TECHNICAL PAPER A-5
DEVELOPMENT OF COMBINED FIRM YIELD OF LAKES BUCHANAN AND TRAVIS
January 2026

1.0 INTRODUCTION

The Final Judgment and Decree relating to the adjudication of water rights for the Lower Colorado River Authority and the City of Austin, which was issued on April 20, 1988, in the 264th Judicial District Court of Bell County, Texas, requires LCRA, pursuant to provisions in its Certificates of Adjudication 14-5478 and 14-5482 that authorize lakes Buchanan and Travis, respectively, to determine the "combined firm yield" of lakes Buchanan and Travis when operated as a reservoir system. As stipulated in Paragraph 2.B(6) of the Buchanan and Travis Certificates, the combined firm yield value represents the maximum amount of water that LCRA can commit to supply annually under Certificates of Adjudication 14-5478 and 14-5482 on a firm, uninterruptible basis to its customers.

TCEQ rules define firm yield as:

> That amount of water that the reservoir could have produced annually if it had been in place during the worst drought of record. In performing this simulation, naturalized streamflows will be modified as appropriate to account for the full exercise of upstream senior water rights is assumed as well as the passage of sufficient water to satisfy all downstream senior water rights valued at their full authorized amounts and conditions as well as the passage of flows needed to meet all applicable permit conditions relating to instream and freshwater inflow requirements.[1]

As described more fully in Section 3.1.2 of this paper, for purposes of this WMP, the combined firm yield calculation employs a cutoff assumption with respect to portions of the upper basin, including above O.H. Ivie Reservoir, similar to previous calculations. [2]

2.0 COMBINED FIRM YIELD DETERMINATION

The approach for determining the combined firm yield of lakes Buchanan and Travis involves application of the Water Availability Model (WAM) of the Colorado River basin developed by the Texas Natural Resource Conservation Commission, the predecessor agency to the Texas Commission on Environmental Quality (TCEQ), in 2001 pursuant to Senate Bill 1 (75th Texas Legislature). This WAM accounts individually for each of the existing surface water rights in the Colorado River basin, including those that authorize lakes Buchanan and Travis. Using monthly streamflow values throughout the basin corresponding to historical hydrologic and climatic conditions, the WAM simulates on a monthly basis the supply, or volume, of surface water available to satisfy the authorized diversion amount for each individual water right.

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[1] 30 Tex. Admin. Code § 297.1(20).

[2] The 1988 Final Judgment and Decree also referred to the Combined Theoretical Yield, the yield of lakes Buchanan and Travis if: 1) there were no other impoundment, diversion or use of the flows of the Colorado River and its tributaries upstream; 2) no portion of the inflows to lakes Buchanan and Travis is passed to honor downstream senior water rights; and 3) Lakes Buchanan and Travis are operated as a system. For this WMP revision, the Combined Theoretical Yield has not been calculated.

In the WAM's monthly simulation process, individual water rights are considered in priority order in accordance with the prior appropriation doctrine, i.e., water is provided to the oldest (or most senior) water right first during times of shortage. Water rights are prioritized according to their priority date, which generally corresponds to the date a particular water right was issued by the State, or for some older rights, the first documented date associated with surface water usage.

Each of the reservoirs in the Highland Lakes chain is represented in the WAM for the Colorado River basin. Demands for water from lakes Buchanan and Travis are specified in the model in accordance with authorized uses and, in some cases, consistent with contractual agreements between LCRA and its customers. For example, the contractual demand for backup water from lakes Buchanan and Travis for the City of Austin's water rights to provide a firm supply for Austin's municipal and industrial customers is included in the WAM. For the combined firm yield analysis, the total annual demand amount specified in the WAM for lakes Buchanan and Travis is, by definition, equal to the combined firm yield of the reservoirs. This quantity is determined through an iterative process whereby multiple simulations are made until all of the available supply of water stored in the reservoirs or flows into the reservoirs, after all senior water rights are fully satisfied, is completely utilized to meet the specified firm yield demand during the most severe drought period within the hydrologic record analyzed, which defines the drought of record.

For this combined firm yield analysis, monthly historical hydrologic and climatic conditions for the period from 1940-2023 are considered. For lakes Buchanan and Travis, the drought of record that determines the combined firm yield value occurs during the period from October 2007 through April 2015. The WAM's representation of lakes Buchanan and Travis attempts to refill both reservoirs multiple times within each simulated timestep. Accordingly, the simulated storage for the lakes may have been full after the first attempt to refill (priority date of 1926) but may end up slightly below full at the end of the timestep. Rather than preserving the initial simulated storage of the system after the 1926 refill occurs, a "99.9 percent rule" has been employed and applied to the final simulated storage of lakes Buchanan and Travis at the end of each monthly timestep for the purposes of defining the beginning of the critical drought period. Using this guideline, when the system storage is greater than 99.9 percent of its conservation storage, the system is deemed to be full for the purposes of determining the beginning of the critical drought period and calculating the associated firm annual yield.

Based on the WAM simulations with this guideline in place, the critical drought period extends from October 2007 (the first month after both reservoirs are full), to April 2015 when lakes Buchanan and Travis are essentially empty and began to refill, which is a total drought duration of 91 months, or 7.58 years. The firm annual yield was determined by adding all of the diversions and releases made from lakes Buchanan and Travis for the period from full to minimum storage and dividing this total quantity by the number of years in the critical drought period (7.58). These computations are summarized in Table 1. This critical drought period is evident on the time-series graph presented in Figure 1, depicting the monthly combined storage in lakes Buchanan and Travis from the 1940-2023 firm yield WAM simulation. As shown, the combined water in storage in the reservoirs almost falls to zero during this period (April 2015), which is the fundamental basis for the determination of the combined firm yield of the reservoir system.

The annual withdrawal amount determined from the WAM simulations to be the combined firm yield value for lakes Buchanan and Travis is 416,892 acre-feet per year as compared to 445,266 acre-feet per year calculated in the original WMP from 1989, and 418,848 in the 2020 WMP. (The original WMP also reported as part of the Combined Firm Yield an additional 90,546 acre-feet per year associated with O.H. Ivie Reservoir.) This is the annualized average amount of water that can be withdrawn from the two reservoirs every year during the critical drought period without causing the reservoirs to go dry. The reduction in combined firm yield from the original WMP is mainly due to sedimentation in the reservoirs that has occurred since the firm yield calculations were performed for the original WMP, as well as the lower inflows experienced in the 2007-2015 period. LCRA conducted sediment surveys completed in 2022 utilizing the Texas Water Development Board's Hydrographic Survey program, and results from these surveys have been used to estimate 2032 sedimentation conditions in lakes Buchanan and Travis for this WMP revision.

3.0 ASSUMPTIONS

Assumptions regarding how lakes Buchanan and Travis are represented and operated in the WAM, and the extent to which water from these reservoirs is used to meet specific demands, can vary considerably depending on the purpose for which WAM simulations are being made. For purposes of the lakes Buchanan and Travis combined firm yield calculation in support of this WMP update, the specific assumptions utilized are outlined and described in the following sections. The particular version of the WAM for the Colorado River basin with these specific combined firm yield assumptions incorporated is referred to as the CFY-WAM.

3.1 General Assumptions

3.1.1 TCEQ's Water Availability Model of the Colorado River basin (Run 3) forms the basic structure for the CFY-WAM. The July 2022 version of the Texas A&M University "Water Rights Analysis Package" (WRAP)[3] is the underlying program code used for all CFY-WAM simulations.

3.1.2 A "no-call" assumption[4] with respect to upper basin water rights has been incorporated into the CFY-WAM. This "no-call" assumption, in effect, makes all water rights upstream of the dams that form O.H. Ivie and Brownwood reservoirs senior in priority to lakes Buchanan and Travis and other downstream water rights; however, the existing priorities of all of the water rights located upstream of these dams are maintained relative to each other, as are those for all of the water rights located downstream of these dams.

[3] Wurbs, R. A. (2025) Water rights analysis package (WRAP) modeling system reference manual. Tech. Rep. 255, Texas Water Resources Institute, College Station, TX.
Wurbs, R. A. (2025) Water rights analysis package (WRAP) modeling system users manual. Tech. Rep. 256, Texas Water Resources Institute, College Station, TX.

[4] The "no-call" assumption in the WAM is an attempt to reflect the various agreements that LCRA has with upstream reservoir owners, i.e. Colorado River Municipal Water District, San Angelo Water Supply Corporation, and Brown County WID No. 1, and to better represent actual conditions with regard to the operation of existing water rights throughout the basin.

3.1.3 The 1940-2023 monthly naturalized flows[5] and net evaporation rates approved by the TCEQ in 2025 are used in the CFY-WAM. These data are considered to be representative of actual variations in hydrologic and climatic conditions sufficient to support simulations of water availability through a repeat of the historic period of record, including through drought periods.

3.1.4 Potential droughts worse than the historical drought of record are not simulated. As stated previously, the firm yield is based upon a repeat of the historic drought of record. As new hydrologic and climatic conditions are encountered, there is the potential that a new drought of record will be determined.

3.1.5 In the CFY-WAM, water demands for all surface water rights in the Colorado River basin are set at their full authorized diversion amounts, and all reservoirs are specified at their authorized storage capacities, except for lakes Buchanan and Travis and Arbuckle Reservoir (See section 3.3.5 and 3.4.1 for more detail). The authorized diversions and priority dates for the major downstream water rights senior in priority to lakes Buchanan and Travis are listed in Table 2. (Note, this table only reflects those senior water rights authorized to divert more than 1,500 acre-feet; all senior water rights are reflected in the model.)

3.1.6 Water rights, represented in the WAM as senior to LCRA's lakes Buchanan and Travis, that are based on a requirement to maintain an upstream water supply contract with LCRA were included in the CFY-WAM model if their contract was long-term with a municipal or industrial purpose of use.

3.2 City of Austin Return Flows

3.2.1 The use of surface water by the City of Austin either from diversions under Austin's municipal water rights or from releases from lakes Buchanan and Travis under contract with LCRA is assumed to generate treated wastewater effluent discharged as return flows back into the Colorado River downstream of Austin. In the CFY-WAM, these return flows are determined using procedures consistent with those employed by the Region K Water Planning Group involving the following calculations:

1) At the end of each monthly time step during a CFY-WAM simulation, the total amount of Colorado River water used by the City of Austin to satisfy its municipal and industrial (M&I)[6] water demands is noted.

[5] Naturalized flows provide the basic hydrologic inputs to the WAM, and they consist of complete records over the WAM simulation period of historical monthly flows at specific locations throughout the Colorado River basin (usually at streamflow gauging stations) after adjustment for the effects of historical surface water use activities, including diversions, return flows, and reservoir storage and evaporation losses. For the CFY-WAM, the 1940-2023 naturalized flows were developed by LCRA and approved by TCEQ in 2025, and were developed using the same methodology applied in developing the original WAM for the Colorado River basin.

[6] In the CFY-WAM, Austin's municipal and industrial demands are set at the total amount of annual diversions authorized under Austin's municipal water rights, Certificates of Adjudication 14-5471 and 14-5489, and these demands equal 292,703 acre-feet per year. These demands do not include any Austin water usage for power generation.

2) The corresponding quantity of Austin's treated wastewater effluent is then calculated by applying the appropriate monthly factor from the following table to Austin's total M&I water right demands, as backed by LCRA. These factors were derived from Austin's actual river diversions and return flows as reported for the 2000-2005 period.

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.7873	0.8027	0.7994	0.6487	0.5509	0.5379	0.4597	0.4213	0.4821	0.5806	0.7215	0.7735

This calculation process results in an annual total of approximately 177,400 acre-feet per year of return flows that are discharged back into the Colorado River.

3) At the beginning of each monthly time step during the CFY-WAM simulation, the calculated amount of Austin's treated wastewater effluent from the previous time step is returned to the Colorado River at a location approximately four river miles downstream of the Highway 71/183 bridge in Austin (mouth of Walnut Creek), and these return flows are then available for use in priority order by all downstream water rights.

4) No direct or indirect reuse of Austin's treated wastewater effluent or return flows is explicitly represented in the CFY-WAM simulations. Austin's return flows are discharged to the river and made available for use by all downstream water users, including LCRA, in accordance with the prior appropriation doctrine and consistent with the 2007 Settlement Agreement.

3.3 LCRA Downstream Water Rights

3.3.1 One hundred thousand acre-feet per year of LCRA's Garwood water right authorization is represented with an agriculture use pattern at the authorized downstream location for the Garwood water right.

3.3.2 The remaining 33,000 acre-feet per year of LCRA's Garwood water right authorization, as well as all of LCRA's other downstream water rights, are set at their full authorized diversion amounts and modeled as industrial use at the authorized downstream locations at the Garwood, Lakeside, Pierce Ranch and Gulf Coast operations (although the water rights now are authorized for multiple purposes of use, including municipal and agricultural and the Garwood water right now has additional diversion locations). The general industrial monthly distribution factors included in TCEQ's Run 3 WAM are used to distribute the annual authorized diversion amounts to monthly demands in the CFY-WAM. The demands for the different lower basin water rights are considered in priority order in the CFY-WAM simulation process including the provision in the City of Austin water right 14-5471 that subordinates the LCRA-owned Gulf Coast, Lakeside and Pierce Ranch water rights to a portion of the City of Austin's Lake Austin Rights.

3.3.3 LCRA's downstream water rights are not simulated as being supplemented or backed up with interruptible stored water from lakes Buchanan and Travis.

3.3.4 No return flows from the downstream water rights are discharged back to the Colorado River.

3.3.5 Arbuckle Reservoir, the off-channel reservoir authorized under LCRA's Gulf Coast water right and located near Lane City, is included in the CFY-WAM. The modeled conservation storage which represents the as-built storage capacity is 41,440 acre-feet. The total senior authorized amount of LCRA's Gulf Coast water right is represented in the CFY-WAM as being divided equally into two parts (114,285 acre-feet of the total 228,570 acre-feet per year authorized) with the first part of this authorization being associated with the portion of the irrigation division on the western side of the Colorado River and simulated as a regular run-of-river water right from the Bay City dam. The remaining portion of the senior authorization is represented as a run-of-river right diverting near Lane City with the additional ability to divert water into the Arbuckle Reservoir for the purposes of meeting demands when there is less run-of-river water in later time steps.

3.4 Lakes Buchanan and Travis Storage and Releases

3.4.1 The conservation storage capacities of all reservoirs in the Colorado River basin represented in the WAM, except lakes Buchanan and Travis and Arbuckle Reservoir, are set at their full authorized storage amounts as stipulated in their respective water rights. The conservation storage capacities for lakes Buchanan and Travis are set at their projected 2032 conservation capacities based on sediment surveys completed in 2022.

3.4.2 The conservation storage capacity of Lake Buchanan at elevation 1020.0 feet above mean sea level (feet msl) is specified as 872,439 acre-feet. This maximum storage capacity is used in the WAM simulations for all months of the year.

3.4.3 The conservation storage capacity of Lake Travis at elevation 681.0 feet msl is specified as 1,108,329 acre-feet. This maximum storage capacity is used in the WAM simulations for all months of the year.

3.4.4 With the exception of the City of Austin, South Texas Project and the Lometa system, direct diversions or releases of water are made from lakes Buchanan and Travis to satisfy the demands of LCRA's contractual customers even if their actual diversions are not made directly from lakes Buchanan or Travis. Diversions are made from the Colorado River above Lake Buchanan for the Lometa system. Releases are made to backup demands for the City of Austin and South Texas Project as described in section 3.4.6.

3.4.5 Conveyance losses are not simulated in the model. However, such losses are accounted for in LCRA's water supply commitments.

3.4.6 Stored water is released from lakes Buchanan and Travis to backup the following downstream water demands:

- City of Austin's municipal and industrial demands (excluding power generation).

- South Texas Project demands for power generation per contract provisions. (See section 3.6).

3.4.7 Stored water is released from Lake Buchanan to maintain the intervening Highland Lakes (Inks, LBJ, Marble Falls and Lake Austin) full at all times.

3.4.8 Procedures for diverting water from either Lake Buchanan or Lake Travis to meet LCRA customer demands use the reservoir system operating rules embedded in the basic WRAP program. Because the firm yield model's primary focus is to provide firm supply from either reservoir, the model only allocates water between lakes Buchanan and Travis at a coarse level as described in this paragraph – actual operations include a greater level of control over releases than can be simulated by the model. In the firm yield model, at any time, the relative storage conditions of the two reservoirs determine from which reservoir diversions or releases are to be made, with the overall objective of using water from Lake Travis at a somewhat higher rate than from Lake Buchanan, particularly when storage levels are higher. Procedures for making diversions or releases under the current reservoir operating rules in the CFY-WAM are as follows:

1) An Upper Zone (Zone 1) and a Lower Zone (Zone 2) are defined in each reservoir using 500,000 acre-feet for Lake Buchanan and 390,197 acre-feet for Lake Travis as the zone delineators.

2) When the storage in one reservoir is in Zone 1 (Upper Zone) and the storage in the other reservoir is in Zone 2 (Lower Zone), diversions or releases to meet demands are made from the reservoir with storage in Zone 1 (i.e., from the reservoir that contains more water in storage relative to its conservation storage capacity).

3) When both reservoirs are in the same storage zone, a quantity called the "zone storage factor" is calculated for each reservoir equal to the percent the zone is full. For example, if both reservoirs are in Zone 1 (Upper Zone) and Lake Travis contains 800,000 acre-feet of water, then the zone storage factor for Lake Travis would be equal to 409,803 (800,000 – 390,197) divided by the volume of Zone 1 in Lake Travis (equal to the full conservation storage capacity minus 390,197).

4) When both reservoirs are in Zone 1 (Upper Zone), the zone storage factor for Lake Travis is multiplied by 2, and if this quantity is greater than or equal to the zone storage factor for Lake Buchanan, diversions or releases are made from Lake Travis. If this quantity is less than the zone storage factor for Lake Buchanan, then diversions or releases are made from Lake Buchanan.

5) When both reservoirs are in Zone 2 (Lower Zone), if the zone storage factor for Lake Travis is greater than or equal to the zone storage factor for Lake Buchanan, diversions or releases are made from Lake Travis. If the zone storage factor for Lake Travis is less than the zone storage factor for Lake Buchanan, then diversions or releases are made from Lake Buchanan.

3.5 Environmental Flow Requirements

3.5.1 No environmental flow requirements for instream flows or freshwater inflows to Matagorda Bay are imposed on LCRA's Lake Buchanan or Lake Travis water rights in the CFY-WAM, and, consequently, no water is released from or passed through lake Buchanan or Travis to support environmental flow requirements at any location downstream along the Colorado River. (Notwithstanding the assumptions in the CFY-WAM model, 33,440 acre-feet per year of the combined firm yield have been set aside to help meet environmental flow needs.)

3.6 South Texas Project

3.6.1 The consumptive demand for the South Texas Project is set equal to the full authorized consumptive demand of 80,125 acre-feet per year stated in Certificate of Adjudication 14-5437, as amended.

3.6.2 The current Water Delivery Plan (WDP) for providing backup water to the South Texas Project, which was adopted as part of the 2006 Settlement Agreement between LCRA and STP Nuclear Operating Company (STPNOC), is implemented in the CFY-WAM. As structured, this WDP stipulates LCRA shall initiate staged deliveries of water to STPNOC from LCRA's available sources upstream of the Bay City Dam when the water surface elevation of STPNOC's main cooling reservoir (MCR) falls below 35 feet msl, and shall continue such deliveries to assist with maintaining the level of the MCR above a minimum elevation of 27 feet msl.

3.6.3 The WDP does not specifically state how the water deliveries are to be staged with regard to either timing or the quantities to be delivered; it only requires they commence when the level of the MCR falls below elevation 35 feet msl. For purposes of the CFY-WAM, the operating procedures for delivery of water is assumed to be consistent with the previous water delivery plan.

3.6.4 The total backup supply from lakes Buchanan and Travis for STPNOC is limited to a rolling 5-year average of 40,000 acre-feet per year.

3.6.5 The CFY-WAM assumes STPNOC will divert under Certificate of Adjudication 14-5437, as amended, whenever the streamflow exceeds the parameters in the certificate without regard to any operational preferences related to salinity or conductivity.

Table 1. Firm Annual Yield Components and Associated WAM Water Right IDs Used to Determine Buchanan-Travis Firm Annual Yield

Water Right ID	Volume (acre-feet)
Municipal and Industrial Firm Supplies from Buchanan-Travis	
11405715002	591
11405730001	24,725
11405790001	11,868
11204007001	17,802
11405677001	6,330
61405482001C	162,010
61405482COABU	31,966
61405480001	15,700
61405473001	10,470
61405474001	37,110
Total (a)	**318,573**
Backup Provided for Austin M&I Water Rights	
61405471005RMBU	48,375
61405471005LMBU	13,608
61405489003MBU	12,462
Total (b)	**74,444**
Backup for South Texas Project	
61405437001BU (c)	**22,629**
Buchanan-Travis 2007-2015 Drought Firm Annual Yield (Sum of a, b, and c)	**415,646**
Minimum System Storage (acre-feet)	9,450
Duration of Critical Period (months)	91
Duration of Critical Period (years)	7.58
Approximate Annual Yield Value of Remaining Storage (acre-feet)	**1,246**
Buchanan-Travis Firm Annual Yield Including Minimum Storage (Sum of Demands Met plus Yield Value of Remaining Storage)	**416,892**

[1]Volumes calculated are annualized average volumes provided during the Drought of Record period from October 2007 to April 2015.

Table 2. Downstream Water Rights Senior in Priority to Lakes Buchanan (14-5478) and Travis (14-5482)[a]

Water Right Owner	Water Right	Authorized Uses	Authorized Diversion Amount (acre-feet/year)	Priority Date
LCRA (Garwood)	14-5434H	Municipal, Industrial, Irrigation	133,000	11/1/1900
City of Corpus Christi	14-5434F	Municipal, Industrial, Irrigation	35,000	11/2/1900
City of Austin	14-5471D	Municipal Municipal Municipal, Industrial, Power	250,000 22,403 24,000	6/30/1913[b] 6/27/1914 6/27/1914
LCRA (Gulf Coast)[c]	14-5476D	Irrigation, Industrial, Mining	228,570	12/1/1900
LCRA (Lakeside)[c]	14-5475B	Municipal, Industrial Irrigation, Mining	52,500 55,000	1/4/1901 9/2/1907
LCRA (Pierce Ranch)	14-5477D	Irrigation, Industrial	55,000	9/1/1907
		Total:	854,473	

[a]Table organized from highest water right priority (oldest date) to lowest water right priority (newest date).
[b]Any water right owned by LCRA with a priority date junior to November 15, 1900 is specifically subordinated to this right.
[c]Gulf Coast and Lakeside water rights have additional authorized diversions for 33,930 and 78,750 acre-feet/year, respectively, with a junior priority date of November 1, 1987.

Figure 1. Monthly Combined Storage in Lakes Buchanan and Travis from Firm Yield WAM Simulation