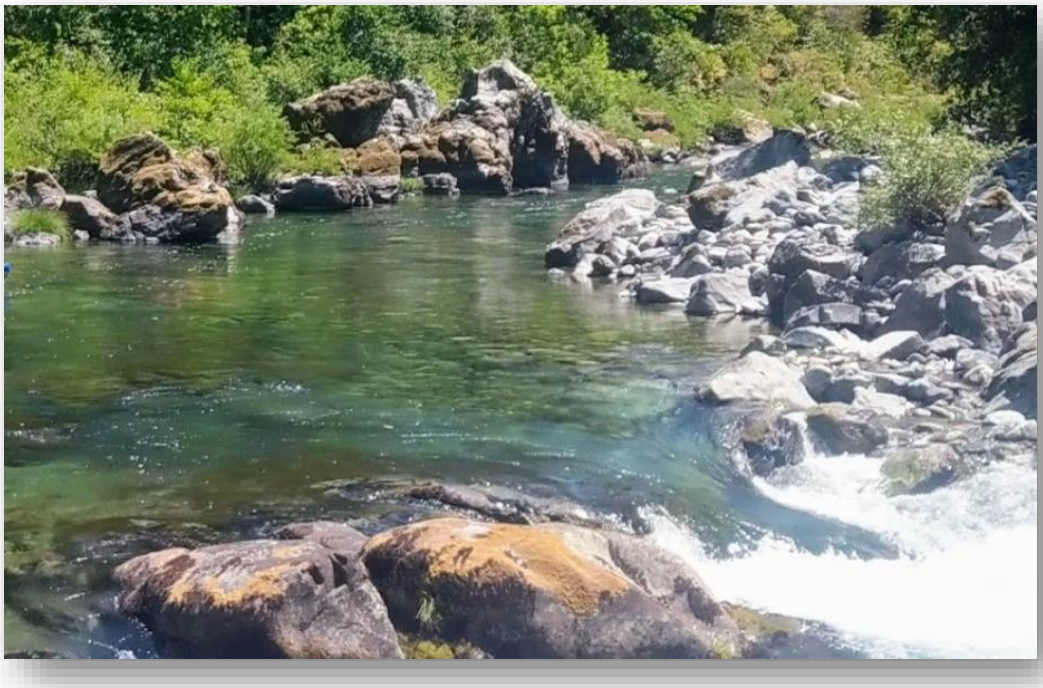
# The County of Tuolumne

WaterSMART-Applied Science Grants for Fiscal Year 2023

# Advancing Nature-Based Solutions for Building Watershed Health and Water Supply Reliability in the Tuolumne River Basin

October 17, 2023

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# Technical Proposal

## Executive Summary

Date October 17, 2023
Applicant Name: County of Tuolumne
Unique Entity Identifier (UEI): **NZ5KFMZLPMB9**
Location: 2 South Green Street, Sonora, California 95370

### Project Summary

Healthy forests provide a range of ecosystem services, from storing, filtering, and delivering clean water for downstream uses to sequestering carbon and provisioning habitat for wildlife. However, many of these ecosystem services are at risk due to forest overgrowth, changing climate, extended fire season, hot droughts, and epidemics of forest pests and diseases. Land and forest managers are undertaking fuel treatments to reduce risk of large-scale wildfires and restore forests to a healthy and more resilient condition. Tuolumne County is working with a non-profit collaborative, Yosemite Stanislaus Solutions (YSS), on advancing Social and Ecological Resilience Across the Landscape (SERAL) project within the larger Stanislaus Landscape located in the headwaters of the Stanislaus and Tuolumne River Basins, California. YSS is a collaborative comprised of federal (e.g., United States Forest Service, Natural Resources Conservation Service, Bureau of Land Management, and Yosemite National Park), state (e.g., CA Fish & Wildlife, Sierra Nevada Conservancy, and Resource Conservation Districts) and local (Tuolumne County, Tuolumne Utility District) agencies, tribal governments (e.g., Tuolumne Band of Me-Wuk and Chicken Ranch Rancheria of Me-Wuk Indians), irrigation districts (e.g., Hetch Hetchy Water and Power), non-profits, and private entities (see the link for full list of partnership: https://yosemitestanislaussolutions.com/member-organizations-partnerships/) working together to assist public and private land managers in achieving healthy forests and watersheds using locally relevant Nature-based Climate Solutions (NbCS) in the form of forest thinning, mastication, prescribed fire, and meadow restorations. The 260,000-acre Stanislaus Landscape project area has been identified as one of the initial 10 fire-prone landscapes and received a second round of funding by the Biden-Harris administration and USDA Forest Service (USDA, 2022) for hazardous fuels reduction projects on national forests and grasslands. Tuolumne County, in partnership with YSS, University of California, and Turlock Irrigation District, will leverage the SERAL and SERAL 2.0 projects to better understand the interactions between NbCS, that are primarily designed and implemented to build landscape resilience and achieve catastrophic wildfire risk reduction goals, and water security. The proposed project is intended to advance our understanding of ecohydrological impacts of watershed restoration treatments in the upper Stanislaus and Tuolumne River Basins. We will achieve this goal by, first, leveraging existing best available science and data, including quantifiable metrics of current and expected

conditions, to separate the combined impacts of climate, watershed management, and wildfire on watershed health and water security. Second, performed strategic ground-based monitoring and numerical modeling for filling data gaps, verification, and scaling. The project outcomes will provide a scientific basis for advancing NbCS for wildfire risk reduction, data for refining NbCS prescriptions in the case of a negative outcome, and build partnerships through the quantification of multiple secondary benefits (e.g., erosion control, water security, forest health, carbon sequestration).

### Length of Time and Estimated Completion Date for the Project

The project will be completed within a two-year (24-month) timeframe with an estimated start of one month from the receipt of the signed financial assistance agreement. Analysis of existing data will be conducted off-site, on-site work will involve installing sensors and running field campaigns throughout the year based-on site access and conditions.

### Federal Facility Information

The proposed research site is located on the USFS Land managed by Stanislaus National Forest.

## Technical Project Description

Applicant Category: Category A

### Detailed Project Description

#### Background

Sierra Nevada mountain range receives 27 percent of the state's precipitation and supplies more than 60% of California's consumptive water use (Bales et al., 2011). Snowmelt from the Sierra Nevada region supplies irrigation water to Central Valley farms that grow half of the USA's vegetables, fruits, and nuts. Also, Sierra Nevada serves as a major drinking water source for more than 75% of Californians. The quality and quantity of this critical natural resource are highly dependent on the condition of its forests and soil. However, California's forestlands face widespread threats from forest overgrowth, drought, insects, wildfires, and a warming climate that is intensifying these risks and further threatening the ability of our forests to provide valuable social, economic, and environmental benefits. Increase in forest density, from historical wildfire suppression activities, and warmer temperatures have altered the water balance with a greater fraction of precipitation being used by the mountain forests for photosynthesis. Moreover, worsening wildfires and drought conditions along with shifting precipitation phase from snow to rain further exacerbate issues surrounding California's water

supply for agriculture and urban uses (Goulden and Bales, 2014; Safeeq et al., 2016; Bart et al., 2021; Yang et al., 2022).

The recent episodes of droughts, wildfires, and flooding in California is a stark reminder of the new climate normal - a world where within a year we move from battling droughts and wildfires in the summer to dealing with flooding and landslides in the winter. To adapt and reduce impacts of these disasters, state and local agencies have laid out climate-action priorities and adaptation strategies (https://climateresilience.ca.gov/; State of California, 2020). Strengthening the resilience of natural systems by accelerating Nature-based Climate Solutions (NbCS) through incentivizing upper-watershed restoration is a cross-cutting theme across multiple state action plans and executive orders (State of California, 2021a, 2021b; California Air Resources Board, 2022; Forest Climate Action Team, 2018; Sierra Nevada Conservancy, 2019; US Forest Service, 2022). The immediate need for forest restoration to reduce wildfire severity and transition the state's mountain forests to a sustainable multi-benefit pathway is estimated to cost over billions of dollars. California state agencies and the US Forest Service have established a target of restoring 1 million acres per year for 10 years under the shared stewardship agreement, projected to cost $1 to 2 billion dollars per year. State and federal agencies, the major owners of the land, lack the funds and capacity to take up this task at the needed pace to avert catastrophic wildfires and their cascading impacts. Partnerships involving beneficiaries and other stakeholders are starting to fill the financing and implementation gaps by monetizing multiple benefits of ecosystem restoration.

Reducing forest fuels by thinning and/or prescribed fire along with restoring ecohydrological functioning of mountain meadows have been the focus for improving and maintaining watershed health under current and future climate. They can arguably not only help sequester and stabilize carbon but also help maximize other ecosystem services, e.g., water supply for the remaining forest and downstream stream users. From the outset of paired catchment synthesis (Hibbert, 1967), the effects of forest management on water yield have been studied extensively (Bart et al., 2021; Goeking and Tarboton, 2020; Saksa et al., 2017). However, despite decades of research, the direction and magnitude of water supply benefits originating from forest management remain contentious. Historically, reducing forest cover was viewed as a viable strategy to increase water yield with an argument that removing vegetation reduces transpiration and wet canopy evaporation. A series of recent studies add more nuance to this argument and demonstrate mixed (i.e., increase, decrease, or no-change) water yield response to changes in vegetation. Additionally, water yield benefits originating from forest management activities were historically viewed from downstream perspective only (Grant et al., 2013) with no consideration for added drought resilience to the remaining trees from the reduced competition (Bart et al., 2021). Managers and other stakeholders are looking for a multi-benefit framework for forest and catchment management that goes beyond gain in water yield (Eriksson et al., 2022). Our initial work on changes in water-balance partitioning due to forest thinning under a range of climatic and regolith environments show a strong control of

subsurface regolith, i.e., storage and movement of water in the subsurface (Bart et al., 2021; Saksa et al., 2017). We found that in catchments with shallow regolith, forest treatments decreased forest mortality during drought (i.e., increase in transpiration) but had no effect on water yield. In contrast, we observed the opposite result in catchments with deeper regolith where water movement occurs below the root zone. Using a series of numerical simulations, we showed that the amount of water being partitioned to streamflow and transpiration of the remaining forest depends on precipitation levels (i.e., aridity), depth of the regolith and water pathways, and forest thinning intensity.

These studies provide a first-order assessment of restoration impacts on water security under current and future climate. However, the current extent and severity of NbCS projects require site-specific verification and understanding of changes in ecohydrological processes, particularly in regions that are facing a multitude of disturbance threats. Moreover, to quickly remove ladder fuels in a cost-effective manner, land managers are leaning towards mechanical thinning and mastication that involves heavy machinery and depositing the material across the forest floor. The intensity and depth of biomass deposit from these treatments is well beyond normative historical. Considering how current NbCS treatments affect water quality (particularly mastication) remains elusive, a fresh look is warranted.

### Water Supply Information

Upper Tuolumne watershed is home to Hetch Hetchy reservoir, providing 117 billion gallons of safe and secure water to 2.7 million residents and businesses in San Francisco, Santa Clara, Alameda, and San Mateo counties. The reservoir is also equipped with 385 MW of hydroelectric generation capacity. Downstream of Hetch Hetchy, Don Pedro reservoir stores up to 650 billion gallons of water for the Turlock and Modesto Irrigation Districts that provides water for farmers and ranchers growing high value agriculture commodities. The Don Pedro reservoir is also equipped with 203 MW of clean hydroelectric generation capacity. Upper Stanislaus watershed supports New Melones Reservoir with 780 billion gallons of water storage capacity for the Central Valley Project (CVP). Runoff from Tuolumne River is a critical source of water for the San Joaquin River, supporting critical habitat and species. Diminishing runoff, from increased evapotranspiration due to increased forest density and warmer climate, and increased risks of sedimentation and large woody debris are a major concern (Turlock Irrigation District, personal communication). Many of the state's reservoirs are losing capacity from sedimentation.

### Project Goals

Our primary goal is to provide a comprehensive assessment of water quantity and quality impacts of current NbCS for watershed management to inform land management and restoration efforts in the region. Our secondary goal is to help NbCS projects like SERAL and SERAL 2.0 within the Stanislaus Landscape succeed through advancing a multi-benefit approach. Through strategic monitoring, numerical modeling, and data syntheses, our goal is to

answer: (i) where and how NbCS in the form of forest thinning, prescribed fire, and meadow restoration impact water storage and fluxes?; (ii) how does stream export of C and sediment change between different treatments and physiographic settings? (iii) do the impacts of NbCS scale up over large areas and to the scale at which water-management decisions are made?; and (iv) are the current NbCS sufficient to mitigate future climate impact? Our hypothesis is that reduced competition for water and nutrients and opening of the canopy for snow and sunlight after thinning will increase stand-level water and C uptake, hence, reducing downstream export.

This proposed applied research builds on the $5 million dollar investment by the state in developing a state-of-the-art database and set of analysis tools under the Center for Ecosystem Climate Solutions (CECS). The initial support for CECS was funding from California Climate Investments (Cap and Trade Program) through the California Strategic Growth Council's Climate Change Research Program. That support ended in the spring of 2023, and this proposal represents one of several next steps growing out of CECS. In parallel, we have also developed a processed-based California water-data information system (CWIS) capable of assimilating vegetation disturbance and predicting its impact on hydrology. We are currently in the process of developing a sediment module. The CECS data and tools and CWIS are an important starting point for the current proposal, which will both provide verification and extend these tools to include water quality. These are gaps not only in our current data, but in the forest-management community more broadly. While we are starting to use available data sets from others to provide initial estimates of benefits, we recognize that current data lack the maturity and accuracy of other products we have developed around water, carbon and ecosystem attributes of natural lands across the state. We will aim to continue working with state agencies, who are also interested in and using CECS and CWIS products.

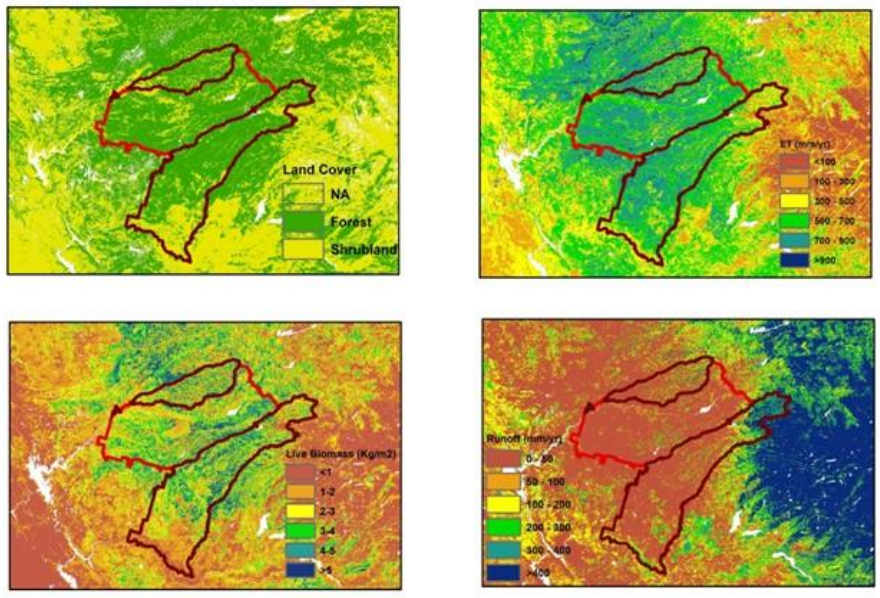



*Fig. 1:Example of mapping of current conditions in 2021 within the project area.*

## Technical Project Description

Project implementation will be broken into four main tasks, each of which is detailed below:

### Task 1: Reconciliation and Validation of Existing Data

The proposed research will use a multi-model approach, evaluated, and verified with field observations at select locations. First, we will compile remote-sensing based CECS products, fill data gaps (CECS data ends in 2021), and intercompare and benchmark against ground observations of actual evapotranspiration ($ET_a$), runoff ($Q$), and soil moisture, and quantify associated uncertainties. While runoff data is available within the project site, local measurements of $ET_a$ and soil moisture are sparse. We will utilize $ET_a$ data from recently eddy-covariance flux towers in the American River Basin (north of the study area) and NEON towers in the Kings River Basin (south of the study area) that were not used in the development of original CECS algorithm. Soil moisture data will be acquired from the Yosemite National Park from their long-term monitoring project (https://www.nps.gov/im/sien/index.htm). Our group has a detailed soil moisture and runoff monitoring network established in the upper Mokelumne watershed located just north of the Stanislaus Landscape project boundary. CECS data is derived from Landsat at 30-m spatial resolution and uses an empirical equation ($ET_a$ = $f$(Normalized Difference Vegetation Index)) for estimating $ETa$ and $Q$ using the approach (Goulden and Bales, 2019) along with an ecosystem (using a modified Carnegie-Ames-Stanford Approach) and a wildfire spread subroutine. These datasets include biomass stocks, carbon dynamics, water balance, vegetation cover, surface fuels, wildfire hazard, drought resilience, and more (Fig. 1). Data were based on ground and satellite (Landsat) measurements. CECS used these data to understand how past disturbances, such as wildfire, management actions, and tree die-offs, affect long-term ecosystem services. The data and tools provide a basis for projecting the effects of future management and disturbance. CWIS uses a process-based model (VIC, Liang et al., 1994) to simulate the effect of disturbance through the assimilation of Landsat and MODIS vegetation products (e.g., LAI, canopy cover, and albedo) at 1-km spatial resolution. A quick analysis of the 2014 Rim fire impact on $ET_a$ shows a strong discrepancy between the two data-products. CECS is not only under-predicting $ET_a$ overall, but also shows a higher decline and slow post-fire recovery (Fig. 2). While the underline mechanisms are largely unknown, we suspect the recovery shown in CWIS data is driven by under-story shrub growth, fueled by the return of moisture post 2012-2015 drought.

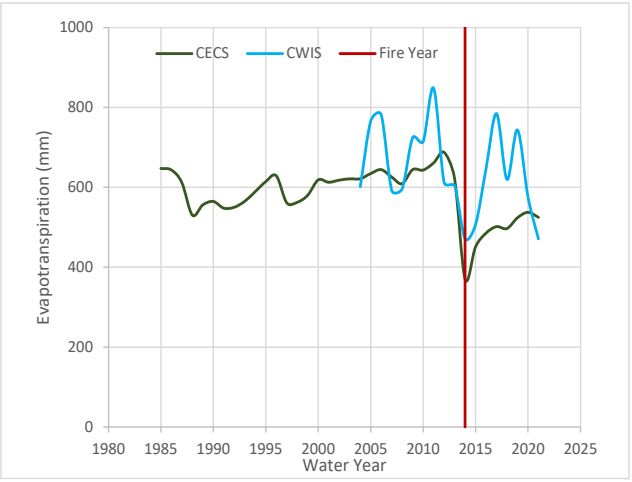



*Fig 2: Changes in Evapotranspiration from the 2014 Rim fire in the Tuolumne watershed predicted by CECS and CWIS.*

### Task 1 Deliverables:

- A curated water balance data product suitable for evaluating forest management impacts. A detailed report describing the data, underlying methods, and associated uncertainties. Archiving data to Hydroshare and other open data repositories.
- A detailed report describing the impact of historical disturbance on water balance and other related ecosystem services. Curated data and analysis for informing the regional synthesis reports.
- A draft manuscript for peer-reviewed publication. Copy of presentations.

### Task 2: Proposed Additional Monitoring

*Soil Moisture and Snow:* Monitoring of soil moisture and snow depth will be performed under treated and control setting to investigate the effect of treatments on soil moisture dynamics and snowpack accumulation and ablation. At first, we will identify three blocks or replicates of paired treated and control sites on south and north aspects of the catchment. These experimental blocks will be established in different elevations and separated by a distance of at least 3 km to capture the spatial variability. Soil moisture and snow depth will be measured along two parallel (thirty meters apart) one-hundred-meter transects within each experimental block. The measurements of snow depth and soil moisture will be performed manually at five-meter intervals along each 100-meter transect using time domain reflectometry (field scout TDR 300) and snow depth probes. Additionally, measurements of snow density and snow water equivalent (SWE) will be performed at every 25 m interval along the transects (5 samples / each parallel transect) using a standard US Federal snow sampler (Maxwell et al., 2019). We will follow standard procedures for sampling snow density and SWE as given in the USDA snow survey sampling guide (USDA, 1984). Snow depth, density, and SWE measurements will be made at the point center and at approximately 3 m from point center in the cardinal directions to collect five subsamples from each measurement point. Overstorey and understory tree characteristics and vegetation density will be measured before and after the treatments. Both the snow-survey and soil moisture measurements will be performed monthly during the snow accumulation, followed by subsequent surveys every two weeks to capture the ablation period. Understory $ET_a$ can be measured using an affordable chamber that captures water vapor in a sealed dome, mixes the chamber contents, and measure residual humidity using a psychrometer or using a sophisticated and trace gas analyzer (e.g., LI-COR Biosciences LI-7810, Lincoln, NE, USA) with associated chamber (e.g., LI-COR Biosciences 8200-104 Opaque Long-Term Chamber, Lincoln, NE, USA). We will utilize a modified version of dome chamber, as described by Kassuelke et al. (2021), to measure understory $ET_a$ under control and different NbCS management scenarios. This improvised chamber covers a total volume of 3,200 $cm^3$ covered with a clear polyethylene and contains two brushless fans for mixing the air within the chamber. We also have access to a portable eddy-covariance flux tower that can be used as needed. The understory $ET_a$ will be compared with the total $ET_a$ measured by the Landsat.

Temperature, light intensity, and relative humidity inside the chamber will be measured using standard sensors (Onset Computer Corporation, Bourne, MA, USA).

In addition to manual snow depth and soil moisture measurements, we will install three nodes of automated digital monitoring stations in each treatment (control, thinning, prescribed and fire), capturing a range of restoration intensity and physiographic conditions (Fig. 3). Each node will be equipped with an ultrasonic snow depth sensor (SnowVUE$^{TM}$10 SDI-12 Digital Snow Depth Sensor), a temperature and relative humidity probe (HMP60-L), and three vertically integrated soil moisture sensors (TEROS 11).

*Figure 3: Snow-depth and soil moisture sensors*

Water quality:

Restoration driven changes in soil erosion and sediment delivery to existing reservoirs is a big concern. We propose to collect bi-weekly stream water samples from treated and control catchments to quantify the export of suspended sediment, total nitrogen, and dissolved carbon, organic and inorganic, from the system. Measurements of Electrical Conductivity (EC), pH, turbidity, and water temperature will also be performed during the water sampling process. Measurement of EC can provide an assessment of the restoration impact on charged ions (e.g., calcium, potassium, chloride, sulphate and nitrate). Similarly, addition of alkaline ash, rich in base cations like calcium and potassium, after prescribed fire can elevate stream water alkalinity and pH. Opening of the canopy can also increase stream water temperature.

Task 2 Deliverables:

- Fabricated and installed 9 nodes of snow depth, temperature, relative humidity, and soil moisture sensors.
- Data and report documenting the manual snow depth and soil moisture.
- Data and report document the water quality parameters as described above.

Task 3: Assessing the Impact of NbCS Implementation

Effects of different restoration treatments (i.e., thinning, prescribed fire, mastication, and re-planting) will be analyzed using before-after control-impact (BACI) design as describe by Roche et al. (2018) for the Stanislaus-Tuolumne Experimental Forest Variable Thinning Project (STEF). Changes in the basal area and understory vegetation will be acquired from the SERAL project silviculturist. Additionally, we will utilize the remotely sensed above-ground biomass and surface reflectance data to assess the impact of NbCS treatments on vegetation. Water balance data from verified and bias-corrected CECS and CWIS products will be extracted over the treated and untreated areas. The analysis of the effect size will be conducted using double-mass, simple ANOVA, and mixed method approach as appropriate (Bart et al., 2021). Mixed-effects modelling will be performed in the *R* programing environment (R Core Team, 2019) using the rstanarm package (Goodrich et al., 2020) which allows Bayesian computation in the Stan Probabilistic Programming Language (Gelman et al., 2015).

Like changes in $ET_a$ from the Rim fire, CECS and CWIS show a very different *Q* response (Fig. 4). While both datasets show a significant gain in runoff, the actual magnitude and longevity of the gain is quite different. CECS data showed a 25% increase in runoff, compared to only 12% using CWIS. We will extend the functionality of the CWIS by incorporating the revised universal soil loss equation (RUSLE), which will be used to map and analyze sediment yield from the two watersheds. RUSLE model predicts the long-term average soil loss potential as a function of rainfall-runoff erosivity, soil erodibility, length, slope, cover, and erosion control practices. Meteorological, topographical and land management information are required for the estimation of soil erosion using RUSLE. By varying these control factors, RUSLE model can be used to evaluate how disturbances such as forest thinning will affect soil loss, sedimentation, and/or water quality degradation, as well as how management actions may mitigate these processes. RUSLE model will be calibrated against the field data collected during this study along with other observations available in nearby catchments (Safeeq et al., 2022).

Task 3 Deliverables:

- A detailed report describing the impact of current management on water balance, water quality, and other related ecosystem services.
- Models for projecting water-balance changes for a range of forest-treatment projects.
- Science outcomes, in the form of factsheets and white papers, and database for informing NbCS projects in California.

- A draft manuscript for peer-reviewed publication. Copy of presentations.

A schedule table is provided under Evaluation Criterion C

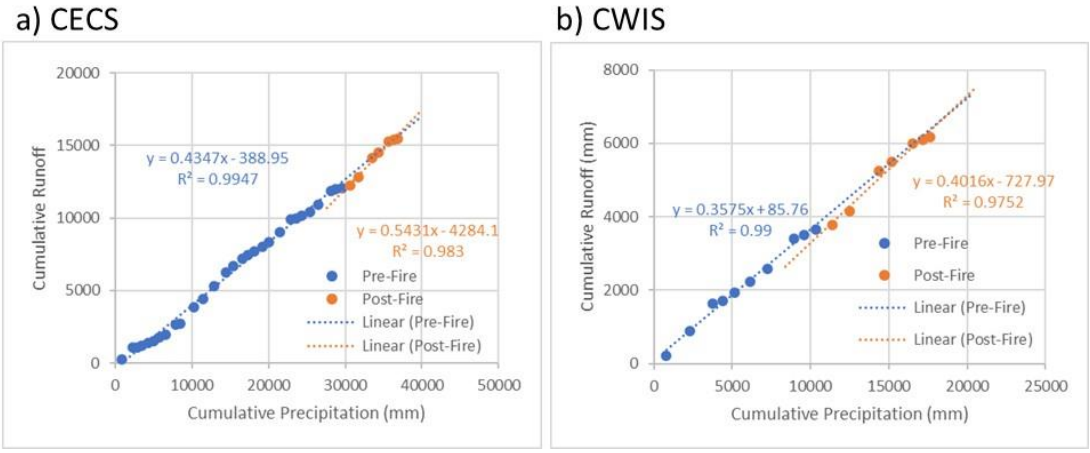



*Figure 4: Pre- and post-fire double-mass analysis of runoff and precipitation using CECS and CWIS data.*

## Data Management Practices

*Expected Data Types:* The project is expected to generate a wide array of data types vital to hydrology, water quality, water supply, climate change and forest health. The data collected and generated from this project will include: (1) existing datasets on water balance, vegetation stress, carbon dynamics, fuels and ignition probability from CECS, (2) existing water balance data from CWIS, (3) model simulation results for sediment yield for the two watersheds (3) climate data from existing climate-data archive (precipitation, temperature, solar radiation and snow water equivalent), (4) geospatial data, including digital elevation models (DEM), land cover, soil, and drainage network maps, (5) time series data of stream flow, evapotranspiration, and soil moisture collected from various existing monitoring stations, (6) water quality parameters such as suspended sediment, total nitrogen, dissolved carbon, organic and inorganic, EC, pH, turbidity, and water temperature with the proposed water sampling course, (7) snow depth, soil moisture, air temperature and relative humidity from the proposed additional monitoring locations, (8) inventory of the forest treatment (location, extent, time), and (9) derived dataset of different watershed restoration treatments on the quantity and quantity of water.

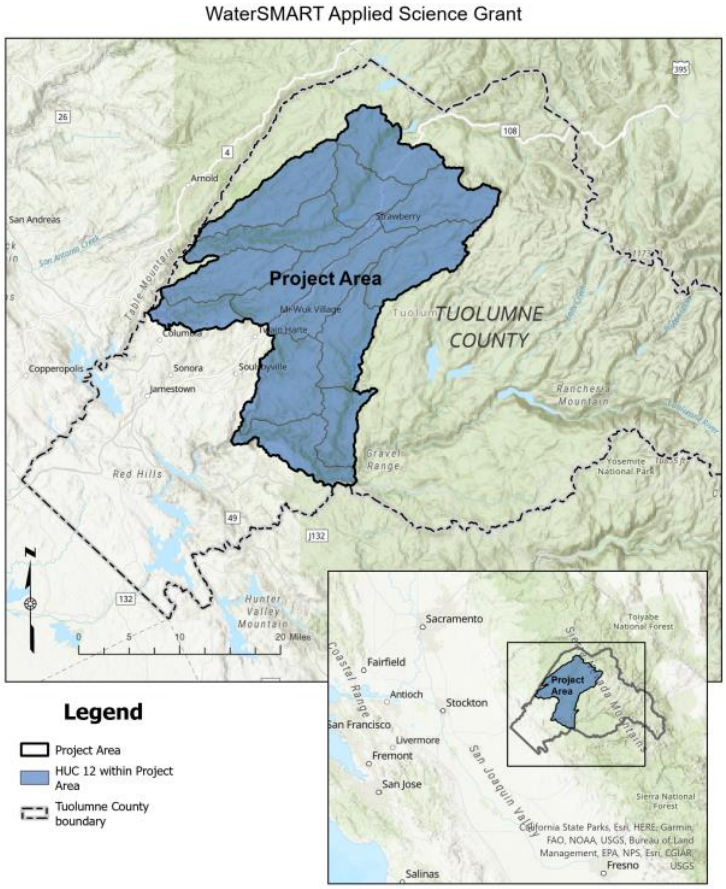
*Data Formats and Metadata*: Data will be meticulously documented and shared according to current best practices. Time series data will be archived using the Consortium of Universities for the Advancement of Hydrologic Science, Inc. Hydrologic Information System (CUAHSI HIS) Observations Data Model (ODM) and presented in Water Markup Language (WaterML). Geospatial raster or vector datasets will be stored in GeoTIFF or ESRI Shapefile formats. Spatiotemporal hydrological and climate model outputs will be stored in NetCDF format. All datasets will be accompanied by comprehensive metadata detailing the variable names, units, date and location of collection, and the methodology employed.

*Data Storage & Preservation:* The primary storage for the project data will be provided via enterprise-grade cloud storage solutions (Box accounts) and CWIS server at the UCM. Codes used for data analysis and model simulations will be version-controlled using Git and hosted on GitHub. Access to this data will initially be restricted to project team members and other authorized collaborators. Long-term data archival will be facilitated through CUAHSI/Zenodo for data types that are compatible with their system.

*Data Sharing, Protection, and Public Access:* Once finalized, datasets will be made publicly available in concordance with the publication of project reports under a Creative Commons Attribution 4.0 License. However, certain datasets may require users to consent to an access/use agreement in coordination with collaborating agencies. During the conduct of this project, all ownership rights rest with the UCM. The sharing of any project results will be consistent with standard institutional policies governing intellectual property, copyright, and the dissemination of research products. Source code developed by this project uses open-source code repositories (e.g., GitHub) for our software development and Open Source Initiative (OSI) approved licensing. In the event commercial products emerge from this effort, we will seek the preservation of non-commercial use licensing.

## Project Location

The Project will be conducted within the upper Tuolumne River Watershed and will produce data from the pre and post-treatment NbCS actions of the Vast SERAL project.



# Evaluation Criteria

## Evaluation Criterion A—Water Management Challenges

Over the last eleven years, the convergence of extreme drought, repeated catastrophic wildfire incidents, epidemic tree mortality, and other indicators have contributed to critical, degenerative changes to watershed hydrology and equilibrium. These degenerative changes, exacerbated by past land management decisions, climate impacts, and other factors represent a dangerous vulnerability to water security and water quality. This vulnerability affects not only this headwater community but all downstream agricultural, community, and environmental water users. The following resulting impacts have been observed:

Loss of available water and water storage capacity:

Soil and aggregate debris flow from record flooding and related erosion contribute to sediment deposition of approximately 375,000 tons per year (289,000 cubic yards per year) into the Don Pedro Reservoir. This represents a cumulative and permanent displacement of reservoir storage volume. Soil degradation and erosion contribute to the loss of soil-water holding capacity and disproportionate runoff also resulted in an increase in spillway release with resulting decreased reservoir catchment, downstream flood risk, and decreased dry season streamflow both above and below the reservoir.

Increased disaster-related operating costs:

In addition to elemental debris, significant floating biomass debris is also a reoccurring problem. From the two federal flooding disasters occurring in the winter of 2023, approximately 100 acres of floating biomass debris field consisting primarily of large-diameter logs was deposited in Don Pedro Reservoir. Dead trees from wildfires and insect-driven die-offs contributed to this severity. This created hazards for boaters and denied access to recreational users for months. This debris was removed at a high monetary and energy cost by loading the logs on barges, transporting them across the Reservoir, and trucking them off-site.

Decreased water quality:

The flooding also contributed to increased turbidity of humus and sediment, increasing nutrient loading. This sedimentation, compounded by the decrease in dry season stream flow, contributes to increased risk for Cyanobacterial Harmful Algal Blooms (HABs) and other water quality concerns.

### Describe the concerns or outcomes if this water management challenge is not addressed.

A failure to adequately address the challenges identified above would see continued degradation resulting in increased hydrologic extremes and related water management costs impacting water purveyors and ratepayers. If unaddressed it is expected that these impacts would grow in severity and frequency. The components identified above cyclically exacerbate and compound each other. Further degrading environmental and soil conditions would increase the loss of available water through sublimation, soil hydrophobicity, increased transpiration, and other factors. This would increase water balance disequilibrium and exacerbate water supply shortfalls and irregularity expressed through catastrophic floods and droughts.

The vulnerabilities caused by these challenges are not limited to water management planners. Nor will the risks and benefits connected to these management choices be limited to water resources or to the upper Tuolumne River Watershed. The impact will include the resilience of ecosystem health and biodiversity as well as the carbon sink efficiency of woody vegetation and soil systems. Beyond these environmental impacts, the monetized costs of flood, drought, and fire suppression, mitigation and recovery as well as secondary impacts such as tourism revenue, fire insurance rates, real estate value, etc. will have a significant impact on communities and local economies.

### Explain how your project will address the water management issues - water supply reliability

This project will identify the NbCS factors that increase available water over a prolonged seasonal catchment timeline. It will increase the accuracy of available information by validating existing data and reconciling available modeling platforms. The ground-based monitoring of control and treated conditions will provide new data for a more robust understanding of the conditions that determine water balance equilibrium and watershed hydrology. This will allow analysis of specific site characteristics and treatments in the upper watershed that improve available water and water quality. This will support a growing nuanced understanding of *which* modalities, *where* and with *what severity* differential treatments produce intended water resource outcomes and benefits.

Too often NbCS projects have been designed based on incomplete, generalized, or anecdotal benefit assumptions. What is needed is a robust decision support tool that is flexible enough to be deployed in a variety of settings yet specific enough to address discrete physical and geomorphologic conditions at work within those project areas. These deliverables will produce actionable improvements for water resource management.

### Management of water deliveries

These deliverables will provide improved accuracy regarding total available water and the anticipated water seasonal catchment timeline. Reducing uncertainty in this regard will inform reservoir release and distribution planning.

### Drought management activities

The impact of improved available water on drought management is self-evident. In addition, this tool will prove useful to disaster mitigation and community planners as a component to

determine the relative risk of various disasters and will inform mitigation investments through comparative analysis options between infrastructure improvement and NbCS-based wildfire and drought mitigation treatment options.

### Conjunctive use of ground and surface water

Increasing accuracy and reducing uncertainty in this regard will also inform conservation and efficiency planning and conjunctive supplementation of diversified water supply planning.

### Ability to meet endangered species requirements

Dry season streamflow is critical for aquatic life including the endangered Sierra Nevada Yellow-Legged Frog *(Rana boylii)* and threatened Yosemite Toad *(Anaxyrus canorus)*. Ephemeral water sources and sustained dry season stream flow supported by this technology will buttress the resilience and biodiversity of the entire food web including these endangered species.

### Watershed health

The project's benefit to watershed health is inherent and comprehensive. By cross-walking specific treatment tools to resource objectives through a multiple-benefit lens, ecosystem biodiversity and resilience will be improved. Benefits for upper watershed basin examples include decreased relative risk of catastrophic wildfires and decreased incidence of tree mortality; thereby protecting critical habitat fundamental to these forest ecotypes.

### Natural features supported

One natural feature to be supported in this project is upland meadow restoration. We will provide an analysis of headwater meadows relative to forest-thinning treatment locations and their respective impact on hydrologic function. A great number of legacy meadows have experienced unnatural tree encroachment impeding there ability to filter sediment and infiltrate stormwater. A recent UC Davis/USFS study (Cummnings *et al.*, 2023) “showed that there is nearly three times more potential meadow habitat (in the Sierra region) than currently documented.” Upland meadows are of critical importance for both built and natural environments. More information regarding the unique hydrology of upland meadows and its impact on the watershed is needed. Note Map in supplemental documents.

### Other improvements to water supply reliability

These data and modeling improvements will provide a robust and flexible decision-support tool to inform water management. It will prove useful for all of the following resource decision-makers. It will provide immediate benefit to water managers by improving accuracy regarding expected water supply flow volume and timing. This will support reservoir release volume and timing and resulting distribution planning and required efficiencies. It will also improve accuracy regarding expected water quality and debris flow and will support cost analysis and planning related to operations and related infrastructure and capital investment cost planning for this recurring damage.

This tool will also provide useful information to landscape managers regarding NbCS. This information will be site-specific and identify treatment design given resource objectives and multiple benefit opportunities including but not limited to improved water resources.

Moreover, this tool will prove useful to disaster mitigation and community planners as a component to determine the relative risk of various disaster types and will inform mitigation investments comparative analysis options between infrastructure improvement and NbCS-based mitigation treatment options.

## Evaluation Criterion B—Project Benefits

### How the need for the project was identified

The origin of this project was collaborative and multifaceted. Turlock Irrigation District (TID) had begun communication with UC Merced faculty to identify opportunities to address water supply reliability and quality challenges brought about by conditions in the upper watershed. Contemporaneously, the Stanislaus National Forest, the County of Tuolumne, and select partners within the Yosemite Stanislaus Solutions Network began to investigate modeling to better understand the benefits (and potential risks) of the expansive Stanislaus Landscape forest health project treatments. There was a sense of urgency to capture preexisting conditions before implementation began. During the summer of 2023, meetings began between both groups to coalesce these two conversations. There was a consensus that the same data and modeling improvement would meet the needs of multiple resource decision-makers. Once the County, USFS, UC Merced and TID agreed upon the project concept it was shared at with Yosemite Stanislaus Solutions and The Tuolumne Stanislaus Integrated Regional Water Management Association (T-StanIRWMA) meetings. This plan was well received at both meetings with constructive input and consensus of approval to proceed.

### How and when the tool will be applied

The project will generate deliverables in a phased approach. The project will provide immediate benefits even before its completion, as it will provide decision support to Turlock Irrigation District and downstream water managers through improved accuracy for available water and seasonal catchment timeline modeling. As the project progresses, the modeling will continue to evolve. Ground-based monitoring data will be collected. Incorporating those ground-based observations, we can further improve the product generated by the modeling applications (Pelak et al., 2022). In the final phase, we will examine the impact of various forest restoration treatments on water yield, quality, and supply reliability.

### Describe in detail the extent of the benefit

In terms of flow and distribution management within the watershed, Turlock Irrigation District will be the primary beneficiary. Downstream water managers would be similarly affected. Additional stakeholders will benefit as noted:

- Forest health and wildfire planners to improve best practice treatment design will use the flexible robust engine to determine both the “what” and the “where”. They will more accurately match NbCS treatments to conditions based on the primary resource

objective. This will facilitate a more comprehensive understanding of all ecosystem services leveraged by various treatment options.

- Similarly, Disaster mitigation planning will use these deliverables to assess the potential to mitigate fire, flood, and drought disasters through NbCS resilience compared to mitigation projects that focus on conventional infrastructure-based mitigation strategies.
- A comparative understanding of NbCS treatment potential versus conventional infrastructure-based mitigation in terms of cost efficiency will inform grant planners, conservation, and philanthropic organizations in the organization of future funding opportunities.

The information from this improved decision support tool will be useful in many settings. The patterns identified from this project will be transferable to other regional settings with similar environmental conditions. With the addition of ground-based monitoring, this tool will be effectively applied across a myriad of locations across Californian inland forest regions and across American western temperate forests.

Moreover, the improved understanding of the impacts of various vegetation treatment modalities will inform forest and land management best practices across the California inland forest regions and across American western temperate forests.

To what extent will the project address the water management challenges described in E.1.1.?

This has been covered at length to summarize, it will address concerns related to watershed health, water quality, and reliability of water supply. Further, it will support better ecosystem services multiple-benefits from NbCS treatments.

Explain how your project complements other similar efforts in the area?

This project will make use of the most pertinent and current modeling datasets including Center for Ecosystem Climate Solutions (CECS), Yosemite National Park from their long-term monitoring project, Stanislaus-Tuolumne Experimental Forest, and other datasets as described in the technical project description. There is no other unreferenced studies or models that compete or contribute meaningfully to this scope and locality.

## Evaluation Criterion C—Project Implementation

### 1. Describe and provide support for the approach and methodology

Describe your project implementation plan:

Workplan delivery milestones are organized quarterly over the two-year study period as described at length in the technical proposal (section 5).

**Schedule**

| Task | Q1 | Q2 | Q3 | Q4 | Q5 | Q6 | Q7 | Q8 |
|---|---|---|---|---|---|---|---|---|
| Task 1 | | | | | | | | |
| Task 2 | | | | | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Sensor Installation | | | | | | | | |
| Manual Snow Depth Surveys | | | | | | | | |
| Manual Soil Moisture and Understory $ET_a$ Surveys | | | | | | | | |
| Water Quality Sampling | | | | | | | | |
| Task 3 | | | | | | | | |

Describe the work plan for implementation.

Cost for each task

Task 1: $121,229, Task 2: $135,271, Task 3: 89,193. *Does not include additional costs not allocated by contractor to tasks.*

3. Provide a summary description of the products to result from the project.

This is covered at length in the Technical Proposal task deliverables.

4. Who will be involved in the project as project partners?

County of Tuolumne will function as Project Proponent with Sean Hembree (staff) as Project Manager. UC Merced will function as the Technical Consultant (under contract) with Safeeq Khan (faculty) as Principal Investigator. USFS Stanislaus Forest, Turlock Irrigation District, Tuolumne River Trust and other Yosemite Stanislaus Solutions member organizations will function in an advisory capacity.

5 Identify staff with appropriate qualifications – describe qualifications.

Senior Water and Natural Resource Analyst – 6 years of water and natural resource experience in project management and development. Dr. Safeeq Khan U.C. Merced (Contractor): PH. D, CEE – U.C. Merced Professor – UCANR Cooperative Extension Specialist in Water and Watershed Sciences – over 50 peer-reviewed journal publications in watershed hydrology and related fields

Have the project team members accomplished projects similar in scope?

Yes, Sean Hembree has had 9 years in project management, grant management and/or water management industry experience. From his post in the County Administrator's Office, he has ready access to all staff for ancillary subject and capacity matter support. Tuolumne County administers scores of millions of dollars in similar projects annually. Dr. Safeeq Khan has extensive experience and is respected as a leader and regional expert in watershed hydrology.

Is the project team capable of proceeding immediately upon entering into an agreement?

Yes, there will be no contingencies or delays.

## Evaluation Criterion D—Dissemination of Results

- A detailed report describing the impact of current management on water balance, water quality, and other related ecosystem services.
- Models for projecting water-balance changes for a range of forest-treatment modalities.

- Science outcomes, in the form of factsheets and white papers, and a database for informing NbCS projects in California.
- Outreach to the following organizations and collaboratives will be given:
    - Project Partners: (YSS member organizations, local Tribes, TRT, et al)
    - State Water Management Authorities
    - State and regional resource priority collaboratives
    - Disaster Mitigation Project Planning units such as the California Office of Emergency Services and FEMA
    - Academic forums

## Evaluation Criterion E—Presidential and Department of the Interior Priorities

### Climate Change E.O. 14008

While many water monitoring projects focus on improving efficiency in water use or distribution, the deliverables of this project will create a more robust understanding of the actions that actually avail more usable water and mitigate floods and drought by leveraging healthy nature-based system solutions. By implication, this available water will drive the sequestration and security of carbon through healthy forests and wetlands within the watershed. Beyond the watershed, this increased available water will also displace other environmental water that would otherwise be dedicated to agricultural and consumptive use. By displacing this water use, it makes water available to support critical Sacramento Delta Flows. The Delta marchlands and estuaries are an important carbon sink. These ecosystems support keystone species such as Salmon. The displaced water demand will also support critically over-drafted groundwater basins and water systems along the San Joaquin River and all downstream users within the California water distribution system. This tool will prove useful to disaster mitigation and community planners as a component to determine the relative risk of various disaster types and will inform mitigation investments comparative analysis options between infrastructure improvement and NbCS-based mitigation treatment options.

### Disadvantaged and underserved communities

This project will affect all downstream DAC water users. It has been established that underserved communities suffer disproportionately from basic water rights inequity.

### Tribal Benefits

This project will advance The Department of Reclamation's commitment to strengthening tribal sovereignty and the fulfillment of Federal Tribal trust responsibilities. A **Tribal Brief Statement** is included in the supplemental documents section which describes a brief history of the indigenous people of this region and their benefit from this project. The identified tribal bands will be among the entities identified in our outreach plan deliverable.

# Project Budget

## Budget Narrative

**Personnel**

Hourly Equivalent: (Salary Position) for Project management and related actions to include: timeline tracking, reporting and related tasks. Hourly rate includes 5% increase (average compensation increase for employees) Compensation rates are consistently applied to Federal and non-Federal activities.

**Fringe Benefits**

34% of base salary. Includes FICA at 6.2% Medicare, retirement, medical/dental/vision. Salary increase calculations were not included.

**Contractual**

Includes the negotiated rate for all services as described including:

Task 1: Reconciliation and Validation of Existing Data

Task 2: Proposed Additional Monitoring

Task 3: Assessing the Impact of NbCS Implementation

**Indirect Charges**

Charges calculated according to option 2 (de minimis)

## Budget Summary

| Summary | | | |
|---|---|---|---|
| 6. Budget Object Category | Total Cost | Federal Estimated Amount | Non-Federal Estimated Amount |
| a. Personnel | $11,760 | | |
| b. Fringe Benefits | $9,478 | | |
| c. Travel | $0 | | |
| d. Equipment | $0 | | |
| e. Supplies | $0 | | |
| f. Contractual | $469,606 | | |
| g. Construction | $0 | | |
| h. Other Direct Costs | $0 | | |
| i. Total Direct Costs | $490,844 | | |
| i. Indirect Charges | $39,813 | | |
| Total Costs | $530,657 | $397,993 | $132,664 |
| | Cost Share Percentage | 75% | 25% |

## Environmental and Cultural Resources Compliance

There will be no impact to soil, air or water quality. Nor will there be any impact on habitat or species of interest or any introduction of any new or invasive vegetation and will not be placed on any identified cultural resource locations. The project will not alter any water course or have any adverse impact on disadvantaged tribal communities.

### Additional information

There are **no permits required** for this scope of work. Monitoring stations will be placed with the permission of the USFS. There is no **duplication of effort** and no overlapping projects except as referenced and/or noted herein. There is **no conflict of interest** for any interests of involved parties and entities to the best of our knowledge.
Appropriate steps will be taken to avoid conflict of interest. Procurement of supplies, equipment, and services will comply with 2 CFR§200.318

# Supporting Documentation

### Maps

**Uploaded to grants.gov**

### Letter of Commitment

**Uploaded to grants.gov**

### Letters of Support

**Uploaded to grants.gov**

### Technical Proposal References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## Statement of Tribal Benefit

The Department of the Interior is committed to strengthening tribal sovereignty and the fulfillment of Federal Tribal trust responsibilities. The President's memorandum, Tribal Consultation and

Strengthening Nation-to Nation Relationships, asserts the importance of honoring the Federal government's commitments to Tribal Nations.

The indigenous people of the Tuolumne River canyon area have a deep appreciation for and understanding of the river environment and have contributed to the overall ecology and heritage of the place. In particular, two groups of Miwok[1] (the Central Sierra Me-Wuk and the Southern Sierra Miwuk) have traditional practices that contribute to river health and resilience.

Some of the practices, such as supporting beaver habitat, biannual burning of brush and duff, and especially cultural burning (a long and slow burn that restores plant health and retains water in the soil) have been curtailed by land ownership, agency policy, inability to gain access, and some loss of cultural knowledge over the years since nonnative people arrived in this part of California. Other practices, including maintenance of black oak groves, or coppicing of certain plants (especially by basket weavers) have contributed to an environmental endurance of some species. This knowledge, named by some as traditional ecological knowledge (or TEK) would be appropriate to the resilience-building technology proposed by this grant application. Partnership with the Miwok on the implementation of this grant would benefit our community for both this project and future projects by building an understanding of deep cultural knowledge, heritage values, scientific goals, and overall proposed stewardship, while strengthening our communication goals and implementation of the project. The indigenous people have a strong connection to the environment, recognizing the interconnectedness of birds and other animals, plants, fungi, and water, and respect for all of those affects the way in which they develop and prosper. This recognition provides overall support for our grant goals.

The Bureau of Reclamation has a responsibly to engage with and consult with Tribes and other interested parties as part of their responsibility pursuant to federal law. At a minimum, the National Environmental Policy Act and the National Historic Preservation Act both call for ongoing good-faith consultation between the federal government and federally recognized Tribes and federally unrecognized, yet established groups. The portion of the Tuolumne River watershed for this study is part of the ancestral homeland of several groups of people, including the aforementioned Miwuk groups, as well as the Kutzedikaa Paiute in the upper watershed and foothill Yokuts groups in the lower watershed. Generally, this area is the homeland of tribal members of the Tuolumne Band of Me-Wuk Indians, the Chicken Ranch Band of Me-Wuk Indians, and the Southern Sierra Miwuk Nation (also known as American Indian Council of Mariposa County). The two former Tribes are federally recognized, while the latter has been undergoing consultation for federal recognition for many years. These three groups have intermarried and continue traditional cultural activities which take them on transportation corridors which traverse this watershed, making each successive generation knowledgeable about the environmental and traditional ecology. For millennia the Me-Wuk have utilized *kuchi pochato* (Central Sierra Me-Wuk for "good places to plant") to cultivate vegetation for food, medicine, basket materials, and other uses. These plants continue to be an important part of their culture and heritage.

[1] Note the spelling of Miwok, is a generic spelling for no less than five Miwokan groups which themselves spell their name differently. The Tuolumne River canyon was homeland to two of these groups: the Southern Sierra Miwuk and the Tuolumne and Chicken Ranch bands of Me-Wuk. The similarity of pronunciation should not be construed to indicate the same group. These are different groups of people.

Disproportionate harm by climate change, past land management decisions, and various forest harvesting activities gave all affected the resilience of these practices. This grant provides a pathway to participate and lead in the restoration of ancestral land and, with ongoing consultation and interaction, supports Reclamation's tribal trust responsibilities.

## Official Resolution

***Pending***

University of California
Agriculture and Natural Resources

**Contracts and Grants**

ANR Office of Contracts and Grants
2801 Second Street
Davis, CA 95618
(530) 297-8760 office
(530) 756-1148 fax
cigallegos@ucanr.edu
http://ucanr.org/contractsandgrants

October 5, 2023

Tuolumne County, CA
Administration Office
2 South Green St.
Sonora, CA 95370-4618

RE: Letter of Commitment

Dear Administrator,

On behalf of The Regents of the University of California – Agriculture and Natural Resources, attached is our proposal entitled "***Advancing Nature-Based Solutions for Building Watershed Health and Water Supply Reliability in the Tuolumne River Basin***" with a projected start date of August 1, 2024, and a requested two-year budget of $469,606. We are pleased to confirm our commitment to serve as a subcontractor to Tuolumne County for this proposal under the Bureau of Reclamation, U.S. Department of Interior WaterSMART-Applied Science Grants solicitation. Our Principal Investigator is Dr. Safeeq Khan, Assistant Cooperative Extension Specialist.

Any questions of a programmatic nature should be directed to Dr. Khan at msafeeq@ucanr.edu. Questions of a contractual nature may be directed to Chantal Gallegos at ocg@ucanr.edu. Correspondence may be sent to the attention of Chantal Gallegos, University of California, Agriculture and Natural Resources, Office of Contracts & Grants, 2801 Second Street, Davis, CA 95618-7717.

Should this proposal result in an award, please issue the agreement in our legal name, The Regents of the University of California, and send it to the address in the above paragraph.

Respectfully,

Kimberly Lamar
Associate Director

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October 17, 2023

Bureau of Reclamation
Financial Assistance Operations
Attn: NOFO Team
P.O. Box 25007, MS 84-27133
Denver, CO 80225

**RE: Tuolumne County's WaterSMART Application for Advancing Nature-Based Solution for Building Watershed Health and Water Supply Reliability in the Tuolumne River Basin Letter of Support from Turlock Irrigation District**

To whom it may concern:

It is with great enthusiasm that Turlock Irrigation District (TID) offers its strong support to the Tuolumne County in its application for a WaterSMART Applied Science Grant Program to advance watershed health and improve water supply in the upper Tuolumne River Watershed.

The importance of a strong scientific foundation for understanding the risks and opportunities for water supply and reliability improvement cannot be overstated. When appropriate, the data improvement and decision support tool resulting from this project will provide actionable information to TID. Moreover, it will inform the work of other resource decision-makers and stewards engaged in this watershed such as the USFS-Stanislaus National Forest, Yosemite Stanislaus Solutions, and Tuolumne-Stanislaus IRWMA among other partners.

TID owns and operates the Don Pedro Project, which provides reliable irrigation water to over 200,000 acres in California's central valley. Additionally the Don Pedro Project provide 203MW of carbon free power, a variety of recreation opportunities, and is the sole flood control project on the Tuolumne River. This decision support tool will provide new data sets to inform our water management decision making and facilitate a multidisciplinary integration and facilitate treatment best practices that build resilience across a spectrum of ecosystem services.

For these reasons, TID offers its strongest support for the County's grant application. If you have any questions, please do not hesitate to contact my External Affairs Manager, Josh Weimer, at 209-883-8461 or by email at jmweimer@tid.org.

Sincerely,

Michelle Reimers
General Manager