TITLE PAGE

Project title: Improving groundwater withdrawal data in a water-scarce agricultural region facing irrigation expansion

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TECHNICAL PROPOSAL AND EVALUATION CRITERIA

EXECUTIVE SUMMARY

Date: October 16, 2023

Applicant name, city, county, and state: Oklahoma State University, Stillwater, Payne County, Oklahoma

Applicant Category: Category B

Project Summary: Oklahoma State University, in partnership with the Lugert-Altus Irrigation District, will generate agricultural groundwater withdrawal data across the Upper Red River Basin. The goal of the project is to develop a data set of active water wells and groundwater use for irrigation to mitigate the unintended consequences of aquifer overdraft due to new water resource development for irrigation. The Upper Red River Basin has witnessed a substantial expansion of irrigated croplands in the last fifteen years. Unsustainable groundwater pumping to support the new irrigation operations can reduce the reliability of downstream agricultural water supply with critical ramifications for ecosystem services. There is a critical need to determine whether groundwater pumping is on par with permitted amounts and understand the extent and hotspots of potential over-pumping in the Upper Red River Basin. Our project will address this critical need through a data fusion approach that combines space observations of groundwater variation through time, high-accuracy maps of irrigated acres, water well records, and groundwater monitoring data. Our objectives are to: (1) estimate the number of active irrigation wells based on groundwater permits, well drilling logs, irrigated area maps, and satellite imagery; (2) providing annual high-resolution remote sensing observations of groundwater storage using data from the Gravity Recovery and Climate Experiment, or GRACE and ground-based water level monitoring; and (3) applying a spatial water balance approach to estimate groundwater withdrawal at wells based on well locations, groundwater storage variation, pumping practices, and climatic data. At the completion of the two-year project, we will share the new dataset of groundwater use for irrigation and the improved understanding of water resource vulnerabilities with stakeholders to inform sustainable water resources management in this water-scarce agricultural region. The developed technical framework will be transferrable to other groundwater-dependent agricultural watersheds to improve water management in the face of increased competing demands for already-strained resources.

Proposed duration of project (Completion Date): 24 months (May 16th, 2026)

Is the proposed project located on a Federal facility? No

TECHNICAL PROJECT DESCRIPTION AND MILESTONES

This project integrates remote sensing data, groundwater management and operations data, and spatial water balance analysis to generate agricultural groundwater withdrawal data and determine the extent and hotspots of potential over-pumping across the Upper Red River Basin (URRB). It builds on ongoing Reclamation efforts in the region to evaluate and better manage the effect of changes in water deliveries on the multitude of water-dependent economic benefits to different water use sectors. The goal of the project is to develop a data set of active water wells and groundwater use for irrigation to mitigate the unintended consequences of aquifer overdraft due to new water resource development for irrigation. In the last fifteen years, the URRB has witnessed a substantial expansion of irrigated croplands that rely on groundwater for irrigation with critical ramifications for the reliability of downstream agricultural water supply and ecosystem services. The primary objectives, the specific activities that will be conducted to achieve them, and the project milestones are explained in detail in the following sections.

Objective 1: Estimating the number of active irrigation wells

Quantifying the number and locations of irrigation wells in the region is a crucial objective because it is essential for understanding of the extent of groundwater usage. Groundwater extraction includes permitted withdrawals as well as pumping in excess of permitted withdrawals either at wells that have a permit or at wells that are operated without a permit. This information is vital for effective water resource management, as unpermitted wells or over-pumping of permitted wells can lead to over-extraction, which can undermine aquifer sustainability and reduce water availability in vulnerable areas in other parts of the URRB. Second, identifying the geographic distribution of wells helps pinpoint areas of high groundwater use, which may alter surface water flows due to the hydraulic connection between surface water and groundwater in alluvial deposits. This information will facilitate targeted groundwater allocation and conservation efforts, and can serve as a foundation for assessing the impact of well operations on groundwater levels and surface water flow. Historically, state and federal agencies have relied on either self-reported estimates or those obtained from basic remote sensing approaches, such as supervised image classification based on visible and near-infrared wavebands of polar orbiting satellites. Although remote sensing approaches can be more accurate than self-reported estimates and have the capability of providing distributed (versus lumped) data, both methods have significant deficiencies due to their limitations and the highly dynamic nature of crop decisions made by agricultural producers.

We will perform two steps to attain objective 1. These steps include: (1) compile data on groundwater permits, well drilling logs, and satellite data on groundwater, and the irrigated area maps that our team has developed for the URRB (**Milestone 1**); and (2) integrate the compiled data to identify irrigation wells that operate with our without a permit (**Milestone 2)**.

These layers of data will be overlayed in a GIS environment to identify active irrigation wells in the past 15 years (2007-2022). Well drilling logs will provide information on the location of new wells. In the next step, we will use our maps of irrigated croplands and terrane imagery from Google Earth Engine to determine whether the new wells are located in irrigated areas. We will then add the GIS layer of permitted wells to determine whether the wells are operated with or

without a permit. The combination of these data layers will allow us to locate active irrigation wells in the study area.

Milestone 1. Compile data on groundwater permits, well drilling logs, and satellite data on groundwater, and the irrigated area maps that our team has developed for the URRB.

Milestone 2. Integrate the compiled data to identify irrigation wells that operate with our without a permit

Irrigated agriculture has been expanding in the upper red river basin and this has been clearly evident in the area upstream of Lake Altus. This expansion affects flow in at least one important way; if farms continue to expand and farmers continue pumping groundwater, the stream that feeds Lake Altus becomes a losing stream and it will feed groundwater, meaning the reliability of inflow to the lake will decline. In other words, the lake will be emptier than it used to be and that affects the reliability of having enough water in the lake for irrigation. We will utilize the well log along with the data layer of permitted wells for the study area (Figure 1) to quantify the number of wells that are currently operated without a permit. We will use remote sensing data and maps of irrigated croplands to ensure that we identify irrigation wells. We will work with OSU extension agents to identify the types and capacities of pumps that farmers typically use in the study region. We will use this information to categorize the pumps into low, medium, and high capacities and, using these ranges, estimate the amount of groundwater extracted per area per year.

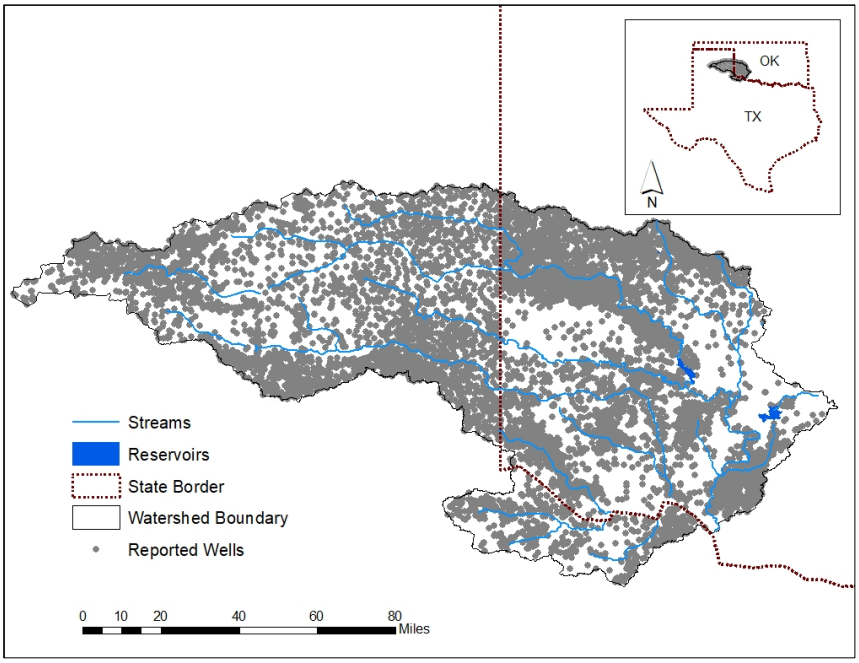

Figure 1. Map showing permitted wells in the study region

Current efforts in mapping irrigated areas face limitations, particularly in terms of frequency, accuracy, and crop type differentiation. Nationwide irrigation maps, such as the MIrAD-US

dataset based on MODIS and county-level irrigation census data from the USDA National Agricultural Statistics Service (NASS) are limited to coarse spatial resolutions spanning from 250 meters to kilometers and broad administrative units. This limitation poses challenges for localized applications, leading to spatial imprecision, uncertainty, inaccurate field edge delineation, and frequent omission of fragmented fields. Some high-resolution maps like the LANID product prepared by Xie et al. (2021) are available, but these maps rely on manual data preparation and threshold methods. They often misclassify winter wheat as irrigated, missing center pivot areas, and they do not extend beyond 2017.

In a previous Reclamation-supported project, we mapped irrigated areas in the URRB from 2007 to 2022 at a spatial resolution of 30 meters, enhancing the accuracy with a rich dataset of ground truth points. Our approach involves using Landsat Surface Reflectance Products, machine learning (Random Forest), and various environmental variables in Google Earth Engine and ArcGIS Pro. We created composite indices like Normalized Difference Vegetation Index (NDVI), Enhanced Vegetation Index (EVI), Normalized Difference Water Index (NDWI), and Green Index (GI), along with factors such as climate, soil, and slope data. Additionally, we applied the water-adjusted green index (WGI) and aridity-normalized green index (AGI) to improve regional classification across diverse climates.

To compile training samples for the study region spanning from 2007 to 2023, we used ground truth data (more than 1000 points located in irrigated acres in the URRB in 2022) and irrigation indexes, based on the assumption that irrigated croplands exhibit greener characteristics compared to rainfed croplands. The approach entails the generation of four intermediary irrigation agriculture dataset maps based on Landsat-Cropscape data, utilizing a thresholding technique. Subsequently, agricultural pixels (identified from the maximum crop mask) displaying yearly maximum crop index values exceeding a specified threshold were categorized as potentially irrigated croplands. The selection of irrigation sample candidates focused on pixels classified as potentially irrigated in both the GI and EVI maps, while non-irrigated samples were those identified as non-irrigated areas in both maps, as illustrated in Figure 2.

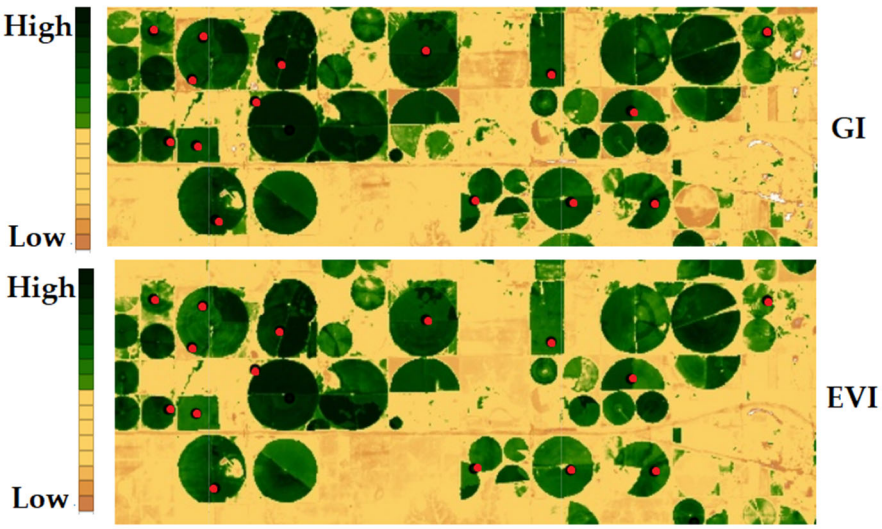

Figure 2: Irrigated field (red points) samples to train ML model based on using Green Index (GI) and Enhanced Vegetation Index (EVI).

Table 1. List of different variables and RS datasets used to train and classify ML Classifiers to map irrigated acres in the URRB

Variables	Resolution	Methods/Formula	Platform
Landsat Bands	30 m	Mean value of Spectral band	Landsat 8
Max annual NDVI	30 m	(NIR – RED) / (NIR + RED)	Landsat 8
Min annual NDVI	30 m		Landsat 8
Range annual NDVI	30 m	maxNDVI – minNDVI	Landsat 8
Max annual NDWI	30 m	(NIR – SWIR) / (NIR + SWIR)	Landsat 8
Min annual NDWI	30 m		Landsat 8
Range annual NDWI	30 m	maxNDWI – minNDWI	Landsat 8
Max annual EVI	30 m	2*(NIR–RED)/(NIR+6* RED-7.5*Blue +1)	Landsat 8
Min annual EVI	30 m		Landsat 8
Range annual EVI	30 m	maxEVI – minEVI	Landsat 8
Max annual GCVI	30 m	(NIR / Green – 1)	Landsat 8
Min annual GCVI	30 m		Landsat 8
Range annual GCVI	30 m	maxGCVI – minGCVI	Landsat 8
Water Adj Green Index	30 m	maxNDWI – maxGCVI	Landsat 8
Annual Precipitation	4 Km	Total prec. From (May 1 – Apr 30)	GRIDMET
Growing Season Precip.	4 Km	Total prec. From (May 1 – Aug 31)	GRIDMET
Early Season Precip.	4 Km	Total prec. From (Dec 1 – Apr 30)	GRIDMET
Annual PDSI	4 Km	Mean PDSI from (May 1 – Apr 30)	GRIDMET
Growing PDSI	4 Km	Mean PDSI from (May 1- Aug 3)	GRIDMET

Objective 2. Providing annual high-resolution remote sensing observations of groundwater storage using data from the Gravity Recovery and Climate Experiment, or GRACE and ground-based water level monitoring

Understanding changes in groundwater storage is essential because it provides continuous data over time and space, allowing for a comprehensive analysis of the water balance in the region. This enables agricultural water managers to pinpoint groundwater withdrawal hotspot areas to help guide practices and permitting actions that mitigate the unintended consequences of unsustainable groundwater pumping to protect downstream ecosystems and water supply systems. The milestone to attain Objective 2 will be acquisitioning and downscaling Gravity Recovery and Climate Experiment (GRACE) data (**Milestone 3**).

Milestone 3. GRACE data acquisitioning and apply our existing methods to downscale GRACE data from ~25 km (~6,178 acres) to ~ 1 km (~247 acres) pixel size.

A spatial downscaling developed by Arshad et al. (2022) will be performed to enhance GRACE-based GWS estimates from coarse (25 km) to relatively high spatial resolution (1km) to assist distributed quantification of GWS anomalies for smaller irrigated areas. We will use different machine learning approaches which include geographically weighted regression (GWR), random forest (RF), and geographically weighted random forest (RFgw) models. The relatively high-resolution (1km) data of covariates variables collected from different remote sensing and earth observations (EOs) and monitoring wells will be used as forcings in the downscaling framework. These variables include actual evapotranspiration (ETa), normalized difference vegetation index (NDVI), land surface temperature (LST), elevation/topography, precipitation, soil moisture storage and canopy water storage, and groundwater level. Overall, the spatial downscaling framework will comprise: (1) a training machine learning model using coarse resolution GRACE-based GWSA and covariates corresponding to 176 observations of GRACE grids (East-West: 16 Grids and North-South=11 Grids). The predicted GWSA at each GRACE grid will be compared to truth values of GRACE-based GWSA to ensure the training accuracy of the models. (2) After the training evaluation, the relatively high-resolution covariates (1km) will be used to test the machine learning models at 1km grid [East-West: 16*25*1km and North-South: 11*25*1km) and generated high-resolution GWSA. These steps will be performed individually each month from 2007-2020 and thus generate high-resolution GWSA (1km) for individual time steps. Figure 3 shows the Selected domain for downslcaling (X=16 grids and Y=11 grids).

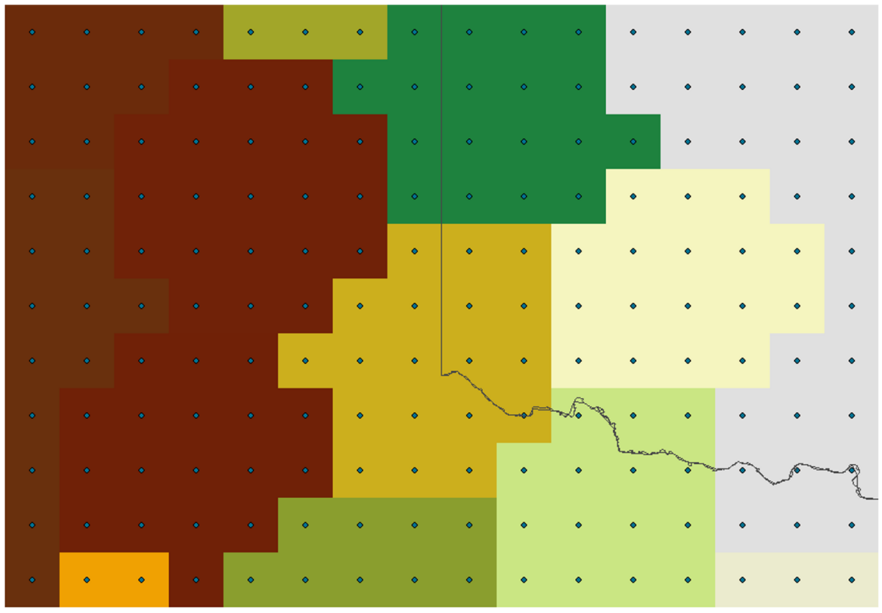

Figure 3. Selected domain for downslcaling (X=16 grid cells and Y=11 grid cells); Grid size = 0.25^0 or ~25 km^2 or ~6,178 acres.

Objective 3: Applying a spatial water balance approach to estimate groundwater withdrawal at wells based on well locations, groundwater storage variation, pumping practices, and climatic data.

Milestone 4. Quantification of groundwater storage dynamics per pixel.

Milestone 5. Performing a spatial water balance approach to estimate groundwater withdrawal per pixel and estimating groundwater withdrawal at wells.

GRACE is a joint mission of NASA-German Aerospace Center which was launched in March 2002 with twin satellites gathering information of Earth's mass variations by providing data with global coverage since 2002. The GRACE GRCTellus Land RL05 provides terrestrial water storage anomalies (TWSA data) using Spherical Harmonic (SH) and Mascon solutions. The TWSA data of Mascon solution are processed by the Center for Space Research (CSR) at a 0.25º (~27.75 km or 6,857 acres) spatial resolution. The GRACE TWSA represents the total amount of water stored on the land surface, and in the subsurface (Equation 2).

$$TWSA = GWSA + SMSA + CWSA + SnWSA + SWSA \quad (2)$$

Where, GWSA, SMSA, CWSA, SnWSA, and SWSA indicate the groundwater storage, soil moisture, canopy water storage, snow water storage and surface water storage anomalies, respectively. GWSA is obtained by subtracting the surface water storage contributions from the TWSA using Equation 3:

$$GWSA = TWSA_{GRACE} - (SMSA + CWSA + SnWSA)_{GLDAS} \quad (3)$$

The information on SMSA, CWSA, SnWSA are obtained from the Global Land Data Assimilation (GLDAS) data. In Equation 2, SWSA is removed because the contribution of surface water to irrigation is negligible in our study area.

We will quantify groundwater storage fluctuations in the irrigated areas of our study region using data from GRACE and groundwater level monitoring. We will estimate grid-scale groundwater storage changes using GRACE data. Its coarse spatial resolution of 0.25° (~25 km) will be downscaled to 1 km (~247 acres) by applying a machine-based data-driven spatial downscaling method to achieve fine-scale GRACE estimates of groundwater storage. The GRACE data will be calibrated using data from the USGS monitoring wells.

The GWSA estimates will be compared with groundwater monitoring data of depth to the water table (DTWT). The DTWT data will be converted to groundwater storage (GWS) by subtracting DTWT from the DTB (depth to bedrock) and, subsequently multiplying the result by Sy (specific yield) of the aquifer (Equation 1).

$$GWS = (DTB - DTWT) \times Sy \quad (1)$$

We will use the soil and water assessment tool (SWAT) model to quantify the hydrologic fluxes (Arnold et al., 1998). The SWAT model will be setup with different HRUs (hydrological

response units) based on unique combinations of slope, land-use types, and soil types. Climate data from weather stations will be used to parameterize the SWAT model from 1997 to 2020. The first ten years (1997–2007) will be used as a warm-up period to initialize the model parameters. The SWAT calibration and uncertainty procedures (SWAT-CUP) will be used to calibrate (2007–2017) and validate (2017–2020) the model with streamflow data from selected USGS gauges. The calibrated SWAT model will be used to simulate the surface runoff (Q_{surf}), lateral flow (Q_{lat}), baseflow entering the main channel (Q_{gw}), evapotranspiration (ET), recharge (GWrech) to shallow and deep aquifers, and percolation (Q_{perc}).

We will apply the pixel-based groundwater abstraction approach previously utilized by Cheema et al., (2014) and Arshad et al., (2022) to estimate groundwater withdrawal. The pixel information on ET_a, precipitation, groundwater storage changes (GRACE-based downscaled data) when integrated with HRU-scale fluxes obtained from the calibrated SWAT model facilitate quantifying total irrigation water supply (IRR_{total}).

$$IRR_{total} = ET + Q_{surf} + Q_{lat} + Q_{per} - Precipitation - (\pm GWSA_{downscaled}) \quad (4)$$

We will assume that the decline in groundwater storage (-) is driven by an increase in irrigation. Since the irrigation from surface channels is negligible, the total irrigation is mainly attributed to groundwater pumping ($IRR_{gw} \sim IRR_{total}$). Thus, the net groundwater depletion/abstraction (DEP_{gw}) will be calculated based on pixel scale information on IRR_{gw}, percolation (Q_{perc}), and baseflow entering the main channel (Q_{gw}) (Equation 5).

$$DEP_{gw} = IRR_{gw} - Q_{perc} + Q_{gw} \quad (5)$$

We will also work with county extension agents and irrigation equipment vendors to obtain information on typical pumps, pump capacities, and pivot nozzles to estimate potential groundwater withdrawal at each well. We will cross compare these estimations with remote sensing based spatial water balance approach to evaluate and refine estimates of groundwater pumping for irrigation.

PROJECT LOCATION

The geographic scope of the proposed project is the URRB (~4,000 mi^2), which occupies all or parts of nine counties in southwestern Oklahoma and fourteen counties in the Texas panhandle (Figure 4). The water resources management challenges in the URRB underscore growing vulnerability of agricultural production in the face of the scarcity of freshwater resources for irrigation, especially during droughts. Water availability in the region has been negatively impacted by extreme wet and dry cycles and upstream extractions. Communities in this region have experienced severe droughts within the past 10 years, a situation which is projected to be exacerbated by increased climate variability (McPherson and Kellog, 2016). Freshwater demands are met primarily by federally-managed reservoirs (e.g., Tom Steed and Altus Reservoirs providing 99 percent of the surface water supply to about 45,000 people and irrigation water for about 50,000 acres of land in Oklahoma), while groundwater is used to make up for surface water shortfalls (OWRB, 2012).

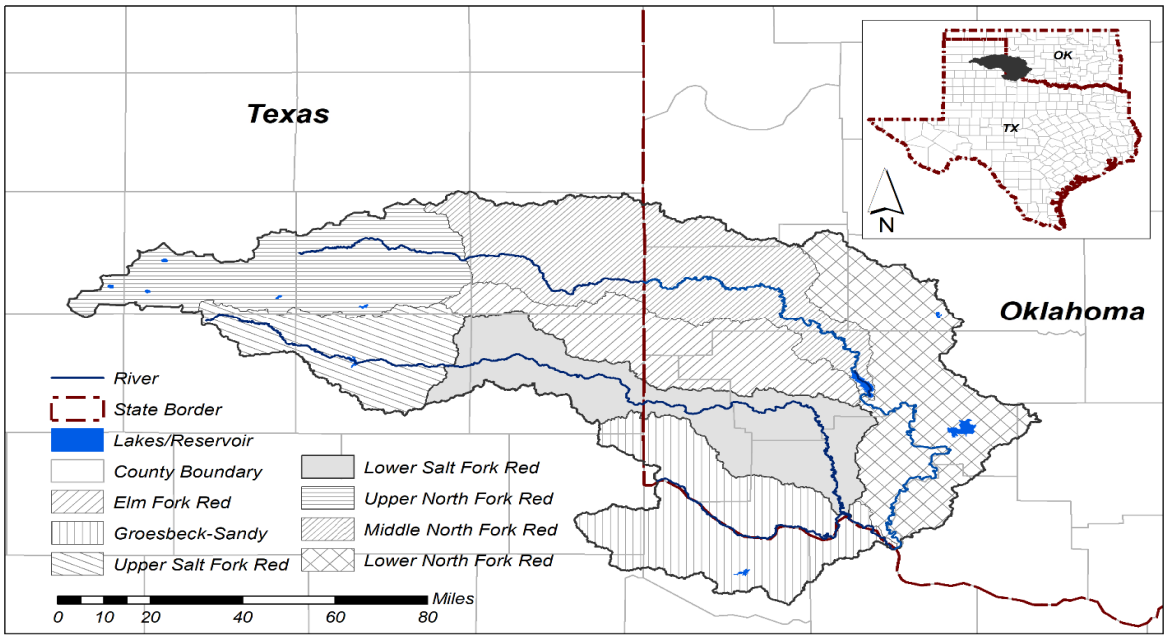

Figure 4. Proposed study area in the Upper Red River Basin.

DATA MANAGEMENT PRACTICES

Data Management

PI Mirchi is ultimately responsible for the management and retention of the data generated during the course of this project. Mirchi will coordinate and ensure data storage related to individual project tasks. Mirchi will work with Co-PIs Mansaray and Alian to store and manage data on OSU data repositories.

Types of Data

The data created by this project will come in the form of data collection and technical analysis results provided by project personnel. The data will include satellite data, the USDA Census of Agriculture data, Cropland Data Layers available from USDA's National Agricultural Statistics Service, hydro-climate data, and well location data. Project personnel will also make tables, graphs, or computer codes for various analyses. These data will be in common file formats such as Microsoft Word, PowerPoint documents, Python scripts, or JPEG.

Metadata Standards

Metadata will include information about time/date of dataset creation, creator, last update, file size, file extension, and contact person. We plan to use Metadata Wizard 2.0 to create metadata records for data sets used in modeling tasks.

Plans for Archiving and Preservation of Access

Data and products developed as a result of this project will be backed up on multiple computers and external drives. Possible mechanisms for storing data include flat files (e.g., text), multimedia files (e.g., image), Access database, Arc Map file geodatabase, and Microsoft Excel spreadsheets. Data and products will be archived on a quarterly basis in long-term repositories through Oklahoma State University's Department of Biosystems and Agricultural Engineering's Windows Server 2008 file server named BAE-FS02, more commonly referred to as the "T:" drive. The hardware that underlies BAE-FS02 consists of one Dell R610 server, one Dell hard drive array directly connected to the R610 server and one Dell tape backup unit directly attached to the R610 server. The storage array contains enough drives to provide 9 TB of storage in a RAID 6 configuration. Furthermore, a directly attached tape unit contains two magazines containing 15 1.5 TB tapes and one cleaning tape. This provides 22.5 TB of uncompressed backup space. Symantec Backup Express 2010 is the software that is used to provide the backups.

Policies and Provisions for Re-use and Re-distribution

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EVALUATION CRITERIA

Evaluation Criterion A — Benefits to Water Supply Reliability

1. What are the water management issue(s) that the project will address?

The proposed project will primarily enhance water supply reliability by equipping decision makers improved groundwater withdrawal data and understanding of the extent and hotspots of groundwater depletion. This capability is fundamental to assessing downstream water supply reliability will, in turn, contribute to improved groundwater permitting, the coordination of drought response efforts, and the optimal utilization of both groundwater and surface water. The project will inform water rights administration and the development of strategies to increase water conservation and irrigation efficiency. This will provide water managers with a better understanding of potential water supply shortfalls, uncertainties, the challenges of meeting competing water demands, issues arising from drought conditions, and the coordination of efforts to address conflicts over water allocation. The project will support improved groundwater management within existing permitting frameworks. Second, it furnishes the data needed to initiate discussions regarding voluntary groundwater pumping curtailments through lease exchanges, particularly in areas where agricultural production is most economically viable. These measures are expected to enhance the reliability of water availability in vulnerable regions. Leveraging both regulatory and voluntary adaptation options, grounded in a quantitative understanding of water supply and demand, is expected to enhance water availability in Lake Altus. This, in turn, will deliver additional benefits, as this reservoir plays a significant role in

supporting recreational and educational opportunities in Quartz Mountain Arts & Conference Center and Quartz Mountain Nature Park. This not only stimulates regional economic activity but also contributes to the provision of ecosystem services in the URRB (Piper, 2018).

2. How severe are the water management issues to be addressed?

Water supply reliability issues and the related water management challenges have profound implications for agricultural production in the URRB. The region's semi-humid climate can support robust agricultural productivity, provided there are sufficient water resources available for irrigation, particularly during hot and arid summers. The prolonged and severe drought conditions experienced from 2011 to 2015 had dire consequences; during this period, water levels in Lake Altus, which provides water for approximately 50,000 acres of irrigated land in the Lugert-Altus Irrigation District, fell below the intake level of the main canal. Consequently, the delivery of water to irrigated farms within the district was suspended for several years, resulting in a devastating impact on the local economy, estimated at more than $200 million annually (The Oklahoman, 2013). The drought finally abated with above-average precipitation in spring 2015, as illustrated in Figure 5. Sustained declines in water levels in the lake create favorable conditions for harmful algal blooms, characterized by calm and warm water. In both 2012 and 2014, Lake Altus experienced harmful golden algae blooms that led to significant fish mortality in the lake. However, this situation reversed when the lake refilled, creating turbulence that disrupted the ecosystem, ultimately rendering it hostile to the harmful algae.

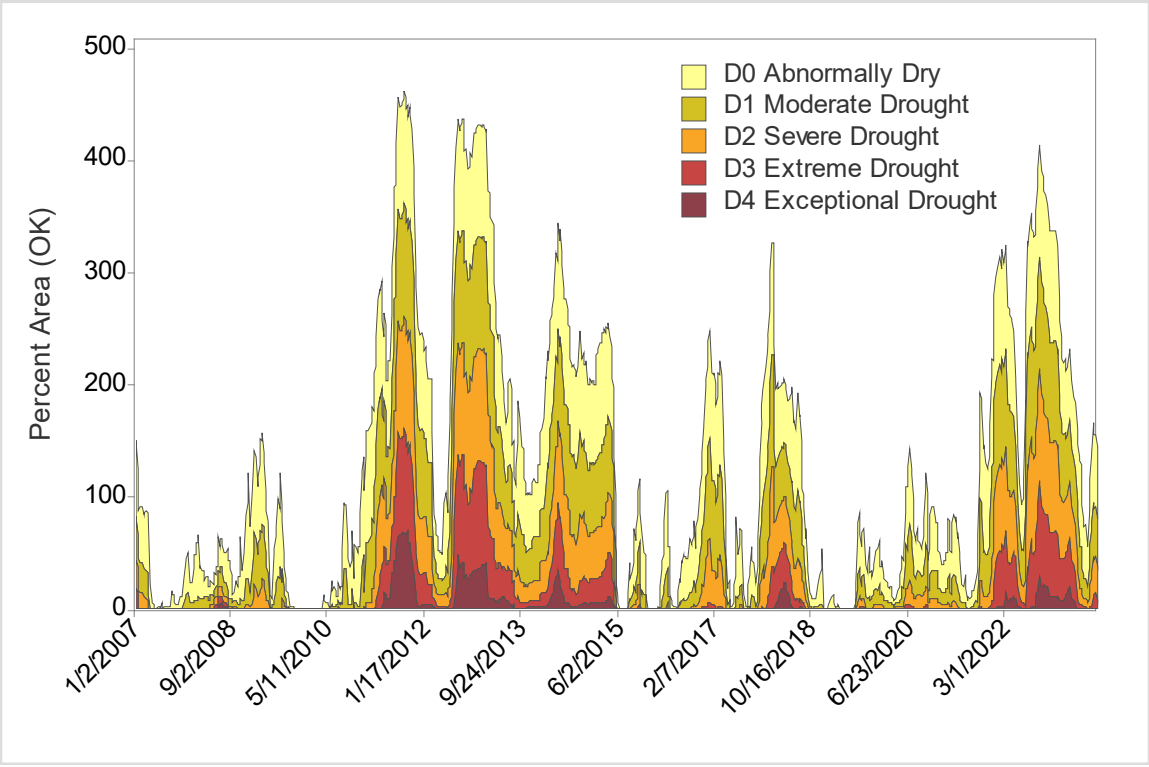

Figure 5. Percent area experiencing different levels of drought in Oklahoma (2007-2023). A new drought-of-record (D4 Exceptional Drought) was registered in 2011 during a prolonged drought in the study area, which lasted until 2015 (Source of drought maps: US Drought Monitor, droughtmonitor.unl.edu).

3. How will the project address the identified water management issue(s)?

The proposed technical approach will generate new groundwater withdrawal data, which is critically needed to evaluate the potential effects of excessive groundwater pumping on the reliability of Lake Altus. We will provide a practical technical framework for objective evaluation of groundwater extraction using geospatial analyses using ground-based and remote sensing capabilities to characterize groundwater storage dynamics. We will integrate these data with well development and operation data and well permitting information, and our characterization of irrigated croplands done as part of a previous Reclamation-supported project, to estimate the amount of water pumped per year across irrigated lands.

4. To what extent will the project benefit one of the water management objectives?

Our project addresses the need for better understanding of groundwater use for irrigation to maintain basin scale reliable water supply under the constraints of growing demand for limited freshwater resources and climate variability and change in the URRB. By addressing this need, the project will reduce growing concerns in the effectiveness of the current groundwater permitting and management and irrigation planning. Thus, the project will contribute to the attainment of multiple water management objectives listed in the in the Funding Opportunity Announcement (No. R23AS00446), including:

- water supply reliability,
- improved management of water deliveries,
- drought management activities, and
- water rights administration.

5. How will the project complement similar studies in the region?

The proposed project is an extension of our previous project that analyzed the expansion of irrigation quantification of total agricultural water use in the study area. In this project, we will focus on quantifying groundwater use to generate a new dataset of active irrigation wells and the corresponding groundwater pumping to evaluate the risk of declining reliability of surface water due to excessive upstream groundwater extraction. Utilizing satellite data from diverse sources (Landsat, MODIS, and GRIDMET), we have generated high-accuracy maps of irrigated croplands at a spatial resolution of 30 meters. These maps were generated by employing machine learning classifiers, including Random Forest and classification and regression tree (CART), implemented within the Google Earth Engine platform. Our findings have revealed a substantial increase in irrigated areas in parts of the URRB, especially near streams. Figure 6 illustrates the expansion of irrigated acres in Beckham County where irrigated areas have nearly tripled in size from 2007 to 2022.

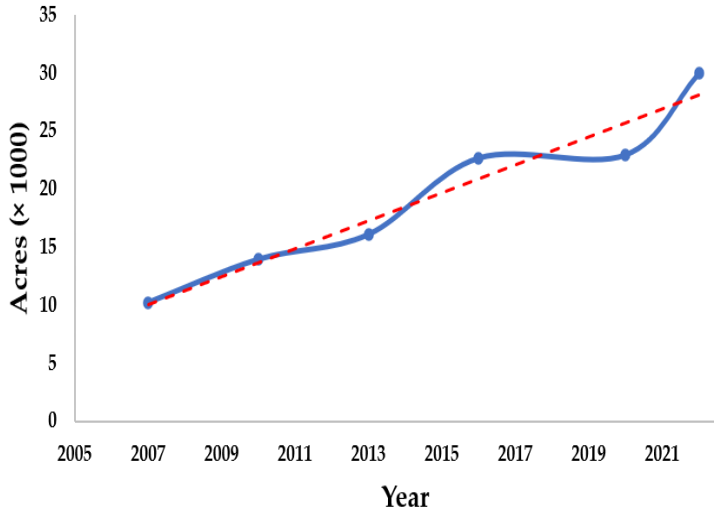

Figure 6. Expansion of irrigated acres in Beckham County where irrigated areas have nearly tripled in size from 2007 to 2022.

The project complements other efforts in estimating irrigation water use and characterizing water resources availability in the URRB by Reclamation, USGS, and other technical service providers. A number of studies have documented hydrologic and hydrogeologic characteristics of the study area. The main surface water resources include the Red River and its major tributaries (e.g., North Fork Red River, Elm Fork Red River, and Salt Fork Red River). Average total annual surface water available from these tributaries is approximately 689,500 acre-ft (Varghese, 1998). Only North Fork Red River (~90,600 acre-ft/yr), the primary source of surface water inflow to Lake Altus, is used for irrigation because of the large total dissolved solids (TDS) concentrations in other tributaries (e.g., up to ~5,000 mg/L in Salt Fork Red River, averaging 2,751 mg/L at Elmer, OK (OWRB, 2020)). The main aquifers in this region are the Blaine aquifer and the alluvium and terrace deposits underlying the rivers. Estimates of safe groundwater yield are provided by the USGS using MODFLOW groundwater flow models based on estimates of major groundwater withdrawals, lateral flows, seepage, and aquifer recharge (Kent, 1980; Smith et al., 2003). Reclamation has applied crop coefficient method using 2012 land use to provide supplemental agricultural irrigation demand estimates as part of an ongoing basin study for the proposed study area (personal communication, n.d.).

Our project will add significant value to these previous and ongoing efforts by applying a dynamic approach to generating groundwater use data and detecting the hotspots and extent of groundwater depletion, which can affect surface water flow to Lake Altus.

Evaluation Criterion B — Need for Project and Applicability of Project Results

1. Does the project meet an existing need identified by a water resource manager(s) within the 17 Western States?

The technical aspects of this proposal have been carefully developed with direct collaboration and input from the Lugert-Altus Irrigation District, notably with Mr. Tom Buchanan, the district's manager, located in southwestern Oklahoma. The project team also conducted extensive background research by consulting experts at Reclamation to gain a comprehensive

understanding of the necessity for this project. It is important to note that water supply reliability challenges are expected to intensify in the future, particularly as Red River streamflows in the study area face a potential reduction of 18-32% (as indicated by the Oklahoma Water Resources Board, OWRB, 2012). Additionally, forecasts predict fresh groundwater depletions in the Lugert-Altus Irrigation District could reach as high as 17,220 acre-feet per year by 2060 (as per Balcombe, 2014). This is attributed in part to the increasing demand for water resources and the depletion of fresh alluvial groundwater from the North Fork Red River, primarily for irrigating upstream agricultural lands, as documented by Krueger et al. in 2017. The successful implementation of this project and the achievement of its intended outcomes will provide direct support for the long-term planning and management of water resources in the Lugert-Altus Irrigation District. Should this project be chosen for funding by Reclamation, the irrigation district will actively support and participate in it by sharing valuable data and on-field experiences to help realize the project's objectives (see Support Letter).

2. Will the project result in an applied science information that is readily applicable, and highly likely to be used by water resource managers in the West?

Indeed, the project will yield valuable applied science information in the form of quantifying groundwater storage change and annual groundwater extraction at irrigation wells across the basin over a fifteen-year time period (2007-2022). This information holds immediate practical relevance and is highly likely to find utility among water resources managers in southwestern Oklahoma. The technical framework employed will be applicable in other water management districts in the West where nuanced groundwater use data for irrigation is lacking. In the short term, our results will guide the planning of improvements to the groundwater permitting and management, and the comprehensive analysis of basin-scale water balances. Furthermore, through ongoing dialogue and collaborative efforts aimed at the future of water resource management to sustain irrigated agriculture in the URRB, these findings will support the development of coordinated surface water and groundwater management strategies and facilitate the assessment of water permitting review requirements.

Evaluation Criterion C — Project Implementation

Project objectives, milestones and timeline

The primary objectives of the project are (1) estimate the number of active wells based on groundwater permits, well drilling logs, irrigated area maps, and Google Earth imagery; (2) provide annual high-resolution (~247-acre) remote sensing observations of groundwater storage using data from the Gravity Recovery and Climate Experiment, or GRACE and ground-based water level monitoring; and (3) apply a spatial water balance approach to estimate groundwater withdrawal at wells based on well locations, groundwater storage variation, pumping practices, and climatic data. We have established several milestones to ensure timely progress of the work. The project milestones are as follows:

Milestone 1. Compiling data on groundwater permits, well drilling logs, and satellite data on groundwater, and the irrigated area maps that our team has developed for the URRB (Objective 1, pages 3-5).

Milestone 2. Integrating the compiled data to identify irrigation wells that operate with our without a permit (Objective 1, pages 3-5).

Milestone 3. Acquisitioning GRACE data and applying our existing methods to downscale GRACE data from ~25 km (~6,178 acres) to ~ 1 km (~247 acres) pixel size (Objective 2, page 6).

Milestone 4. Quantifying groundwater storage dynamics per pixel (Objective 3, page 7-8).

Milestone 5. Performing a spatial water balance approach to estimate groundwater withdrawal per pixel and estimating groundwater withdrawal at wells (Objective 3, page 8).

The project team will work closely to complete project tasks within a two-year time frame as chronologically outlined in Table 1. PI Mirchi will be responsible for managing the project and delivering outcomes. We will meet monthly throughout the course of the project for coordinated integration of project components and attainment of the specified milestones.

Table 1. Project tasks and timeline.

Project Task (Milestone; M)	**Yr 1**				**Yr 2**			
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Collect data and develop the project geodatabase (M1)	X	X						
Identify irrigation wells that operate with our without a permit (M2)			X	X				
Acquisition GRACE data (M3)	X	X						
Downscale GRACE data to (~247 acres		X	X	X				
Quantify groundwater storage dynamics per pixel				X	X	X		
Performing a spatial water balance approach to estimate groundwater withdrawal per pixel and estimating groundwater withdrawal at wells					X	X	X	
Information transfer		X		X		X		X
Final report writing and manuscript development								X

Availability and quality of existing data and models

The input data for applying the proposed technical framework are publicly available through a number of different data sources that perform data quality assessments prior to public release. An exception is self-reported agricultural acreage and water use data that are collected at the irrigation district level without completing rigorous data quality assessment protocols. Table 2 summarizes the existing data that will be used in this project and the sources where the data will be obtained from.

Table 2- Existing data and data sources.

Data	**Tool or Model**	**Source(s)**
Census of Agriculture	Excel spreadsheets and Arc GIS 10.8	USDA NASS web-based data retrieval system (https://quickstats.nass.usda.gov/)
Cropland Data Layers	Arc GIS 10.8	USDA NASS CropScape: https://nassgeodata.gmu.edu/CropScape/
Self-reported Crop Acreage	Excel spreadsheets	Lugert-Altus Irrigation District and Texas Agricultural Statistics Service (TASS) District 11
Self-reported Irrigation Water Use	Excel spreadsheets	Lugert-Altus Irrigation District and Texas Agricultural Statistics Service (TASS) District 11
Regional scale hydro-climatic data	Excel spreadsheets	USA Divisional Climate Data: https://wrcc.dri.edu/spi/divplot1map.html
Ground-based meteorological data (air temperature, relative humidity, incoming shortwave solar radiation, wind speed and atmospheric pressure)	Excel spreadsheets, text files, and energy balance model	Oklahoma Mesonet: http://www.mesonet.org/index.php/past_data/category/past_data_links
Water rights permits	Arc GIS 10.8	https://www.owrb.ok.gov/maps/PMG/owrbdata_WR.html
Remote sensing groundwater data (GRACE)	NetCDF (Network Common Data Form) and HDF (Hierarchical Data Format)	http://grace.jpl.nasa.gov
Climate data	Text file	NOAA: https://www.ncei.noaa.gov/cdo-web/ Oklahoma Mesonet: https://mesonet.org/
Soil and water assessment tool	Text file	https://swat.tamu.edu/software/

Project team members and qualifications

Our team has expertise in hydrology and water resources systems (Mirchi and Mansaray), irrigation (Mirchi), remote sensing (Mansaray and Alian) and geographic information systems (Alian, Mansaray, and Mirchi). The project personnel will work closely with Mr. Tom Buchanan, manager of the Lugert Altus Irrigation District in southwestern Oklahoma. The project team is capable of proceeding with tasks within the proposed project immediately upon entering into a financial assistance agreement with Reclamation.

Dr. Ali Mirchi is an Associate Professor of water resources engineering at the Department of Biosystems and Agricultural Engineering at Oklahoma State University. He holds a Ph.D. in civil/water resources engineering from Michigan Technological University, a Master's in water resources engineering from Lund University, and a BSc in civil/water engineering from the University of Tabriz. Mirchi has over 15 years of experience in various applications of water resources engineering. He applies systems modeling and analysis techniques, including system dynamics simulation, hydro-economic optimization and watershed hydrologic modeling to advance understanding of coupled human-natural systems at different scales. His research focuses on water resources planning and management to derive policy insights that promote water sustainability by understanding the tradeoffs associated with meeting the water demands of the agricultural sector and growing urban areas while maintaining the ecological integrity of natural environments. Dr. Mirchi is currently working on similar projects in the southwestern US. (funded by the USDA NIFA, USDA ARS, and USGS) and northeastern Tunisia (funded by USAID), investigating adaptive water resources management strategies in the face of population growth, competing demands, and climatic extremes.

Dr. Abubakarr Mansaray (Abu) is a Research Project Manager in water resources science and management at the Oklahoma Water Resources Center and the Department of Biosystems and Agricultural Engineering at Oklahoma State University. He holds a Ph.D. in Environmental Science from Oklahoma State University, a Master's in Environmental Science from the University of Idaho, a Master's in Environmental Chemistry from the University of Sierra Leone, and a Bachelor's in Environmental Chemistry from the University of Sierra Leone. His research focuses on integrating data from multiple sources into frameworks that support preparedness and response to severe water resource challenges. Dr. Mansaray has more than ten years of experience exploring adaptive water resources management strategies in the face of population growth, competing demands, and climatic extremes.

Dr. Sara Alian is a Teaching Assistant Professor of geographic information systems (GIS) at the Department of Biosystems and Agricultural Engineering at Oklahoma State University. She holds a Ph.D. and a Master's degree in Forest Sciences from Michigan Technological University. Alian has over 9 years of experience in geospatial science applications in natural resource management and geospatial science education. Her expertise is in the areas of geospatial sciences, GIS technology, and remote sensing to inform resource management decisions, including land, water, and forest management. She has worked on interdisciplinary projects funded by the National Science Foundation (NSF), Great Lakes Protection Fund, and US Department of Agriculture (USDA) to generate new information, geospatial data, and insights for sustainable biofuel feedstock management and production of biofuel feedstocks, to evaluate ecological water stress in the Great Lakes Region, and New Mexico-Texas-Mexico border

region. Dr. Alian has also applied geospatial technologies including remote sensing and GIS to assess the impact of land use change on payment for hydrological services programs and ecosystem services and their relationship with social and economic drivers and responses in Veracruz, Mexico.

We will conduct the project in consultation with Dr. Saleh Taghvaeian, an Associate Professor of Irrigation Engineering at the Department of Biological Systems Engineering at the University of Nebraska, Lincoln. Dr. Taghvaeian holds a Ph.D. in irrigation engineering from Utah State University, as well as Master and Bachelor of Science degrees in irrigation and drainage engineering from Ferdowsi University, Iran. For the past 14 years, Dr. Taghvaeian has been working on quantifying water fluxes in irrigated agriculture across California, Utah, Colorado, Oklahoma, and Nebraska. He has conducted numerous research projects on mapping crop water use, monitoring soil moisture and deep percolation, developing precision irrigation scheduling, and estimating irrigation pumping energy efficiency and application uniformity. He has completed several projects in southwest Oklahoma and has established a network of agricultural producers within and outside the Lugert-Altus irrigation district who collaborate with him on a range of extension and demonstration projects. He is also involved in collaborative research projects in the Texas Panhandle with his irrigation engineering counterparts from Texas A&M University and USDA-ARS in Bushland, TX.

Summary description of expected *products*

The project will yield several significant outcomes. It will deliver a groundwater withdrawal dataset and associated metadata containing readily usable applied science information that stems from the project's findings. This dataset will serve as a practical example for generating groundwater data for other agricultural regions in the western U.S. The high-resolution groundwater storage mapping over both space and time, will enable us to capture the historical fluctuations in the extent and magnitude of agricultural water usage within the study area. This historical perspective is crucial for improving assessments of the water balance in the basin and for planning future adaptive water resources within the project's jurisdiction. The new dataset and understanding of groundwater status will be provided to water managers and stakeholders in the URRB to improve agricultural water management to cope with extreme water shortage. Furthermore, the project will support and provide training opportunities for two water professionals at doctoral and post-doctoral levels. The technical framework and outcomes of this project, as published in technical reports and peer-reviewed scientific publications, will provide valuable insights for studies related to the impact of agricultural water withdrawal. Thus, the framework will have broader applicability to irrigation districts in the Western region, and the results will be of interest to regional water management agencies.

Evaluation Criterion D — Dissemination of Results

Our dissemination strategy aims to foster effective communication of the project's outcomes both within our proposed study area and to a broader audience. We intend to maximize the project's influence by employing the following methods to convey the results and policy implications to various stakeholder groups at different levels, ranging from local to national:

We will deliver the final results and policy implications to key organizations such as the Lugert-Altus Irrigation District, Texas Agricultural Statistics Service (TASS) District 11 (Northern High Plains), Oklahoma Water Resources Board, Texas Water Development Board, Choctaw Nation, and Chickasaw Nation. This will be accomplished through virtual presentations, published technical reports, and stakeholder meetings.

To effectively communicate the findings of our water adaptation analysis, we will create policy briefs, fact sheets, and infographics. These materials will be distributed to decision-makers at various levels (from county to state to congressional representatives) and to the general public within our proposed study area and beyond. This effort will leverage the outreach capabilities of Oklahoma State University.

Our results will be shared with fellow researchers and water professionals through several channels, including a Reclamation-sponsored webinar where we will present deliverables and discuss their application to management questions. We will also participate in a seminar as part of the USGS South Central Climate Adaptation Science Center's seminar series and engage with national/international professional meetings, such as the American Society of Agricultural and Biological Engineers.

To facilitate the broader application of our methodology, we will publish the technical framework and project results in reports and peer-reviewed journal articles, ensuring that the knowledge reaches a wide audience throughout the United States.

SUPPORTING THE DEPARTMENT OF THE INTERIOR PRIORITIES

By addressing the challenge of agricultural water supply reliability, the project supports the Biden-Harris Administration’s priority E.O. 14008: Tackling the Climate Crisis at Home and Abroad. Specifically, the project approach and resulting applied science information about agricultural groundwater use will be useful to build long-term resilience to future droughts. The project is a critical step in facilitating the mitigation of the unintended consequences of groundwater overdraft in the URRB through water resources governance in the face of climate change.

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Vice President for Research
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www.research.okstate.edu

October 12, 2023

U.S. Department of the Interior
Bureau of Reclamation
Water Resources and Planning Office
Mail Code: 86-63000
P.O. Box 25007
Denver, CO 80225-0007

To whom it may concern:

Oklahoma State University, Division of Agricultural Sciences and Natural Resources, is pleased to submit and be a part of the proposal entitled, "Improving groundwater withdrawal data in a water-scarce agricultural region facing irrigation expansion" under the direction of Dr. Ali Mirchi. This proposal falls within the guidelines of the strategic plan for OSU Agriculture. We seek funding in the amount of $200,640 over two years with a proposed start date of May 17, 2024. OSU Agriculture along with continuing salary support, facilities, secretarial and financial support, and other infrastructure support commits to providing cost share in the amount of $200,642 over the two-year period of the project. The appropriate programmatic and administrative personnel of Oklahoma State University are aware of the funding agency's grant policy and are prepared to establish the necessary agreements consistent with that policy.

Sincerely,

Julie Swaringim-Griffin on behalf of

Kenneth W. Sewell
Vice President for Research
research@okstate.edu

DATE: October 13, 2023

FROM: Tom Buchanan

Re: Letter of Support for Oklahoma State University's WaterSMART- Applied Science Grants Proposal

TO WHOM IT MAY CONCERN

I am writing in support of Oklahoma State University's WaterSMART- Applied Science Grants proposal entitled "Improving groundwater withdrawal data in a water-scarce agricultural region facing irrigation expansion."

The proposed project is a logical next step in addressing data needs in the Upper Red River Basin. It builds on foundational work done by Reclamation, Oklahoma State University, and other technical service providers. The project team aims to generate a critically needed dataset that encompasses information on operational water wells and groundwater pumping for irrigation purposes. The Upper Red River Basin has experienced a substantial expansion in the cultivation of irrigated crops. This growth has led to unsustainable practices in groundwater extraction, endangering the reliability of downstream agricultural water supplies. A dataset of active groundwater wells and estimated annual groundwater pumping is essential to improve water resources management in the region. The project combines remote sensing, well data, and groundwater monitoring to estimate active well numbers, assess groundwater storage, and calculate withdrawals. Upon the project's conclusion, which will span two years, the project team will disseminate the newly created dataset of groundwater usage for irrigation. This information will prove invaluable in shaping sustainable water resource management in this agriculturally vital yet water-scarce region.

This project and its intended outcomes will directly support long-term water resource planning and management at the Lugert-Altus Irrigation District. If selected for funding by the Bureau of Reclamation, I will support the project by sharing data and field experiences to facilitate the attainment of project objectives.

Thank you for your consideration.

Sincerely,

Tom Buchanan

Manager

Lugert-Altus Irrigation District

Budget Narrative

A budget estimate and budget narrative for our project is given below. The budget includes at least the minimum Federal to non-Federal required cost share. The budgeted rates represent the actual labor rates for the identified personnel and positions and are consistently applied to Federal and non-Federal activities.

a. Personnel

Dr. Ali Mirchi (PI) will direct the project work and perform the overall management of the progress over the year-round activities conducted at Oklahoma State University (OSU). $5,000 is requested to cover 0.217 of a month of summer salary per year for the PI for the duration of the two-year project. Mirchi will lead the downscaling of satellite data to assess groundwater storage variation and apply the spatial water balance approach. In addition, the PI will contribute 3.647 months of salary in project year 1 and 3.618 months of salary in project year 2 in cost share for a total of $83,661. The PI will dedicate time year round to lead the technical activities to implement the proposed methodology. Mirchi will also provide guidance to one postdoc and one PhD student in Biosystems Engineering, and will ultimately be responsible for and produce project reports and delivering project outputs.

Dr. Sara Alian (Co-PI) will lead geospatial analysis and data management tasks, and development of GIS data products. $4,000 is requested to cover 0.249 of a month of summer salary per year for Alian for the duration of the two-year project. In addition, the Co-PI will contribute 0.54 months of salary per year in cost share in project years 1 and 2 for a total of $8,660. Dr. Alian will also contribute to advising the graduate research assistant.

Dr. Abubakarr Mansaray will supervise the application of remote sensing data products. $5,000 is requested to cover 0.467 of a month of summer salary per year for Mansaray for the duration of the two-year project. In addition, the Co-PI will contribute 0.6 months of salary per year in cost share in project years 1 and 2 for a total of $6,424. Dr. Mansaray will also contribute to advising the graduate research assistant.

Post-doc: $32,000 is requested to support a full-time post-doctoral researcher in Biosystems Engineering for 7.5 months (@$4,266/month). The postdoc will assist with downscaling satellite-based groundwater observations to quantify annual variations of groundwater storage in the study area. The post-doc will also assist with reporting the results.

Graduate Student: $55,200 is requested to support a full-time PhD student in Biosystems Engineering for the duration of the project. The BAE PhD student will receive a full year of research assistantship support per project year ($27,600/Yr for 2 Years) to help with compiling input data and implementation of technical tasks under the supervision of the investigators. The PhD student will also assist with reporting the results.

b. Fringe Benefits

Fringe benefits are for health care and other benefits for the employees, faculty, and students. Fringe benefit rates are negotiated annually with the Office of Naval Research and will be adjusted accordingly. The following are the current approved rates: 35.42% for faculty, 41.64% for staff, 14.30% for post-docs, and 9.69% for graduate students. A total of $15,194 is requested from federal funds and $35,374 will be provided as cost share.

c. Travel

The budget includes $500 in estimated travel costs for the principal investigator and a team member to travel to the study area and meet with stakeholders (e.g., manager of the Lugert-Altus Irrigation District). Costs include average rate for lodging in the area ($91 per traveler), per diem ($44 per traveler) for first and last day of the trip calculated at 75% of the base rate, and vehicle rental and gas from Oklahoma State University Motor Pool for a round trip from Stillwater to Altus, Oklahoma ($230).

d. Equipment

N/A

e. Supplies

N/A

f. Contractual

Dr. Saleh Taghvaeian will provide consulting services. $10,000 (@$5,000/Yr) is requested to compensate Dr. Taghvaeian for consulting services related to irrigation and estimating required groundwater pumping for irrigation. Actual compensation per year is estimated as follows $68.5/hr x 73 hrs.

g. Construction

N/A

h. Other

Tuition Remission funds will be used by OSU to cover tuition cost for the graduate student. $10,808 (@$5,404/Yr) is requested based on OSU's FY24 rate of 19.58%.

i. Total Direct Costs

Total Direct Cost is $271,821, which includes $137,702 requested from the federal agency and $134,119 provided as cost share by OSU.

j. Indirect Costs

Indirect costs of $129,461 ($62,938 requested from the federal agency and $66,523 provided as cost share by OSU) are calculated based on the OSU's federally negotiated on-campus research rate of 49.6% of Modified Total Direct Costs (MTDC) until further amended. This is the predetermined rate negotiated with Oklahoma State University by the Department of the Navy, Office of Naval Research, 800 North Quincy Street, Arlington, VA, 22217-5660, for the Federal Government. Facility & Administrative Costs are calculated on total direct costs less items of equipment, capital expenditures, charges for patient care and tuition remission, rental costs, scholarships, and fellowships as well as the portion of each subgrant and subcontract in excess of $25,000. Fringe benefits applicable to direct salaries and wages are treated as direct costs.

DEPARTMENT OF THE NAVY
OFFICE OF NAVAL RESEARCH
875 NORTH RANDOLPH STREET
SUITE 1425
ARLINGTON, VA 22203-1995

IN REPLY REFER TO:

Agreement Date: June 21, 2021

NEGOTIATION AGREEMENT

INSTITUTION: **OKLAHOMA STATE UNIVERSITY**
STILLWATER, OK

The Facilities and Administrative (F&A) Cost rates contained herein are for use on grants, contracts and/or other agreements issued or awarded to the Oklahoma State University by all Federal Agencies of the United States of America, in accordance with the provisions and cost principles mandated by 2 CFR Part 200. These rates shall be used for forward pricing and billing purposes for the Oklahoma State University Fiscal Years 2022 through 2024. This rate agreement supersedes all previous rate agreements/determinations related to these rates for Fiscal Years 2022 through 2024.

Section I: RATES - TYPE: PREDETERMINED (PRED)

TYPE	FROM	TO	ON CAMPUS	OFF CAMPUS	BASE	APPLICABLE TO
Stillwater Campus*						
Pred	7/1/21	6/30/24	49.8%	26.0%	(a)	Instruction
Pred	7/1/21	6/30/24	49.6%	27.7%	(a)	Research
Pred	7/1/21	6/30/24	37.8%	26.3%	(a)	Extension
Institute of Technology**						
Pred	7/1/21	6/30/24	56.0%	26.0%	(a)	All Programs
Oklahoma City Campus						
Pred	7/1/21	6/30/24	50.9%	26.0%	(a)	All Programs
Center for Health Sciences						
Pred	7/1/21	6/30/24	33.4%	23.2%	(a)	All Programs
Tulsa Campus						
Pred	7/1/21	6/30/24	49.6%	N/A	(a)	All Programs

*Rates also applicable to Oklahoma State University Research Foundation (formerly known as Oklahoma State University Center for Innovation and Economic Development, Inc. (CIED)).

** Formerly Okmulgee Campus

DISTRIBUTION BASE

(a) Modified Total Direct Costs (MTDC), as defined in 2 CFR Part 200, consisting of all direct salaries and wages, applicable fringe benefits, materials and supplies, services, travel, and subawards and up to the first $25,000 of each subaward (regardless of the period covered by the subawards under the award). MTDC excludes equipment, capital expenditures, charges for patient care, rental costs, tuition remission, scholarships and fellowships, participant support costs and the portion of each subaward in excess of $25,000.

SECTION II - GENERAL TERMS AND CONDITIONS

A. **LIMITATIONS**: Use of the rates set forth under Section I is subject to availability of funds and to any other statutory or administrative limitations. The rates are applicable to a given grant, contract or other agreement only to the extent that funds are available and consistent with any and all limitations of cost clauses or provisions, if any, contained therein. Acceptance of any or all of the rates agreed to herein is predicated upon the following conditions: (1) that no costs other than those incurred by the institution were included in this indirect cost pool as finally accepted and that such costs are legal obligations of the institution and allowable under governing cost principles; (2) that the same costs that have been treated as indirect costs are not claimed as direct costs; (3) that similar types of costs have been accorded consistent accounting treatment; and (4) that the information provided by the institution which was used as a basis for acceptance of the rates agreed to herein, and expressly relied upon by the Government in negotiating and accepting the said rates is not subsequently found to be materially incomplete or inaccurate.

B. **ACCOUNTING CHANGES**: The rates contained in Section I of this agreement are based on the accounting system in effect at the time the agreement was negotiated. Changes to the method(s) of accounting for costs, which affect the amount of reimbursement resulting from the use of these rates require the prior written approval of the authorized representative of the cognizant agency for indirect costs. Such changes include but are not limited to changes in the charging of a particular type of cost from indirect to direct. Failure to obtain such approval may result in subsequent cost disallowances.

C. **PREDETERMINED RATES**: The predetermined rates contained in this agreement are not subject to adjustment in accordance with the provisions of 2 CFR Part 200, subject to the limitations contained in Part A of this section.

D. **USE BY OTHER FEDERAL AGENCIES**: The rates set forth in Section I are negotiated in accordance with and under the authority set forth in 2 CFR Part 200. Accordingly, such rates shall be applied to the extent provided in such regulations to grants, contracts, and other agreements to which 2 CFR Part 200 applies, subject to any limitations in part A of this section. Copies of this document may be provided by either party to other federal agencies to provide such agencies with documentary notice of this agreement and its terms and conditions.

E. **DFARS WAIVER**: Signature of this agreement by the authorized representative of Oklahoma State University and the Government acknowledges and affirms the University's request to waive the prohibition contained in DFARS 231.303(1) and the Government's exercise of its discretion contained in DFARS 231.303(2) to waive the prohibition in DFARS 231.303(1). The waiver request by Oklahoma State University is made to simplify the University's overall management of DoD cost reimbursements under DoD contracts.

F. **SPECIAL REMARKS**: The Government's agreement with the rates set forth in Section I is not an acceptance of the Oklahoma State University's accounting practices or methodologies. Any reliance by the Government on cost data or methodologies submitted by Oklahoma State University is on a non-precedence-setting basis and does not imply Government acceptance.

Accepted:

FOR OKLAHOMA STATE UNIVERSITY:

Tamera Eck

TAMERA ECK
Associate Vice President for Administration
And Finance

6/22/2021
Date

FOR THE U.S. GOVERNMENT:

SNYDER.BETH.A.1379326664 Digitally signed by SNYDER.BETH.A.1379326664 Date: 2021.06.22 14:20:57 -04'00'

BETH A. SNYDER
Contracting Officer

6/22/2021
Date

For information concerning this agreement contact:

Beth Snyder
Office of Naval Research
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DEPARTMENT OF THE NAVY
OFFICE OF NAVAL RESEARCH
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SUITE 1425
ARLINGTON, VA 22203-1995

IN REPLY REFER TO:

Agreement Date: June 23, 2023

NEGOTIATION AGREEMENT

INSTITUTION: **OKLAHOMA STATE UNIVERSITY**
STILLWATER, OKLAHOMA 74078

The Fringe Benefits rates contained herein are for use on grants, contracts and/or other agreements issued or awarded to the Oklahoma State University by all Federal Agencies of the United States of America, in accordance with the provisions and cost principles mandated by 2 CFR Part 200. These rates shall be used for forward pricing and billing purposes for the Oklahoma State University Fiscal Year 2024. This rate agreement supersedes all previous rate agreements/determinations related to these rates for Fiscal Year 2024.

Section I: RATES - TYPE: FIXED (FIXED)

Fringe Benefits Rates:

TYPE	FROM	TO	RATE	BASE	APPLICABLE EMPLOYEE	LOCATION
Fixed	7/1/23	6/30/24	31.42%	(a)	Faculty	OSU - General University
Fixed	7/1/23	6/30/24	19.82%	(a)	Non-Retirement Faculty	OSU - General University
Fixed	7/1/23	6/30/24	36.31%	(a)	Staff	OSU - General University
Fixed	7/1/23	6/30/24	9.61%	(a)	Temporary	OSU - General University
Fixed	7/1/23	6/30/24	9.81%	(a)	Graduate Student	OSU - General University
Fixed	7/1/23	6/30/24	1.62%	(a)	Student	OSU - General University
Fixed	7/1/23	6/30/24	35.42%	(a)	Faculty	OSU - Agricultural Sciences
Fixed	7/1/23	6/30/24	14.30%	(a)	Non-Retirement Faculty	OSU - Agricultural Sciences
Fixed	7/1/23	6/30/24	41.64%	(a)	Staff	OSU - Agricultural Sciences
Fixed	7/1/23	6/30/24	10.33%	(a)	Temporary	OSU - Agricultural Sciences
Fixed	7/1/23	6/30/24	9.69%	(a)	Graduate Student	OSU - Agricultural Sciences
Fixed	7/1/23	6/30/24	2.29%	(a)	Student	OSU - Agricultural Sciences
Fixed	7/1/23	6/30/24	28.36%	(a)	Faculty	OSU - Veterinary Medicine
Fixed	7/1/23	6/30/24	23.42%	(a)	Non-Retirement Faculty	OSU - Veterinary Medicine
Fixed	7/1/23	6/30/24	38.72%	(a)	Staff	OSU - Veterinary Medicine
Fixed	7/1/23	6/30/24	5.92%	(a)	Temporary	OSU - Veterinary Medicine
Fixed	7/1/23	6/30/24	9.27%	(a)	Graduate Student	OSU - Veterinary Medicine
Fixed	7/1/23	6/30/24	2.43%	(a)	Student	OSU - Veterinary Medicine

TYPE	FROM	TO	RATE	BASE	APPLICABLE EMPLOYEE	LOCATION
Fixed	7/1/23	6/30/24	37.14%	(a)	Faculty	Institute of Technology
Fixed	7/1/23	6/30/24	38.00%	(a)	Staff	Institute of Technology
Fixed	7/1/23	6/30/24	10.85%	(a)	Temporary	Institute of Technology
Fixed	7/1/23	6/30/24	0.26%	(a)	Student	Institute of Technology
Fixed	7/1/23	6/30/24	36.12%	(a)	Faculty	Oklahoma City Campus
Fixed	7/1/23	6/30/24	38.78%	(a)	Staff	Oklahoma City Campus
Fixed	7/1/23	6/30/24	9.33%	(a)	Temporary	Oklahoma City Campus
Fixed	7/1/23	6/30/24	7.82%	(a)	Student	Oklahoma City Campus
Fixed	7/1/23	6/30/24	19.58%	(a)	Faculty	Center for Health Sciences
Fixed	7/1/23	6/30/24	22.79%	(a)	Non-Retirement Faculty	Center for Health Sciences
Fixed	7/1/23	6/30/24	32.65%	(a)	Staff	Center for Health Sciences
Fixed	7/1/23	6/30/24	10.00%	(a)	Temporary	Center for Health Sciences
Fixed	7/1/23	6/30/24	10.41%	(a)	Graduate Student	Center for Health Sciences
Fixed	7/1/23	6/30/24	3.96%	(a)	Student	Center for Health Sciences
Fixed	7/1/23	6/30/24	37.02%	(a)	Staff	Tulsa Campus
Fixed	7/1/23	6/30/24	5.29%	(a)	Temporary	Tulsa Campus
Fixed	7/1/23	6/30/24	0.04%	(a)	Student	Tulsa Campus

DISTRIBUTION BASES

(a) Salaries and Wages of respective Employee Category

SECTION II - GENERAL TERMS AND CONDITIONS

A. **LIMITATIONS**: Use of the rates set forth under Section I is subject to availability of funds and to any other statutory or administrative limitations. The rates are applicable to a given grant, contract or other agreement only to the extent that funds are available and consistent with any and all limitations of cost clauses or provisions, if any, contained therein. Acceptance of any or all of the rates agreed to herein is predicated upon the following conditions: (1) that no costs other than those incurred by the institution were included in this indirect cost pool as finally accepted and that such costs are legal obligations of the institution and allowable under governing cost principles; (2) that the same costs that have been treated as indirect costs are not claimed as direct costs; (3) that similar types of costs have been accorded consistent accounting treatment; and (4) that the information provided by the institution which was used as a basis for acceptance of the rates agreed to herein, and expressly relied upon by the Government in negotiating and accepting the said rates is not subsequently found to be materially incomplete or inaccurate.

B. **ACCOUNTING CHANGES**: The rates contained in Section I of this agreement are based on the accounting system in effect at the time the agreement was negotiated. Changes to the method(s) of accounting for costs, which affect the amount of reimbursement resulting from the use of these rates require the prior written approval of the authorized representative of the cognizant agency for indirect costs. Such changes include but are not limited to changes in the charging of a particular type of cost from indirect to direct. Failure to obtain such approval may result in subsequent cost disallowances.

C. **FIXED RATES WITH CARRY-FORWARD PROVISIONS**: The fixed rates contained in this agreement are based on estimates of the costs for FY 2024. When actual costs for this fiscal year are determined, adjustments will be applied to a rate negotiation for a subsequent fiscal year to recognize the difference between the FY 2024 estimated costs used to establish the fixed rates and the negotiated actual FY 2024 costs.

D. **CARRY FORWARD AMOUNTS**: The Office of Naval Research Negotiation Agreement dated June 4, 2021 established fixed Fringe Benefits rates with carry-forward provisions for Oklahoma State University's Fiscal Year ending June 30, 2022. This negotiation agreement records agreement on the final carry-forward amounts resulting from determination of actual costs for Fiscal Year 2022. These costs have been determined in accordance with the provisions of 2 CFR Part 200. The fixed Fringe Benefits rates set forth in SECTION I are inclusive of the Final Fiscal Year 2022 carry-forwards amounts shown below. The final 2022 carry-forward amounts are liquidated in their entirety with the exception of the Tulsa-Student carry-forward. The unliquidated carry-forward balance of ($292) for the Tulsa-Student category will be liquidated in a future rate negotiation.

( ) represents over-recovery

	Fringe Benefit Employment Category						
Location	Faculty	Non-Retirement Faculty	Staff	Temporary	Graduate Student	Student	Student Unliquidated CFW Balance
OSU - General University	($394,717)	($43,008)	($2,045,871)	$113,580	$367,203	$38,918	
OSU - Ag. Sciences	($99,427)	($111,240)	($282,274)	($5,530)	$48,945	$5,017	
OSU - Veterinary Medicine	($136,052)	($12,586)	($85,234)	($48,015)	$17,204	$1,417	
Institute of Technology	($99,985)		($203,000)	$4,925		($18)	
Oklahoma City Campus	($22,830)		($86,334)	$617		$5,287	
Center for Health Sciences	($389,948)	($10,909)	($592,760)	$24,363	$17,658	$701	
Tulsa Campus			($40,023)	($1,143)		($60)	($292)

E. **USE BY OTHER FEDERAL AGENCIES**: The rates set forth in Section I are negotiated in accordance with and under the authority set forth in 2 CFR Part 200. Accordingly, such rates shall be applied to the extent provided in such regulations to grants, contracts, and other agreements to which 2 CFR Part 200 applies, subject to any limitations in part A of this section. Copies of this document may be provided by either party to other federal agencies to provide such agencies with documentary notice of this agreement and its terms and conditions.

F. **SPECIAL REMARKS**: The Government's agreement with the rates set forth in Section I is

not an acceptance of the Oklahoma State University's accounting practices or methodologies. Any reliance by the Government on cost data or methodologies submitted by Oklahoma State University is on a non-precedence-setting basis and does not imply Government acceptance.
Accepted:

FOR OKLAHOMA STATE UNIVERSITY:

Tamera Eck

TAMERA ECK
Associate Vice President for Administration
And Finance

6/26/2023
Date

FOR THE U.S. GOVERNMENT:

SNYDER.BETH.A.1379326664 Digitally signed by SNYDER.BETH.A.1379326664 Date: 2023.06.26 12:05:26 -04'00'

BETH A. SNYDER
Contracting Officer

6/26/2023
Date

For information concerning this agreement contact:

Beth Snyder
Office of Naval Research
875 North Randolph Street
Arlington, VA 22203-1995

Phone: (571) 416-9032
E-mail: beth.a.snyder14.civ@us.navy.mil

ENVIRONMENTAL AND CULTURAL RESOURCE CONSIDERATIONS

The proposed technical framework will primarily involve analysis of existing geospatial and remotely sensed data. As such, the project will be compliant with Environmental and Cultural Resource Considerations.

• Will the proposed project impact the surrounding environment (e.g., soil [dust], air, water [quality and quantity], animal habitat)? Please briefly describe all earth-disturbing work and any work that will affect the air, water, or animal habitat in the project area. Please also explain the impacts of such work on the surrounding environment and any steps that could be taken to minimize the impacts.

The proposed project will not impact the surrounding environment.

• Are you aware of any species listed or proposed to be listed as a Federal threatened or endangered species, or designated critical habitat in the project area? If so, would they be affected by any activities associated with the proposed project?

No. No species listed or proposed to be listed as a Federal threatened or endangered species, or designated critical habitat will be affected by any activities associated with the proposed project.

• Are there wetlands or other surface waters inside the project boundaries that potentially fall under CWA jurisdiction as "Waters of the United States?" If so, please describe and estimate any impacts the proposed project may have.

No wetlands or other surface waters inside the project boundaries that potentially fall under CWA jurisdiction as "Waters of the United States" will be affected by any activities associated with the proposed project.

• When was the water delivery system constructed?

Lake Altus is the major reservoir providing irrigation water to Lugert-Altus Irrigation District. The construction of Lake Altus was completed in 1947. The system of canals delivering Lake Altus irrigation water to farmlands were completed by 1953. No major reservoir exists in the Texas Panhandle portion of the study area.

• Will the proposed project result in any modification of or effects to, individual features of an irrigation system (e.g., headgates, canals, or flumes)? If so, state when those features were constructed and describe the nature and timing of any extensive alterations or modifications to those features completed previously.

No.

• Are any buildings, structures, or features in the irrigation district listed or eligible for listing on the National Register of Historic Places? A cultural resources specialist at your

local Reclamation office or the State Historic Preservation Office can assist in answering this question.

We are not aware of any buildings, structures, or features in the irrigation district listed or eligible for listing on the National Register of Historic Places. However, we are sure that the proposed project activities will not impact any buildings, structures, or features in the irrigation district listed or eligible for listing on the National Register of Historic Places in the study area.

• Are there any known archeological sites in the proposed project area?

We are not aware of any known archeological sites in the proposed project area. The proposed project activities will not impact archeological sites.

• Will the proposed project have a disproportionately high and adverse effect on low income or minority populations?

No.

• Will the proposed project limit access to and ceremonial use of Indian sacred sites or result in other impacts on tribal lands?

No.

• Will the proposed project contribute to the introduction, continued existence, or spread of noxious weeds or non-native invasive species known to occur in the area?

No.

REQUIRED PERMITS OR APPROVALS

No permits or approvals are required to conduct the proposed project.

OVERLAP OR DUPLICATION OF EFFORT STATEMENT

The proposed project does not overlap duplicate previous efforts. The project is a logical next step to our previous project that analyzed the expansion of irrigation quantification of total agricultural water use in the study area. In this project, we will focus on quantifying groundwater use to generate a new dataset of active irrigation wells and the corresponding groundwater pumping to evaluate the risk of declining reliability of surface water due to excessive upstream groundwater extraction.

CONFLICT OF INTEREST DISCLOSURE STATEMENT

The investigators do not have any conflict of interest in performing the proposed project.

UNIFORM AUDIT REPORTING STATEMENT

Oklahoma State University (OSU) was required to submit a Single Audit report for the most recently closed fiscal year and it is available through the Federal Audit Clearinghouse website. OSU's EIN is 73-1383996.