lee Ferry. The 13 million acre-feet per year is a "mixed" number, both natural, 12.2 maf at Lees's Ferry, and 800 kaf of actual inflow between Lee's Ferry and Lake Mead.

natural inflow to Lake Mead has only averaged about 13 million acre-feet per year.<sup>26</sup> With 13 million acre-feet per year of water available at Hoover Dam, there is not enough water to meet the Upper Basin's current uses, 1928 Act apportionments to the Lower Division States, and treaty deliveries to Mexico. To make up the difference between the system demands, about 14.5 million acre-feet per year, and the available supply, about 13 million acre-feet per year, Lakes Mead and Powell have been drained to dangerously low levels.<sup>27</sup>

With Deblor's assumption of 18.5 million acre-feet per year,<sup>28</sup> there was enough water to meet all foreseeable system needs and take evaporation and system losses off the top. With only 13 million acre-feet per year of natural inflow to Lake Mead, there is system deficit of about 1.5 million acre-feet per year which just happens to be about the same as Lower Basin evaporation and system losses. Two different alternatives have been proposed: First, continue to consider these losses as a limitation on the supply of water available to Lake Mead users and let the current law of the river, as set forth by the 1928 Act, the 1964 Decree in *AZ v. CA*, and the 1968 Colorado River Basin Projects Act and formalized by the 2007 Interim Guidelines and 2019 Drought Contingency Plan, allocate the shortages. Under this option, which California favors, the primary impacts are on the junior users, most notably, the Central Arizona Project. Second, assess these losses to all Lake Mead users, including Mexico, on a pro-rata basis. This is the six-state proposal. Implementation of this approach, referred to as "infrastructure protection volume," puts a greater burden on the California agencies, the mainstream Native American tribes, and the Yuma Project in Arizona.<sup>29</sup>

**The 1944 International Water Treaty with Mexico.** In 1944 the United States signed a treaty with Mexico. The treaty was ratified by the Senate in 1945. Under the treaty, the United States delivers 1.5 million acre-feet of water per year to Mexico as measured at the international boundary (the "Limitrophe Section"). The treaty includes provisions for delivering up to 1.7 million acre-feet during surplus years and for delivering less than 1.5 million acre-feet during extraordinary drought periods.

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<sup>26</sup> The data are estimates from the Natural Flow Data Base published by the USBR. The latest version only covers through 2019, the 20-22 numbers are estimates published separately by the USBR. By using the 1930-2022 period, the extraordinarily wet early 1900s Pluvial (1906-1930) is excluded from the analysis.

<sup>27</sup> Over the last 23 years, the Upper Basin's uses have averaged about 4.5 million acre-feet per year. The Lower Basin's uses of Lake Mead have recently been about 7.0 million acre-feet per year. Adding in 1.5 million acre-feet per year for both Mexico and for evaporation and losses, the total is 14.5 million acre-feet per year.

<sup>28</sup> An assumption of 18.5 af/year at Hoover at Hoover Dam is equivalent to about 17.5 maf/year at Lee Ferry. This assumption was common before the 1930s drought but as we point out in *Science Be Dammed*, policy makers were ignoring well-documented science pointing to a long-term natural flow at Lee Ferry in the range of 15-16 maf/year.

<sup>29</sup> The six-state proposal technically does not refer to assessing reservoir evaporation and system losses. Instead, it refers to the reductions as infrastructure protection volumes (IPV). This is clearly a wording "workaround" to avoid a conflict with the 1964 *AZ v. CA* decree.



Under the treaty, the United States committed to build and operate Davis Dam at its expense.<sup>30</sup> Water is delivered to Mexico from Davis Dam (Lake Mojave). The treaty uses the term “metered.” Annual evaporation from Lake Mojave averages about 150,000 acre-feet per year.<sup>31</sup> The treaty language is clear that Mexico is not responsible for evaporation losses within the United States, but there has never been a consensus agreement among the basin states on how Lake Mojave evaporation is assessed within the basin.

California and the other Lower Basin states have on occasion suggested that the obligation of the Upper Division States to Mexico if there is a deficiency includes transit losses from Glen Canyon Dam to Mexico which would include evaporation from Lake Mojave.<sup>32</sup> The upper states have countered that the 1922 Compact states that the Upper Division States will deliver one half of the deficiency, not one half plus transit losses. Further, the beneficiaries of power operations of Davis Dam are all located in the Lower Basin.<sup>33</sup>

Under the current operation, evaporation from Lake Mojave is offset by releases from Lake Mead reducing the water available for delivery to contractors. This means that the burden again falls on Lake Mead’s junior users.

**The Upper Colorado River Basin Compact.** Under the Upper Colorado River Basin Compact (1948 Compact), signed on October 11<sup>th</sup>, 1948, net reservoir evaporation is considered a consumptive use charged against the apportionments made to the five individual states. Net evaporation and net system losses from conveyance systems are also charged against apportionments. Evaporation from the surface of river channels and evapotranspiration from riparian vegetation along the riverbanks are not generally charged to the individual states.<sup>34</sup>

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<sup>30</sup> Davis Dam may have helped diffuse a political argument against ratification of the Mexican Treaty based on language in the 1928 Act stating that the benefits of the Lake Mead were limited to water users in the United States. But it can also be argued that the United States used the treaty as a convenient excuse to build Davis Dam and that its primary purposes were always an afterbay to allow the Hoover Dam hydroelectric generators to operate in a peaking or load following manner and the additional power the dam produced.

<sup>31</sup> The 150,000 acre-feet per year is for water year 2022 from the latest 24-month study. In 2021 (and back to 2011) the 24-month studies showed annual evaporation as 200,000 acre-feet per year. The annual operation and surface area of the reservoir does not vary much from year to year. The change reflects an updated methodology for calculating surface evaporation off Lake Mojave provided by the USGS.

<sup>32</sup> W. Patrick Schiffer, Herbert R. Guenther & Thomas G. Car, “FROM A COLORADO RIVER COMPACT CHALLENGE TO THE NEXT ERA OF COOPERATION AMONG THE SEVEN BASIN STATES”, *Arizona Law Review*, Volume 49. 217-33, 2007. On page 225, the paper’s authors claim that the Upper Division States should be delivering an additional 143,000 acre-feet per year to cover the transit losses for the delivery of water to Mexico. In 2007 Guenther was the Executive Director of the Arizona Department of Water Resources.

<sup>33</sup> During its deliberation over the Mexican Treaty, Davis Dam was often discussed by the Committees of 14 and 16. During the January 27 and 28, 1944 meeting in response to a question about evaporation, Royce Tipton pointed out that Davis Dam had three primary purposes: producing hydroelectric power, reregulating Hoover Dam releases to allow it power plants to be operated as load following or peaking plants, and metering out water to Mexico under the Treaty. Tipton was wearing two hats, Colorado’s principal engineering representative and an advisor to the State Department.

<sup>34</sup> It may depend on how each state administers reservoir releases and the subsequent refilling. In Colorado for example, the water administrative officials often assess a transit loss charge for deliveries of reservoir water to a downstream use. The vacated space associated with these transit losses is then refilled during the next fill season.

Unlike the Colorado River Compact, the 1948 Compact includes a detailed, but nuanced, definition of consumptive use.<sup>35</sup> Article III(b)(1) states “the apportionment is of any and all man-made depletions.” Article VI directs the Upper Colorado River Commission (UCRC) to “determine the quantity of the consumptive use of water, which use is apportioned by Article III hereof, for the Upper Basin and for each State of the Upper Basin by the inflow-outflow method in terms of man-made depletions of the virgin flow at Lee Ferry, unless the Commission, by unanimous action, shall adopt a different method of determination.”

Article VI was the subject of considerable discussion and debate by the compact commissioners and their advisors. Colorado Commissioner Clifford Stone and his principal advisors, Gene Breitenstein and Royce Tipton, believed that by measuring consumptive use as the impact of man-made depletions to the virgin (natural) flow at Lee Ferry, the Upper Division States could take advantage of salvage by use.<sup>36</sup> An example where this definition makes a major difference is in the assessment of reservoir evaporation. Under the 1948 Compact, the consumptive use for Lake Powell evaporation is determined and reported as the total annual evaporation from the surface of the reservoir minus an estimate of the natural losses that would have occurred in the inundation area had the dam and reservoir not been built. This number for Lake Powell is surprisingly large, 220,000 acre-feet per year.<sup>37</sup>

**The 1963 Arizona v. California Decision.** In 1952 Arizona filed suit against California in the United States Supreme Court. At stake was the water supply available to, and thus, the feasibility of the Central Arizona Project. In its original filing, one of Arizona’s claims for relief asked the court to allocate the evaporation from Lake Mead to the three Lower Division States in proportion to how much water each was using from the reservoir. In the early years of the case the parties assumed that the court would be interpreting the Colorado River Compact, but that is not what happened. After decisions by two special masters<sup>38</sup> and an amended filing by Arizona in 1958, in 1963 the Supreme Court concluded that the Colorado River Compact did not need to be interpreted to dispose of the case. Instead, the court limited its decision to an interpretation of what Congress did or intended to do when it passed the 1928 Act.

The end result of the 1963 decision and the 1964 Decree which implements the decision is that the “(diversions less return flows)” provision from the 1928 Act is the controlling language for defining consumptive use on the mainstream. Special Master Rifkind addressed the question of

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<sup>35</sup> The drafters of the Colorado River Compact always intended to include a definition of consumptive use, but the drafting committee, primarily made up of water lawyers from the different states, could never agree on common definition forcing Chairman Hoover to recommend the definition be dropped from the compact.

<sup>36</sup> See, Record of the Upper Colorado River Basin Compact Commission, V II, Minutes of the 7<sup>th</sup> Meeting, pages 51-83. On page 54 Royce Tipton walks through an example of a transmountain export that would divert 500,000 acre-feet per year out of the basin into the Colorado Front Range but might only have an impact of the virgin flow at Lee Ferry of 450,000 acre-feet because had the export project not been built, natural river losses would have reduced the 500,000 acre-feet per year of natural flow at the diversion point to 450,000 acre-feet per year at Lee Ferry. In this example, the diversion would be 500,000 acre-feet, but the compact depletion at Lee Ferry would only be 450,000 acre-feet.

<sup>37</sup> Jian Wang and John C. Schmidt. White Paper 5, “Stream Flow and Losses of The Colorado River in The Southern Colorado Plateau” Utah State University, Center for Colorado River Studies.

<sup>38</sup> The first Special Master was George Haight. After his death in 1955, Simon Rifkind was appointed.

reservoir evaporation and river conveyance losses. He concluded “Section 4(a) as here interpreted does not charge California for evaporation and channel losses on water in the mainstream which occur before the water is diverted for use within the state. California is charged only the amount of water which she actually diverts and which does not return to the mainstream. Losses of water which occur before diversion are a diminution of the available supply under Section 4(a), not a consumptive use.”<sup>39</sup>

Special Master Rifkind further concluded that provisions in the 1944 Arizona and Nevada Hoover Dam water contract that allowed the secretary to reduce deliveries to Arizona and Nevada to account for uses on tributaries upstream of Lake Mead were illegal and unenforceable under the 1928 Act. The Arizona contract provision, Article 7(d), also included language allowing the Secretary to reduce deliveries for evaporation: “such obligation shall be subject to such reduction on account of evaporation, reservoir, and river losses as may be required to render this contract in conformity with said compact and said act.”<sup>40</sup> Rifkind explains his reasoning for voiding these provisions in ten pages of detail, but does not mention the evaporation language. He concludes: “it should be pointed out that voiding these provisions does not impair the Secretary’s control and management of Hoover Dam and Lake Mead, nor does it leave California helpless to protect her interests. The Secretary will still be able to control the supply of water in Lake Mead since it is within his reasoned discretion to determine how much water is to be released for use in the three states each year. And California will be able to protect herself against undue depletions on the tributaries and the mainstream above Lake Mead by compact, or, if necessity arises, by suit.”<sup>41</sup>

Under the 1964 Decree consumptive use means “diversions from the stream less such return flow thereto as is available for consumptive use in the United States or in satisfaction of the Mexican treaty obligation.”<sup>42</sup>

In *Science Be Dammed* we conclude that one of the consequences of the court’s decision in *Arizona v California* in the Lower Basin was to put the Colorado River Compact on the back bench. In its original 1952 filing, Arizona sought a ruling that could have been a full substitute

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<sup>39</sup> Special Masters Report, page 187.

<sup>40</sup> Special Masters Report, pages 237-247. Interestingly, the Nevada contract had no similar provision dealing with reservoir evaporation and system losses. A reason may be the Arizona contract language was hotly debated by the Committee of 14 during several meeting in late 1943. It was Colorado’s Royce Tipton and Clifford Stone that insisted reservoir evaporation be considered. It’s apparent from the many discussions the committee had during its tenure of 1938-1944, that committee members from all seven states recognized that reservoir evaporation was a beneficial use under the 1922 Compact. This is another point where the Supreme Court did not totally agree with the Special Master. The court found that the Secretary could reduce contract deliveries for upstream use on the mainstream of the Colorado in Arizona and Nevada, but not the tributaries. There are currently no mainstream diversions upstream of Hoover Dam and below Lee Ferry.

<sup>41</sup> During an early review of this paper, one commentor suggested that the decision in *AZ v. CA* may preclude a Lower Basin Compact. The statement calls for a legal conclusion that authors are not qualified to make, but we can point out that Rifkind concluded (pages 198-200) that in passing the Boulder Canyon Project Act, Congress did not bar California from obtaining a share of III(b) water by compact. Further, our basic assumption is that if the Lower Basin States were ever successful in negotiating a basin compact, once approved by Congress, it would become the Law of the River.

<sup>42</sup> 376 U.S. 340

for a Lower Basin Compact. It asked the court to allocate (apportion) the 8.5 million acre-feet of beneficial consumptive use apportioned to the Lower Basin by the 1922 Compact Articles III(a) and (b) to all five states with Lower Basin interests, including all Lower Basin tributary use. It asked the court to assess Lake Mead evaporation to the three Lower Division States on a pro-rata basis and it asked the court to decide that Lower Basin compact apportionments were to be measured by the stream depletion theory.<sup>43</sup>

No 1922 Compact issues were decided. Instead, the court limited its decision to interpreting the 1928 Act, leaving the unresolved compact issues for another day. At least as to the question of evaporation and conveyance losses, that day may have arrived. Thus, the problem facing the three Lower Division States is how resolve one of the disputed issues that has prevented the successful negotiations of a Lower Basin Compact, the assessment of evaporation and conveyance losses. If the affected states can reach a consensus, there are paths forward. The optimal solution would be a negotiated agreement among the three Lower Division States addressing mainstream reservoir evaporation and conveyance losses. To make such an agreement permanent, it could be implemented through a partial, or full Lower Basin Compact or a Congressional amendment to the 1928 Act.

**Seventy-Five Years ago.** Seventy-five years ago in the Spring of 1948, Congress became embroiled in the disputes between Arizona and California over the Colorado River. At that time the Bureau of Reclamation had completed and submitted to Congress a detailed report on the development of the Colorado River. The report, commonly referred to as the “Blue Book” included an enticing list of potential projects that could be authorized and built by the USBR. The problem was that the Truman Administration had concluded that it could not support any further development until the basin compacts contemplated by the 1922 Compact had either been completed or an allocation of water to individual states had been made by the United States Supreme Court.

The Upper Basin States were in the middle of negotiating an Upper Basin Compact and were confident they would succeed, but Arizona and California were hopelessly deadlocked. Several senators suggested a joint resolution directing the Attorney General to file suit in the Supreme Court against the Lower Division States forcing a judicial resolution of the disputed issues.<sup>44</sup> As the Senate hearings commenced, the first witness was Senator William Knowland from California who described the problem this way:

*“The trouble is that there is not enough water in the river, available to the lower basin, to satisfy the demands of the lower basin States, particularly the States of Arizona and California. Somehow, somewhere the issues must be settled. It is unfortunate that the*

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<sup>43</sup> Because the Gila River naturally lost about a million acre-feet per year of water as it flowed from Phoenix to Yuma, this definition allowed Arizona to consume two million acre-feet of Gila River annually in and upstream of Phoenix, but only be charged for one million acre-feet per annum of apportionment.

<sup>44</sup> Hearings before a Subcommittee of the Committee on Interior and Insular Affairs United States Senate, Eightieth Congress, Second Session on S.J. Res. 145. May 10, 11, 12, 13, and 14, 1948. A House of Representatives Subcommittee of the Judiciary Committee met a week later to hold hearing on a companion resolution JHR 225. The witnesses and the testimony in both hearings were almost identical.

*economic situation in the states will not likely permit any negotiator for either state to give up enough of his state's demands to reach a compromise."*

Two states, California, and its nominal ally Nevada, supported the resolution. California's primary concern was that Congressional authorization of the CAP would take water away from projects it had already developed.<sup>45</sup> Five states, Arizona and the four Upper Division States opposed the resolution. Arizona opposed the resolution because it believed extended litigation would delay Congressional approval of the CAP and that it had the ability to overcome California's political opposition to the project in Congress. Similarly, the Upper Division States were concerned that extended Colorado River litigation would delay Congressional approval of the 1948 Compact and the federal development of the river that they believed would follow.

The subcommittee heard from many of the Colorado River Basin State agency directors and attorneys as well as key water managers, including Colorado's Clifford Stone, Royce Tipton, and Jean Breitenstein and California's Northcut Ely.<sup>46</sup> Ely detailed the major disputed issues. There were three:

- The status and meaning of Article III(b) of the 1922 Compact – the Lower Basin's extra one million acre-feet; was the III(b) water apportioned or unapportioned surplus under the 1928 Act and was it solely for Arizona's use or did California have a claim to a portion of it? California took the position that under the 1928 Act, the III(b) water, not mentioned in the act, was a part of the unapportioned surplus. Therefore, it had a right to at least some portion of the one million acre-feet.
- The definition of consumptive use under the 1922 Compact and how compact apportionments are measured; There were two competing theories, California's diversions less return flows method and the stream depletion method favored by Arizona and the four Upper Division States.<sup>47</sup> The Arizona/Upper Division State approach let Arizona use over two million acre-feet of Gila River water, but only be charged for one million acre-feet of compact apportionment.<sup>48</sup>
- The assessment of evaporation from Lake Mead to the three Lower Division States. Ely acknowledged that reservoir evaporation had to be addressed, but that California also

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<sup>45</sup> By 1948 California's major projects, the All-American Canal, the Coachella Canal, the Colorado River Aqueduct, and the MWD to San Diego conduit, were already either in operation or very close to being completed.

<sup>46</sup> Clifford Stone was the first Executive Director of the Colorado Water Conservation Board (CWCB) from 1937 – 1952. He served as Chairperson of the Committees of 14 and 16 and was Colorado's 1948 Compact Commissioner. Breitenstein was Stone's chief legal counsel. He later served as a federal district and appeals court judge. Tipton was Stone's primary engineering advisor. He wore many hats, including as an engineering advisor to the U.S. State Department and to the Central Arizona Project Association, the "private" entity that lobbied Congress for the authorization of the CAP. Ely had a long career as Washington D.C. based attorney primarily working for California. He began his career as a special assistant to Interior Secretary Wilbur negotiating the Hoover Dam water and power contracts.

<sup>47</sup> The four Upper Division States were not all of one mind on this issue. Wyoming's William J. Wehrli was concerned that the Arizona/Upper Basin State position would add to the Upper Basin's Mexican treaty burden. Wehrli stayed away from his concerns during the hearings.

<sup>48</sup> See *Science Be Dammed* Chapter 12.

believed its share of this evaporation could be partially assessed to its share of the Lower Basin's III(b) water.<sup>49</sup>

The Arizona and the Upper Division States agreed with California's list of three major disputed issues, but obviously disagreed with California's (and Nevada's) interpretation of them. Witness after witness pointed out that under the language of Articles III(b) and (f), the III(b) water is apportioned water, not unapportioned surplus. The Upper Division representatives, however, did not totally agree with Arizona's position that the III(b) water for its exclusive use. Colorado's Stone told the Senators that the 1922 Compact apportioned a total of 8.5 million acre-feet to the Lower Basin, how and where that water is used was a matter of negotiations among the five exclusive Lower Basin States.

There was general agreement that evaporation from Lake Mead and from future Upper Basin Reservoirs was a consumptive use under the 1922 Compact and needed to be assessed. Colorado's Breitenstein pointed out that to measure and assess evaporation, there first needed to be a common definition of consumptive use. Breitenstein told the subcommittee that the Upper Basin Compact negotiators were busy working on how the 1948 Compact would address evaporation.

Representatives of the five opposing states also focused on the legal issues associated with the proposed resolution. They argued that although someday there might be a problem, as of 1948, millions of acre-feet per year of water were flowing unused into the Gulf of California. There was no current controversy. Further, under the constitution, Congress had no business expanding the jurisdiction of the Supreme Court. They had an ally in the Truman Justice Department that questioned the appropriateness of the proposed resolution.

In the end, the Senate and House joint resolutions all failed. The Upper Basin States completed their compact and it was approved by Congress in 1949. Arizona's gamble, however, failed. California's continued opposition to the authorization of the CAP based on water supply issues forced Arizona to file suit in 1952. The case was not decided until 1963 and the court's decision avoided resolution of all three of the contested issues identified by Ely. The issues remain unresolved today.

### **Further Questions and Project Specific Issues.**

**Lake Havasu (Parker Dam).** Lake Havasu is not a classic water storage reservoir. It has a unique purpose. The primary purpose for which it was built was to provide a stable pumping forebay for Metropolitan Water District's Colorado River Aqueduct. The reservoir now serves the same function for the Central Arizona Project. In many ways Lake Havasu is like Navajo Reservoir in the Upper Basin where the UCRC has determined that its evaporation should be charged to New Mexico. Average annual evaporation from Lake Havasu averages about 140,000 acre-feet per year. A legitimate question is should the full amount of evaporation from Lake Havasu be split between the Colorado River Aqueduct (MWD) and the Central Arizona Project? It could be split 50/50 or in proportion to how much water is pumped annually by each project.

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<sup>49</sup> S.J.Res. 145.Hearings, opening statement by N. Ely of California, page 87.

**Lake Mojave (Davis Dam).** Like Lake Havasu, Lake Mojave has a unique water supply purpose coupled with its power generation purposes, metering out water to Mexico under the 1944 Treaty.<sup>50</sup> The treaty, however, requires the United States to measure deliveries to Mexico at the international boundary. There are three basic options:

- The United States could ask Mexico to cover the evaporation from Lake Havasu as a part of a successor to Minute 323. Evaporation would be deducted from the annual deliveries. Mexico has consistently shown a willingness to share shortages with the United States, but it could be argued that sharing shortages during an extraordinary drought is contemplated by the treaty. Changing the location of water deliveries to Mexico and how they are measured is a more significant change.
- Evaporation from Lake Mojave could be considered a part of each Basin's Mexican Treaty burden and if the surplus is insufficient, evaporation off Lake Mojave would be added to the deficiency. The net impact would be that each basin would be responsible for about 75,000 acre-feet per year. Because it could increase the required annual releases from Glen Canyon Dam, this option would almost certainly be opposed by the States of the Upper Division.
- The status quo is option number three. Evaporation off Lake Mojave is made up annually by releases from storage in Lake Mead. If the states can reach an agreement, evaporation on both Mead and Mojave would be assessed to each of the Lower Division States (or the users in three states) based on the agreement.

**Present Perfected AKA Pre-Compact Water Rights.** Article VIII of the 1922 Compact states that "Present perfected rights to the beneficial use of waters of the Colorado River System are unimpaired by this compact." It further provides that once five million acre-feet of storage has been provided for the benefit of the Lower Basin, a requirement that was met with the construction of Hoover Dam, then any claims that Lower Basin mainstem appropriators might have against Upper Basin appropriators are satisfied by Hoover Dam water. There are major present perfected rights in both Arizona and California. Collectively these rights consume about 3.5 million acre-feet per year.<sup>51</sup>

The theory behind this provision is that before the compact was approved, these "pre-compact" perfected rights like those perfected by the Imperial Irrigation District had a right under the 1922 Wyoming v. Colorado Laramie River case to call for water from junior upstream users during

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<sup>50</sup> It could also be argued that Lake Mojave's treaty purpose was always creative legal fiction, and its real purpose was always to produce additional power and to improve the power operations at Hoover Dam by providing a reregulating afterbay. The Upper Basin equivalent is Crystal Reservoir in the Aspinall Unit.

<sup>51</sup> The 1979 decree that lists and quantifies present perfected rights by diversion amounts and the dates the rights were perfected. The largest present perfected right in California is the Imperial Irrigation District for a diversion of 2.6 million acre-feet per year. IID has water rights totaling about 3.1 million acre-feet per year, but only 2.6 million acre-feet had been perfected by use as of June 25<sup>th</sup>, 1929, the day the Boulder Canyon Project Act became effective and the 1922 Compact was formally approved. The largest present perfected right in Arizona belongs to the Colorado River Indian Tribes totaling over 700,000 acre-feet per year of diversions.

shortages. The 1922 Compact took this right away from them once Hoover Dam was built.<sup>52</sup> It's possible that any attempt to assess reservoir evaporation to present perfected rights might be challenged as a violation of Article VIII.

It's also possible that assessing reservoir evaporation to the Native American communities along the mainstem of the Colorado River that were adjudicated by the 1963 Supreme Court decision might be challenged as a violation of both Article VII, which protects tribal rights, and Article VIII.

**Ponding Behind Diversion Dams.** In addition to the three major reservoirs there is ponding behind three mainstem diversion dams; Headgate Rock, the Palo Verde Diversion Dam, and Imperial Diversion Dam.<sup>53</sup> Of the three, the ponding behind the Imperial Diversion Dam is the largest. For this paper, we've ignored the incremental additional evaporation off the ponding behind these diversions but if the states so agree, the incremental evaporation could be assessed to the specific beneficiaries of the diversion dams.

**How Would a Lower Basin Compact and the 1963 Arizona v. California Decision Fit Together?** There are three aspects to this question: legal, water management/policy, and political. The authors are not qualified to address the legal issues. We can point out that based on his analysis, Special Master Rifkind may have believed that such a compact was unlikely to happen because of the major policy differences between Arizona and California, but he did not preclude it. He suggested a compact as one of California's options to address a future situation where uses on the Lower Basin tributaries could impact its Hoover Dam supplies. From a water management perspective, it's unlikely that the three Lower Division States would want to change the basic mainstream apportionment scheme under the 1928 Act, but if they chose to do so, why couldn't Congress amend that act as a part of the Lower Basin Compact approval process?<sup>54</sup>

The primary obstacles to a Lower Basin Compact have always been and remains the political challenges caused by not enough river water to meet the collective needs of Arizona, California, and now Nevada. A complicating factor is that both New Mexico and Utah have Lower Basin interests. Again, we see two basic options, these two states could be parties to a five-state Lower Basin Compact or a three-state compact could be structured such that it does not impair existing and future water uses on the Lower Basin tributaries within New Mexico and Utah.

**A Consistent and Accurate Method of Measuring and Assessing Reservoir Evaporation is Critical to Future Water Management in the Basin.** Evaporation from the basin's large federal reservoirs is a significant water use. Depending on the level of storage, the loss of water is in the range of 1.5 – 2 million acre-feet per year, more than the annual consumption of four of the seven individual basin states. Yet currently there is no common basin-wide approach to measuring and reporting evaporation. For example, the evaporation numbers reported by the 24-

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<sup>52</sup> Article VIII turned out to be the most difficult to write. The commissioners considered numerous drafts before reluctantly agreeing to article as written.

<sup>53</sup> Below the Imperial Diversion Dam is the Laguna Dam which before the Imperial Diversion dam replaced it was used to divert water to the Yuma Irrigation project. There is normally not much ponding behind this dam.

<sup>54</sup> By basic scheme, we mean the 4.4/2.8/.3 mainstem apportionments.



month studies for Lake Mead are based on actual surface evaporation, but for Lake Powell they are based on actual surface evaporation less a guestimate of the natural losses in the reservoir basin had the reservoir not been built. The numbers for Lakes Mojave and Mead are based on recently updated USGS science.<sup>55</sup> The Lake Powell numbers are based on science from the 1970s and 80s.<sup>56</sup>

The renegotiations of the post-2026 reservoir operating rules (Interim Guidelines) will require a thorough evaluation of a range of different reservoir management options, including operating Lake Mead and Powell as a unit and favoring storage in one or the other based on water supply and environmental conditions. It's also likely that each reservoir will continue to have multiple administrative pools for storing intentionally created surplus (ICS), demand management water, and other saved water from conservation programs. For alternatives evaluation and system accounting purposes, evaporation numbers based on a common methodology and the best available science will be essential.

In recent years the Reclamation and the USGS have conducted detailed research on measuring evaporation from Lakes Mojave, Mead, and Powell, but more research is needed. Estimating river channel losses is different and much more subjective than reservoir evaporation. While it may be possible to estimate evapotranspiration from bank vegetation, the complex interaction between surface flows and alluvial groundwater and questions of how much water is salvaged by lower streamflow makes any estimate highly speculative.<sup>57</sup>

As a minimum Reclamation needs to report actual monthly and annual surface evaporation numbers for all its major system reservoirs. If these numbers need to be adjusted to fit the definition of consumptive use under the 1948 Compact or a future Lower Basin Compact this can be done separately and so noted.

**Concluding Remarks.** The assessment of reservoir evaporation and system losses is a major problem that in times of shortages and critically low reservoir levels must be resolved. The 1.5 million acre-feet per year of losses represents about 20% of the available water supply for mainstream users on the Lower Colorado River.

Two different methods of assessing reservoir evaporation and system losses have been proposed, but there could be others. The California approach is to maintain the current status quo first put in place in the 1930s. Under this approach reservoir evaporation and system losses are considered a limitation of the water supply available from Lake Mead. The available water is then distributed in accordance with Arizona v. California and the 1968 Act. Because of its “junior” status under the 1968 Act, this approach primarily impacts the CAP. The second method

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<sup>55</sup> For a summary of the recent USGS evaporation studies see: <https://www.usgs.gov/centers/nevada-water-science-center/science/evaporation-lake-mead-and-lake-mohave-lower-colorado>

<sup>56</sup> In October 2021 Reclamation published a report on Lake Powell evaporation by Collison and Llewellyn ST-2018-81 1901. The study concluded that the current methodology understates actual net evaporation by about 15%. The study recommended more research.

<sup>57</sup> During the Senate Hearings on the ratification of the 1944 Treaty with Mexico, several engineers including the CWCB's Royce Tipton testified that development of the river below Hoover Dam has increased the water supply available for use by about 400,000 acre-feet per year.

proposed by Arizona and Nevada and supported by the four Upper Division States is to consider these losses a common cost of doing business on the river and divide them in pro-rata way among all beneficiaries of the development on the lower river. This approach favors Arizona and Nevada to the detriment of California because its agencies use the most Lake Mead water. It also impacts tribal and non-tribal pre-compact rights in Arizona.

These two approaches expose the fundamental problem on the river. There is not enough river water to meet the needs of Arizona, California, and Nevada on the Lower River, to meet the current needs and future aspirations of the Upper Division States, to address the unmet senior rights of the Basin's Native Americans, and to satisfy the 1944 Treaty obligations to Mexico. The simple reality is that the three Lower Division States need to cut their collective mainstream uses by at least 1.5 million acre-feet per year, the only questions are which entities are cut and by how much. Both proposals accomplish the necessary cuts, but the way each distributes the pain is different.

The dispute is exacerbated by basic flaws and inconsistencies in the Law of the River. Key water management and governance issues remain unresolved and in limbo. There is no Lower Colorado River Basin Compact. There has never been a division of the 8.5 million acre-feet of consumptive use apportioned to the Lower Basin by the 1922 Compact. Without a Lower Basin Compact definition of consumptive use, how can each state's Compact use be measured? Without knowing how much water each state is using, how can water supply shortages or ever be determined and shared among Lower Basin States? The Hoover Dam water contracts are, in theory, all subject to water availability under the Colorado River Compact but as a practical matter, without a Lower Basin Compact, that provision is meaningless!

Lacking the structure and discipline of a compact, the three Lower Division States have no choice but to skirmish at every available opportunity over the same basic dispute, how to distribute the inevitable cuts necessary to balance water supply and water use.

Assuming the Colorado River Basin States can find their way past the current near-term storage crisis (the current 2023 winter snowpack suggests nature may be helping), and before the negotiations on the post-2026 river guidelines begin, the Lower Basin States should consider a process to assess basic unresolved and unanswered questions about how their 1922 Compact share should be apportioned, measured, and governed, including how water supply shortages are shared. The focus needs to be on an agreement that addresses the river that nature has given us today, not the one we thought we had many decades ago.