Study Report

Falcon Lake Water Levels and Recreational Fisheries





Prepared by Texas Parks and Wildlife Department in fulfillment of Rider 39 of the 2022-2023 General Appropriations Act, titled "*Study on Water Level at Falcon Lake*"

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Inland Fisheries Division
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Study Purpose

This study report was prepared in fulfillment of the Texas 2022-2023 General Appropriations Act, Texas Parks and Wildlife Department, Rider 39, entitled *"Study on Water Level at Falcon Lake."* Rider 39 mandates that *"Inland Fisheries Management, the Texas Parks and Wildlife Department (TPWD) shall collaborate with the Texas Commission on Environmental Quality to conduct a study to determine the optimum water level for recreational fishing and the factors that contribute to the rise and fall in water levels. TPWD shall make recommendations on how to maintain the optimum water level for recreational fishing on Falcon Lake. Not later than December 1, 2022, TPWD shall report the findings and recommendations of the study to the Governor, Lieutenant Governor, and the Speaker of the House of Representatives."*

Executive Summary

Falcon Lake is situated on the international border between the U.S. and Mexico and is located 283 miles upstream of the Gulf of Mexico within Zapata and Starr counties, Texas, and the state of Tamaulipas, Mexico. It encompasses 86,265 acres at conservation pool elevation [301.2 feet above mean sea level (MSL)] and was constructed in 1954 for conservation, storage, and regulation of water in the Rio Grande. In addition to serving as the primary water supply for the Rio Grande Valley, the lake is highly regarded for its recreational fishery. It was ranked #1 in *Bassmaster Magazine's* top 100 bass lakes in 2012, #7 in 2013, and #12 in 2014. Within Texas Congressional District 28, which encompasses Falcon Lake, 88,884 anglers were responsible for $89 million in retail sales and 993 jobs in 2016. Although the total economic value of the Falcon Lake fishery has not been estimated, it is likely substantial given the economic value of the nearby recreational fishery at Amistad Reservoir was recently valued at $22.7 million. Falcon Lake has experienced substantial fluctuations in water level, prolonged periods of low water level, and an overall decline in water level since 1960. This inconstant water level has had substantial impacts on the lake's recreational fishery. Fish habitat in Falcon Lake consists primarily of flooded terrestrial vegetation, which is a product of water level fluctuation. When water levels recede, the exposed lake bottom is rapidly colonized by terrestrial vegetation. The subsequent inundation of this terrestrial vegetation by a rise in water level increases availability of fisheries habitat, and in turn, fish reproduction and recruitment, particularly if the rise in water level is substantial (≥5 feet) and occurs from spring through summer. However, water level typically declines spring through summer due to water releases for downstream water supply needs. Objectives of this study were 1) determine the factors that contribute to water level fluctuations at Falcon Lake, 2) identify the optimum water level for recreational fishing at Falcon Lake, and 3) assemble recommended strategies to maintain the optimum water level for recreational fishing at Falcon Lake.

Factors that Contribute to Water Level Fluctuations at Falcon Lake – Numerous factors influence water levels in Falcon Lake, including but not limited to inflows from the Rio Grande and Rio Salado, discharge (i.e., downstream water releases from the dam), area precipitation and evaporation, and diversions (water withdrawals). Through this study, a water budget accounting for flow into and out of the lake was formulated annually from 1960 to 2020 to determine the relative influence of each factor on lake volume. Rio Grande flow was the principal inflow factor comprising 84% of total inflow, on average, and lake discharge was the primary outflow factor accounting for 83% of total outflow, on average. Contribution of Rio Salado flow and precipitation to total inflow averaged 9% and 5%,

respectively. On average, evaporation accounted for 14% of total outflow, and diversion was the least impactful factor comprising 1% of total outflow.

Identifying the Optimum Water Level for Recreational Fishing – Through this study, a theoretical discharge reduction model identified a minimum water level of 268 feet above mean sea level (MSL) and occurrence of spring through summer water level increases ≥5 feet every 2-4 years are ideal for maintaining a high-quality recreational fishery at Falcon Lake. Angler access would be unimpacted by water level as all boat launch lanes in Falcon State and Zapata County parks are useable when water level is ≥268 feet above MSL. Largemouth bass angling effort and catch would be consistently high as a result of frequent increases in fisheries habitat availability. A minimum water level of 268 feet above MSL can be achieved by a relatively small reduction in total releases from the lake of approximately 2-4%, and a spring through summer water level increase of ≥5 feet would, on average, require a 37% reduction in discharge over the 7-month period from March 1 to September 30.

Strategies to Maintain the Optimum Water Level for Recreational Fishing – The ecological, recreational, and economic importance of Rio Grande water is now better understood and more widely recognized by decision-makers than in previous decades. A variety of strategies can be taken to improve environmental flows and lake water levels in the basin. Water rights may be acquired, donated, leased, or purchased for environmental purposes with the option to deposit in the Texas Water Trust. A water conservation plan purposed to reduce the loss or waste of water, maintain or improve the efficiency in the use of water, and increase reuse of water is required for new and amended water right permits. A drought contingency plan, having specific targets consistent with the Texas Water Development Board Region M water plan, is required for wholesale and retail public water suppliers and irrigation districts in the Lower Rio Grande Valley. The conversion of water rights from agricultural use to municipal, domestic, or industrial use in the Lower Rio Grande Valley results in a 50-60% reduction in converted water right volume. These strategies, if successful in increasing water availability, could positively affect the water level and recreational fishery in Falcon Lake. The long-term decline in Falcon Lake water level, however, foretells the need for additional conservation measures to maintain Falcon Lake's recreational fishery, including watershed restoration, water conservation, and river basin-scale water management.

Introduction

Construction, operation, and maintenance of Falcon Dam and International Reservoir (hereafter referred to as Falcon Lake) was authorized by Article 5 of the February 3, 1944 Water Treaty for the "Utilization of Waters of the Colorado and Tijuana Rivers and of the Rio Grande" between the U.S. and Mexico (1944 Treaty; see Appendix A) for conservation, storage, and regulation of water in the international segment of the Rio Grande from Fort Quitman, Texas to the Gulf of Mexico (IBWC 1944). Falcon Lake encompasses 86,265 acres and has a volume of 2,665,222 acre-feet (AF) at conservation pool elevation (TWDB 2022a), which is 301.2 feet above mean sea level (MSL). The dam contains six discharge gates, three each in the U.S. and Mexico, and supports two hydrolelectric power plants, one each in the U.S. and Mexico (TWDB 2022a). The lake is situated on the international border between the U.S. and Mexico and is located 283 miles upstream of the Gulf of Mexico within Zapata and Starr counties, Texas, and the state of Tamaulipis, Mexico (Figure 1). It is located within the semi-arid South Texas Plains Ecoregion (TPWD 2022) wherein annual rainfall averages 20 inches (U.S. Climate Data 2022). Most of the land surrounding the lake is privately owned, undeveloped, and characterized as shrub/scrub or unimproved pasture (TWDB 2021a). Two census-designated places are adjacent to Falcon Lake on the U.S. side: Zapata (population 5,383 in 2020) and Falcon Heights (population 18 in 2020, U.S. Census Bureau 2020). One city is located on the Mexico-side of the lake, Nuevo Ciudad Guerrero (population 3,451 in 2020; City Population 2022). The nearest Texas metropolitan areas (>50,000 population) are Laredo, situated approximately 49 miles to the north, and McAllen, Texas, located about 80 miles to the south. The population in the Lower Rio Grande Valley (Cameron, Hidalgo, Starr, and Willacy counties) is projected to increase by 11% from 2020 to 2040. However, minimal population change is expected in the counties encompassing Falcon Lake over the same time period (Texas Demographic Center 2021).

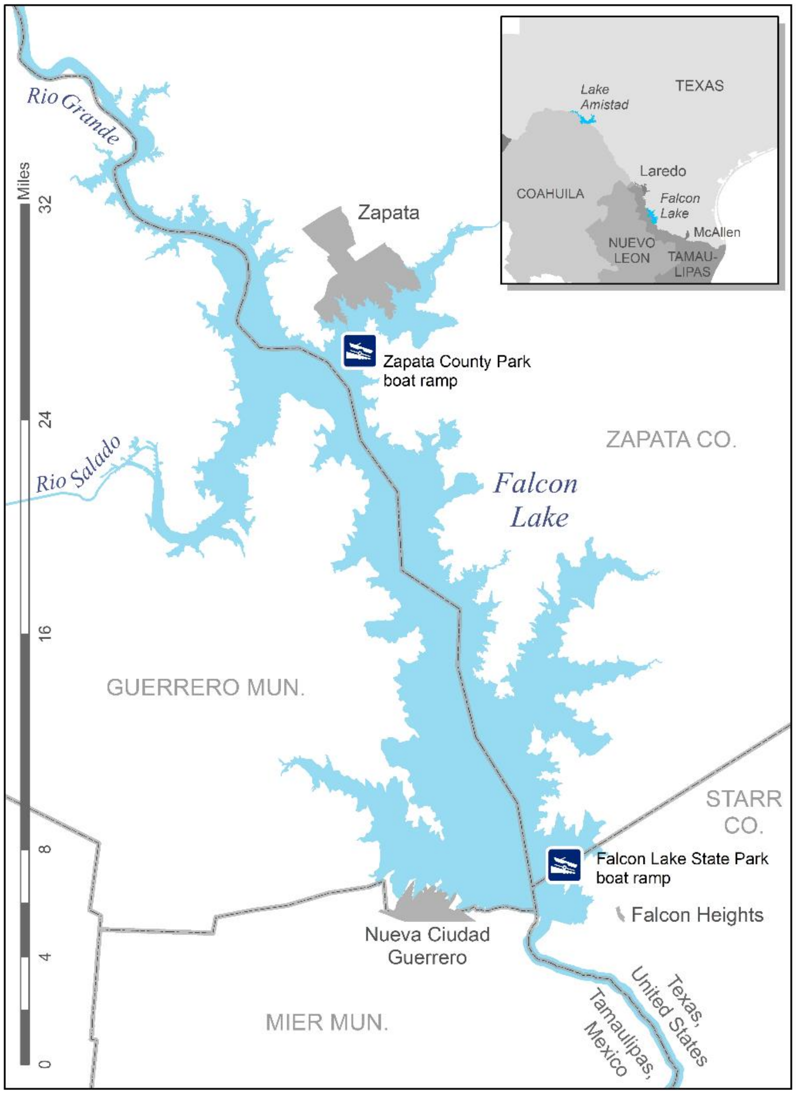

Figure 1. Map of Falcon Lake, boat ramps, and surrounding area.

Falcon Lake has experienced widely fluctuating water levels and prolonged periods during which water levels remained more than 25 feet below conservation pool elevation (Figure 2). The inconstant water level in the lake is due to a myriad of factors, some of which are interdependent. Lake inflow is a culmination of upstream influences, which include Rio Grande flows, tributary inflows, water delivery from Mexico tributaries (including releases from Mexican reservoirs), discharge from Amistad Reservoir (located 288 miles upstream), upstream diversions (water withdrawals), precipitation, and evaporation. Per Article 4 of the 1944 Treaty, Mexico is to supply 350,000 AF annually, measured in 5-year cycles, from their tributaries to the Rio Grande downstream of Fort Quitman, Texas (IBWC 1944). Falcon Lake outflow is comprised of discharge for downstream water rights holders, diversions for lake-adjacent water right holders (e.g., Zapata County), and evaporation. Evaporative losses from Falcon Lake and Amistad Reservoir can be significant, representing up to 23% of the annual flow of the lower Rio Grande basin (Sandoval-Solis and McKinney, 2011). Studies have been conducted examining these and other factors as they relate to water availability and allocation in the Rio Grande system (RJ Brandes Company 2004, Sandoval-Solis and McKinney 2011, Karimov 2016). However, the relative impact each inflow and outflow factor has on water level in Falcon Lake has not been evaluated.

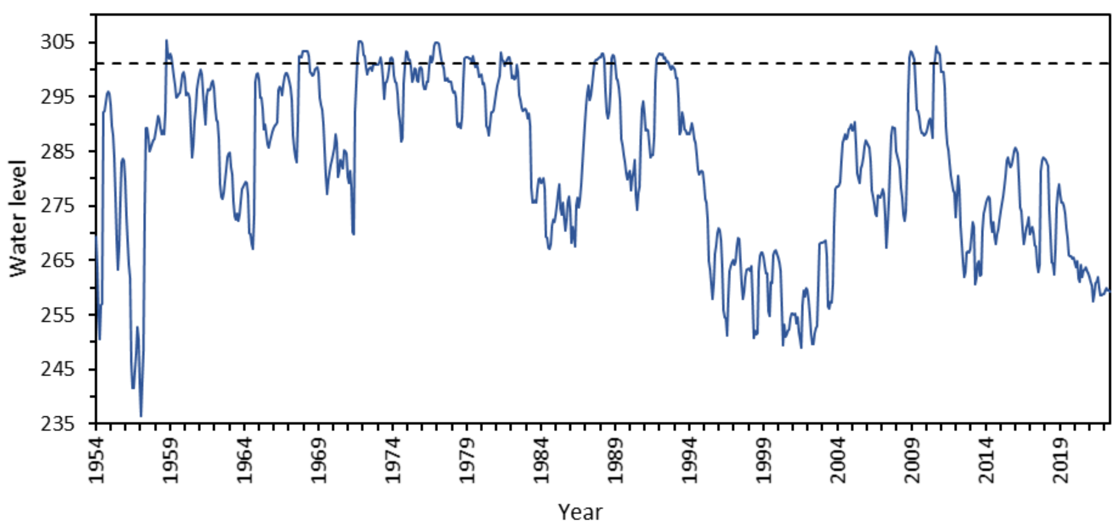

Figure 2. Mean monthly water level (feet above mean sea level) in Falcon Lake from January 1954 to June 2022. Dashed horizontal line represents conservation pool elevation.

Article 2 of the 1944 Treaty established the International Boundary and Water Commission (IBWC), consisting of equitable U.S. and Mexico sections, to implement the policies and activities specified in the treaty. Both sections manage their allotments of water following a hierarchy of preferred uses established in Article 3 of the 1944 Treaty. These are (1) domestic and municipal; (2) agriculture and stock raising; (3) electric power; (4) other industrial uses; (5) navigation; (6) fishing and hunting; and (7) any other beneficial uses, which may be determined by the IBWC (CRS 2018). The U.S. owns 58.6% of the lake's storage capacity at conservation pool elevation (IBWC 1944). Determinations of water ownership for each country are based on previous discharges and current conservation storage and are made weekly by IBWC (IBWC 2022). The Texas Commission on Environmental Quality (TCEQ) and the Comisión Nacional del Agua (CONAGUA) administer each nation's respective share of Falcon Lake water. The TCEQ Rio Grande Watermaster Program (See Appendix A) is responsible for allocating, monitoring, and controlling the use of the U.S. portion of surface water, which is governed by Texas statute. The watermaster requests releases from Amistad and Falcon lakes from the IBWC. The CONAGUA issues permits to Mexican individuals, water-user associations, irrigation districts, and municipalities for water deliveries (Eaton 2013). Both Mexico and Texas have fully appropriated water of the lower Rio Grande (Sandoval-Solis and McKinney 2011, Karimov 2016, Sandoval-Solis et al. 2022). Prior to 1967, Texas water right claims, many of which were unrecorded and unquantified, had various origins and were loosely administered (Templar 2019). The Water Rights Adjudication Act of 1967 allowed certification of previously unrecorded and nebulous water right claims and limited water rights to a specific maximum quantity of water (Templar 2019), but also led to codification of more water rights than water available in the lower Rio Grande. Authorized water rights in the Lower Rio Grande Valley total 4.4 million AF (TCEQ 2022a). Fulfillment of U.S. water rights is prioritized according to the 1944 Treaty. Municipal, domestic, and industrial water rights are effectively assured with respect to timing and quantity, whereas fulfillment of water rights for agricultural irrigation and other purposes is partial and contingent on inflow and current storage in the Amistad-Falcon system (Sandoval-Solis and McKinney 2011, Karimov 2016). Of the total water supplied from Falcon Lake to the Lower Rio Grande Valley, 80-87% is used for agricultural irrigation (Sandoval-Solis and McKinney 2011, Karimov 2016). The Texas Water Development Board (TWDB), established through a state constitutional amendment, prepares regionally specific, long-term plans concerning Texas' water resources, thus has a tangential role in water management at Falcon Lake. Falcon Lake is located within TWDB's Region M, which spans the Rio Grande from the Maverick-Kinney County boundary to the Gulf of Mexico. Plan development involves the assimilation of relevant information from state and federal agencies and public and private stakeholders (e.g., municipalities, water supply companies, irrigation districts, researchers, and other benefactors). These plans prioritize future projects and actions to best develop, conserve, and manage water resources.

Angling, an increasingly popular outdoor activity in Texas (Southwick 2019, ASA 2021), is the primary recreational pursuit at Falcon Lake. The lake's largemouth bass fishery gained national notoriety because of a televised, professional fishing tournament in 2008 (Bass Anglers Sportsman Society's Lone Star Shootout) during which record catches occurred. Thereafter, Falcon Lake was ranked #1 in *Bassmaster Magazine's* top 100 bass lakes in 2012, #7 in 2013, and #12 in 2014. The lake also provides fisheries for channel catfish, blue catfish, black crappie, white bass, and alligator gar (Myers and Dennis

2016). A robust commercial fishery exists on the Mexico side of the lake where gill nets have been used to capture Blue Tilapia and other desirable species, which are sold within Mexico. The Texas Parks and Wildlife Department (TPWD) routinely monitors fish populations, assesses fisheries habitat, and estimates utilization and fish catch by anglers in the lake. These data are assimilated into biennial reports which contain fisheries management recommendations to provide the best possible angling without placing fish populations at risk. Past fisheries enhancement activities conducted by TPWD in Falcon Lake include fish stockings to re-establish populations, increase population abundance, and enhance population genetics, and application of fish harvest regulations to conserve and enhance size structure of fish populations.

Angling has been shown to have high socio-economic importance (Lynch et al. 2016), and this is especially true for rurally located fisheries like Falcon Lake that attract anglers from distant locations. The total economic value of the Falcon Lake fishery has not been estimated. However it is likely substantial given that the upstream Amistad Reservoir recreational fishery was valued at $22.7 million in 2007 (Schuett et al. 2012). Within Texas Congressional District 28, which encompasses Falcon Lake, 88,884 anglers were responsible for $89 million in retail sales and 993 jobs in 2016 (Southwick 2019). Anglers traveling long distances to a fishing location typically fish for multiple days, which generates a localized need for lodging, fuel, food, and fishing supplies. Fishing trip length averaged 5.9 days for non-local anglers at Amistad Reservoir (Schuett et al. 2012). Municipalities benefit from non-local anglers via local taxes. The magnitude that angling impacts a local economy directly corresponds to angler utilization of the adjacent fishery; the more anglers, the greater the impact.

Reservoir water level influences fisheries habitat (Daugherty et al. 2015), fish populations (Hayes et al. 1996), angler utilization (Jakus et al. 2000, Miranda and Meals 2013), and fish catch and harvest (Chizinski et al. 2014). Fisheries habitat in Falcon Lake consists primarily of flooded terrestrial vegetation (Figure 3). When the water level recedes, terrestrial vegetation (e.g., mesquite, retama, huisache, acacia, salt cedar, and various grasses) rapidly colonizes the exposed lake bottom (Myers et al. 2020). When inundated during a subsequent rise in water level, both the quantity and quality of fisheries habitat increases, which leads to increases in fish reproduction and recruitment and formation of strong year classes, which support the fishery in subsequent years (Nisbet and Myers 2018, Myers et al. 2020). The timing and magnitude of change in water level and duration of low- and high-water level periods are important as these factors influence the level of fish production change. Alligator gar recruitment in Falcon Lake was benefitted by high water during spring and increasing water level from spring through summer (Myers et al. 2020). Extreme or prolonged periods of low water level can cause decreases in angling effort, fish catch and harvest, and alter the species composition of catch (Miranda and Meals 2013, Chizinski et al. 2014).


Figure 3. Flooded terrestrial vegetation in Falcon Lake.

Reservoir water level also affects angler access (Platt 2000, Daugherty et al. 2015). Most Falcon Lake anglers fish from boats because nearly all of the shoreline is privately owned. There are two primary boat launch sites at Falcon Lake: Falcon State Park located on the south end of the lake near the dam and Zapata County Park located on the north end of the lake in Zapata, Texas. Multi-lane concrete boat launching ramps are present at both of these locations (Figure 4). There are six private sites with concrete ramps (Juan Vela's, Beacon Lodge, Siesta Shores, Lakefront Lodge, Four Seasons, and Los Lobos) adjacent to residential areas, but these receive minimal use by anglers compared to the two public sites. Useability of all boat launch ramps at the lake is impaired during periods of low water level. Both Falcon State and Zapata County Parks provide boat launch contingencies when low water level limits the use of the multi-lane concrete ramps. Zapata County Park contains a separate single-lane concrete ramp that becomes exposed and available for use when water level is low and Falcon State Park allows boat launching at designated unimproved shoreline locations.

Figure 4. The primary boat ramps and low-water boat launch sites in Zapata County Park (left) and Falcon State Park (right). Photos were taken on July 12, 2020, when water level was was 261.1 feet above mean sea level.

Initial development and subsequent evolution of water policy for the Rio Grande has centered on allocation of water for consumptive use by humans (Sandoval-Solis et al. 2022). An environmental flow recommendations report (LRGBBEST 2012) for the Rio Grande, Rio Grande Estuary, and Lower Laguna Madre downstream of Falcon Lake was prepared in support of the Texas Environmental Flows Process (Senate Bill 3, 80th Legislature, 2007). While TCEQ adopted flow standards for several reaches of the Rio Grande and some major tributaries, no standards were adopted downstream of Falcon Lake. Because no unappropriated water was available, TCEQ did not adopt set-asides of water for the environment as contemplated by the provisions of Senate Bill 3 (see Appendix A for additional context). Although recreation, fishing, and hunting are identified in the hierarchy of preferred water uses listed in the 1944 treaty, these and other non-consumptive uses of water have not been addressed to date in the Rio Grande Regional Water Plan (RGRWP 2020). This study evaluates the impacts of water level on fisheries habitat and the recreational fishery in Falcon Lake and provides a basis for incorporating fisheries considerations into future Rio Grande water management planning and operations.

Methods

Falcon Lake area and volume data corresponding to 0.005-meter water-level increments were obtained from the IBWC and converted to english measures (acres, acre-feet, and feet, respectively) and abbreviated to 0.1-feet water-level increments. Curves describing the relation of water level to lake area and volume were developed using least-squares regression consisting of multi-ordered functions of the predictor variables (e.g., lake $area^2$, $volume^3$). The adjusted r^2 diagnostic was used to select parsimonious models. These curves were used to estimate lake area and volume corresponding to historical and simulated water levels.

Daily water level data were obtained from the IBWC website for the period January 1, 1954 to June 30, 2022 and used to compute mean monthly and average annual water level in feet above MSL. Water level data recorded prior to 1960 were omitted due to rapid lake fill in 1954 followed by an unexplained decline in water level of 65 feet occurring in 1956-1957. Linear regression, modified to account for autocorrelation, was used to evaluate trajectory of mean monthly water level from January 1960 to June 2022. Time-series data, such as monthly water level, are often autocorrelated; water level in a given month is influenced by water level in preceeding months or seasonally. This correlation between successive time intervals can cause the estimated variances of the regression coefficients to be biased, leading to unreliable hypothesis testing (SAS 2014). Therefore, an autoregressive error model was used within the regression procedure to adjust for autocorrelation occurring over the preceeding 1-12 months in 1-month increments. Descriptive statistics (mean, median, 25^{th} and 75^{th} percentiles) were computed for mean monthly water level to provide insight about historic water levels relative to conservation pool elevation. Mean monthly water level was used to calculate water level fluctuation within year. Daily average water level was used to compute the frequency at which water level was higher and lower on September 30, than March 1, of each year, and the magnitude of difference.

Data were obtained for factors that potentially influence Falcon Lake water level. Factors were Rio Grande streamflow (IBWC gage 08-4590.00) recorded 76 miles upstream of the lake (RGFL), local precipitation (PR), flow of the Rio Salado River (IBWC gage 08-4597.00) recorded 25 miles upstream of its confluence with the lake (RSFL), water diversion occurring on the U.S. side between the RGFL gage and Falcon Dam (DIV), local evaporation (EV), and lake discharge as recorded by IBWC gage 08-4613.00 located immediately downstream of Falcon Dam (DIS). These data were aquired from the IBWC staff or website (RGFL, RSFL and DIS), TCEQ's Rio Grande Watermaster staff (DIV), and TWDB website (PR and EV; TWDB 2022b) and spanned from 1960 to 2020. Pearson's correllation analysis was used to assess collinearity among factors and the same analysis procedure described above for evaluating water-level trajectory was used to test for a temporal trend in each factor. Additionally, country-specific discharge from 2010-2021 was provided by IBWC staff. These data were examined to compare the magnitude and timing of discharge between the U.S. and Mexico.

Using the factors described above, a water budget that accounts for flows into and out of the lake annually was developed according to Healy et al. (2007) to determine the relative influence of each factor on lake volume. Inflow and outflow factors used in the budget were standardized to AF. To obtain PR and EV in AF, monthly precipitation and evaporation obtained from TWDB were converted from inches to decimal-feet values, with PR multiplied by mean monthly lake area (computed from the water level-lake area curve) and river area between Falcon Lake and IBWC gage 08-4590.00 (digitized as 5,616 acres in Google Earth®). The water budget was formulated as:

$$\Delta\text{lake volume} = [(RGFL + RSFL + PR) + UNDI] - [(DIS + DIV + EV) + UNDO], \text{ where}$$

Δlake volume is the predicted difference in lake volume on January 1 and December 31. The sum of RGFL, RSFL, and PR represent known total inflow and the sum of DIS, DIV, and EV comprise known total outflow. Lake volumes on January 1 and Decmber 31 were imputed from the water level-lake volume curve. Unidentified inflow (UNDI) and outflow (UNDO) were added to achieve equation equilibrium and deduced as the absolute difference between Δlake volume and actual difference in lake volume on January 1 and December 31. This absolute difference was deemed UNDI for years during which Δlake volume was positive and UNDO during years in which Δlake volume was negative relative to actual differrence in lake volume. Thus, UNDI and UNDO represent the culmination of potential inflow and outflow uncertainities such as ungauged inflow, unaccounted water withdrawals, groundwater impacts, and streamflow measurement error.

A theoretical discharge reduction model was constructed to simulate the impact of discharge reduction on water level. The model operated on a monthly time-step for accurracy, encompassed the last 10 years of data (2011-2020) for recency, used actual monthly PR, RGFL, SAFL, EV, and DIV, and estimated lake volume at the end of each month given discharge over the time period had been reduced by 2-10% in 2% increments. Two water level constraints were included in the model. First, lake volume would reset to conservation pool capacity if lake volume exceeded conservation pool capacity. Second, in response to the need to retain flood control capacity, discharge reductions were disabled in the model when lake volume exceeded 75% of conservation pool capacity (291.2 feet above MSL). End of the month lake level was computed using the water level-lake volume curve.

The minimum water level necessary for safe boat launching was estimated for each concrete boat launch lane in Zapata County and Falcon State parks. The bottom terminus of each submerged lane was located using a metal rod, at which point, a water depth measurement was recorded. This depth measurement was then subtracted from the current water level to determine elevation at bottom terminus. For lanes not submerged, a string was affixed at the bottom terminus and extended in a level position based on a string level to the edge of the water where a measurement was recorded from the level string to the water surface. This measurement was summed with current water level to determine actual elevation at bottom terminus. A minimal water depth of three feet is necessary for safe launching of 16-21 foot fishing boats typically used by Falcon Lake anglers. Therefore, three feet was added to the bottom terminus elevations to determine water level necessary for safe boat launching. Elevation at the top terminus of the separate low-water lane in Zapata County Park was similarily estimated. The number of months that each lane was unusable due to insufficient water level was calculated using historic mean monthly water levels.

Results of fisheries habitat, fisheries-independent (fish populations), and fisheries-dependent (angling pressure) surveys were queried from TPWD-Inland Fisheries Division databases. Six habitat surveys were conducted since 2009 and these estimated percent occurrence of flooded terrestrial vegetation on the U.S. side of the lake in late summer (August-September). Habitat sampling consisted of determining presence-absence at random locations within the lake, with sampling intensity scaled to lake area at time of sampling. A total of 13 standardized fisheries-independent surveys (electrofishing) targeting largemouth bass were conducted from 1998 to 2021 during fall to assess largemouth bass abundance, which was indexed as mean number of fish captured per 1 hour of electrofishing (CPUE). Electrofishing was conducted for five minutes at 24 random sites on the U.S. side of the lake each sample year. Annual largemouth bass CPUE was computed for total fish ($CPUE_t$), sub-adult fish ($\leq$8 inches in length, $CPUE_s$), and legally-harvestable fish ($\geq$14 inches in length $CPUE_{14}$). Fisheries-dependent surveys (creel surveys) were conducted in 2006, 2011, 2016, 2019, and 2022 from January to June, except in 2019 when surveys were conducted from April to September. Total angling effort (hours), total catch (number of fish), and fish catch rate (mean number of fish caught per 1 hour of fishing) were estimated by species in accord with Pollock et al. (1994). Protocols for all fisheries habitat, independent, and dependent surveys conformed with TPWD Fishery Assessment Procedures (TPWD 2017).

The reduction in discharge (DIS) needed to achieve a water-level increase from spring through summer that would benefit fish production was also evaluated. For this analysis, a water-level increase of five feet was selected and the spring summer period was defined as March 1 to September 30. A five feet higher water level from historic median water level (284.8 feet above MSL) yields innundation of 7,990 acres of flooded terrestrial vegetation based on the water level-lake area curve for Falcon Lake, and sportfish species in the lake begin spawning in March. This magnitude of increase in habitat availability would lead to highly successful fish reproduction and greater recruitment of spawned fish to a size less vulnerable to predation, and in turn, development of strong year classes. The percent reduction in DIS needed for water level to be five feet higher on September 30 than on March 1 was computed for years from 1960 to 2020 during which water level was not already five feet higher on September 30 than March 1. Additionally, percent reduction in DIS needed was not computed for years during which water level exceeded 75% of conservation pool capacity on March 1 so to maintain flood control capacity. Percent reduction in DIS needed was calculated as:

$(VOLM_{+5} – VOLS) / DIS_p * 100$, where:

$VOLM_{+5}$ is lake volume corresponding to a water level that is 5 feet higher than water level on March 1, VOLS is volume corresponding to water level on September 30, and DIS_p is total DIS occurring from March 1 to September 30.

Residency of Falcon Lake anglers was evaluated using zip code data collected from anglers during creel survey interviews. Anglers were classified as local (Zapata and Starr counties), non-local Texas (all other Texas counties), or out-of-state (non-Texas residents) based on their home zip code. Percent local, non-local Texas, and out-of-state anglers were computed by creel year. Linear distances from angler home zip codes to Falcon Lake were determined and used to calculate the percent of anglers traveling $\geq$200 miles roundtrip distance and <200 miles round-trip distance to the lake by year. Those anglers traveling $\geq$200 miles were presumed to be on a multi-day trip and those traveling <200 miles on a single-day trip. Additionally, the annual number of freshwater fishing licenses sold in Zapata and Starr County from 2005 to 2021 was obtained from the TPWD license sales database and annual Zapata County hotel tax revenue from 2010 to 2020 was obtained from county officials.

Fisheries habitat, fisheries independent and dependant surveys, angler residency, fishing license, and local hotel tax measures were evaluated relative to water level. Pearson's correlation analyses were conducted to identify significant associations to water level variables when sample size was sufficient ($N \geq 10$). All statistical analyses were performed using SAS, version 9.4 software (SAS 2014) and were considered significant at an alpha of 0.05.

Results

Second order (quadratic) regression models accurately predicted lake area (N = 1,116, P <0.001, adjusted r^2 = 0.999) and volume (N = 1,116, P <0.001, adjusted r^2 = 0.994) using water level (Figure 5). Lake level increases resulted in proportionally greater increases in lake area and volume, which is a product of the relatively flat topography of the lake bottom. For example, a 5% increase in water level from 270 to 283.5 feet MSL yields a 50% increase in lake area (from 37,507 to 56,125 acres) and a 80% increase in lake volume (from 839,199 to 1,508,458 acre-feet). Relatively small changes in water level can substantially affect area and volume of Falcon Lake.

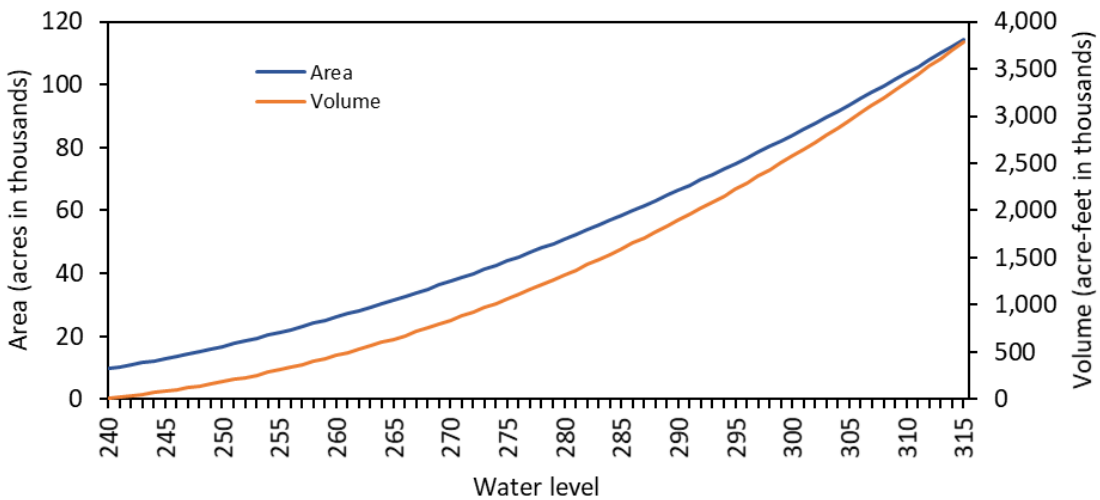

Figure 5. Water level-lake area (acres) and water level-lake volume (acre-feet) curves for Falcon Lake. Water level was recorded as feet above mean sea level.

The regression model, which controlled for autocorrelation of time-series data, revealed a significant decreasing trend in Falcon Lake water level from January 1960 to June 2022 (n= 750, P <0.001, total r^2 = 0.288, Figure 6). High water level, defined as $\geq$297.4 feet MSL (75th percentile), occurred on 14 occassions for a total of 151 months prior to 1990, but on only three occassions for a total of 33 months since 1990. The maximum consecutive duration of high water level was 21 months from 1971 to 1973. Low water level, defined as $\leq$272.5 feet MSL (25th percentile), occurred on 7 occassions for a total of 22 months prior to 1990 and on 9 occassions for a total of 171 months since 1990. The maximum consecutive duration of low water level was 118 months from 1995 to 2003. Median monthly lake level was 284.8 feet above MSL, indicating that 50% of the time water level was at least 16.4 feet below conservation pool elevation.

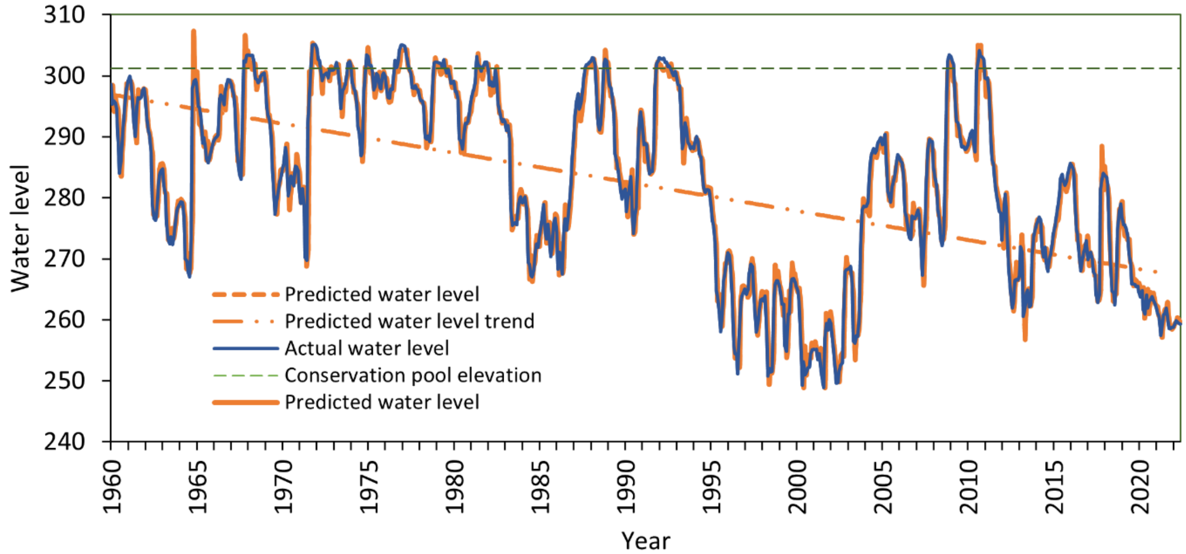

Figure 6. Mean monthly actual and predicted water level (feet above mean sea level) with linear trendline for Falcon Lake from 1/1960 to 6/2022.

Water level in Falcon Lake has fluctuated widely since 1960 with mean monthly water level ranging from 249 to 305 feet above MSL. Lake area estimates corresponding to these low and high water level marks were 15,981 and 93,977 acres, respectively. Intra-year water level fluctuations ranged from 3 to 35 feet and averaged 14 feet. Water level typically decreased from spring through summer, the period during which fish reproduce and recruit to juvenile size. Water level was lower in 41 of the 62 years (66%) on September 30, than on March 1 (Figure 7). Spring through summer water level decreases ≥5 feet occurred in 42% of years resulting in lake size reductions ranging from 6,009 to 32,823 acres (average = 14,995 acres). Spring through summer water level increases ≥5 feet occurred 10 years (16%) resulting in lake size increases ranging from 8,860 to 35,227 acres (average = 17,438 acres). The most recent spring-summer water level increase was in 2015 (6.1 feet).

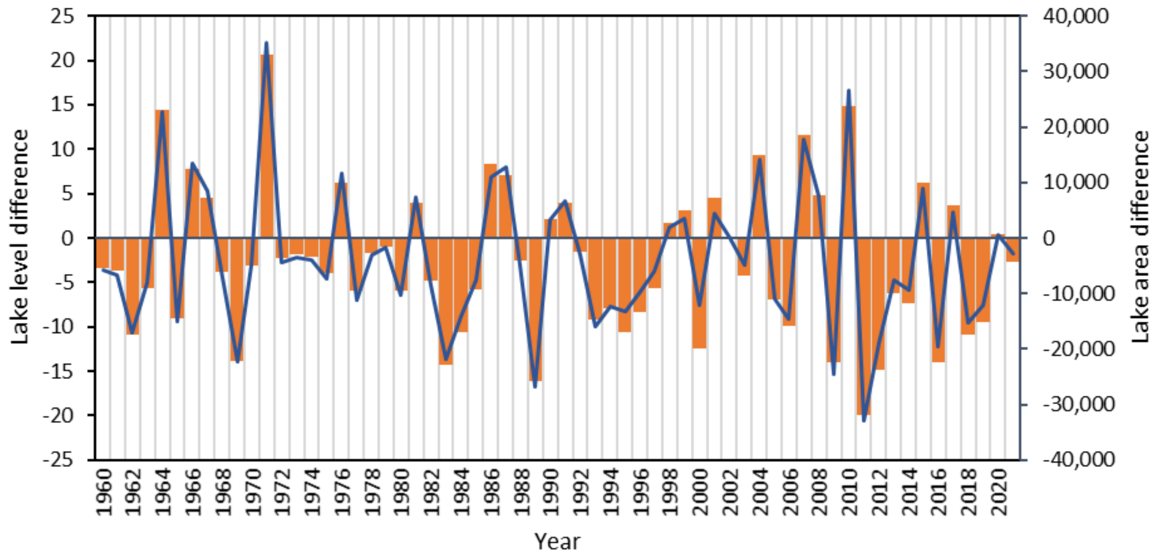

Figure 7. Difference in lake level (feet) and lake area (acres) between March 1, and September 30, for each year from 1960 to 2021.

Collinearity existed among factors that influence Falcon Lake water level. Annual PR and EV were inversly related (c = -0.39, P = 0.002, N = 61) indicating evaporation was lower in wet years and greater in dry years. Weak to moderate associations existed between PR and RGFL (c = 0.25, P = 0.048, N = 61) and RSFL (c = 0.43, P < 0.001, N = 61) implying that Rio Grande and Rio Salado River flows increased as local PR increased. As expected, DIS and RGFL were positively related (c = 0.63, P <0.001, N = 61) indicating DIS increased as RGFL increased, however the strength of this correllation was more moderate (c = 0.40-0.60) than strong (c = 0.60-1.00), which suggests that factors other than RGFL influence DIS. A positive correlation also existed between DIS and DIV (c = 0.35, P =0.007, N = 61) indicating water quantity released from the reservoir corresponded to water quantity withdrawn from the reservoir proper and river upstream to IBWC gage 08-4590.00. Autocorrelation was identified for each of the factors. However, when controlled for, no significant temporal trends existed in PR, EV, DIV, DIS, RSFL, and RGFL (P = 0.147-0.836, N = 732 months). This suggests that no factor was singularly responsible for the long-term decrease in water level.

Discharge by the U.S. and Mexico varied widely among years and U.S. discharge exceeded Mexican discharge in all but one year from 2010 to 2021 (Figure 8). Discharge was greatest for both countries in 2010 when water level increased 26 feet over a 3-month period surpassing conservation pool elevation, which prompted flood and safety concerns, resulting in a 2-week lake closure. Discharge by the two countries trended similarly, decreasing from 2010 to 2015 to <0.3 million AF, then increasing in 2016 to 0.9-1.0 million AF and remaining at this level before discharge began declining again in 2020 for Mexico and in 2021 by the U.S.. Total discharge over the 12-year period was 23% greater for the U.S. than Mexico. Monthly discharge was significantly related to mean monthly water level for both the U.S. ($c = 0.29$, $P < 0.001$, $N = 132$) and Mexico ($c = 0.35$, $P < 0.001$, $N = 132$). Monthly U.S. discharge was unrelated to monthly PR_d ($c = 0.12$, $P = 0.159$, $N = 132$), but was significantly related to monthly EV_d ($c = 0.26$, $P = 0.002$, $N = 132$). Thus, U.S. discharge increased with increasing water level and evaporation. Discharge was highest in July-August for the U.S. and April-May for Mexico. However, in June, between these high discharge months, discharge was considerably lower (Figure 9).

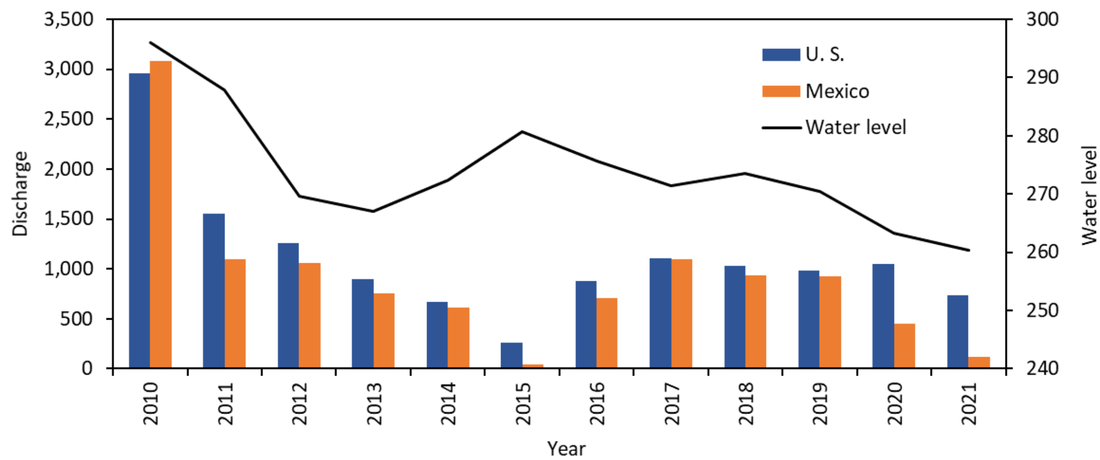

Figure 8. Annual discharge (in thousands of acre-feet) from Falcon Lake by country from 2010 to 2021. Mean annual water level (feet above mean sea level) is shown for reference.

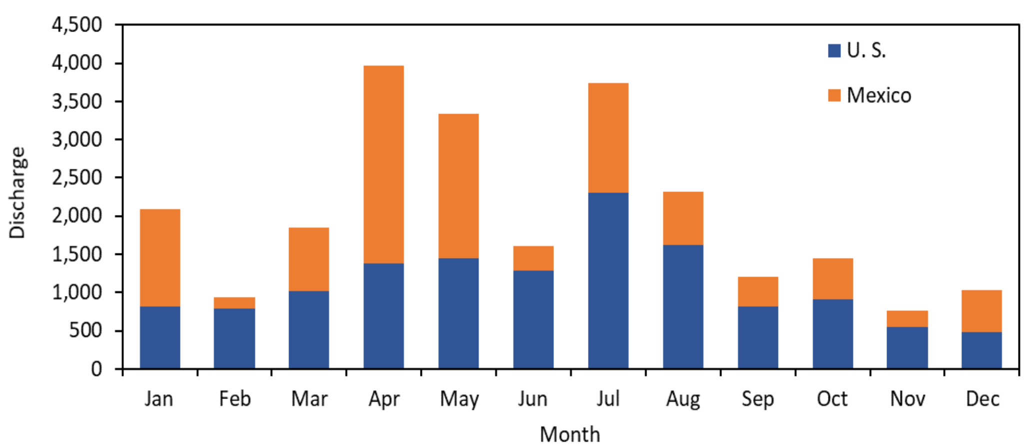

Figure 9. Total discharge (in thousands of acre-feet) from Falcon lake by month and country from 2010 to 2021.

The water budget formulated for Falcon Lake was accurate. Lake volume difference between January 1 and December 31 predicted by the budget closely aligned with actual volume difference in most years. Inflow and ouflow factors used in the budget (RGFL, RSFL, DIS, DIV, PR, and EV) together accounted for 86-100% (average = 95%) of the actual difference in lake volume (Figure 10). Percent contribution of undetermined inflow (UNDI) and outflow (UNDO) ranged from <1-14% (average = 5%) across years. The budget underestimated volume difference in 27 years by an average of 101,858 AF and overestimated volume difference in 34 years by an average of 187,593 AF. The greatest absolute difference between actual and budget-derived volume difference was in 2010 (630,458 acre-feet) when flood conditions caused inflow and outflow to exceed conservation capacity by 301% and 245%, respectively. The principle inflow and outflow factors were RGFL and DIS, respectively. On average, RGFL contributed 84% (range 50-95%) of total inflow and DIS comprised 83% (range 52-93%) of total outflow (Appendix A). Mean annual RGFL (2,073,511 AF) and DIS (2,104,033 AF) were similar over time since 1960 (Figure 11). However, during the most recent 10 years (2011-2020), DIS exceeded RGFL by 16%. Likewise, contribution of RSFL to total inflow ranged widely across years, from 1% to 40%. The sum of RGFL and RSFL was 4% less than DIS during the last 10 years. In all years, outflow attributed to EV exceeded inflow attributed to PR. On average, EV accounted for 14% (range = 6-47%) of total outflow and PR comprised 5% (range = 2-13%) of total inflow. The greatest contribution of EV to total outflow was in 2015 (47%) when DIS was lowest over the 61-year period. The least impactful outflow factor was DIV, which accounted for <1% of total outflow on average.

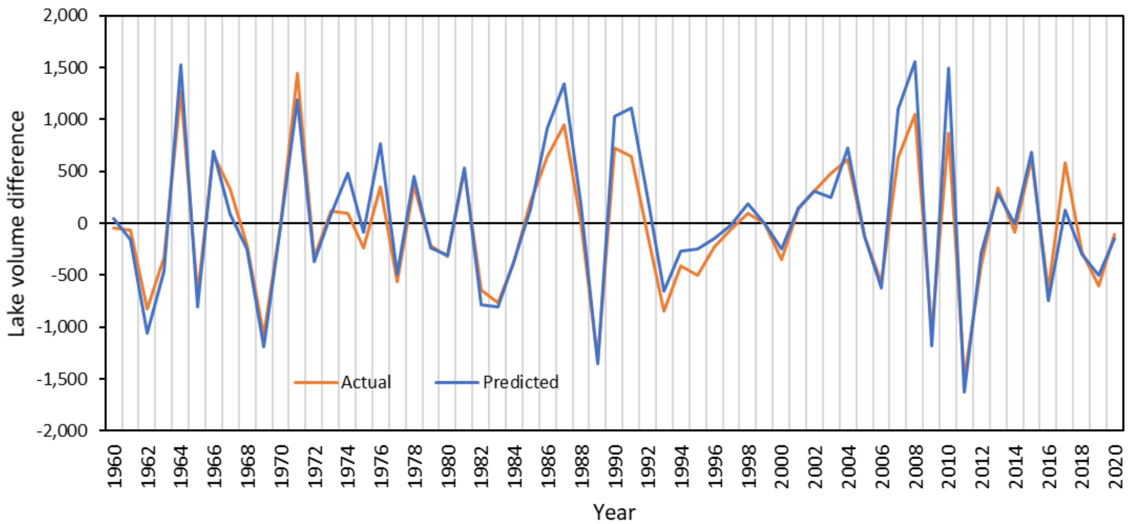

Figure 10. Actual and predicted difference in lake volume (in thousands of acre-feet) between January 1 and December 31 each year from 1960 to 2020. Predicted difference was derived from a water budget model.

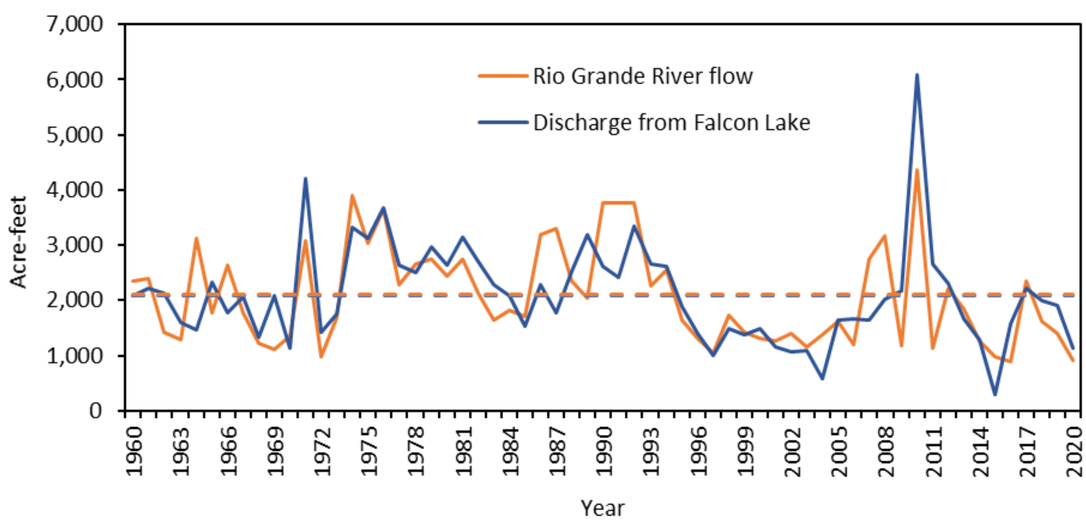

Figure 11. Total annual discharge from Falcon Lake and annual flow of the Rio Grande measured 76 miles upstream of the lake from 1960 to 2020. Both metrics are in thousands of acre-feet. Dashed horizontal lines represent annual averages over the entire time period.

The theoretical discharge reduction model revealed that small reductions in DIS would have a dramatic positive effect on water level over time. Although discharge reductions up to 10% yielded small increases in water level initially (2011-2012), the culmination of annual discharge reductions over time resulted in large increases in water level in later years (Figure 12). The model predicted that initiation of a 4% reduction in total discharge in January 2011 caused water level to be 4 feet higher three years later (2014), 7 feet higher six years later (2017), and 13 feet higher nine years later (2020) compared to actual water level. The magnitude of discharge reduction had a large effect on water level in subsequent years. A discharge reduction of 2% yielded a water level 8 feet higher than actual water level in December 2020, whereas a discharge reduction of 10% caused water level to be 31 feet higher than actual water level in December 2020. In the 4% total discharge reduction scenario, an average of 69,286 AF of water (range = 11,760-92,593 AF) would be retained in the lake annually that would have otherwise been discharged. Total discharge is shared unequally between the two countries; the U.S. share of total discharge during the 10-year period was 56%. Thus, if Mexican discharge was unchanged, U.S. discharge reductions of 3.6% and 7.2% would be necessary to achieve total discharge reductions of 2% and 4%, respectively.

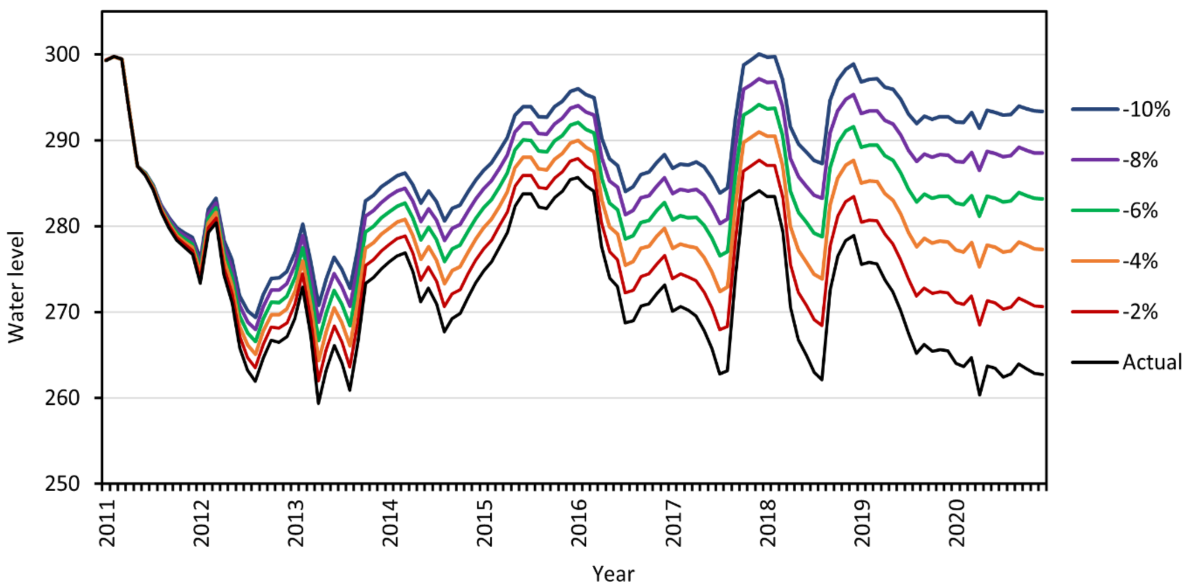

Figure 12. Actual water level and predicted water level (feet above mean sea level) had monthly discharge been reduced 2-10% in 2% increments in Falcon Lake from 2011 to 2020.

Boating access at Falcon Lake was mildly impacted by water level from January 1960 to June 2022. However, the impact was greater during the last decade. The minimum water level necessary for safe launch of boats at the Falcon State Park boat ramp was 264.5 feet above MSL for the two center lanes and 267.5 feet above MSL for the four outside lanes (Table 1). Based on historic water levels, the two center lanes were unuseable in 15% of months and the four outer lanes were unuseable in 20% of months (Table 1). In 10 years, no lanes in Falcon State Park were useable for >50% of the year. In Zapata County Park, the minimum water level necessary for safe launch of boats was 259.1 feet above MSL for the two east lanes lanes, which were unusable in 7% of months, and 262.9 feet above MSL for the 3 west lanes, which were unusable in 12% of months. In 5 years, none of the lanes were useable for >50% of the year. The separate low-water lane in Zapata County Park was unuseable for 4% of months. Most impacts to boating access coincided with the prolonged period of low water levels occurring from 1995 to 2003 (Figure 13). Overall, boat-based anglers could launch their boats on concrete lanes in Zapata County Park 93% of the time and in Falcon State Park 85% of the time. However, boating access was more severely impacted by low water levels during the most recent 10 years. Falcon State Park ramp was useable 66% of the time and three of the five lanes at Zapata County Park were useable 75% of the time. Had annual total discharge been 2% less since 2011, boating access would have been susbstantially improved. The Falcon State Park boat ramp would have been unusable only 7% of the time and the number of lanes available for launch of boats in Zapata County Park would have been reduced only 1% of the time.

Table 1. Falcon Lake water level elevation necessary (in feet above mean sea level) for safe launching of motorized watercraft at Falcon State Park and Zapata County Park concrete boat ramps by lane designation. Also shown for each ramp and lane combination are percent of total months boat launching lanes were unusable and number of years boat launching lanes were unusable for ≥50% of the year from 1/1960 to 6/2022 because of insufficient water level.

Ramp	Lane designation	Elevation necessary	Percent unusable	Number years unusable ≥50% of year
Falcon State Park	2 center lanes	264.5	15	10
	4 outside lanes	267.5	20	14
Zapata County	2 east lanes	259.1	7	5
	3 west lanes	262.9	12	6
	Low water lane	255.9	4	3

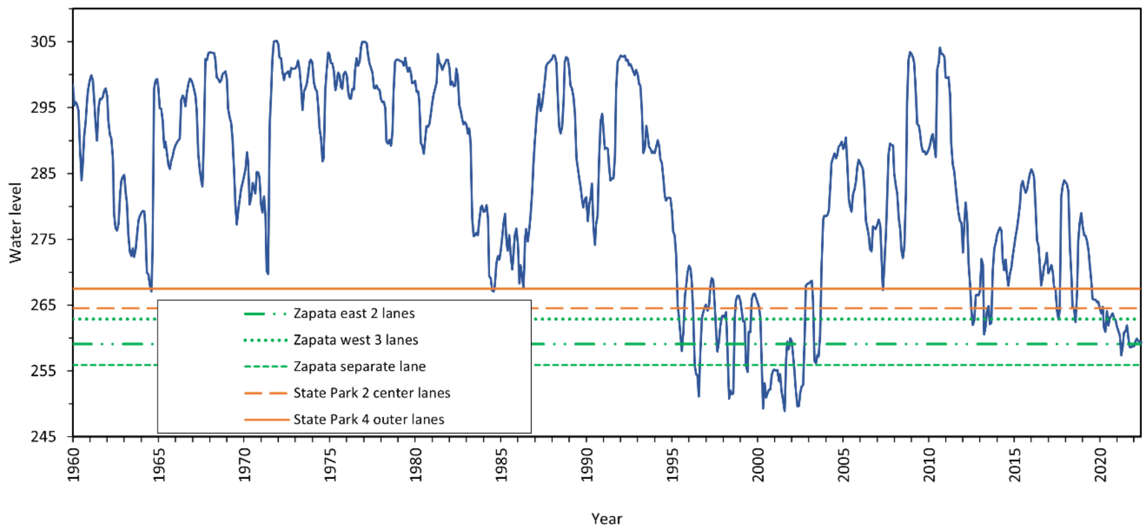

Figure 13. Water level elevations (feet above mean sea level) necessary for safe boat launching at Falcon State and Zapata County Parks by lane designation relative to mean monthly water level from 1/1960 to 6/2022.

Occurrence of flooded terrestrial vegetation (i.e., availbility of fisheries habitat) ranged from 8 to 68% across the six survey years and corresponded with water level (Figure 14). Flooded terrestrial vegetation was lowest in 2021 (8% occurrence), which was preceeded by a 3-year period (2019-2021) during which water level decreased by 16 feet. Conversely, flooded terrestrial vegetation was greatest in 2009 (68% occurrence), which followed a three-year period (2007-2009) during which water level increased by 25 feet.

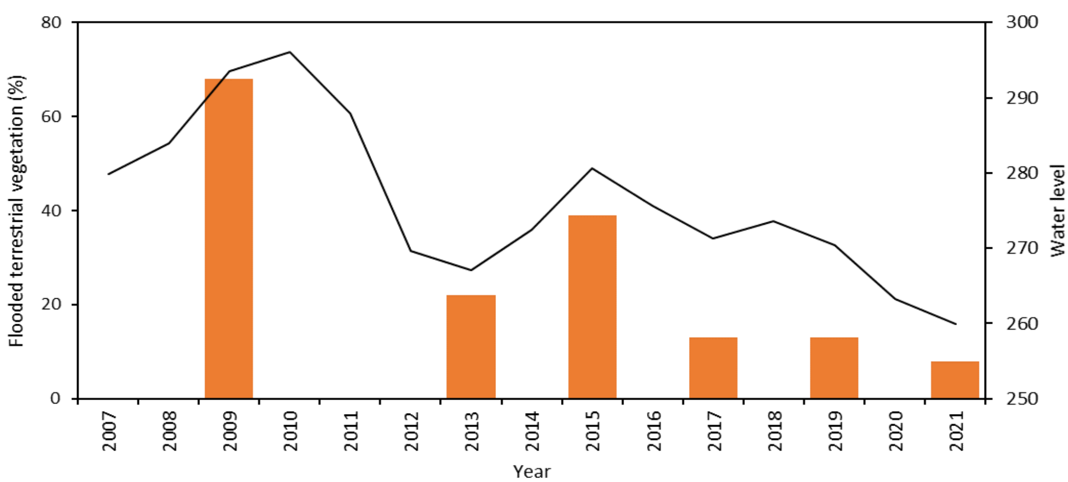

Figure 14. Percent occurrence of flooded terrestrial vegetation (bars) according to habitat surveys conducted during late summer in six years from 2009 to 2021 in Falcon Lake. Average annual water level (feet above mean sea level) is depicted by the line.

Largemouth bass population abundance varied over time, with $CPUE_t$ ranging from 15 to 92 fish/hour, $CPUE_s$ ranging from 0 to 67 fish/hour, and $CPUE_{14}$ ranging from 0 to 26 fish/hour. Largemouth bass $CPUE_t$ and $CPUE_s$ generally corresponded to water level (Figure 15). In 2001-2002, when water level was lowest, averaging 255.6 feet above MSL, $CPUE_t$ and $CPUE_s$ averaged 27 and 2 fish/hour, respectively, whereas in 2015 when water level was 25 feet higher, $CPUE_t$ and $CPUE_s$ were highest (92 and 67 fish/hour, respectively). The high CPUEs in 2015 corresponded to a spring-summer water level increase of 6.1 feet and the lowest annual DIS occurring during the 1998-2021 period. Statistically significant associations did not exist between any largemouth bass CPUE metric and mean water level during the survey (c = -0.14-0.38, P = 0.025-0.956, N = 13) and mean water level during the previous two years (c = 0.21-0.51, P = 0.073-0.494).

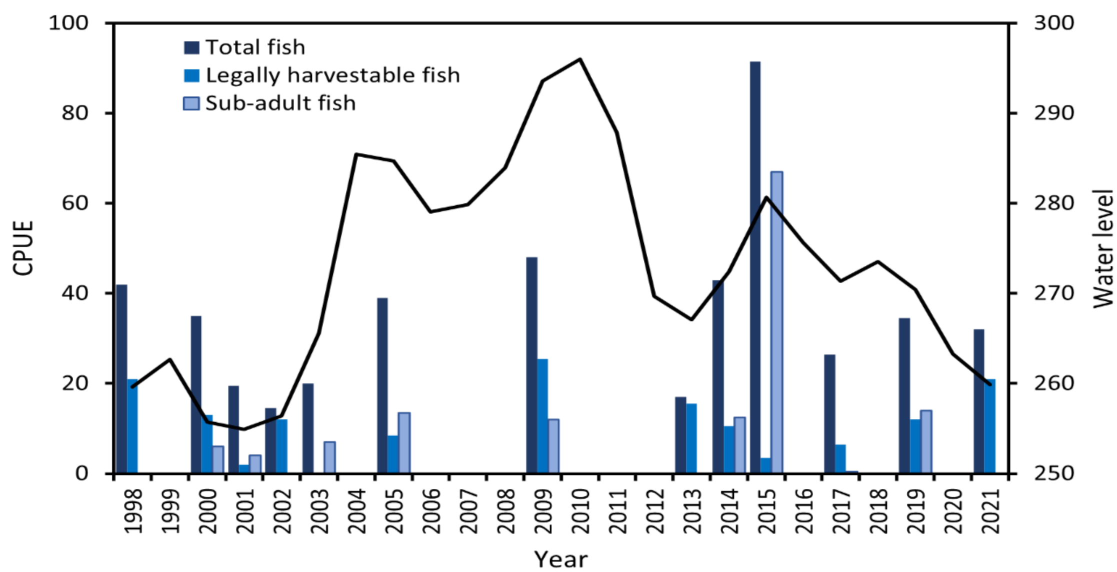

Figure 15. Electrofishing catch-per-unit-effort (mean number of fish per hour of sampling, CPUE) of total, legally-harvestable (≥14 inches in length), and sub-adult (<8 inches in length) largemouth bass in Falcon Lake from 1998 to 2021. Average annual water level (feet above mean sea level) is depicted by the line.

Total angling effort varied substantially among creel survey years, ranging from 40,947 hours to 123,898 hours (Figure 16). Angling effort was lowest in 2022 (40,947 hours) when water level was lowest. Angling effort in 2006 was also very low (50,939 hours). However, this survey was conducted prior to media publicization of the lake's largemouth bass fishery. Angling effort was highest in 2019 when the 6-month survey was conducted from April to September instead of from January to June.

Angling effort directed towards largemouth bass comprised 74-95% of total angling effort (Table 2). Angling effort targeting black crappie increased over time, while angling effort directed towards alligator gar and white bass was low and variable. Total catch and catch rate varied among creel survey years for all species. Largemouth bass total catch was lowest in 2022 (17,207 fish) when water level averaged 259 feet above MSL and greatest in 2011 (144,177 fish) when water level averaged 288 feet abobe MSL. Average catch rate of largemouth bass was lower in recent years ranging from 0.36-0.59 fish/hour in 2019-2022, whereas it exceeded 1.04 fish/hour from 2006 to 2016 when water level was higher.

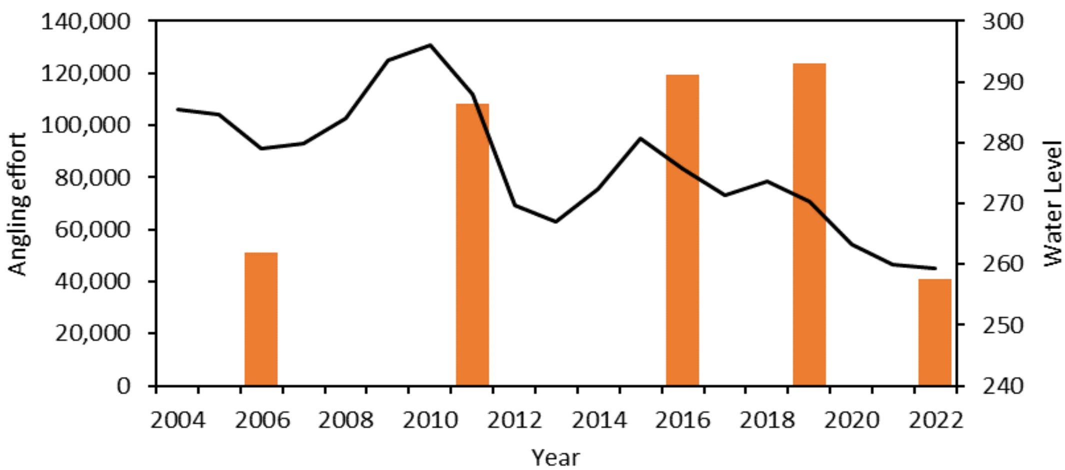

Figure 16. Total angling effort (in hours, bars) by year according to creel surveys conducted from January to June, except in 2019 (April-September), in Falcon Lake. Average annual water level (feet above mean sea level) is depicted by the line.

Table 2. Creel survey statistics for important sport fishes in Falcon Lake in 2006, 2011, 2016, 2019, and 2021. Creel surveys were 6 months in duration and conducted from January to June except in 2019 (April-September). Angling effort (total hours fished) and catch rate (mean catch/1 hour of angling) were derived for anglers targeting the indicated species, while catch represents total number of fish caught regardless of species targeted.

Species	Year	Effort	Catch	Catch rate
Alligator gar	2006	160	0	0.0
	2011	0	0	n/a
	2016	1,668	187	0.11
	2019	4,202	85	0.04
	2022	2,191	87	0.06
Black crappie	2006	0	0	-
	2011	477	2,048	1.86
	2016	1,342	2,234	1.17
	2019	2,307	7,188	0.57
	2022	2,701	9,669	0.98
Catfishes	2006	8,308	12,714	1.2
	2011	5,213	15,065	2.7
	2016	4,224	2,111	0.83
	2019	5,693	2,264	0.37
	2022	4,617	2,656	0.74
Largemouth bass	2006	42,472	80,542	1.41
	2011	99,654	144,177	1.17
	2016	110,930	115,114	1.02
	2019	108,008	57,211	0.36
	2022	30,089	17,207	0.59
White bass	2006	0	0	n/a
	2011	0	0	n/a
	2016	0	725	n/a
	2019	1,008	30,616	4.25
	2022	0	4,273	n/a

Percent reduction in DIS needed to achieve a five feet higher water level on September 30 than on March 1 was calculated for 27 of 61 years from 1960 to 2020. Water level was either five feet higher on September 30 than on March 1, exceeded 75% of conservation pool capacity on March 1, or both in the other 34 years. Percent reduction in DIS needed to achieve a five feet higher water level ranged from 1 to 80% and averaged 37% (Figure 17). Over the 1960-2020 time series, reducing DIS to achieve a five feet higher water level on September 30 was more frequently applicable from 1990 to 2020 than from 1960 to 1990.

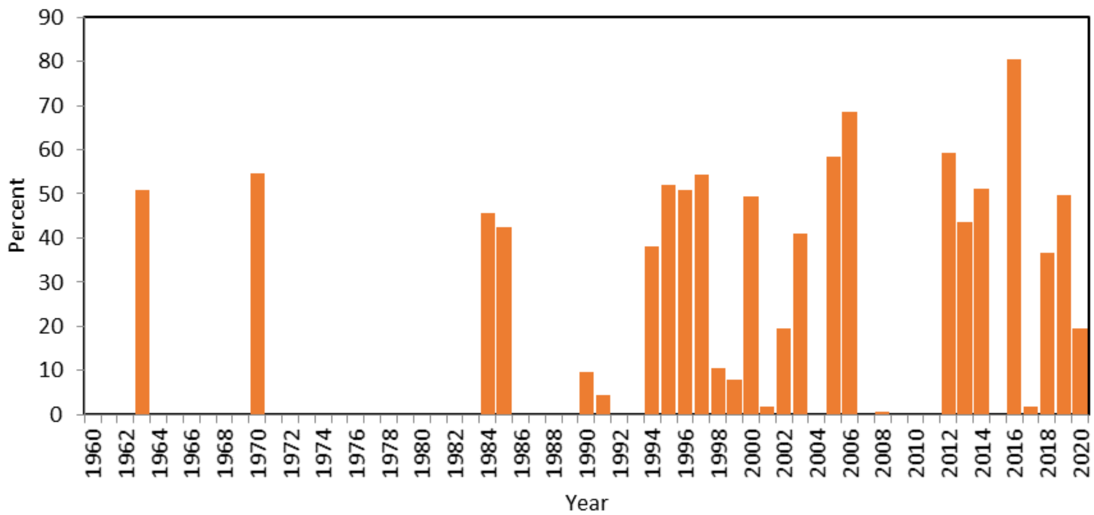

Figure 17. Percent reduction in discharge necessary to achieve a five feet higher water level on September 30, than on March 1, in Falcon Lake by year from 1960 to 2020. Years for which percent reduction in discharge is not shown are years during which water level exceeded 75% of conservation pool capacity, water level was five feet higher on September 30 than on March 1, or both.

The home-residency composition of Falcon Lake anglers varied among years (Tables 3). Local residents (Zapata and Starr county) comprised 24-52% of all anglers across creel survey years. In 2022, when water level was lowest, the percent of local anglers was highest (52%) and the percent of non-local Texas anglers was lowest (28%). In 2006, prior to media publicization of the lake's largemouth bass fishery, out-of-state anglers represented only 1% of all anglers. However in subesequent years, home residency composition shifted to proportionately more out-of-state anglers (10-20%). A high number of angling trips to Falcon Lake were likely multi-day, as 29-54% of anglers traveled a round-trip distance of more than 200 miles from their home zip codes. The percent of anglers traveling more than 200 miles was highest in 2016 (54%). Most recently in 2022, 35% of anglers traveled more than 200 miles to fish in the lake.

Table 3. Percent of Falcon Lake anglers residing locally in Zapata and Starr counties, non-local Texas counties, and out-of-state. Home residency zip codes were collected from anglers interviewed during creel surveys.

Year	Local	Non-local Texas	Out-of-state	<200 miles	≥200 miles
2006	46	53	1	71	29
2011	24	61	15	50	50
2016	26	61	13	46	54
2019	35	55	10	55	45
2022	52	28	20	65	35

The total number of annual freshwater fishing licenses sold in Zapata and Starr Counties ranged from 1,105 to 5,490. License sales were lowest in 2005, steadily increased through 2011, and remained consistent, except in 2020 (Figure 18). The largest year-over-year increase was from 2010 to 2011 (78%), which was one year after the lake filled to conservation pool elevation. The second largest year-over-year increase occurred from 2019 to 2020 (65%). This 2020 spike in license sales coincided with a 25% statewide increase in fishing license sales over the same time frame, which has been attributed to greater participation in outdoor recreational activities, including angling, during the COVID-19 pandemic. Total license sales was negatively related to water level (c = -0.52, P = 0.032, N = 17).

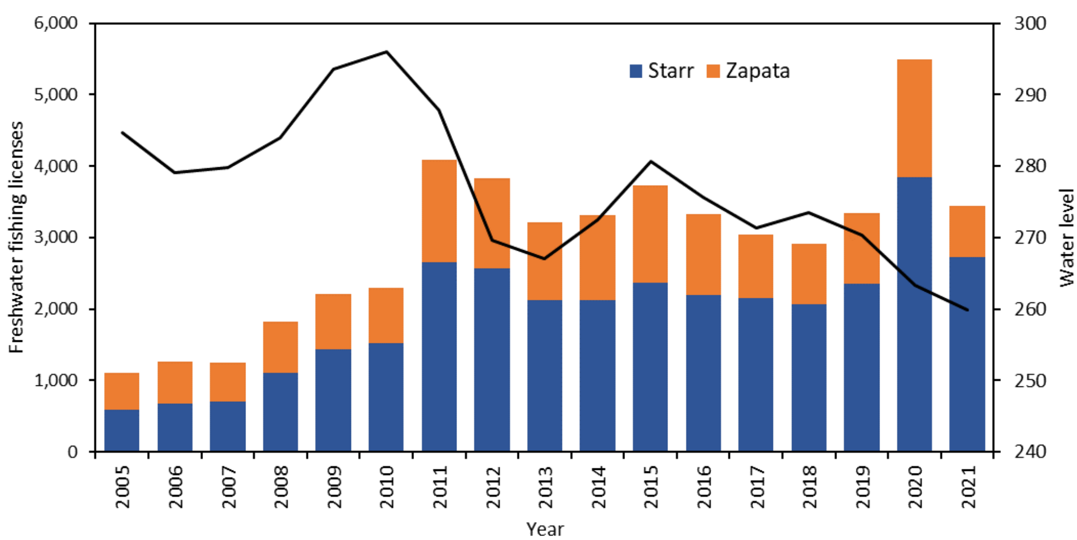

Figure 18. Number of freshwater fishing licenses sold in Starr and Zapata counties from 2005 to 2021 by license year. Average annual water level (feet above mean sea level) is depicted by the line.

Annual hotel tax revenue collected by Zapata County was highest in 2014 ($217,160) and lowest in 2019 ($94,198; Figure 19). Average annual tax revenue was lower from 2016-2020 when water level was declining ($109,510) compared to prior years ($182,651). However, annual tax revenue was not significantly related to water level (c = 0.47, P = 0.148, N = 11).

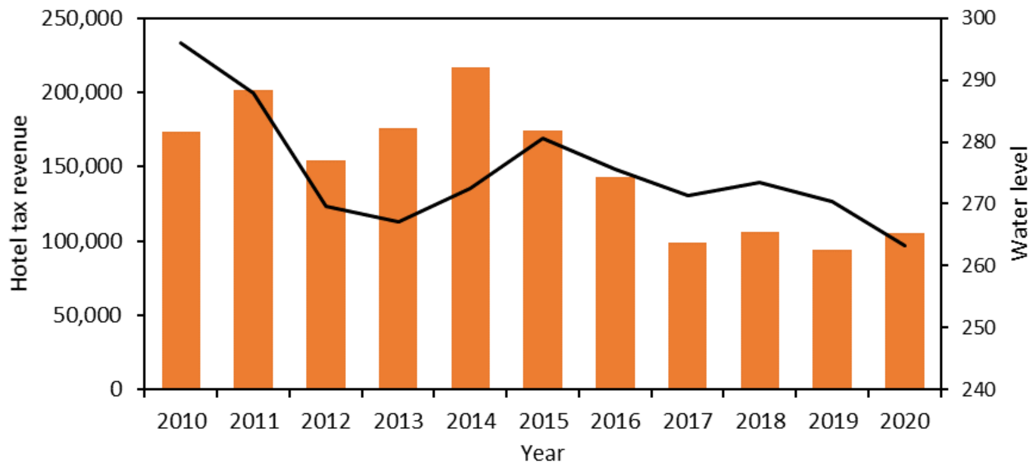

Figure 19. Annual Zapata County hotel tax revenue ($) from 2010 to 2020. Average annual water level (feet above mean sea level) is depicted by the line.

Discussion

This study examined relationships among water availability, water management, and recreational fisheries at Falcon Lake. The principal reservoir inflow factor controlling water level was RGFL, which accounted for 84% of total inflow on average. Although a statistically significant trend did not exist for RGFL since 1960, examination of historic data reveals that Rio Grande flow immediately upstream of the Falcon Lake diminished substantially over the course of the 20th century. Average annual flow at Laredo, Texas (IBWC gage 08-4590.00) was 32% lower following construction of Falcon Lake in 1954 (2.1 million AF) than from 1900 to 1953 (3.2 million AF). Subsequent upstream actions, such as construction of additional storage reservoirs and increased diversions to support population growth in river-adjacent municipalities have likely reduced inflow into Falcon Lake and availability of water for lower Rio Grande users beyond initial expectations when the dam was constructed. The principal outflow factor controlling water level was DIS, which is managed by TCEQ to fulfill water requests of downstream water right holders. Since 1960, average annual DIS (2,104,033 AF) and RGFL (2,073,511 AF) were very similar. However, DIS has exceeded RGFL in seven of the last ten years, by a total of 16%. Other inflow (RSFL and PR) and outflow factors (EV) influenced water level. However, these were not responsible for the recent water level decline. Average annual contribution of RSFL and PR to total annual inflow over the last ten years (10% and 4%, respectively) differed little from 1960-2020 averages (9% and 5% respectively). Likewise, average annual contribution of EV to total outflow over the last ten years (15%) was similar to the 1960-2020 average (14%). Therefore, the 28-feet decline in water level over the recent 10-year period to 40 feet below conservation pool elevation is largely attributable to water releases for water right holders (DIS) exceeding RGFL.

When newly constructed, reservoirs are typically most fertile as inundated vegetation decomposes, releasing nutrients into the system (McCartney et al. 2018). This supports rapid fish colonization of the new, large, lentic habitat and explains why reservoir fisheries are typically most productive during the first decade following construction (Miranda and Meals 2013). Sportfishing effort and harvest (Jenkins and Morais 1971) and fish growth rate (Miranda and Durocher 1986) in reservoirs are highest soon after impoundment. However, as reservoirs age, fertility and fisheries habitat typically decline, which causes fish production to also decrease, and aging reservoirs generally support sport fisheries inferior to new reservoirs. However, water level fluctuations can rejuvenate fish populations in older reservoirs that have relatively flat basins, like Falcon Lake. The timing, frequency, and extent of water level fluctuation influences the magnitude of a fisheries' response. A water level increase that is substantial, occurs from spring through summer, and is preceded by a low water level period of sufficient length to allow establishment of a terrestrial vegetation community is ideal to maximize reproduction and recruitment of forage and sport fishes in Falcon Lake (Myers et al. 2020). Since 2000, there were four instances of water level increases meeting these criteria (2004, 2007, 2010, and 2015). During these events, water level rose 6-16 feet from spring through summer, resulting in lake sizes increases of 20-40% and inundation of 8,860-26,683 acres of terrestrial vegetation. In 2004, 2007, and 2015, DIS was 69-236% lower than RGFL, hence the increase in water level. In 2010, however, DIS exceeded RGFL by 28%, but DIS and RGFL were 110% and 189% greater than average annual DIS and RGFL, respectively. This was due to remnants of Hurricane Alex causing flooding throughout the middle and lower Rio Grande regions and water level in Falcon Lake to exceed conservation pool elevation. Lower DIS relative to RGFL in 2004, 2007, and 2015, may have been in part due to above average precipitation downstream of the lake reducing the need to send water downstream for agricultural irrigation. Precipitation in the Lower Rio Grande Valley (quadrangles 1109-1110 and 1210; TWDB 2022b) exceeded the 1960-2020 annual average (25 inches) by 5% in 2004, 16% in 2007, and 39% in 2015. Fisheries habitat, fish population and sport fishery data were not collected annually, but on a predetermined interval basis over the period encompassing the 2004, 2007, 2010, and 2015 water level increases. Thus, evaluating the habitat and fisheries response of each water increase was not possible. However, the 2007 and 2015 water level increases at Falcon Lake yielded increases in largemouth bass abundance and catch. The highest largemouth bass $CPUE_t$ and $CPUE_s$ recorded for the lake coincided with the 2015 water level rise and the second highest $CPUE_t$ occurred two years following the 2009 water level rise. The highest largemouth bass catches on record, 144,177 in 2011 and 115,114 fish in 2016, occurred one year after the 2010 and 2015 water level increases. From a fisheries production standpoint, a fluctuating water level is advantageous over a stable water level in Falcon Lake because, apart from flooded terrestrial vegetation, which is a product of water level fluctuation, no other significant fisheries habitat such as boat docks and aquatic vegetation are present in the lake. Water level fluctuation in Falcon Lake provides periods during which fish production and fishery metrics are increased, whereas a stable water level would likely lead to consistent but low fish production and a depressed sport fishery.

Reservoir water level can impact angler access (Platt 2000, Daugherty et al. 2015) and angler utilization (Jakus et al. 2000, Miranda and Meals 2013). This was the case at Falcon Lake in recent years. Low water level resulted in decreased angler utilization, proportionally fewer non-local Texas anglers, and reduced angler access. In 2022, when water level was lowest, total angling effort was lowest (40,947 hours) and the percent of anglers traveling a round-trip distance of more than 200 miles to the lake (35%) was the second lowest recorded. The Falcon State Park ramp was unuseable 33% of the time and three of the five lanes at Zapata County Park were unuseable 8% of the time (Figure 19).

Figure 19. View from the top of the boat ramp at Falcon State Park on July 6, 2022, showing closed boat ramp and terrestrial vegetation growth on the exposed lake bottom.

The sum of lower angler utilization, proportionally fewer anglers making overnight trips to the lake, and reduced angler access likely diminished the economic impact the Falcon Lake recreational fishery had on the local economy in recent years. Annual average local hotel tax collected by Zapata was 40% lower from 2016 to 2020 ($109,510) when the water level averaged 30 feet below conservation pool than from 2010 to 2015 ($182,651) when the lake averaged 22 feet below conservation pool elevation. The number of freshwater fishing licenses sold in Zapata and Starr Counties did not decrease along with water level over the last decade. This suggests that although fishing effort expended by local residents decreased in recent years, participation in the recreational activity of fishing by local residents was unaffected.

Relatively small decreases in DIS can elevate water level, which in turn would benefit the recreational fishery in Falcon Lake. The hypothetical DIS reduction model developed in this study revealed that had DIS been 2% lower each year from 2011 to 2020, water level would have been eight feet higher in 2020, at 271 instead of 263 feet above MSL. Given this 2% DIS reduction scenario and resultant water level increase, angler access and angler utilization would have been improved. The

Falcon State Park boat ramp would have been unusable only 7% of the time as opposed to 33% of the time. Total angling effort would have been closer to that estimated in 2019 (123,898 h) when water level averaged 270 feet above MSL than in 2022 (40,947 h) when water level averaged 259 feet above MSL. Also, a higher economic impact would likely result from a reduction in DIS and subsequent increase in water level. A 42 feet water level increase in Amistad reservoir caused local (Val Verde County) fishing expenditures to increase 183% from $4.2 million in 2002-2003 (Bradle et al. 2002) to $11.9 million in 2007 (Schuett et al. 2012).

The governing of water use in the Rio Grande is complex. It involves two countries, state and federal agencies, is predicated on both an international treaty and state regulations, and affects numerous private enterprises, millions of citizens, and ecosystem function. Thus, changes to water policy and management can have diverse and far-reaching implications. Although fishing and hunting is identified as a preferred use of water, this use ranks sixth among seven total uses specified in the 1944 Treaty. In addition to many factors, population growth and increased water use upstream over a river distance of approximately 1,600 miles into south-central Colorado have diminished the quantity of water entering Falcon Lake. This water supply issue is compounded by the full allocation of water to users located downstream of Falcon Lake (Sandoval-Solis and McKinney 2011, Karimov 2016, Sandoval-Solis et al. 2022). Total authorized volume of water rights in the four-county Lower Rio Grande Valley, of which approximately 90% are for agricultural irrigation (TCEQ 2022a), exceed average annual inflow into Falcon Lake by 110%. These circumstances suggest that policy change proposals that set-aside water for Falcon Lake fisheries would be difficult to implement.

The ecological, recreational, and economic importance of Rio Grande water is now better understood and more widely recognized by decision-makers than in previous decades. A variety of strategies can be taken to improve environmental flows and lake water levels in the basin. Water rights may be acquired, donated, leased, or purchased for environmental purposes with the option to deposit in the Texas Water Trust (TWDB 2022c). A water conservation plan purposed to reduce the loss or waste of water, maintain or improve the efficiency in the use of water, and increase reuse of water is required for new and amended water right permits (TCEQ 2022b). A drought contingency plan, having specific targets consistent with the Texas Water Development Board Region M water plan, is required for wholesale and retail public water suppliers and irrigation districts in the Lower Rio Grande Valley (TCEQ 2022c). The conversion of water rights from agricultural use to municipal, domestic, or industrial use in the Lower Rio Grande Valley results in a 50-60% reduction in converted water right volume (TCEQ 2022d). These strategies, if successful in increasing water availability, could positively affect the water level and recreational fishery in Falcon Lake. The long-term decline in Falcon Lake water level, however, foretells the need for additional conservation measures to maintain Falcon Lake's recreational fishery, including watershed restoration, water conservation, and river basin-scale water management.

Water Level Recommendations

1) **Minimum water level.** A minimum water level of 268 feet above MSL would benefit the recreational fishery at Falcon Lake. Angler access would be unimpacted at this water level as all boat launching lanes in Falcon State and Zapata County Parks would be useable. Fisheries habitat availability, angler utilization, largemouth bass population abundance and angler catch, and local economic contributions generally correspond with water level. In 2021-2022, when water level averaged 259 feet MSL, most recreational fishery metrics were the lowest recorded. A minimum water level of 268 feet MSL would ameliorate the negative impacts of low water level on the recreational fishery. When water level averaged 270 and 276 feet MSL in 2016 and 2019, respectively, fisheries habitat availability, angler utilization, Largemouth Bass population abundance and angler catch, and Zapata local hotel tax revenue were substantially greater than in 2021-2022. A minimum water level of 268 feet above MSL can be achieved by a relatively small reduction in total discharge (2-4%).
2) **Water level fluctuation regime.** A water level rise of ≥5 feet over the spring-summer period occurring every 2-4 years on average is ideal for maintaining a high-quality recreational fishery at Falcon Lake. This regime transpired from 2007 to 2015, with spring-summer water level increases ≥5 feet occurring in 2007, 2010, and 2015. As a result, total angling effort and largemouth bass catch were high in subsequent years (2011, 2016, and 2019) averaging 117,320 hours and 105,501 fish, respectively. In 2022, seven years following the most recent spring-summer water level increases of ≥5 feet, total angling effort and largemouth bass catch were substantially lower, 40,947 hours and 17,207 fish, respectively. Generation of a spring through summer water level increase of ≥5 feet would require a discharge reduction of 37% on average over the seven-month period from March 1 to September 30.

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Appendix A.

Overview of water policy and water management in the Rio Grande basin, provided by staff of the Texas Commission on Environmental Quality (TCEQ).

1944 Water Treaty

The 1944 Water Treaty for the "Utilization of Waters of Signing of 1944 Treaty the Colorado and Tijuana Rivers and of the Rio Grande" allocated the waters in the international segment of the Rio Grande from Fort Quitman, Texas to the Gulf of Mexico. The 1944 Water Treaty also authorized the United States and Mexico to construct operate and maintain dams on the main channel of the Rio Grande.

Article 4 allocates the waters of the Rio Grande to the United States and Mexico as follows:

To Mexico	To the United States
1. 100% of waters reaching the Rio Grande from San Juan and Alamo Rivers.	1. 100% of waters reaching the Rio Grande from the Pecos and Devils Rivers, Good-enough Spring, and Alamito, Terlingua, San Felipe, and Pinto Creeks.
2. One-half of flow in main channel below lowest major international storage reservoir (Falcon) as long as flow is not specifically allotted to either country.	2. One-half of flow in main channel below lowest major international storage reservoir (Falcon) as long as flow is not specifically allotted to either country.
3. Two-thirds of flow reaching the Rio Grande from the Conchos, San Diego, San Rodrigo, Escondido and Salado Rivers, and the Las Vacas Arroyo (6 named tributaries).	3. One-third of flow reaching the Rio Grande from the Conchos, San Diego, San Rodrigo, Escondido and Salado Rivers, and the Las Vacas Arroyo.
4. One-half of all other flows not otherwise allotted, including contributions from unmeasured tributaries, between Fort Quitman and lowest major international storage reservoir (Falcon).	4. One-half of all other flows not otherwise allotted, including contributions from unmeasured tributaries, between Fort Quitman and lowest major international storage reservoir (Falcon).

Texas receives all water allocated from the Rio Grande to the United States under the 1944 Water Treaty. Texas statute governs the management of that surface water in Texas.

Surface Water Management in Texas

TCEQ is the state agency charged with managing state surface water in Texas. State water is the water of every river, natural stream, and lake, and of every bay or arm of the Gulf of Mexico and the stormwater, floodwater, and rainwater of every river, natural stream, canyon, ravine, depression, and watercourse in the state. If a person wants to divert, use, or store state water, or to use the bed and banks of a watercourse, a water rights permit is required, unless the water is being used for one of several specific exempt uses such as domestic and livestock use.

A water right is a property right and, once issued, is a perpetual right. In general, most water rights do not expire nor is there broad authority for future review and consideration of changes unless that future review is required in the water right itself or a change to the water right is requested by the water right owner.

Texas' surface water rights law comes from a mixture of Spanish, English, and riparian water law, as well as the prior appropriation doctrine used across the Western states. The adjudication process was designed to sort through competing claims to water. The path to a statewide adjudicative process started in the Rio Grande with the Valley Water Case, filed in 1956 as a result of ongoing drought conditions (See documents related to the Valley Water Case and other court cases at Lower Rio Grande Documents). This case, which took thirty years to decide and involved over 3,000 parties, resulted in a 1971 final court decree adjudicating water rights in the lower Rio Grande (below Falcon Reservoir). The court's judgement created a water reserve for municipal, industrial, and domestic and livestock uses and two priority classes of irrigation rights.

The Valley Water case highlighted that a more efficient process was needed for adjudicating water rights. The Texas legislature passed the 1967 Adjudication Act, which created a framework for defining and quantifying water rights throughout Texas (Texas Water Code (TWC) Chapter 11, Subchapter G).

During the adjudication process for the Middle Rio Grande and its tributaries between Amistad Reservoir and Falcon Reservoir, the commission considered, among other things, that Amistad and Falcon reservoirs would be operated together as a system to achieve the maximum yield and to minimize waste; therefore, the commission followed the court decision in the Valley Water Case for water rights on the main stem of the Rio Grande (Final Determination Middle Rio Grande.

After the adjudication of water rights, TCEQ and its predecessor agencies continue to permit the use of state water. In addition to certificates issued during the adjudication process, TCEQ issues new perpetual water rights and amendments to existing water rights under TWC Chapter 11. The vast majority of water rights in the Rio Grande prior to the court decision in the Valley Water Case and the adjudication of water rights were based on river flows. Pursuant to the 1944 Treaty, Amistad and Falcon reservoirs were constructed to store water allocated to both the US and Mexico. The water rights administration system was put in place in the Amistad/Falcon system in the Rio Grande to implement the adjudication of water rights and recognized that all of the United States' share of the water in the main stem of the Rio Grande from Amistad reservoir to the Gulf Of Mexico is committed to existing users.

Water rights applications in the Amistad/Falcon system are for amendments to existing water rights that do not request a new appropriation of water because the available water supply is already committed. These water rights are administered as storage-based rights and an environmental review is not required although TCEQ does consider water conservation and drought contingency plans for applications to change a purpose or place of use, if required by TCEQ rules.

In 2007, the 80th Legislature passed Senate Bill 3 (SB 3), requiring the TCEQ to adopt environmental flow standards for Texas’ rivers, including the Rio Grande. SB 3 applies to new appropriations of water issued after 2007 in basins with adopted standards. The statute did not include provisions for reducing the amounts available to existing water rights or otherwise altering those rights (TWC 11.147(e-1)). SB 3 also recognized that the Rio Grande is unique. In adopting environmental flow standards for the Rio Grande, the statute also required TCEQ to consider the water accounting requirements of any international water sharing treaty, minutes, and agreement applicable to the Rio Grande and any possible effects on water allocation by the Rio Grande Watermaster in the Middle and Lower Rio Grande (TWC 11.02362 (m) and (o)).

SB 3 also included provisions related to set asides of water for the environment. These set asides were to come from unappropriated water, not from water authorized under existing water rights. In addition, water was to be set aside only to the maximum extent reasonable considering human water needs (TWC 11.1471 (a)(2)). TCEQ did not adopt set-asides in the Rio Grande because the available water was already committed to existing water right holders.

Some applicants for amendments to water rights in the Rio Grande are required to submit a drought contingency plan or DCP (More information on DCPs can be found on TCEQ's website at Drought Contingency Plans - Texas Commission on Environmental Quality - www.tceq.texas.gov). A DCP is a strategy or combination of strategies that a water supplier, such as a city, develops and implements to monitor and respond to a drought or other temporary water supply shortage that can severely disrupt the supply of water to customers. The purpose of a DCP is to conserve available water supply in times of drought and temporary water supply shortages by limiting the water available for non-essential uses, such as outdoor watering, and maintain supplies for essential uses, such as drinking water, sanitation, and fire protection, in order to protect and preserve public health, welfare, and safety. DCPs are developed at the local level, by the water supplier, and focus on potential issues related to their water system's production capacity or water supply sources. Each DCP is unique to each water supplier's specific needs and water supply operations. A DCP must also document coordination with the appropriate regional water planning group to ensure consistency with the approved regional water plan.

Rio Grande Watermaster Program

The TCEQ's Rio Grande watermaster program operates under 30 Texas Administrative Code Chapter 303: Operation of the Rio Grande. The Rio Grande watermaster is responsible for allocating, monitoring, and controlling the use of United States portion of surface water in the Rio Grande basin from Fort Quitman, TX to the Gulf of Mexico, excluding the Devils and Pecos River watersheds. One of the watermaster's major responsibilities is to request releases from Amistad and Falcon reservoirs based on water demand by permitted water right holders and United States water ownership in both reservoirs. These release requests are placed with the International Boundary and Water Commission (IBWC). The IBWC and its Mexican counterpart Comisión Internacional de Límites y Aguas (CILA) are responsible for determining the national ownership of the waters in the Rio Grande reservoir and river system, which in turn are managed by the Rio Grande watermaster for the U.S., and Comision National del Auga (CONAGUA) and CILA for Mexico.

In recent years, it appears that Mexico primarily maintains sufficient storage in the Amistad/Falcon system to fulfill their municipal, industrial, and domestic demands. Agricultural water appears to be held in interior Mexican reservoirs and not stored in the Amistad/Falcon system. These management practices contribute to lower water levels at Falcon Reservoir.

Texas' water demands on the Rio Grande vary throughout the year depending on weather. Normally, the spring/summer irrigation peak demand occurs in the months of April through August. There is also a minor winter peak in irrigation that appears in late November through December.

The Rio Grande Watermaster requests releases of water from the Amistad/Falcon system as follows:

- Releases from Falcon Reservoir are requested to satisfy the current demand generated by irrigation season peaks and year-round municipal, industrial, and domestic demand downstream of Amistad Dam.
- Releases from Amistad reservoir are requested and managed to support meeting the water demand releases out of Falcon based on inflows, outflows, losses, and water ownership projections; and to satisfy year-round municipal, industrial, and domestic demand between Amistad Dam and Falcon reservoir.
- Stored water is maintained in Amistad Reservoir in order to:
  - minimize the impact of evaporation losses that are normally higher in Falcon Reservoir due to its surface area and depth.
  - Ensure that any large-scale rainfall events that occur between Amistad and Falcon can be captured at Falcon.

Appendix B.

Annual water budget of Falcon Lake from 1960 to 2020. Inflows are local precipitation (PR), Rio Grande flow (RGFL, IBWC gage 08-4590.00), Rio Salado River flow (RSFL, IBWC gage 08-4597.00), and undetermined (UNDI), and outflows are evaporation (EV), discharge (DIS, IBWC gage 08-4613.00), diversions (DIV), and undetermined (UNDO). Inflow and outflow values are in thousands of acre-feet and values contained within parentheses are percent of total inflow and outflow.

	Inflow				Outflow			
Year	PR	RGFL	RSFL	UNDI	EV	DIS	DIV	UNDO
1960	160 (6)	2,356 (91)	69 (3)	-	449 (17)	2,079 (79)	15 (1)	84 (3)
1961	96 (4)	2,383 (91)	137 (5)	-	543 (19)	2,217 (77)	17 (1)	91 (3)
1962	68 (4)	1,412 (92)	62 (4)	-	468 (17)	2,118 (75)	17 (1)	233 (8)
1963	67 (4)	1,294 (86)	145 (10)	-	345 (17)	1,599 (76)	20 (1)	129 (6)
1964	67 (2)	3,132 (87)	138 (4)	252 (7)	342 (19)	1,455 (80)	18 (1)	-
1965	91 (5)	1,770 (89)	124 (6)	-	460 (16)	2,318 (79)	19 (1)	125 (4)
1966	155 (5)	2,633 (89)	160 (5)	26 (1)	459 (20)	1,782 (79)	17 (1)	-
1967	162 (6)	1,781 (62)	688 (24)	251 (9)	472 (19)	2,061 (81)	17 (1)	-
1968	182 (12)	1,224 (78)	158 (10)	-	460 (25)	1,332 (72)	19 (1)	40 (2)
1969	111 (9)	1,113 (86)	75 (6)	-	381 (15)	2,092 (81)	15 (1)	105 (4)
1970	84 (6)	1,363 (91)	48 (3)	-	357 (23)	1,144 (75)	16 (1)	7 (<1)
1971	262 (4)	3,073 (51)	2,399 (40)	253 (4)	321 (7)	4,199 (93)	18 (<0.5)	-
1972	196 (13)	981 (65)	336 (22)	-	441 (23)	1,423 (74)	16 (1)	42 (2)
1973	227 (10)	1,680 (75)	311 (14)	30 (1)	355 (17)	1,762 (83)	17 (1)	-
1974	162 (14)	3,892 (85)	156 (3)	388 (8)	387 (10)	3,323 (89)	18 (<0.5)	-
1975	163 (5)	3,024 (88)	265 (8)	-	397 (11)	3,120 (85)	20 (1)	154 (4)
1976	246 (5)	3,663 (70)	923 (18)	414 (8)	367 (9)	3,680 (90)	21 (1)	-
1977	116 (4)	2,289 (87)	212 (8)	-	445 (14)	2,638 (83)	21 (1)	73 (2)
1978	118 (3)	2,664 (77)	568 (16)	91 (3)	371 (13)	2,506 (87)	20 (1)	-
1979	146 (5)	2,751 (86)	286 (9)	-	435 (13)	2,965 (86)	24 (1)	23 (11)
1980	100 (4)	2,436 (89)	193 (7)	-	382 (13)	2,636 (87)	24 (1)	2 (<1)
1981	278 (7)	2,754 (68)	1,027 (25)	18 (<1)	369 (10)	3,139 (89)	22 (1)	-
1982	113 (5)	2,127 (90)	131 (6)	-	432 (13)	2,700 (82)	22 (1)	137 (4)
1983	72 (4)	1,632 (92)	71 (4)	-	267 (10)	2,294 (87)	21 (1)	40 (2)
1984	48 (2)	1,828 (93)	91 (5)	-	246 (10)	2,074 (88)	21 (1)	6 (<1)
1985	138 (7)	1,704 (85)	92 (5)	73 (4)	245 (14)	1,538 (85)	17 (1)	-
1986	85 (2)	3,192 (85)	197 (5)	276 (7)	246 (10)	2,289 (90)	19 (1)	-
1987	137 (4)	3,304 (85)	65 (2)	395 (10)	382 (18)	1,766 (82)	18 (1)	-
1988	97 (3)	2,343 (70)	723 (22)	175 (5)	433 (15)	2,531 (85)	18 (1)	-
1989	88 (4)	2,034 (92)	83 (4)	-	355 (10)	3,182 (89)	18 (1)	27 (1)
1990	113 (3)	3,770 (88)	78 (2)	308 (7)	300 (10)	2,613 (89)	17 (1)	-
1991	121 (3)	3,757 (86)	44 (1)	472 (11)	368 (13)	2,423 (86)	18 (1)	-

	Inflow				Outflow			
Year	PR	RGFL	RSFL	UNDI	EV	DIS	DIV	UNDO
1992	188 (5)	3,772 (94)	45 (1)	-	433 (10)	3,349 (81)	9 (<0.5)	355 (9)
1993	98 (4)	2,261 (94)	38 (2)	-	382 (12)	2,657 (82)	12 (<0.5)	193 (6)
1994	111 (4)	2,539 (95)	28 (1)	-	326 (11)	2,607 (84)	11 (<0.5)	148 (5)
1995	93 (5)	1,641 (89)	107 (6)	-	190 (8)	1,889 (81)	10 (<0.5)	251 (11)
1996	64 (4)	1,311 (92)	54 (4)	-	171 (10)	1,393 (84)	9 (1)	85 (5)
1997	71 (6)	1,039 (90)	44 (4)	-	155 (13)	1,012 (84)	8 (1)	34 (3)
1998	39 (2)	1,734 (90)	59 (3)	93 (5)	143 (9)	1,493 (91)	8 (1)	-
1999	46 (3)	1,429 (93)	67 (4)	-	173 (11)	1,366 (88)	8 (1)	1 (<1)
2000	38 (3)	1,301 (94)	42 (3)	-	134 (8)	1,484 (86)	9 (<0.5)	103 (6)
2001	31 (2)	1,260 (87)	138 (10)	11 (1)	118 (9)	1,154 (90)	9 (1)	-
2002	38 (2)	1,407 (92)	79 (5)	4 (<1)	140 (12)	1,066 (88)	9 (1)	-
2003	79 (5)	1,155 (66)	291 (17)	227 (13)	184 (14)	1,083 (85)	7 (1)	-
2004	153 (9)	1,379 (79)	113 (6)	111 (6)	333 (36)	578 (63)	8 (1)	-
2005	77 (4)	1,629 (86)	182 (10)	-	366 (18)	1,63 (81)3	11 (1)	0 (<1)
2006	81 (6)	1,203 (86)	121 (9)	-	345 (17)	1,667 (80)	13 (1)	46 (2)
2007	127 (4)	2,745 (79)	136 (4)	460 (13)	271 (14)	1,634 (85)	7 (<0.5)	-
2008	106 (2)	3,172 (72)	633 (14)	505 (11)	323 (14)	2,017 (86)	12 (1)	-
2009	75 (5)	1,174 (80)	217 (15)	-	466 (17)	2,174 (78)	10 (<0.5)	132 (5)
2010	189 (2)	4,367 (50)	3,472 (40)	630 (7)	433 (17)	6,090 (93)	7 (<0.5)	-
2011	37 (2)	1,129 (74)	350 (23)	-	476 (15)	2,653 (81)	10 (<0.5)	122 (4)
2012	54 (2)	2,212 (95)	50 (2)	-	276 (10)	2,315 (85)	10 (<0.5)	127 (5)
2013	69 (3)	1,841 (83)	267 (12)	54 (2)	219 (12)	1,663 (88)	6 (<0.5)	-
2014	68 (4)	1,266 (83)	187 (12)	-	241 (15)	1,282 (80)	6 (<0.5)	74 (5)
2015	123 (9)	988 (76)	137 (10)	57 (4)	267 (47)	294 (52)	4 (1)	-
2016	78 (7)	891 (82)	120 (11)	-	257 (13)	1,576 (81)	6 (<0.5)	108 (6)
2017	95 (3)	2,355 (77)	404 (13)	202 (7)	261 (11)	2,211 (89)	5 (<0.5)	-
2018	76 (4)	1,611 (92)	73 (4)	-	141 (6)	1,989 (89)	5 (<0.5)	94 (4)
2019	44 (3)	1,395 (95)	77 (2)	-	188 (9)	1,897 (90)	8 (<0.5)	23 (1)
2020	57 (5)	1,303 (90)	81 (6)	-	148 (8)	1,498 (85)	7 (<0.5)	110 (6)