Forecast and Planning Tools to Bolster Water Supply Reliability from Multi-purpose Reservoirs in Texas

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List of acronyms

ADSC	Agua del Sol Consultants, LLC
CFEP	Collison Floating Evaporation Pan
DLEM	Daily Lake Evaporation Model
DRI	Desert Research Institute
ESP	Ensemble Streamflow Prediction
FIRO	Forecast-informed Reservoir Operations
HEFS	Hydrologic Ensemble Forecast Service
LCRA	Lower Colorado River Authority
NOAA	National Oceanic and Atmospheric Administration
NWS	National Weather Service
TAMU	Texas A&M University
TWDB	Texas Water Development Board
UTA	The University of Texas at Austin
USACE	U.S. Army Corps of Engineers
WAM	Water Availability Model
WGRFC	West Gulf River Forecast Center

Technical Proposal and Evaluation Criteria

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1. Executive Summary

November 7, 2023
Texas Water Development Board
Austin, Travis County, Texas

The applicant, the Texas Water Development Board (TWBD), is a Category A applicant. The application is for Task Area C – *i.e.,* Projects to Improve Water Management through Decision Support Tools, Modelling, and Measurement – and for Funding Group III. The proposed project can be classified as a project for: ***Developing water management and modeling tools to help communities evaluate options and implement strategies to address drought; and, installing water measurement equipment and monitoring instrumentation devices to accurately track water supply conditions.***

TWDB is the state agency charged with leading efforts to ensure a secure water future for Texas. It is the designated water supply and flood planning agency for the state. As part of its responsibilities under Section 16.012 of the Texas Water Code, TWBD collects, compiles and disseminates reservoir evaporation data. Per its charge under Section 16.053 of the Texas Water Code, TWBD provides technical assistance to the regional water planning process in Texas, which is the key drought planning process in Texas. As part of its charge under Section 16.055 of the Texas Water Code, the TWDB is a representative on the Texas State Drought Preparedness Council and is responsible for reporting on drought and water supply updates in the state.

Since 2019, TWBD has been a core partner in a collaborative effort to lay the technical foundation for implementing Forecast-Informed Reservoir Operations (FIRO) in Texas, which includes a FIRO pilot project in the Little River Watershed of the Brazos River Basin. FIRO supports the agency's mission by improving upon the methods currently used with existing infrastructure to better manage water resources for increased water supply reliability or flood protection. In addition, TWDB has led, since 2019, a collaborative effort to enhance the accuracy and the spatial and temporal resolution of reservoir evaporation data for Texas, which is a key input to the water availability models (WAMs) for Texas used by the Texas Commission on Environmental Quality for water rights permitting and by regional water planning groups for water planning in the state. This work includes the release, in May 2023, of a new reservoir-specific daily evaporation dataset for Texas (https://dri-apps.earthengine.app/view/twdb-reservoir-evaporation). Both the efforts to advance FIRO and to enhance reservoir evaporation data are complementary and aimed at ensuring that the State's water supply is drought resilient. While the ongoing FIRO pilot project has yielded valuable information on potential use cases, much remains to be done to develop, adapt, and improve forecasts and decision support tools to make FIRO an effective strategy to improve water supply reliability for reservoirs in Texas. Additionally, work is needed to continue essential — as

stressed by key partners at the U.S. Army Corps of Engineers–Fort Worth District (USACE Fort Worth District) and the Lower Colorado River Authority (LCRA) — calibration and validation efforts on the operational, reservoir-specific daily evaporation dataset so that reservoir operators across the state have confidence in the dataset.

We are proposing a project that will achieve the following goals:

1. Develop the groundwork needed to promote FIRO as a viable water supply strategy for Texas.
2. Develop a systematic approach for the continuous calibration and validation of the operational, reservoir-specific daily evaporation dataset for Texas.

Key activities proposed to support goal (1) include: (1a) establishing a suite of forecast-based decision support tools to assist with reservoir operations and drought preparedness planning in Central and North Texas and (1b) providing forecasts of reservoir-specific daily evaporation for all 189 major water supply reservoirs at a 1–28-day lead time to assist reservoir operators throughout the state with estimating projected reservoir drawdown due to evaporation.

Key activities proposed to support goal (2) include: (2a) deploying a reservoir evaporation monitoring buoy on Sam Rayburn Reservoir, (2b) deploying a Collison Floating Evaporation Pan (CFEP) station on Lake Buchanan, and (2c) calibrating and validating the operational, reservoir-specific daily evaporation dataset using the daily data being collected from the new stations and from previously deployed evaporation buoys on Lake Buchanan, Choke Canyon Reservoir, Lake Meredith, and Red Bluff Reservoir and from the Collison Floating Evaporation Pan station on Twin Buttes Reservoir in Texas. Project collaborators include the Brazos River Authority, Dallas Water Utilities, Lower Colorado River Authority, USACE Fort Worth District, the National Weather Service–West Gulf River Forecast Center, and the National Oceanic and Atmospheric Administration–Physical Sciences Laboratory. Project co-principal investigators include the University of Texas at Arlington, Texas A&M University, Desert Research Institute (Nevada), and Agua del Sol Consultants (New Mexico).

The project length is three years, and the estimated completion date is September 30, 2027. The proposed project is not located on a federal facility. However, we propose to deploy an evaporation monitoring buoy on a reservoir owned by the U.S. government and operated by the USACE Fort Worth District.

In 2022 and 2023, extreme to exceptional drought conditions affected much of central Texas, portions of north Texas, the mid-coast, and southeast Texas. Statewide reservoir conservation storage in mid-October was 15% below the long-term median. Regionally, some reservoirs reached record low storage conditions, prompting mandatory water restrictions impacting several counties in densely populated regions of the state. By adapting forecast tools and developing decision support systems to facilitate the adoption of FIRO strategies in multi-purpose reservoirs, the proposed project will enable reservoir operators to harness the potential of FIRO to increase water supply reliability in their service areas. It will also contribute to developing drought resiliency across Texas by providing access to forecast-based tools and enhanced reservoir evaporation data that can inform the adaptive management of surface water reservoirs.

2. Project Location

The project location is Texas statewide (Figure 1). The FIRO project will cover five reservoirs with the service region of the Brazos River Authority in in the Brazos River Basin (blue shading), four reservoirs in in the service region of Dallas Water Utilities in the Upper Trinity (dark pink shading), two reservoirs in the Sabine River Basin that supply water to the service region of Dallas Water Utilities (light pink shading), the reservoir evaporation rate forecasts will be provided for all 189 major water supply reservoirs in the state (turquoise shading), a new buoy station will be deployed on Sam Rayburn Reservoir (red shading), a new Collison Floating Evaporation pan station will be deployed on Lake Buchanan (orange shading) where there is an existing evaporation buoy that will continue to provide data to be used in the proposed study, and data will continue to be collected for use in the proposed study existing open water evaporation buoys on Lake Meredith, Red Bluff Reservoir, Choke Canyon Reservoir (black shading) and a Collision Floating Evaporation Pan station on Twin Buttes Reservoir (black shading).

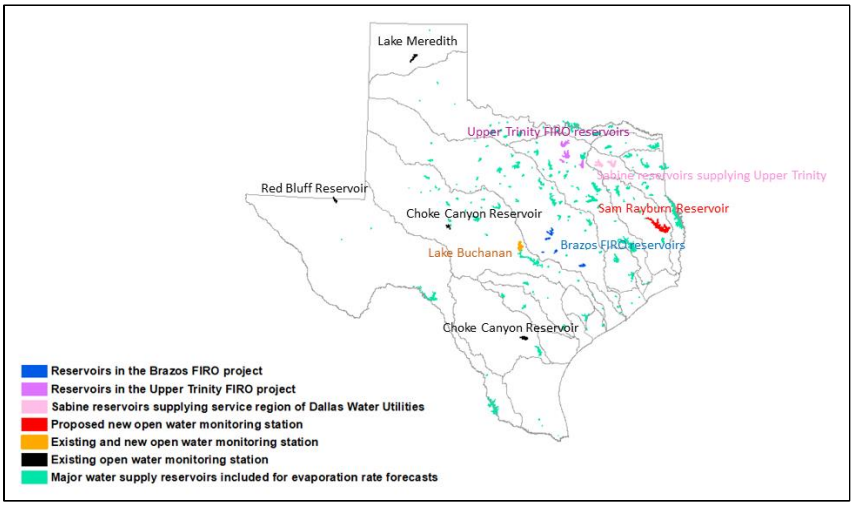

Figure 1: Reservoir locations included in the study

Annual statewide water use for Texas in 2020 was estimated at 14.7 million acre-feet (https://www.twdb.texas.gov/waterplanning/waterusesurvey/estimates/doc/2020TexasWaterUseEstimatesSummary.pdf). Current water users (percent of total use) include irrigation (55%), municipal (31%), manufacturing (7%), power (3%), livestock (2%), and mining (2%). Major crops cultivated include corn, rice, wheat, sorghum, cotton, forage hay pasture, sugarcane, and alfalfa (Texas Water Development Board, 2022). Existing water supply is estimated at 16.8 million acre-feet for 2020. Existing sources of water are surface water, groundwater, and reuse water. Surface water supply sources contribute 8.9 million acre-feet or about half of the total water supply [Texas Water Development Board, 2022 (a)]. Most major municipalities in the state, except for San Antonio, El Paso, Amarillo and Lubbock, depend on surface reservoir storage for their supply (Texas Water Development Board, 2016).

3. Project Description

Introduction

The Texas Water Development Board (TWDB) was created by the Texas Legislature in 1957, in response to the statewide drought of the 1950s, to develop water supplies and prepare plans to meet the state's future water needs. In 1997, the 75th Texas Legislature established a "bottom-up" consensus-driven approach to water planning. Sixteen regional water planning areas were charged with developing regional water plans every five years to address how to meet water needs during a repeat of the drought of record. The state water plan is based on the 16 regional water plans. The state and regional water planning process in Texas is, therefore, the main drought planning mechanism in the state.

The TWDB has been working for several years, in collaboration with the USACE Fort Worth District, the University of Texas at Arlington, and the National Weather Service (NWS)–West Gulf River Forecast Center (WGRFC) to lay the technical foundation for implementing FIRO in Texas. FIRO supports the agency's mission by improving upon the methods currently used with existing infrastructure to better manage water resources for increased water supply reliability. The TWDB is currently coordinating the development of a FIRO Steering Committee for the state comprising upper-level leadership from entities such as river authorities, water districts, water utilities, or state and federal entities. With general revenue, TWDB has also funded studies since the fall of 2022 to support the first Texas FIRO pilot project in the Little River Watershed of the Brazos River Basin, which has been led by the University of Texas at Arlington (UT Arlington) (Co-PI, Dr. Yu Zhang). The Texas FIRO pilot is a multi-agency initiative aimed at facilitating the adoption of FIRO by Texas reservoir operators to enhance water supply. Launched in 2022 with partial sponsorship from a USBR WaterSmart Grant entitled ***Adapting Ensemble Inflow Forecasts to Inform Operations of a System of Reservoirs along the Brazos River in Central Texas***, the Texas FIRO pilot focuses on a system of four reservoirs in central Texas that happen to be at the epicenter of the current drought episode. To date, the project has: adapted the National Weather Service Hydrologic Ensemble Forecast Service (HEFS) for the Little River System; validated streamflow, reservoir inflow, and reservoir levels at medium-seasonal (1-day to 9-month) forecast lead times for potential use in guiding reservoir flood pool reallocation decisions by USACE Fort Worth District; ingested seasonal ensemble forecasts into Brazos River Authority's water planning model; completed a preliminary assessment of the feasibility of adopting a seasonal guide curve by the USACE Fort Worth District; and convened a workshop in September 2023 that expanded partnerships and identified ways forward with advancing FIRO practice in Texas. (see Annex 1: 2023 FIRO workshop agenda).

Outcomes from qualitative analyses suggest that the risks of reallocation are typically low for the summer, but the efficacy of climatology-based reallocation in mitigating impacts of droughts is limited as reservoirs may already be depleted prior to the summer. The study also indicates that to attain accurate forecasts of reservoir levels through drought periods it is important to improve the representation of evaporation and water withdrawal when developing forecasts of reservoir pool levels.

The TWDB has also led a collaborative effort to enhance the accuracy and the spatial and temporal resolution of the reservoir evaporation dataset used by the Texas Commission on Environmental

Quality and regional water planning groups as one of the key input datasets to water availability models, which are used for water rights permitting and regional water planning in Texas. With grant funding from the U.S. Bureau of Reclamation's WaterSMART Drought Resiliency funding line awarded in Fiscal Year 2019, the TWDB established a limited open water reservoir evaporation monitoring network for the first time in the state. Also, using TWDB general revenue and grant funding from the Lower Colorado River Authority and the USACE Fort Worth District, the TWDB coordinated the development and release of an operational (updated with 3-day latency), reservoir-specific daily evaporation dataset (https://dri-apps.earthengine.app/view/twdb-reservoir-evaporation) for 188 major reservoirs in Texas [Co-PIs, Dr. Huilin Gao from Texas A&M University (TAMU) and Christopher Pearson from the Desert Research Institute (DRI); Annex 2 – Monitoring daily evaporation losses for the State of Texas). The daily reservoir evaporation dataset is based on the Daily Lake Evaporation Model (DLEM, Zhao and Gao, 2019). While the new daily evaporation dataset is a vast improvement—in terms of temporal resolution, data latency, and accounting for physical drivers of evaporation in the computational equation—over the legacy TWDB quadrangle evaporation dataset, the validation of the daily dataset using *in-situ* data from Texas has been limited, with the other validation points being in other western states. Our core partners at the USACE Fort Worth District and the Lower Colorado River Authority have stressed the need for additional calibration and validation efforts so that reservoir operators across Texas have confidence in the dataset.

We propose to develop the groundwork needed to promote FIRO as a viable water supply strategy for Texas and to develop a systematic approach for the continuous calibration and validation of the operational, reservoir-specific daily evaporation dataset for Texas through the following activities:

1. Establish a suite of forecast-based decision support tools to assist with reservoir operations and drought preparedness planning in central and north Texas.
2. Provide forecasts of reservoir-specific daily evaporation for all 189 major water supply reservoirs at the 1–28-day lead time through an Application Programming Interface (API) tool.
3. Deploy an evaporation monitoring buoy on Sam Rayburn Reservoir to expand the *in-situ* open water evaporation sites to the humid region of Texas.
4. Deploy a Collison Floating Evaporation Pan station on Lake Buchanan and continue with two independent open water evaporation stations on the lake.
5. Develop a methodology for bi-annual validation of the reservoir-specific daily evaporation dataset with daily data collected at the new stations, along with data being collected from previously deployed evaporation buoys on Lake Meredith, Lake Buchanan, Choke Canyon Reservoir, and Red Bluff Reservoir and data collected from a Collison Floating Evaporation Pan at the Twin Buttes.

Specific activities

Task 1: Establish a suite of forecast-based decision support tools to assist with reservoir operations and drought preparedness planning in Central and North Texas

As part of our proposal, the UT Arlington will develop or augment a suite of decision support tools for guiding operations at multi-purpose reservoirs in the USACE Fort Worth District which are also important for water supply planning at two water suppliers, namely, Brazos River Authority and Dallas Water Utilities, with the ultimate goal of improving water supply reliability and reducing

operational costs during droughts. The reservoirs in question include five reservoirs in the Little River System along the Brazos (four that are part of the Texas FIRO Pilot in the Little River System: Belton Lake, Stillhouse Hollow Lake, Lake Georgetown, and Granger Lake) plus Lake Somerville on Yegua Creek, a tributary of the Brazos River, and four reservoirs in the Upper Trinity that provide water supply for Dallas Water Utilities (Lewisville Lake, Lake Ray Hubbard, and Ray Roberts Lake), and two in the Sabine River Basin that supply inter-basin transfer water to the service region of Dallas Water Utilities (Lake Fork Reservoir and Lake Tawakoni). Together, these reservoirs are important for water supply in the Central Texas and North Texas regions of the state, which happen to be some of the fastest growing regions in the state and in the nation.

The suite of tools to be developed include:

- Adapting the Hydrological Ensemble Forecast System (HEFS) for central Brazos and Upper Trinity River basins with the following improvements from the current baselines:
    - Correct systematic errors and biases in the hydrologic model in simulating inflows for flooding events.
    - Ingest analog-based seasonal forecasts from the National Oceanic and Atmospheric Administration's (NOAA) Physical Sciences Laboratory.
- Enhancing Ensemble Streamflow Prediction (ESP) to account for El Niño Southern Oscillation (ENSO) conditions (i.e., analog ESP) for the central Brazos and Upper Trinity River basins
- Estimating water supply storage gained versus risk of excessive flood pool storage based on climatology and HEFS-informed guide curves.
- Developing a forecast system of water demand for multi-use reservoirs in the Dallas-Fort Worth Metroplex (four reservoirs in the Upper Trinity within the service area of Dallas Water Utilities).
- Updating the water supply planning model (includes all reservoirs that supply the utility) for Dallas Water Utilities that integrates improved lake evaporation for 1980 – present.

The project will infuse experimental products from the National Weather Service (NWS) Climate Prediction Center and NOAA Physical Science Laboratory and will leverage concurrent initiatives at NWS WGRFC for implementing HEFS for its entire service area, and the FIRO Pilot project led by the University of Texas at Arlington to perform collaborative hindcasts, operational assessments, and training. The operational assessments will determine potential gains in water supply reliability, drought preparedness, and potential saving in energy expenses (i.e., pumping costs) through the application of these tools.

Task 2: Provide forecasts of reservoir-specific daily evaporation for all 189 major water supply reservoirs at the 1–30-day lead time through an Application Programming Interface (API)

As part of our proposal, TAMU and the DRI will develop an API tool for the provision of daily reservoir evaporation forecasts for 189 major water supply reservoirs in Texas. Evaporation forecasts will be produced using the CFS-gridMET (https://support.climateengine.org/article/51-cfs-gridmet) 28-day meteorological forecasts dataset, which are gridded 1–30 day forecasts from the Climate Forecast System – Version 2 (Saha et al., 2014) downscaled using statistics from the Gridded Surface Meteorological Dataset (gridMET, Abatzoglou, 2013). The CFS-gridMET product includes forecast estimates from 48 ensemble members providing a range of possible future weather

conditions. The 30-day forecast is averaged using a 3-day moving window to control miscellaneous noise, trimming the forecast coverage down to 28-days. To be consistent with the non-forecast evaporation data, we will further bias correct the forecast forcings using the Real-Time Mesoscale Analysis (RTMA, De Pondeca et al., 2011.) data. The bias corrected forecast forcings from 48 ensemble members will be used as input to the DLEM model, resulting in 48 separate DLEM runs. Finally, the ensemble DLEM estimates will be aggregated to represent a range of possible future evaporation rates (e.g., 10^{th}, 25^{th}, median, 75^{th}, 90^{th} percentiles). The evaporation rate forecasts will help bridge the 3-day latency in the operational, reservoir-specific daily evaporation dataset.

DRI will lead the API tasks including development of custom API endpoints, example python scripts and jupyter notebooks, as well as data processing and formatting. TAMU will assess the forecasting skill and collaborate with DRI to incorporate the skill assessment matrix data into the API. The daily evaporation forecasts skill will be evaluated at different lead times (e.g., 1-, 2-, 3-, 4-week) by comparing long-term hindcasts with the dataset generated from the operational, reservoir-specific daily evaporation dataset for Texas. We will provide error and uncertainty statistics as information on evaporation forecast performance for different seasons and lead times through the API information. While we will not provide skill assessment at the seasonal lead time, we will use the historical comparison to provide general skill metrics based on month/season (for example, skill in the daily evaporation forecasts is better in March than in February). We will also provide historical minimum, maximum, and mean daily evaporation rates along with the forecasts. In addition, TAMU will work with DRI to assess potential biases in the meteorological forecasts by using data collected through Task 5. This information will be used for improving the forcing downscaling algorithm (Blankenau et al., 2020 and Zhao et al., in-review) adopted in the API.

Task 3: Deploy evaporation monitoring buoy on Sam Rayburn Reservoir. As part of our proposal, the TWDB will deploy a buoy station equipped with meteorological sensors to estimate daily reservoir evaporation using the bulk dynamic mass transfer equation. TWDB will use the python program, aeroevap.py, developed by the DRI as part of Reclamation's Science and Technology Program's Project ID 7662, to estimate reservoir evaporation from the data collected at the buoy station. TWDB currently uses aeroevap.py to estimate reservoir evaporation at existing evaporation buoys on Choke Canyon Reservoir, Lake Buchanan, Lake Meredith, and Red Bluff Reservoir.

Task 4: Deploy a Collison Floating Evaporation Pan station on Lake Buchanan. As part of our proposal, Agua del Sol Consultants, LLC will install, operate, and maintain a Collision Floating Evaporation Pan (CFEP) system in Lake Buchanan for a two-year period. Being the second open water evaporation station on Lake Buchanan, the Collision floating evaporation pan will enable the comparison of *in-situ* open water evaporation observations from two independent stations.

Task 5: Develop a methodology for bi-annual validation of the reservoir-specific daily evaporation dataset. As part of our proposal, the TWDB will establish a data sharing protocol to provide DRI and TAMU access to the daily *in-situ* data for site specific validation of gridded forcing inputs and DLEM evaporation estimates. *In-situ* datasets provided to TAMU and DRI will be QA/QC'd for standard issues such as outages and sensor failures. TAMU and DRI will provide a secondary review of *in-situ* data to ensure quality. DRI will focus on gridded climate data validation, while TAMU will evaluate

the evaporation estimates. TWDB will compare the observations with both the non-forecast and forecast datasets. Comparisons with the non-forecast datasets will help to quantify DLEM uncertainties and identify areas for future improvement. For instance, how much uncertainty is associated with the climate forcings versus simulated heat storage? Can improved downscaling better capture extreme evaporation events? Comparisons between *in-situ* and forecast datasets will also offer the most direct assessment of the forecasting skill including both absolute error and skill metrics. Last, bi-annual comparisons of *in-situ* and modeled data will also support identifying issues related to *in-situ* data acquisition and real-time DLEM estimates.

Data sets generated by this project will include:

1. Enhanced HEFs inflow forecasts for lakes Georgetown, Granger, Belton, Stillhouse Hollow, Somerville, Ray Hubbard, Ray Roberts, Lewisville, Grapevine, Tawakoni, and Fork.
2. Daily and 15-minute evaporation measurements from the Collision floating evaporation pan on Lake Buchanan.
3. Meteorological measurements from buoy weather stations at daily and 5-minute intervals, and daily estimated gross evaporation rates for Sam Rayburn Reservoir.
4. Computed reservoir-specific daily lake evaporation rate forecasts using the DLEM at 1–28-day lead times. A forecasting assessment matrix for each reservoir at different lead times.
5. Validation results against *in-situ* observations, both for the non-forecast and forecast evaporation rates.

4. Performance measures

We intend to quantify the project's performance by using the following measures:

1. We will survey the Brazos River Authority and Dallas Water Utilities at the end of year 2 and year 3 to obtain quantitative data on the following:
    a. Increase in reservoir conservation storage compared to the 2022–2023 water year, achieved at each of the FIRO study reservoirs within their service areas directly attributable to the incorporation of the improved forecast and planning tools developed by the project.
    b. Decrease in inflation-adjusted pumping costs attributable to the incorporation of improved forecast and planning tools developed by the project.
2. We will survey the Lower Colorado River Authority at the end of year 1, year 2, and year 3 to seek quantitative data on how incorporation of the enhanced daily reservoir evaporation data and the 1–28 day forecasts of evaporation reduced errors in reservoir water balance projections for lakes Travis and Buchanan (the two major water supply reservoirs managed and operated by the Lower Colorado River Authority) compared to when they used the legacy monthly TWDB quadrangle evaporation data in their lake forecast models.
3. At the end of year 2 and year 3, we will use the modified seasonal guide curves to inform adjustments to the conservation pool elevation of the FIRO reservoirs as represented in the water availability models for the Brazos River Basin, the Trinity River Basin, and the Sabine River Basin, and we will assess the potential for increasing, compared to 2020 yield estimates, surface water availability from these reservoirs 50-years into the future. Any long-term yield increases resulting from the adoption of FIRO at these reservoirs will indicate the

potential for recommending FIRO as a viable water management strategy for inclusion in the 2031 regional water planning cycle.

4. We will aim to achieve a 95 percent or greater completeness of observational records for data collection from the evaporation buoy deployed on Sam Rayburn Reservoir and the CFEP on Lake Buchanan over at least a 24-month period.
5. We will track usage of the 1–28-day reservoir evaporation forecasts one month following the launch of the API tool by documenting the number API calls received, and we will track this count every month to gauge interest in the forecasts and to track who uses the dataset.

5. Evaluation criteria

E.1.1. Evaluation Criterion A—Project Benefits

E.1.1.1. Sub-criterion A1: Water Better Managed

- **How will the project build long-term resilience to drought? How many years will the project continue to provide benefits?**

The project will lay the groundwork for using FIRO as a water management strategy for routine reservoir operations and for consideration in future regional water planning cycles. We anticipate that the need to optimize water supply from existing surface water reservoirs will continue to grow as the population of Texas grows and climate change stresses the reliability of supply from existing sources. As such, tools developed by the project will provide reservoir operators with options for adaptively managing multi-purpose reservoirs many years after the project has been completed.

Enhanced lake evaporation data resulting from the project will allow reservoir owners and water planners to evaluate available water management strategies to minimize water loss from their reservoirs. These strategies can then be adopted by regional water planning groups for inclusion in the state water plan, thus becoming eligible for low-cost water infrastructure funding from the TWDB. Texas carries out regional and state water planning on five-year cycles to examine needs and develop strategies for a 50-year time horizon; the resulting data will be useful in an ongoing manner, both for daily operational evaluation and for long-term planning. The knowledge resulting from the whole of this project will provide water managers and water planners in Texas with both novel methods and enhanced information—items not currently available—to better prepare for and withstand drought cycles in Texas.

- **How will the project improve the management of water supplies? For example, will the project increase efficiency, increase operational flexibility, or facilitate water marketing (e.g., improve the ability to deliver water during drought or access other sources of supply)? If so, how will the project increase efficiency or operational flexibility?**

The project will provide forecast tools that reservoir operators can adopt when deciding on whether to store a percentage of water in the lower reaches of a reservoir's flood control pool for use during dry times. It will also provide enhanced real-time and forecast daily reservoir evaporation, a critical factor affecting a reservoir's water balance in the near term, particularly during drought episodes. The availability of enhanced real-time and forecast reservoir evaporation data, and the availability for reservoir inflow forecasts, will enable reservoir operators to adopt proactive water demand

management measures (i.e., voluntary conservation) during drought events and delay or reduce the need to implement drought stage-dependent water use restrictions.

- **What is the estimated quantity of water that will be better managed as a result of this project? How was this estimate calculated?**

The quantity of water that is estimated to be better managed as a result of this project in North Texas is 397,221 acre-feet and in Central Texas is 155,574 acre-feet. These figures are based on the assumption that: five flooding events occur in the next ten years, producing at least 10% of flood pool storage, and the USACE Fort Worth District is able to retain 10% of flood pool storage for each flood event

- **What percentage of the total water supply does the water better managed represent? How was this estimate calculated?**

In North Texas (Upper Trinity), we estimate that the amount of water that can be better managed as a result of this project represents 26% of the total water supply from three reservoirs (Lake Lewisville, Ray Hubbard, and Ray Roberts). For Central Texas, the amount of water equates to 17% of the total water supply from the following five reservoirs: Belton, Georgetown, Granger, Stillhouse Hollow, and Somerville. These estimates were calculated by dividing the storage in the flood pool by the full storage of the water conservation pool. Note the estimates reflect the benefits of FIRO strategies for years with sufficient inflow and storage in the flood pool (assumed to be five years out of ten). The assumption of flooding occurring every other year is consistent with the engineering design of these reservoirs in which bankfull flow is associated with a 2-year average recurrence interval.

- **Provide a qualitative description of the degree/significance of anticipated water management benefits.**

By using climatology or forecast-guided reservoir operations, a small portion of the flood pool can be used to store water in anticipation of drought conditions. This operational change will considerably alleviate stress on the water supply in both regions of Texas, stress occurring as a result of population growth and recurring droughts. The surplus will benefit not only water supply but may also be used to benefit ecosystem services and recreation.

Will the project make new information available to water managers? If so, what is that information and how will it improve water management?

The project will provide a suite of new information, including:

1) Improved probabilistic forecasts of inflow and reservoir level for impactful drought and flooding events at lead times extending from 1-day to 270-days.
2) Potential gains as well as associated risks of retaining water in the flood pool based on forecasts, climatology, or a combination of both for multi-use reservoirs.
3) Outlook of water consumption for five reservoirs in the central Brazos and four reservoirs in the Upper Trinity at 1- to 3-month lead times.
4) Improved estimates of daily lake evaporation for all major water supply reservoirs in Texas (a total of 189 reservoirs).
5) Forecasts of lake evaporation at 1–28-day lead time for 189 major water supply reservoirs.

Additional information for metering/water measurement projects.
The proposed buoy evaporation monitoring system and the Collison Floating Evaporation Pan system are consistent with evaporation monitoring efforts currently implemented by the Reclamation at other reservoirs in the western U.S. (Department of the Interior, 2021; Department of Interior, 2022) and are consistent with ongoing efforts supported by the TWDB. These systems have demonstrated capacity to accurately measure lake evaporation. The CFEP is currently deployed in Twin Buttes Reservoir in Texas, and four buoy stations are deployed in four reservoirs in Texas.

This work is proposed to provide *in-situ* data, particularly for the humid and sub-humid portions of the state, to enable better calibration and validation of the existing operational, reservoir-specific daily evaporation dataset for Texas. The proposed additional open water evaporation monitoring sites were identified in consultation with the USACE Fort Worth District and the Lower Colorado River Authority, who jointly funded the development of the reservoir-specific daily evaporation dataset for Texas and who have continuously stressed the need to develop a plan for on-going calibration and validation of the dataset to increase stakeholder confidence.

Data from these stations, and the enhanced daily evaporation dataset for Texas, can provide near real-time reservoir evaporation loss estimates that alert reservoir operators to the likely risk of water storage dropping below certain drought response thresholds. Such timely information allows water managers to promptly implement water conservation measures – e.g., enacting outdoor lawn water restrictions – and may serve to minimize the economic impacts resulting from the non-delivery of committed water supplies from a given source.

E.1.1.2. Sub-criterion A2: Environmental & Other Benefits

Sub-Criterion A2.a: Climate Change

- **In addition to drought resiliency measures, does the proposed project include other natural hazard risk reductions for hazards such as wildfires or floods?**

Texas faces both droughts and floods, with fluctuations between these hydrologic extremes stressing communities, water providers, and emergency responders. The FIRO component of the project is a strategy for both drought resiliency and flood control. Storing water in the flood pool to increase water supply reliability or pre-releasing water from the conservation storage of a reservoir to increase flood control capacity, based on weather forecasts, is FIRO in a nutshell. At this time in Texas, FIRO is being developed to enhance drought resiliency by increasing water supply reliability. While FIRO can be applied to enhance flood mitigation, reservoir owners and water managers in Texas are unwilling at this juncture to pursue FIRO for activities beyond enhancing water supply reliability. This is largely due to the lack of accuracy and resolution available from precipitation and streamflow forecasts.

Sub-Criterion A2.b: Environmental Benefits
Storing water in the lower 10% of the flood pool of multi-purpose reservoirs will increase the ability of reservoir operators to meet the instream flow requirements of several threatened and endangered species (as listed by the Texas Parks and Wildlife Department, https://tpwd.texas.gov/gis/rtest/) downstream of the reservoirs in the FIRO pilot project in the Little River Watershed and the Yegua Creek tributary of the Brazos River Basin and the Upper Trinity.

These include several fish species such as the Texas shiner, small eye shiner, Guadalupe bass, mountain mullet, American eel, and Mississippi silvery minnow; reptiles such as the Western chicken turtle, alligator snapping turtle, Western box turtle, Eastern box turtle, Texas garter snake, Texas horned lizard; amphibians such as Woodhouses's toad, tiger salamander, Salado Springs salamander; and mollusks such as the Texas fawnsfoot, Brazos heelsplitter, Texas heelsplitter, Louisiana pigtoe, Trinity pigtoe, and sandbank pocketbook.

Sub-Criterion A2.c: Other Benefits

- **Will the project benefit multiple sectors and/or users (e.g., agriculture, municipal and industrial, environmental, recreation, or others)? Describe the associated sector benefits.**

The FIRO component of the project will benefit water users in Central Texas that rely on stored water from reservoirs in the Little River watershed and Yegua Creek of the Brazos River Basin and water users that rely on Dallas Water Utilities to provide water from reservoirs in the Upper Trinity and Sabine River Basin. The range of water users include municipal, agricultural, industrial, and recreational, as well as the environment, particularly in river reaches where the Texas Commission on Environmental Quality has established environmental flow and instream flow standards.

The forecast reservoir-specific daily evaporation data will benefit reservoir operators, water managers, industries and wastewater treatment providers that manage wastewater ponds, and water providers who hold treated water in reservoirs prior to distribution. While the evaporation rate forecasts will be provided for major water supply reservoirs, entities managing smaller water bodies can use the forecasts from major water supply reservoirs to estimate the projected rate of water loss from smaller water bodies. The enhancements to reservoir-specific daily evaporation data will benefit reservoir operators, water rights regulators, and regional water planning groups.

- **Will the project benefit a larger initiative to address sustainability?**

The project will yield datasets and planning tools that enable reservoir operators to adaptively manage their respective reservoirs and optimize water available from these reservoirs. Such adaptive management will provide "low hanging fruit" for addressing water supply needs in rapidly growing regions of the state and reduce the need to build new surface water reservoirs.

- **Will the project help to prevent a water-related crisis or conflict? Is there frequently tension or litigation over water in the basin?**

The project will enable reservoir operators to incorporate real-time evaporation datasets, forecasts of evaporation, and enhanced forecasts of reservoir inflow, which will allow these operators to track and forecast how soon water levels might reach and drop below drought contingency trigger levels. Such information will enable operators to send out calls for voluntary water conservation measures in advance of reservoirs reaching trigger levels, necessitating the implementation of mandatory water use reduction measures. Early adoption of conservation measures can limit the necessity to limit or suspend diversions to temporary water rights holders and can limit the number of priority calls during times of drought from senior water right holders.

E.1.2 Evaluation Criterion B – Drought Planning and Preparedness

The goal of the state's water planning process is to ensure adequate water supplies for all Texans in times of drought. The state is divided into 16 regional water planning areas with each represented by a planning group consisting of approximately 22 members representing the public, counties, municipalities, industries, agriculture, environment, small businesses, electric-generating utilities, river authorities, water districts, water utilities, and groundwater management areas, where applicable. Each five-year cycle, the 16 regional water planning groups develop regional water plans that identify potential water shortages under drought of record conditions for 50 years into the future and recommend water management strategies to address those potential shortages. The TWDB provides administrative support and technical assistance to the regional water planning process and develops a state water plan based on the 16 regional water plans. All told, the Texas State Water Plan and water planning process addresses the needs of all water user groups in the state — i.e., municipal, irrigation, manufacturing, livestock, mining, and steam-electric power — **during a repeat of the drought of record** making this the main drought planning mechanism in the state.

The FIRO-related task of the proposed project addresses Section 3.2 Historical and Potential New Droughts of Record in the 2022 State Water Plan ((Drought Plan – Section 1) which states: "*Planning for the near-term timescale will allow a measure of flexibility in how water supply sources are managed (for example, variable flood pools in surface water reservoirs). Near-term planning could allow Texans to harness some of the supply side benefits of excess water during periods of higher precipitation for use later in drier times.*"

The proposed reservoir evaporation forecasts and data enhancement tasks of the project address Section 3.5 Uncertainty of Drought in the 2022 State Water Plan (Drought Plan – Section 1) where it states that: "*TWDB continues to develop datasets, analysis tools, and information to monitor and prepare for future drought conditions and impacts to water resources, including improving and expanding estimates of reservoir evaporation…*" and "*TWDB seeks to better understand drought risk to water supplies and to create tools for assessing the reliability of reservoir yields currently used to plan for existing and future water supplies.*"

Enhancements to reservoir evaporation data also are key to improving the accuracy of the state's water availability models which are used by regional water planning groups to estimate future surface water availability (and by the Texas Commission on Environmental Quality in surface water rights permitting). Improved models are particularly important in regions receiving a significant proportion of their water supply from surface water sources. As such the proposed project will directly impact the assessment of surface water availability for each regional water plan. We provide Chapter 3 Drought and Drought Response in Texas of the State Water Plan to demonstrate how surface water availability fits into the assessment of water supply for drought planning purposes in the state. We also include Section 2.3.1 – Evaluation of Surface Water Availability of the Second Amended *General Guidelines for the sixth cycle of regional water planning in Texas* (Drought Plan – Section 2) to describe the methodology that regional water planning groups are required to follow when assessing surface water availability water supply for the next 50-year planning horizon.

Texas Water Code Section 16.053 (e-2) states that a regional water planning group may plan for drought conditions worse than the drought of record when developing a regional water plan under 16.053 (e). This is a statutory update effective September 1, 2023. Previously, state and

regional water planning used the observed drought of record as the planning baseline, which for many regions of the state was the 1950s drought of record. The TWDB has started developing methodologies for the incorporation of projected trends in reservoir evaporation in the assessment of future available surface water (Principal investigators Dr. Fernando and Dr. Zhu are leading the development of technical assistance for this work).

E.1.3 Evaluation Criterion C – Severity of Actual or Potential Drought Impacts or Water Scarcity Impacts to be addressed by the Project

Describe the severity of the impacts that will be addressed by the project

Per the U.S. Drought Monitor map for October 24, 2023, 75.21% of the land area of Texas had drought conditions ranging from moderate (D1) through exceptional (D4) drought. Exceptional drought covered 6.8% of the land area of the state and has had stranglehold over counties in the south central and central portions of the state, e.g., Bell, Bexar, Blanco, Comal, Coryell, Hays, and Lampasas, extending back one year or more.

Statewide reservoir conservation storage, in 119 major water supply reservoirs in Texas and Elephant Butte Reservoir in New Mexico, has been below average since November 2021 and as of mid-October 2023 approximately 15% below the median for this time of year. Conservation storage in some reservoirs in the Brazos River Basin has been well below average throughout 2023 with record lows in Belton, Waco, and Stillhouse Hollow reservoirs. As of October 23, 2023, within the Colorado River Basin, Hords Creek Lake storage was at a record low for this time of year. The Guadalupe River Basin was also at a record low for this time of year, in which Canyon Lake has had near record lows all year and as of October 23, storage was still at a record low. The Nueces River Basin had a near record low for this time of year, with Choke Canyon Reservoir also at near record levels for this time of year. The Rio Grande basin was at a record low in October, including record lows for lakes Amistad and Falcon. The San Antonio River Basin has also had near record lows this year with Medina Lake at a record low in October (see Annex 3 – Surface water storage conditions in Texas).

According to the Texas Commission on Environmental Quality, as of October 19, 2023, 547 public water systems reported restrictions, of which 93 were voluntary and 448 were mandatory (https://www.tceq.texas.gov/drinkingwater/trot/droughtw.html). Eighteen public water systems reported less than 180 days of water remaining.

In August 2023, much of the state was in extreme to exceptional fire risk (Figure 2). Fire risk spread rapidly between July and August 2023 as a result of the intense heat and dryness experienced in July and August 2023.

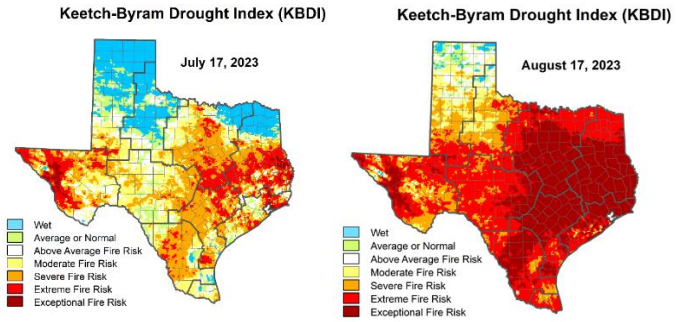

Figure 2: Keetch-Byram Drought Index for fire risk for July 2023 (left) and August 2023 (right).

Texas AgriLife Extension reported that as of September 2023, more than 200 counties met drought severity levels to trigger eligibility requirements for U.S. Department of Agriculture assistance this year. Due to lack of rainfall across the state, there have been poor cotton yields, low hay counts, and wheat going to forage instead of harvest. Livestock inventory remains low due to drought. As of August 2023, more than 2.66 million cattle were reported to have been sold this year, which is 480,000 more than last year. In October 2023, the Texas Parks and Wildlife Department reported drought related fish kills in communities of Round Rock, Buda, and Andrew and mussel kills in areas of the state. Red Tide has also been reported along the coast due to low in-flows. Recreation and access to reservoirs has been affected as many boat ramps across the state have been closed due to low water levels caused by drought. Some state park water sources are closed or have limited access to fishing, swimming, and boating due to low water levels, and some state parks have reported high toxicity levels of Cyanobacteria or blue-green algae that thrive in hot, dry weather, which pose a danger to dogs and people recreating in lakes.

Between 1980 and 2023, 19 billion-dollar drought disaster events affected Texas; three of these events occurred in the 2020–2023 time period, with the most recent event being the April through September heat wave of 2023 (National Oceanic and Atmospheric Administration – National Centers for Environmental Information, 2023). With record low inflows into the Highland Lakes in 2022 and 2023, the Lower Colorado River Authority cut off interruptible supply from lakes Buchanan and Travis in the summer of 2022 to agricultural customers in Colorado, Wharton, and Matagorda counties. As drought continued, cutoff of interruptible supply to these agricultural customers occurred again in March 2023, with the cutoff applicable for the full year of 2023. In August 2023, the combined storage in lakes Buchanan and Travis dropped below the Stage 2 Drought Response Trigger, initiating a 10–20% reduction in water use [LCRA 2023(a) and LCRA 2023 (b)].

Texas is no stranger to drought. In the 20th century, the 1950–1957 drought was the drought of record for all of Texas, ultimately leading to the formation of the TWDB. The 2010–2014 drought included the hottest and driest 12-months on record, with streamflow dropping to new lows and widespread emergency actions implemented to maintain water supplies [TWDB, 2022 (b)]. The direct agricultural loss from the 2011 drought is estimated at $7.6 billion (Fannin 2012), while the total cost to the Texas economy from indirect and induced impacts is estimated at almost $17 billion (Ziolkowska, 2016), primarily from crop and livestock losses. For most regions of the state, the 1950s drought remains the drought of record. However, the 2022 State Water Plan identifies the 2010–

2014 drought as the new drought of record for several river basins/sub-basins, including the Canadian, Colorado, Nueces, Red, Sulphur, and upper portions of the Brazos Basin.

Describe any projected increases to the severity or duration of drought in the project area resulting from climate change.
The risk of extreme drought in Texas is enhanced by warmer temperatures, increased evaporation, and increasingly variable precipitation, as experienced in recent years (Nielsen-Gammon et al., 2019). During the 2010–2014 drought the cumulative streamflow deficit measured 10 million acre-feet at unregulated streamflow index sites; this was 400,000 acre-feet more than the total streamflow deficit measured during the 1950s drought which was two years longer [TWDB, 2022 (b)]. Projected increases in temperature due to climate change are expected to increase aridity in the Southern Great Plains, with an increase in evapotranspiration and decrease in soil moisture (Kloesel et al. 2018). If the current observed temperature trend continues, summertime evaporative loss from reservoirs could increase ~4% increase by 2036, compared to summertime evaporative loss over the period 2000–2018 (Nielson-Gammon et al., 2021). In addition, Fort Hood and Joint Base San Antonio, in Texas, are threatened by current and potential climate-related events of recurrent flooding, drought, and wildfire (Department of Defense, 2019).

Describe ongoing or potential drought impacts to specific sectors in the project area if no action is taken.
In the 2022 State Water Plan, the estimated statewide impacts of not meeting the identified water needs in Texas would result in water user groups in the state facing a potential shortage ranging between 2.2 - 2.9 million acre-feet between 2020 and 2070, with maximum shortages in 2030. An annual combined lost income of $110 billion in 2020, increasing to $153 billion by 2070 is estimated. Lost jobs would increase from 615,000 in 2020 to almost 1.4 million in 2070 [TWDB 2022 (a)].

E.1.4.Evaluation Criterion D—Presidential and DOI Priorities

E.1.4.1. Disadvantaged or Underserved Communities

Using the White House Council on Environmental Quality's interactive Climate and Economic Justice Screening Tool, available online at Explore the map – Climate & Economic Justice Screening Tool (https://screeningtool.geoplatform.gov), we identified several counties with disadvantaged communities within the project area. By providing tools for increasing water supply reliability in these counties, these disadvantaged communities will not have to face potential income losses cascading from curtailments to water use during drought events. Increased water supply reliability may also provide additional economic growth opportunities within these counties directly benefitting these communities.

Counties (43) with disadvantaged communities in the Brazos River Basin include: Austin, Bailey, Bell, Bosque, Castro, Comanche, Coryell, Crosby, Dickens, Eastland, Erath, Falls, Fisher, Floyd, Fort Bend, Garza, Grimes, Hale, Hamilton, Haskell, Hill Johnson, Hockley, Hood, Jones, Kent, King, Lamb, Lampasas, Lee, Limestone, Lubbock, McLennan, Milam, Palo Pinto, Parmer, Robertson, Somervell, Stonewall, Throckmorton, Waller, Washington, Williamson, and Young. Counties (38) with disadvantaged communities in the Colorado River Basin include: Andrews, Bastrop, Brown, Burnet,

Callahan, Cochran, Coke, Coleman, Colorado, Concho, Dawson, Ector, Edwards, Fayette, Gaines, Gillespie, Glasscock, Hays, Howard, Kimble, Llano, Lynn, Mason, Matagorda, McCulloch, Menard, Midland, Mills, Nolan, Runnels, San Saba, Scurry, Sterling, Taylor, Terry, Tom Green, Wharton, and Yoakum). Counties (28) with disadvantaged communities in the Trinity River Basin include: Anderson, Archer, Chambers, Collin, Cooke, Dallas, Denton, Ellis, Fannin, Freestone, Grayson, Henderson, Houston, Hunt, Jack, Kaufman, Leon, Liberty, Madison, Montague, Navarro, Parker, Polk, San Jacinto, Tarrant, Van Zandt, Walker, and Wise.

E.1.4.2. Tribal Benefits *Not applicable.*

E.1.5. Evaluation Criterion E—Readiness to Proceed and Project Implementation

Task implementation

Task 1: Establish a suite of forecast-based decision support tools to assist with reservoir operations and drought preparedness planning in Central and North Texas.

As part of our proposal, TWBD will establish an interagency agreement with the University of Texas at Arlington to undertake the following:

Operational assessment 1: Hindcasts of reservoir inflow and pool levels for severe droughts and high inflow episodes, including droughts of 2011, 2018, 2022, and 2023 and floods of 1992, 2002, 2007, 2015, and 2016. The operational assessment will gauge the gains in forecast skills of inflow and reservoir levels from the augmentations of ensemble inflow forecasts at medium-range to seasonal scales for guiding drought planning. A particular focus will be given to skills in forecasting drought onset and intensification.

Operational assessment 2: Application of the forecast-based risk assessment tool to determine flooding risks of temporary allocation of flood storage for water supply for the five multi-use reservoirs in the Brazos River Basin and three in the Upper Trinity. In particular, the experiment will examine the following: potential gain in water supply storage from applying a seasonal guide curve alone to reservoir operations, and by applying baseline ESP as the reference, and concomitant flooding risks, and potential gain in water supply storage from applying a seasonal guide curve but using HEFS forecasts to guide release of seasonal pool to reduce flooding risks. The assessment will also entail water right analysis by Dallas Water Utilities to determine their ability to use retained water for water supply purposes.

Operational assessment 3: Integration of seasonal ensemble forecasts for extended lead times, using the augmented forecast system, into the updated version of the water availability model. The operational assessment will involve using ensemble forecasts, lake evaporation, and estimated customer withdrawal to predict reservoir level depletion during droughts and to formulate drought contingency plans.

Operational assessment 4: Run Dallas Water Utilities' Riverware System with revised historical lake evaporation data for recent drought episodes (2011–2014, 2022–2023) to determine the impacts on water supply.

Operational assessment 5: Run Brazos River Authority's planning model with revised historical lake evaporation data for recent drought episodes (2011–2014, 2022–2023) to determine the impacts on water supply.

Task 2: Provide forecasts of reservoir-specific daily evaporation for all 189 major water supply reservoirs at the 1–28-day lead time through an Application Programming Interface (API) tool. As part of our proposal, TWDB will establish a purchase order with DRI and an inter-agency agreement with TAMU to collate reservoir-specific evaporation forecast datasets for each major water supply reservoir in Texas. Hindcast-derived DLEM estimates from 2011–2022, used for forecast skill assessment, will be provided as needed to support forecast decision support tool development. Forecasts analysis will leverage existing data being developed by TAMU and DRI through the NASA-ROSES funded project *Satellite Assisted Operational Reservoir Evaporation Monitoring and Forecast for the Western U.S*.

Task 3: Install one data buoy with telemetry for computation of open water evaporation. A NexSense CB-650 data buoy will be deployed on Sam Rayburn Reservoir (Sabine River Basin). The buoy will be equipped with sensors to measure aerodynamic and radiative parameters influencing evaporation, as listed below. Buoy design is based on input from the Desert Research Institute (DRI) received by the TWDB when staging and deploying four reservoir evaporation monitoring buoys in Texas as part of the project funded through R19AP00112. Data will be collected using a Campbell Scientific CR-1000 datalogger. Near real-time data transmission using a cell modem will connect the data buoys to the TWDB's TexMesonet network website and to a dedicated desktop computer within the TWDB headquarters in Austin that runs 24/7 to download transmitted data via LoggerNet Admin. TWDB will work with the USACE Fort Worth District's Operations Division on locating the best site within Sam Rayburn Reservoir for deploying the buoy and obtaining the permit needed for deployment.

Task 4: Install a Collision Floating Evaporation Pan (CFEP) on Lake Buchanan with telemetry and quarterly data quality control. As part of our proposal, we will establish a purchase order with Agua del Sol Consultants to install, operate, and maintain a Collision floating evaporation pan (CFEP) system on Lake Buchanan reservoir for a two-year period. TWDB has an existing memorandum of agreement with the LCRA for deploying an evaporation buoy on Lake Buchanan. We will request an amendment to this agreement to include the deployment of the new CFEP station.

Task 5: Develop a methodology for the bi-annual validation of the reservoir-specific daily evaporation dataset for Texas. Share daily data collected at the new stations (along with data being collected from the buoys on Lake Meredith, Lake Buchanan, Choke Canyon Reservoir, and Red Bluff Reservoir, and data collected from the Collison floating evaporation pan on Twin Buttes) with TAMU and DRI for continuous calibration and validation of the daily evaporation dataset.

Major tasks, milestones, and dates

Major tasks and milestones	Date
Task 1:	
Establish a suite of forecast-based decision support tools to assist with reservoir operations and drought preparedness planning in Central and North Texas	March 2026 – September 2026
Task 2:	
Provide forecasts of reservoir-specific daily evaporation for all 189 major water supply reservoirs at the 1–28-day lead time through an Application Programming Interface (API) tool	September 2025 onwards
Task 3:	
Deploy an evaporation monitoring buoy on Sam Rayburn Reservoir	March 2025
Task 4:	
Deploy a Collison Floating Evaporation Pan (CFEP) station on Lake Buchanan	March 2025
Task 5:	
Develop methodology for bi-annual validation of the reservoir-specific daily evaporation dataset with in-situ data from open water evaporation stations	October 2025 – March 2026

Plan for data post-processing, evaporation computation, data transfer, and data sharing

UTA will provide reservoir inflow forecasts and water demand forecasts to the Brazos River Authority, Dallas Water Utilities, USACE Fort Worth District, and WGRFC. DRI and TAMU will provide reservoir evaporation forecasts through a dedicated API tool that will be developed by DRI. Enhancements to the daily reservoir evaporation dataset, based on the routine bi-annual calibration and validation steps, will be released through versioning of the datasets through the existing daily reservoir evaporation database website (https://dri-apps.earthengine.app/view/twdb-reservoir-evaporation) and the dedicated API for this dataset: (https://twdb.dri.edu/). TWDB will use existing workflows (e.g., aeroevap.py) to compute daily reservoir evaporation rates from Sam Rayburn Reservoir. The meteorological data collected from the evaporation buoy on Sam Rayburn Reservoir will be ingested into TexMesonet and shared through the TexMesonet Viewer (www.texmesonet.org). Project data will be stored on TWDBs servers, which are managed by Amazon Web Services. All meteorological data collected at, and reservoir evaporation estimated for *in-situ* open water evaporation stations will be shared through a OneDrive folder with TAMU, DRI, LCRA, the U.S. Bureau of Reclamation – Oklahoma-Texas Area Office, Albuquerque Area Office, and Technical Service Center. We will also include an alert on the offline availability of the *in-situ* open water reservoir evaporation estimates on TWDB's legacy evaporation data site (https://waterdatafortexas.org/lake-evaporation-rainfall) and provide the contact information for how to request the data..

Steps for contacting lake owners/operators for the installation of monitoring stations

We have contacted USACE Fort Worth District about identifying the best location and permit for deploying the buoy on Sam Rayburn Reservoir deployment and for obtaining the permit to install We have an existing memorandum of agreement with the Lower Colorado River Authority for

deployment of the buoy on Lake Buchanan. We will initiate a new agreement to cover the CFEP on Lake Buchanan. The TWDB has experience of developing and executing these agreements through the previous buoy deployments.

Steps for proceeding with contractual agreements for professional services.

We will follow state and federal procurement procedures for obtaining the services of UTA, TAMU, DRI, and ADSC. We have existing inter-agency agreements with UTA and TAMU for research projects. We will use new inter-agency agreements as the contract instrument of choice for the proposed project as well. Inter-agency agreements do not allow indirect costs and, therefore, provide better value for the state. With DRI and ADSC, given that they are out-of-state entities, we will use proprietary and sole source justifications when seeking bids for vendors. Once DRI and ADSC officially respond to the bid, we will establish new purchase orders for the proposed work. We will enter into a memorandum of understanding with the U.S. Geological Survey – Woodlands Office data collection from, and maintenance of, the evaporation buoy to be deployed on Sam Rayburn Reservoir.

E.1.6 Evaluation Criterion F – Nexus to Reclamation

How is the proposed project connected to a Reclamation project or activity?

The proposed enhancement to reservoir evaporation data and the provision of reservoir-specific evaporation forecasts will build on existing strong collaboration that the TWDB has with several Reclamation Offices in the field of enhancing reservoir evaporation estimation. The TWDB convenes monthly reservoir evaporation calls on the third Tuesday of each month to exchange updates on on-going and planned research and monitoring activities pertaining to reservoir evaporation. These meetings have been convened since 2020 and are attended by three Reclamation Offices, i.e., Oklahoma-Texas Area Office (Marisela Castro), Albuquerque Area Office (Dagmar Llewellyn, David Park, and Genevieve Allen), and Technical Service Center (Dr. Katie Holman), and attended by TAMU, DRI, LCRA, USACE Fort Worth District, and Brazos River Authority staff. The proposed work also leverages past and current collaborations that DRI has with Reclamation Office, particularly Technical Service Center. The following Reclamation offices have expressed interest in the reservoir-specific daily evaporation data and the daily forecasts of reservoir evaporation: Technical Service Center, the Albuquerque Area Office, Western Colorado Area Office, Eastern Colorado Area Office, Upper Colorado Basin Regional Office, and Lahontan Area Office. The City of El Paso in far West Texas obtains surface water from Elephant Butte Reservoir through Reclamation's Rio Grande Project. Understanding reservoir evaporation and improving accuracy of reservoir evaporation estimates for Elephant Butte Reservoir and along the Rio Grande is of interest to Reclamation (Holman et al., 2023).

Data from the buoys deployed in two Reclamation reservoirs (i.e., Lake Meredith and Choke Canyon) and from the CFEP station on Twin Buttes will continue to be collected over the project's duration and will feed into the calibration and validation of the reservoir-specific daily evaporation dataset. The project may leverage a proposed Reclamation internal WaterSMART Applied Science Tools project led by Dr. Katie Holman titled *Open-Water Evaporation: Expanding Access to Technical Tools for Modern Water Resource Management* that TWDB is a collaborator on. Enhanced reservoir evaporation data may also support the Reclamation internal WaterSMART Applied Science project led by Collins Balcombe (Oklahoma-Texas Area Office) titled *Quantifying Risk Exposure and*

Tolerance of Conjunctively-Managed Water Supplies to Enhance Drought Preparedness and Response that TWDB is a collaborator on.

The proposed FIRO work builds on a WaterSMART Applied Science grant awarded to UTA in fiscal year 2021. The project will develop tools that enable water managers incorporate flexible reservoir operations to maximize supply options and to track daily reservoir drawdowns both in real-time and at 28-day lead time, which will help inform the need to implement water demand management strategies to extend supplies during drought. The project, therefore, promotes a proactive approach to drought, which places it well within the goals of Reclamation's Drought Response Program. The project builds on existing collaboration across several stakeholders in the Texas Water sector and demonstrates that: ***"Collaboration with a multitude of customers, partners, and stakeholders is essential to identifying successful strategies to address complex water management issues such as drought."*** It is also consistent with Reclamation's approach to addressing drought in the West through collaboration.

Is the project on Reclamation project lands or involving Reclamation facilities?
The project will ingest data being collected by the buoy stations at Choke Canyon (Nueces River Project) and Lake Meredith (Canadian River Project), and the CFEP on Twin Buttes (San Angelo Project). Install equipment on three Reclamation Projects. These Reclamation Projects are still federally owned.

E.1.7 Evaluation Criterion G—Stakeholder Support for Proposed Project

This project has broad stakeholder support. We have provided letters of support from the Brazos River Authority, Lower Colorado River Authority, Dallas Water Utilities, National Weather Service – West Gulf River Forecast Center, USACE Fort Worth District, and NOAA – Physical Sciences Laboratory (see Annex 4). The LCRA has committed to providing cash cost-share of $130,000 to cover two years of the deployment of a Collison Floating Evaporation Pan on Lake Buchanan. The Brazos River Authority has committed to providing $50,000 as in-kind cost share, and Dallas Water Utilities has committed $60,000 as in-kind cost share on the project. The USACE Fort Worth District and West Gulf River Forecast Center will provide technical guidance, review, and test products developed by the project for operational integrating in their workflows pertaining to forecasting reservoir elevations, streamflow, and flood risk. NOAA – Physical Sciences Laboratory will provide guidance on new forecast product of potential applicability for operational assessments.

The cost-sharing River Authorities and Dallas Water Utilities are major stakeholders in the Texas Water Sector. The Lower Colorado River Authority manages the lower 600 miles of the Colorado River in Texas and is a wholesale water provider and supplies approximately 1.4 million people in central Texas, provides flood control, is a wholesale power provider, a transmission service provider, maintains a public park system, and provides recreational access to lakes and river access points. The Brazos River Authority develops and manages water resources in the entire Brazos River Basin, which is approximately the size of the State of Tennessee. The Brazos River Authority is a wholesale water provider, provides water and wastewater treatment services, monitors water quality, and has public education programs to promote water conservation. Several major petrochemical industries along the Texas Gulf Coast obtain water supply from its reservoirs. Dallas Water Utilities is one of the largest water utilities in the Nation. It provides water, wastewater, and stormwater services to over 2.6 million customers in the City of Dallas and 27 surrounding cities.

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Project Budget

Funding Plan

Table 1: Total Project Cost Table

SOURCE	AMOUNT
Costs to be reimbursed with the requested Federal funding	$718,978.00
Costs to be paid by the applicant	$478,982.04*
Value of third-party contributions 1	$130,000.00
Value of third-party contributions 2	$110,000.00*
TOTAL PROJECT COST	**$1,437,960.04**

*in-kind support

Table 2: Summary of Non-Federal and Federal Funding Sources

FUNDING SOURCE	AMOUNT
Non-Federal Entities	
1. Texas Water Development Board	$478,982.04
2. Lower Colorado River Authority	$130,000.00
3. Brazos River Authority	$50,000.00
4. Dallas Water Utilities	$60,000.00
Non-Federal Subtotal	$718,982.04
Other Federal Entities	
1. U.S. Bureau of Reclamation	$718,978.00
Other Federal Subtotal	$718.978.00
REQUESTED RECLAMATION FUNDING	**$718,978.00**

Budget proposal

Table 3: Budget proposal

Budget Item Description	Computation		Quantity Type	Total Cost ($)
	$/hour	Quantity	(hours)	
Salaries and wages				
Nelun Fernando	46.81	960	hours	44,938.00
John Zhu	38.49	960	hours	36,947.75
Amanda Burke	30.26	960	hours	29,049.69
			hours	-
			hours	-
Total base salary				***110,935.44***
Fringe benefits				
Nelun Fernando			29.57%	13,288.17
John Zhu			29.57%	10,925.45
Amanda Burke			29.57%	8,590.00
				-
				-
Total fringe				***32,803.60***
Equipment				
Buoy with meteorological sensors to estimate evaporatio	$35,000	1	data buoys	35,000.00
				-
				-
Total equipment				***35,000.00***
Contractual				
University of Texas at Arlington (Development of FIRO tools)	200,000	3	years	***600,000.00***
Texas A&M University (Reservoir evaporation forecasts and data calibration)	83,462	3	years	***250,386.00***
Desert Research Institute (API tool development for evaporation forecasts and data validation)	62,209	3	years	***186,627.00***
Agua del Sol Consultants (New Collison pan deployment on Lake Buchanan and data package)	65,000	2	years	***130,000.00***
U.S. Geological Survey - Oklahoma-Texas Water Center/Gulf Coast Office (data collection, quality control, and maintenance of buoy on Sam Rayburn Reservoir)	10,000.00	2	years	***20,000.00***
Total contractual				***1,187,013.00***
Other				
Total Direct Costs (only base salaries)				110,935.44
Indirect Costs - 65.09%				***72,208.00***
Total Study Costs (Direct, Indirect, Fringe, and Contractural)				**1,437,960.04**

Budget narrative

The proposed project budget covers partial salary costs and associated fringe benefits for three full-time staff members from the Texas Water Development Board (TWDB), indirect costs (at the rate of 65.09 percent that is approved by the U.S. Environmental Protection Agency, see Annex No. 5), equipment costs, and contractual costs.

The total project cost for the three-year period, from 1 October 2024 to 30 September 2027, is estimated at $1,437,960.04. The Texas Water Development Board will provide 50 percent of the total cost – i.e., $ 718,982.00 – as state match to the project. State match includes in-kind support to cover partial salary, fringe, and indirect costs for two months per year of the three full-time staff members of the TWDB, in-kind support from two contracted studies that are directly relevant to the proposed project that partially offset the contract cost for the development of Forecast-Informed Reservoir Operations (FIRO) tools, and local match provided by matters. The latter includes both cash match and in-kind support for full-time staff of partner organizations collaborating on this study. The total cost for year 1 (FY 2025) is $490,994.00, with a federal cost of $174,724.00. The total cost for year 2 (FY 2026) is $505,943.00, with a federal cost of $199,385.00. The total cost for year 3 (FY 2027) is $441,023.00, with a federal cost of $344.869.00.

TWDB staff commitment

TWDB staff time estimates proposed for this project includes the following:

Technical staff

- N. Fernando, Manager – Water Availability Department
  – 6 months (2 months per year in years 1 through 3)

- J. Zhu, Senior Hydrologist – Water Availability Program
  – 6 months (2 months per year in years 1 through 3)

- A. Burke, Hydrologist – Water Availability Department
  – 6 months (2 months per year in years 1 through 3)

The hourly rates of compensation for Dr. Fernando, Dr. Zhu, and Ms. Burke (above). These rates include base salary and longevity pay and the 5% increase, effective from September 1, 2024, mandated by the Texas Legislature. The fringe benefit rate is 29.57 percent of the base salary. This rate is approved by the U.S. Environmental Protection Agency. The indirect cost of the project, calculated on base salaries, is $72,208.00.

Justification for labor hour estimate for N. Fernando based on previous experience.

Dr. Nelun Fernando, Manager of the Water Availability Department at the TWDB, will be a Principal Investigator on the project, the project manager and contact person on the grant. She will be responsible for project and technical oversight, and program administration and reporting. Compiling and disseminating reservoir evaporation datasets, technical support to the regional

water planning process in Texas, including leading technical explorations to assess the feasibility of FIRO as a water management strategy, and the provision of drought and water supply condition updates to the Texas Drought Preparedness Council are some of the key responsibilities of the Water Availability Department. Dr. Fernando will have overall responsibility for developing contracts for procuring the services of contractors on this project, for developing land/lake access agreements with cooperators/reservoir operators, for providing technical oversight to Dr. Zhu, and for leading and coordinating the efforts of the TWDB team on the project.

In **year one**, we estimate that 0.5 months of Dr. Fernando's time will be allocated for oversight of contract and project management duties undertaken by Dr. John Zhu and Ms. Amanda Burke for the professional services contracts and equipment procurement required for this project. Dr. Fernando has extensive experience of providing technical and management oversight of agency contracted studies. She is also a Certified Texas Contract Manager (CTCM certification #1900002919). Our estimate of 0.5 months in year one for contract and project management duties is based on Dr. Fernando's experience with developing, executing, and closing out such contracts. An additional 1.0 months of Dr. Fernando's time will be allocated for the provision of technical oversight, attendance at project progress meetings for the FIRO component of the project led by the University of Texas at Arlington, progress meetings for evaporation forecasting and evaporation data enhancement component of the project, and the review of interim work products. An additional 0.5 months of her time will be allocated for estimating daily reservoir evaporation using the Aeroevap.py scripts using data collected from the new evaporation buoy on Sam Rayburn Reservoir, and for collating the data from the new station plus the data collected from existing open water evaporation buoys on Lake Meredith, Choke Canyon, and Red Bluff Reservoir. She will be responsible for establishing and communicating the data sharing protocols for the reservoir evaporation enhancement component.

In **year two**, we estimate that 1.0 months of Dr. Fernando's time will be allocated for the provision over technical oversight on Task 1, Task 2, and Task 5, which will include review of interim project deliverables, and user acceptance testing of the reservoir evaporation forecast API tool. An additional 0.5 months will be allocated for attendance at project progress meetings and the estimation of daily reservoir evaporation with data collected from the five open water reservoir evaporation buoys and the initial QA/QC of these data. 0.5 months of her time will be spent on project administration and reporting.

In **year three**, we estimate that 1.0 months of Dr. Fernando's time will be allocated for the provision over technical oversight on Task 1, Task 2, and Task 5, which will include review of project deliverables, and convening project deliverable review meetings with project stakeholders providing local match on the project to ensure that their information and data needs have been fully addressed. 1 month of her time will be spent on project administration and reporting.

The estimate of time needed for Dr. Fernando's technical oversight of task implementation, estimation of buoy-based reservoir evaporation data, and for program administration and reporting are based on her experience with providing technical oversight and program management for the project funded by the WaterSMART Drought Resiliency Funding (RR19AP00112) in FY2019 and for several contracted studies funded by the Texas Water Development Board.

Justification for labor hour estimate for J. Zhu based on previous experience.

Dr. John Zhu, Senior Hydrologist in the Water Availability Program at the TWDB, will be a Principal Investigator on this project and will have overall responsibility for providing technical assistance to the FIRO, reservoir evaporation forecasting, and reservoir evaporation data enhancement components of the project. Dr. Zhu is also responsible for providing technical assistance to the regional water planning process, including running the Texas Water Availability Models (WAMs) to assess surface water availability for near-term and long-term forecasts. Dr. Zhu will participate in user acceptance testing and provide technical input and feedback to the planning tool updates proposed under the FIRO component (Task 1). He will participate in user acceptance testing of the evaporation forecasting API, and update reservoir-specific net evaporation (.eva) files, using the enhanced reservoir evaporation dataset, for ingest to the WAMs.

In **year one**, we estimate needing 0.5 months of Dr. Zhu's time for the development and execution of the inter-agency contract with the University of Texas at Arlington (FIRO component). An additional 1.0 months of his time will be allocated for updating the Aeroevap.py script to ingest data collected from the buoy station on Sam Rayburn Reservoir, running comparative assessment of data collection from the *in-situ* stations, the computed daily reservoir-specific evaporation dataset, and the legacy monthly reservoir evaporation dataset, based on pan-based data collection, used in the Texas WAMs. 0.5 months of his time will be allocated for attending project progress meetings and for project administration.

In **year two**, we estimate needing 1.5 months of Dr. Zhu's time for the review of interim deliverables, and participation in user acceptance testing of the tools developed through the project. We estimate needing a further 0.5 months of Dr. Zhu's time for attending project progress meetings and managing and reporting on the contract with the University of Texas at Arlington for Task 1.

In **year three**, we estimate needing 1.5 of Dr. Zhu's time for the review of project deliverables, and for the update of the .eva files using the enhanced daily reservoir evaporation dataset. We estimate needing a further 0.5 months of Dr. Zhu's time for attending project progress meetings and managing, reporting and closing out the contract with the University of Texas at Arlington for Task 1.

The estimates of the time needed for Dr. Zhu's contribution to the project come from current estimates of the time needed for developing and executing interagency contracts currently managed by Dr. Zhu, the time needed for user acceptance testing of new data products and API end points (e.g., daily reservoir-specific evaporation dataset's API endpoints and structure), and time needed to attend progress meetings and review project deliverables on ongoing contracted studies managed by Dr. Zhu. The time needed to undertake evaporation data comparisons and develop the .eva files is based on experience developing new .eva files and comparing multiple evaporation datasets for the project funded by the WaterSMART Drought Resiliency Funding (RR19AP00112) in FY2019.

Justification of labor hour estimate for Amanda Burke

Ms. Amanda Burke, Water Conditions Hydrologist in the Water Availability Program, will be a principal investigator on this project. Ms. Burke is a Certified Texas Contract Manager (CTCM certification # 1900043210). She will lead the implementation of Task 3 and Task 4 and will manage the new inter-agency contracts with Texas A&M University and the Lower Colorado River Authority,

the purchase orders with the Desert Research Institute and Agua del Sol Consultants, and the memorandum of understanding with the U.S. Geological Survey – Woodlands Office.

In **year one**, we estimate needing 1 month of Ms. Burke's time for developing and executing two new inter-agency contracts, two purchase orders, and one memorandum of agreement. We estimate needing 0.5 months of Ms. Burke's time for the coordination of all equipment purchases and field installation needed for Task 3. We estimate needing a further 0.5 months of Ms. Burke's time for attending project progress meetings, and administration of the project contracts.

In **year two**, we estimate needing 0.5 month of Ms. Burke's time for the review of interim project deliverables and for participation in user acceptance testing of the reservoir evaporation rate forecasts. We estimate needing 0.5 months of Ms. Burke's time for the initial review of data collected from the evaporation buoy on Sam Rayburn Reservoir and the data from the new Collison Floating Evaporation Pan station on Lake Buchanan. We estimate needing 0.5 months of Ms. Burke's time to coordinate maintenance on the existing evaporation buoys on Lake Buchanan, Choke Canyon Reservoir, Lake Meredith, and Red Bluff Reservoir. We estimate needing a further 0.5 months of Ms. Burke's time for attending project progress meetings, and administration of the project contracts.

In **year three**, we estimate needing 1 month of Ms. Burke's time for the review of project deliverables. We estimate needing 0.5 months of Ms. Burke's time to coordinate maintenance on the existing evaporation buoys on Lake Buchanan, Choke Canyon Reservoir, Lake Meredith, and Red Bluff Reservoir. We estimate needing 1 month of Ms. Burke's time to ensure completion of data delivery and reporting requirements on the purchase order with Agua del Sol Consultants and the associated inter-agency agreement with the Lower Colorado River Authority, for attending project progress meetings, and the administration of project contracts.

The estimate of Ms. Burke's time needed on the proposed project is based on her experience with coordinating the maintenance and re-deployment (when needed) of existing reservoir evaporation buoys in Texas, for managing several contracted studies, for developing existing purchase orders requisitions with Agua del Sol Consultants and the Desert Research Institute, and for order equipment deployed on open water evaporation stations in Texas.

5. **Memorandum of understanding with the U.S. Geological Survey for data collection, data quality control, and maintenance of the evaporation buoy in Sam Rayburn Reservoir.**

We estimate a cost of $10,000/year for a two-year memorandum of understanding with the U.S. Geological Survey – Woodlands Branch for the provision of quality-controlled data through the National Water Information System and the maintenance of meteorological sensors deployed on the buoy station. This estimate is derived based on experience that the Texas Water Development Board has with contracting with the U.S. Geological Survey for data collected at streamflow gauges and coastal meteorological buoy stations in Texas.

dallas water utilities
city of dallas

October 30, 2023

US Bureau of Reclamation
Drought Resilience Program

Dear Review Panel,

I am writing on behalf of Dallas Water Utilities (DWU) to confirm our support of the proposed multi-agency project entitled "*Developing Forecast and Planning Tools to Bolster Water Supply Reliability for Multi-purpose Reservoirs in Texas*" led by Dr. Nelun Fernando at the Texas Water Development Board (TWDB).

DWU provides water, wastewater and stormwater services, including storm drainage and flood control services, to more than 2.6 million customers in Dallas and 23 wholesale customer cities. Dallas' water supply system is composed of seven water supply reservoirs located in the Trinity, Sabine, and Neches river basins, run-of-river diversions from the Elm Fork of the Trinity River (Elm Fork) and both direct and indirect reuse. In the Trinity River Basin, Dallas' supply system is located along the East Fork and the Elm Fork of the Trinity River. The Elm Fork of the Trinity River consists of Ray Roberts Lake, Lewisville Lake, Grapevine Lake and run-of-river diversions from the Elm Fork of the Trinity River. The East Fork of the Trinity River consists of Lake Ray Hubbard, Lake Tawakoni and Lake Fork reservoirs. One of Dallas' reservoirs (Lake Palestine) is not currently connected to the Dallas system but is planned to be connected through the Integrated Pipeline Project (IPL).

The three Elm Fork of the Trinity reservoirs (Lakes Ray Roberts, Lewisville, Grapevine) are operated by the U.S. Army Corps of Engineers – Fort Worth District (USACE-SWF). The City of Dallas owns and operates Lake Ray Hubbard on the East Fork of the Trinity River and imports water from the Sabine River Basin from Lake Tawakoni and Lake Fork.

As noted in the proposal, the DFW metroplex has experienced phenomenal growth in the past few decades and meeting the increasing water demand has been a top priority of DWU and its regional partners. The proposed project is particularly timely as the region has been under drought conditions since 2021 which intensified in the past two summers. DWU has interests in exploring Forecast-Informed Reservoir Operation (FIRO) as a potential option for meeting the increasing water demand. In addition, the city has been seeking updates to the water planning model to incorporate dynamic water demand and reservoir evaporation data, and this project responds to these

Dallas Water Utilities · City Hall, 1500 Marilla Street, 4AN · Dallas, TX 75201
Telephone: (214) 670-3146

dallas water utilities
city of dallas

needs.

As a partner for this proposal, DWU will provide an in-kind contribution of $60,000 over the project duration. The support comprises salaries and fringes of staff members who will participate in meetings, offer input to the development of tools and data, work on integrating the data into the DWU water planning model and assist with operational assessments.

Sincerely,

Sarah Standifer
Interim Director
Dallas Water Utilities

Brazos River Authority

QUALITY • CONSERVATION • SERVICE

October 24, 2023

Dr. Nelun Fernando
Manager, Water Availability Department
Surface Water Division
Texas Water Development Board
1700 N. Congress Avenue
Austin, TX, 78701

Dear Dr. Fernando:

Thank you for the invitation to collaborate on the proposal titled ***Forecast and Planning Tools to Bolster Water Supply Reliability in Texas*** that you are submitting in response to the U.S. Bureau of Reclamation's Drought Resiliency funding opportunity for Fiscal Year 2024.

We consider it important that the Brazos River Authority collaborates with you on this project because it will: 1.) D*evelop the groundwork needed to promote Forecast Informed Reservoir Operations as a viable strategy to enhance water supply reliabilities in the Brazos River basin; and 2.) Provide access to forecast-based tools and enhanced reservoir evaporation data that can inform the adaptive management of surface water reservoirs.*

We are committed to providing up to $50,000 of in-kind support as local match on this project to cover staff time for Aaron Abel, Water Resources Manager and Philip Price, Sr. Water Resources Engineer to undertake the following in support of the proposed project: (a) Participate in project planning meetings; (b) Ensure that methodologies developed through the project are consistent with current regional water planning guidance material; (c) Ensure compliance with water rights pertaining to reservoir water supply storage; (d) Provide peer review of models and technical notes; and (e) Ensure that the tools developed through the project can be applied to the Brazos River Authority's operations.

Sincerely,

Aaron Abel
Water Services Manager, Brazos River Authority

4600 Cobbs Drive • P.O. Box 7555 • Waco, Texas 76714-7555
254-761-3100 • FAX 254-761-3202

ENERGY • WATER • COMMUNITY SERVICES

October 23, 2023

Dr. Nelun Fernando
Manager, Water Availability Department
Surface Water Division
Texas Water Development Board
1700 N. Congress Avenue
Austin, TX, 78701

Dear Dr. Fernando:

Thank you for the invitation to collaborate on the proposal titled Forecast and Planning Tools to Bolster Water Supply Reliability in Texas that you are submitting in response to the U.S. Bureau of Reclamation's drought resiliency funding opportunity for fiscal year 2024.

The Lower Colorado River Authority considers it important to collaborate with the Texas Water Development Board on this project. The project will give LCRA greater confidence in lake evaporation measurements, which are useful for better understanding the lake water balances and developing better lake storage projections.

LCRA is committed to providing up to $130,000 towards the local match for the project to help cover deploying a Collison Floating Evaporation Pan station on Lake Buchanan for two years.

Sincerely,

Monica P. Masters

Monica Masters
Vice President, Water Resources

DEPARTMENT OF THE ARMY
U.S. ARMY CORPS OF ENGINEERS, FORT WORTH DISTRICT
P.O. BOX 17300
FORT WORTH, TX 76102-0300

October 23, 2023

Dear Dr. Fernando:

Thank you for the invitation to collaborate on the proposal titled Forecast and Planning Tools to Bolster Water Supply Reliability in Texas that you are submitting in response to the U.S. Bureau of Reclamation's Drought Resiliency funding opportunity for Fiscal Year 2024.

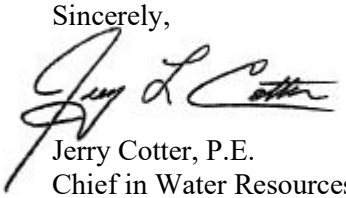
The Fort Worth District, U.S. Army Corps of Engineers operates and maintains 25 multi-purpose reservoirs across Texas. These reservoirs mitigate flooding and contain a significant portion of the surface water supply. For the central part of the state, these reservoirs supply over 50% of the surface water and are critical for the region's economic health.

The U.S. Army Corps of Engineers – Fort Worth District (USACE – SWF) is a core partner with the Texas Water Development Board, the Lower Colorado River Authority, Texas A&M University, and the Desert Research Institute on the project that delivers an operational, daily reservoir-specific dataset for 188 major water supply reservoirs in Texas. USACE – SWF is also a core collaborator on the Texas Forecast-informed Reservoir Operation (FIRO) pilot project in the Litter River Watershed in Texas.

We consider it important for the U.S. Army Corps of Engineers – Fort Worth District to collaborate with you on this project because it will help USACE predict water supplies during significant drought periods. During significant droughts, water use for various purposes is reduced, and this data will help USACE better understand water availability during these critical drought periods and provide better data to stakeholders.

We are committed to participating in the project by providing input on technical reviews, helping determine the best location for deploying the buoy on Sam Rayburn Reservoir, and obtaining the permit necessary for deploying the buoy on Sam Rayburn Reservoir.

Sincerely,



Jerry Cotter, P.E.
Chief in Water Resources
U.S. Army Corps of Engineers
Fort Worth District
Email: Jerry.L.Cotter@usace.army.mil
Tel: (817)886-1549

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL WEATHER SERVICE
West Gulf River Forecast Center
3401 Northern Cross Blvd
Fort Worth, TX 76137

October 17, 2023

US Bureau of Reclamation
Drought Resilience Program

Dear Program Manager,

I am the Development and Operations Hydrologist (DOH) at National Weather Service (NWS) West Gulf River Forecast Center (WGRFC). This letter is to confirm the role of WGRFC as a partner for the proposal entitled "*Developing Forecast and Planning Tools to Bolster Water Supply Reliability for Multi-purpose Reservoirs in Texas*" led by Dr. Nelun Fernando at the Texas Water Development Board (TWDB).

The WGRFC has been partnering with US Army Corps of Engineers – Fort Worth District (USACE-SWF), TWDB and University of Texas Arlington (UTA) to adapt the Hydrologic Ensemble Forecast System (HEFS) in guiding potential FIRO operation that entails temporal storage of water in the flood pool. In a project funded by USBR WaterSmart Program, the UTA collaborated with WGRFC in adapting HEFS for the Texas FIRO Pilot in central Brazos. The earlier project has resulted in improved HEFS configurations and value-added products that serve to inform decisions at USACE and Brazos River Authority, a regional water supplier.

In the proposed project, the earlier work will be extended to four reservoirs in the Upper Trinity River Basin. This effort is closely aligned with the goals of the Texas FIRO Initiative, and addresses the need of the WGRFC to assess and improve robustness of HEFS forecasts to facilitate their use in the operations of multi-use reservoirs in the region.

As a partnering agency, WGRFC will provide HEFS hindcast configurations to the project team, assist with resolving technical issues, and review outcomes for potential integration into the operational HEFS workflow. I look forward to working closely with the team should it be funded.

Sincerely Yours

Kris Lander

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
Office of Oceanic and Atmospheric Research
Physical Sciences Laboratory
325 Broadway – David Skaggs Research Center
Boulder, Colorado 80305-3337

October 24, 2023

US Bureau of Reclamation
Drought Resilience Program

Dear Program Manager,

I am a Research Meteorologist at NOAA's Physical Science Laboratory (PSL) leading a project to improve NOAA's water forecasting capabilities, which includes a focus on improvements to the Hydrologic Ensemble Forecasting Service (HEFS). As part of this effort, my team is developing postprocessed sub-seasonal to seasonal forecasts for water resources applications. I am writing to confirm my intent to serve as a collaborator for the proposal entitled "Developing Forecast and Planning Tools to Bolster Water Supply Reliability for Multi-purpose Reservoirs in Texas" led by Dr. Nelun Fernando at the Texas Water Development Board.

The PSL has been a critical partner in the Texas Forecast Informed Reservoir Operation (FIRO) initiative since 2020. As noted in the proposal, my team has developed experimental seasonal precipitation probabilistic forecasts and is currently disseminating the products through a website. We have been discussing with the TWDB and UTA on integrating these products as forcings in the HEFS maintained by the National Weather Service (NWS) West Gulf River Forecast Center (WGRFC), which serves as the primary forecast platform for FIRO assessments in the western US. The proposed initiative will provide an opportunity to perform experimental integration and inform the WGRFC and US Army Corps of Engineers on the efficacy of the resulting enhancements on FIRO.

As an unfunded collaborator, my role will involve providing hindcast products and guiding the adoption of the products in HEFS, designing operational assessments, and reviewing outcomes. I look forward to working closely with the team should it be funded.

Sincerely Yours,

Mimi Hughes
Research Meteorologist, NOAA PSL
Mimi.Hughes@noaa.gov