WaterSMART Drought Response Program:
Drought Resiliency Projects for Fiscal Years 2020 and 2021

An Intelligent Hydroclimatic Information System for Water and Power Management in the American River Basin

August 5, 2020

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1.0 TECHNICAL PROPOSAL AND EVALUATION CRITERIA

1.1 Executive Summary

1.1.1 Applicant Contact Information

Below is the information requested in the Funding Opportunity Announcement (FOA) No. BOR-DO-20-F002 for the WaterSMART Drought Response Program: Drought Resiliency Projects for Fiscal Years 2020 and 2021. Our submittal is responding to Task B of the FOA: Projects to Improve Water Management through Decision Support Tools, Modeling, and Measurement.

Date	**August 5, 2020**
Applicant Name	El Dorado Water Agency
City/County/State	City of Placerville, El Dorado County, California

1.1.2 Project Summary

This project involves upgrades to two of the 12 sensors in the existing American River Basin Hydrologic Observatory (ARHO) wireless sensor network (WSN), and development of an online operations management dashboard (dashboard) to display the spatially representative, and downloadable continuous stream data collected from the sensors. The improved data to be collected by the project is calculated to increase the forecast reliability and availability of up to 18,000 acre-feet of snow water runoff per year. The project is a partnership between El Dorado Water Agency (EDWA), and the University of California (UC Agriculture and Natural Resources and UC Merced Sierra Nevada Research Institute), with support provided by the U.S Bureau of Reclamation (Reclamation) and with engagement of an active working group of stakeholders including local water purveyors, the Sierra Nevada Conservancy, the California Department of Water Resources, State Water Resources Control Board, U.S. Forest Service, and the National Oceanic and Atmospheric Administration (NOAA). Approximately one million-acre feet of California's useable water supply is calculated to originate from snowmelt runoff in the American River Basin (ARB) where the ARHO WSN is located. During the 2012-2016 drought, reduced snowpack dramatically impacted downstream water availability. Central Valley Project water allocations from Folsom Reservoir to water contractors were reduced by 25% in 2013, by 50% in 2014, and by 75% in 2015. This project lays the groundwork needed to better prepare for and respond to future droughts. The ARHO WSN sensors and dashboard will provide substantively more accurate data on water availability, data that is needed to improve the accuracy and efficiency of meteorological forecasting and hydroclimatic modeling that is the foundation for improved water management, including for determining water allocations. The wide suite of independent data resulting from the project will provide a critical upgrade in predictive modeling, one of increasing importance as the demand for water increases while the snowpack in the Sierra Nevada decreases.

Key Outcome: Accurate, reliable, spatially representative, and downloadable continuous stream data on watershed conditions within approximately one year (24 month) for local, regional, and Sacramento River water system operations, increasing the forecast reliability and availability of up to 18,000 acre-feet of snow water runoff per year.

1.1.3 Length of Time and Estimated Completion Date for the Project

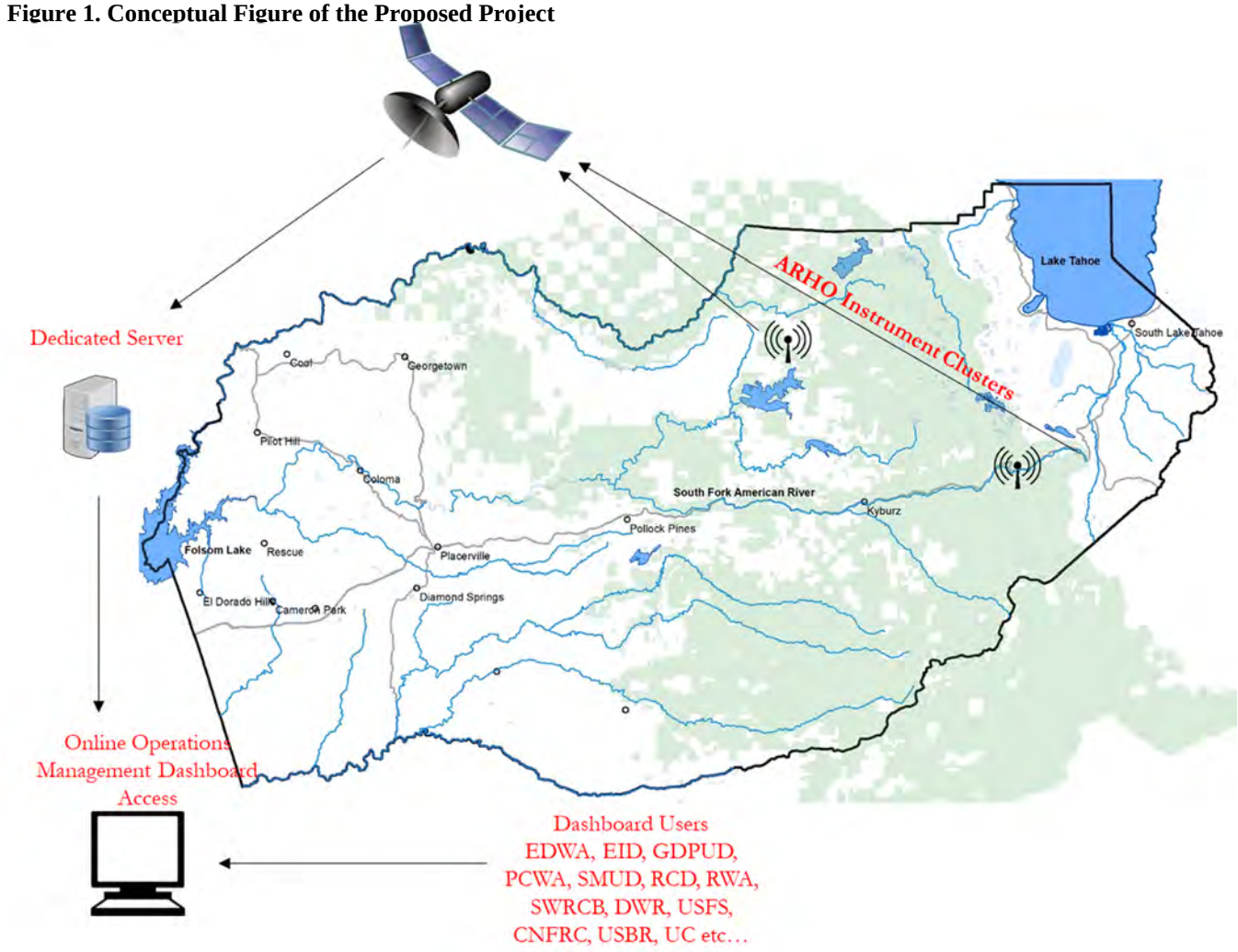
The project will be completed within approximately one year (24 month) timeframe with an estimated start date of August 2021 and an estimated completion date by August 2023. While some pieces of the wireless sensor hardware can be assembled offsite, on-site installation will take place during the summer months. Development of the online dashboard will be an ongoing

process beginning in August 2021 with a pilot launch anticipated by the end of 2022 and a public version of the dashboard available by early summer of 2023.

1.1.4 Federal Facility Information

The wireless sensor networks proposed to be upgraded are located on National Forest land in the upper snow dominated portion of the American River Basin on the western slope of the Sierra Nevada. The American River Watershed forms a drainage basin of approximately 2,140 square miles (1.3 million acres) above Folsom Reservoir, the main impoundment on the American River. Folsom Reservoir is part of Reclamation's Central Valley Project (CVP).

Figure 1. Conceptual Figure of the Proposed Project



1.2 Project Location

The two sensor stations proposed for upgrade are both located within El Dorado County, California on the Eldorado National Forest in the Upper American River Basin. They are remote locations. The coordinates for the locations are as follows:

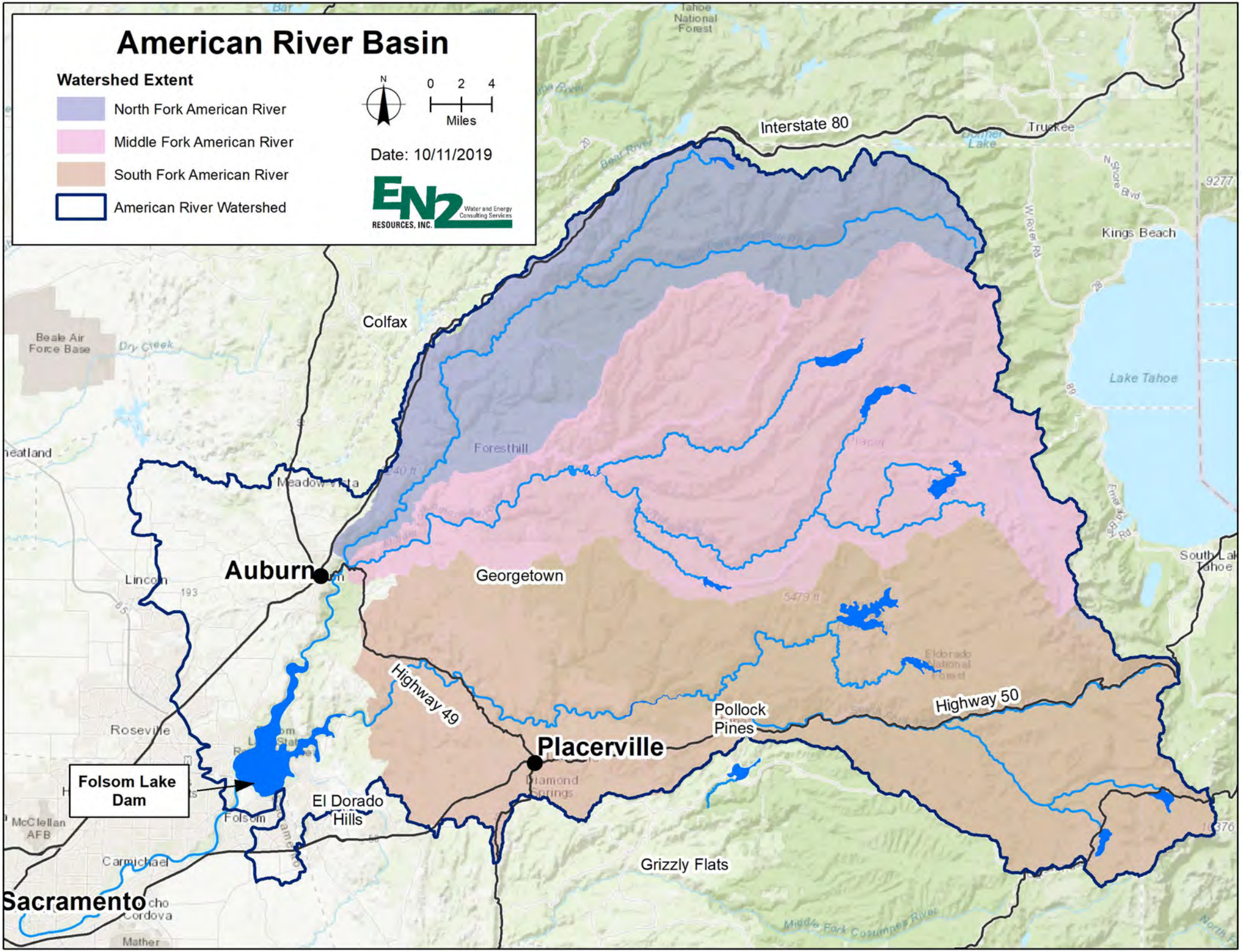
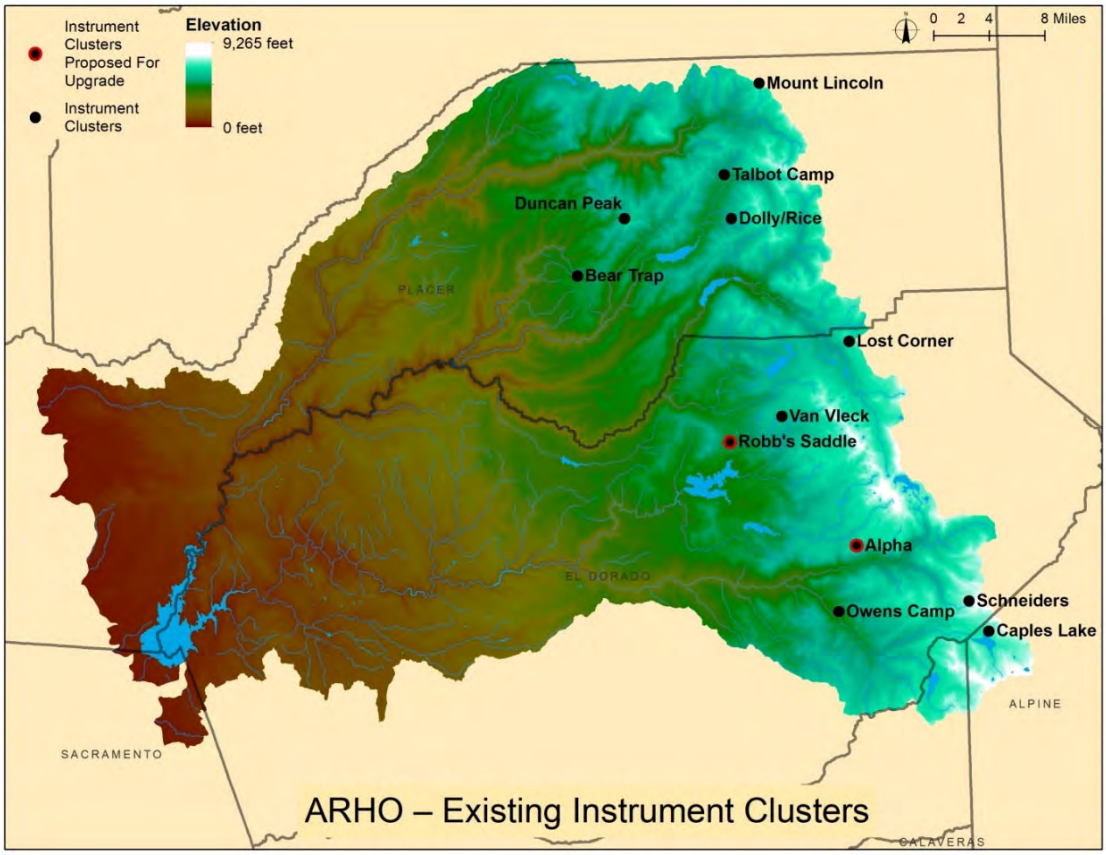

American River Basin
Watershed Extent
North Fork American River
Middle Fork American River
South Fork American River
American River Watershed
N
0 2 4
Miles
Date: 10/11/2019
EN2 RESOURCES, INC.
Water and Energy Consulting Services
Interstate 80
Truckee
Kings Beach
Lake Tahoe
Colfax
Beale Air Force Base
Foresthill
Auburn
Georgetown
Lincoln
Highway 49
Highway 50
Pollock Pines
Placerville
Roseville
Folsom Lake Dam
Folsom
El Dorado Hills
McClellan AFB
Carmichael
Grizzly Flats
Sacramento
Cordova
Mather

Table 1. Wireless Sensors Cluster Sites GPS Coordinates, Elevation, and Watershed Location

Wireless Cluster Site	Latitude	Longitude	Elevation m/ft	Sub-Watershed
Robbs Saddle	38.91572	-120.379125	1,799/5900	South Fork American
Alpha	38.942	-120.309	2,290/7511	South Fork American

Data generated by the wireless cluster sites will be transmitted by signal to a satellite and then to a centralized server. The server will be first built at UC Merced and then transferred and networked to a permanent location at the EDWA office in Placerville. After installation and testing, the server will be maintained by EDWA and the sensors will be maintained by the UC Merced Sierra Nevada Research Institute.

Figure 2. American River Hydrologic Observatory (ARHO) Research-Grade Wireless Sensor Network (WSN) Instrument Clusters within the American River Basin



1.3 Technical Project Description

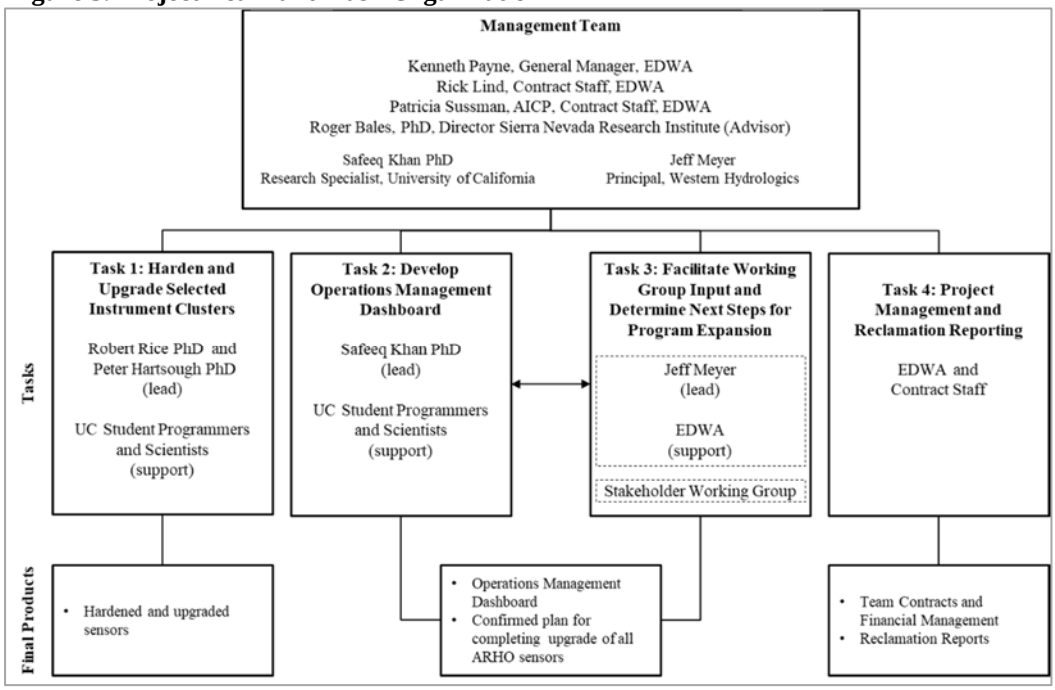
Existing wireless remote sensing instrument clusters throughout the Upper American River Basin (ARB) have been providing real-time data to scientists at the University of California (UC) interested in building accurate models of the water supply in the Sierra Nevada since 2008 when the first sensors were installed. This research-grade network, called the American River Hydrologic Observatory (ARHO), is now ready to be upgraded to become an all-weather permanent wireless sensor network (WSN) that decision-makers charged with on-the-ground water management can rely on for accurate, reliable, spatially representative, and downloadable continuous stream data. Such data is currently not available, and in fact, forecasts based on data collected from existing instrumentation (often collected only a few times per month or less) are known to underestimate snowpack by as much as 30%. As a result, water management decisions based on forecasts and models that use this data tend to be conservative, affecting water allocations involving tens of thousands of acre-feet in drought years and subsequently impacting California's agricultural economy that relies on water allocations to plan the acreages and types of seasonal crops.

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

- Task 1: Harden and Upgrade Selected Instrument Clusters
- Task 2: Develop Operations Management Dashboard
- Task 3: Facilitate Stakeholder Working Group Input and Determine Next Steps for Program Expansion
- Task 4: Project Management and Reclamation Reporting

Figure 3 displays the relationship of each of the tasks to the final products, and the management team and leads for each task.

Figure 3. Project Team and Task Organization



1.3.1 Task 1: Harden and Upgrade Selected Instrument Clusters

Task 1 will involve hardening and upgrading the existing wireless nodes and base stations of two sensor clusters in the American River Basin (see Table 1). Each of the two wireless sensor clusters consist of ten measurement nodes and a base station which stores and transmits the data.

Hardening and upgrading the sensors and base stations will involve the following tasks at each of the two wireless sensor clusters. Specific installation techniques may be adjusted based on new technology and information.

- The existing aluminum pipes at the 10 sensor nodes within each of the two clusters will be replaced with larger diameter and thicker walled material to decrease the likelihood of bending/breaking due to snow loads (Figure 5).
- A sub-set of nodes at each cluster will be pulled into a tighter cluster to improve communication performance in the local network, without sacrificing data quality.
- Problematic nodes in each sensor cluster will be removed from emplacements and relocated within the network.
- All nodes will be attached (e.g. bolted) to steel u-channel supports which will be set in concrete.
- Plastic weather-proof enclosures, which house the electronics for each node, will be replaced with stronger metal enclosures.
- All electronics will be updated with the latest versions/firmware.
- All sensors (temperature/relative humidity, snow depth sensors, and soil moisture) will be updated, calibrated, or replaced.
- Flexible metal conduits, which protect external sensor wires, will be replaced with rigid PVC.
- Base communication stations will be rebuilt with stronger material and raised up to accommodate heavier and deeper winter snowpacks (Figure 6).
- The communication systems at the base stations will be updated from problematic cellular or commercial satellite to the NOAA GOES system. This will allow for more reliable data transfer from the wireless cluster to the end users.

Figure 4. Hardened Wireless Sensor Node in Feather River Basin

Figure 5. Hardened Base Station in Feather River Basin with Upgraded Hardwire and Communications

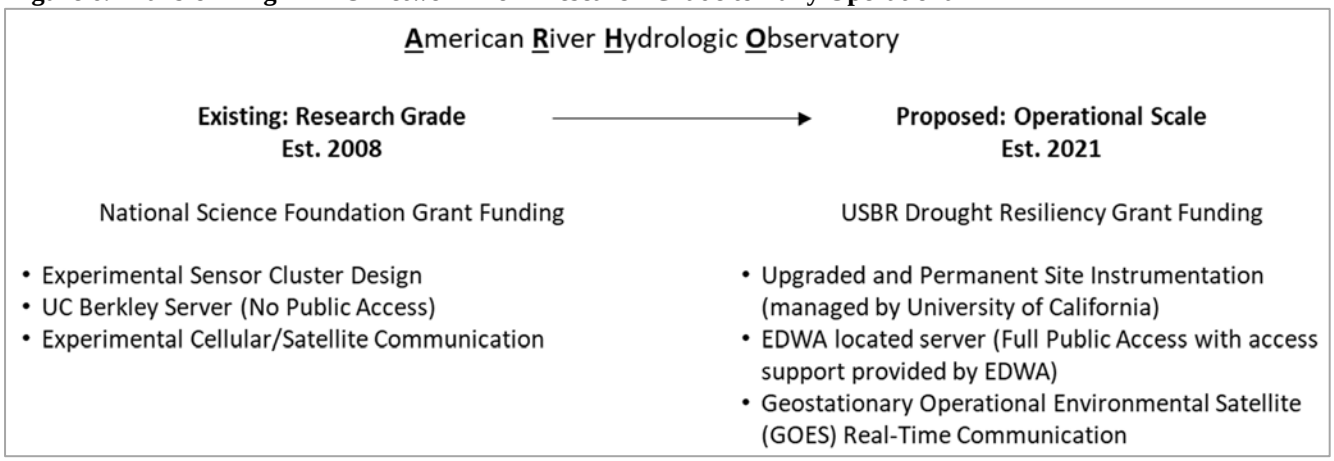
The wireless sensor nodes will be assembled, in-part, at University of California, Davis, and driven to the field sites for final installation. All sensors and data logging systems will be tested in the lab. The system is designed to function autonomously throughout the winter using solar panels and Li-ion batteries and deliver data to the server at EDWA. During the first winter of operation (winter

of 2022), periodic site visits may be required to make final adjustments, and other necessary maintenance. Finally, during summer 2022, all wireless sensor clusters will be surveyed to ensure future reliability.

Task 1 Deliverables:

- Two wireless sensor networks (each composed of ten nodes and a base station) installed and operating
- Telemetry connection to data server
- Data server transmitter for communicating with GOES Satellite

Figure 6. Transforming ARHO Network from Research-Grade to Fully Operational



1.3.2 Task 2: Develop Operations Management Dashboard

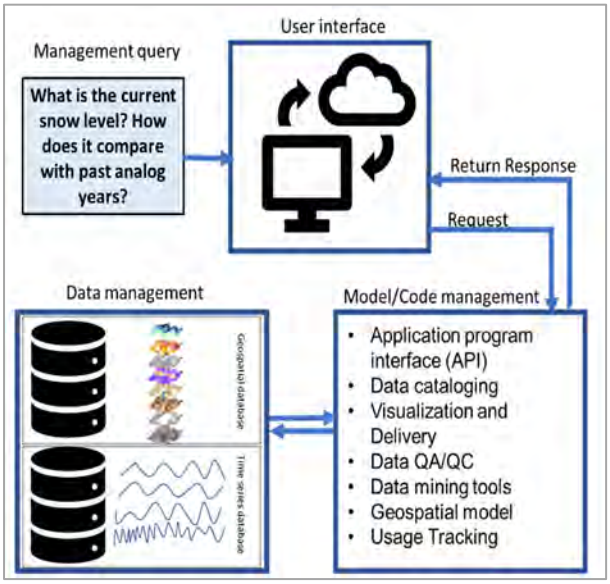
Task 2 involves designing, developing and refining the online Operations Management Dashboard (dashboard) for the project. The dashboard is the online tool that will store, sort, process and display the data from the wireless sensor clusters for use by local, regional, state and federal agencies, water and reservoir managers, and researchers. The dashboard will be designed, developed and refined with input from the stakeholder Working Group (see Table 2) to ensure its programming supports user information needs. Task 2 is broken into two subtasks.

Task 2a: Develop programing to clean the data and transmit it to the designated server

This task will support automation of data quality assurance (QA) and quality control (QC) and preparing metadata before final reporting and public access. UC scientists will apply the QA/QC method for range checking, negative and extreme value check, low and high frequency cyclic and random noise, instrument noise etc. following the established procedure as described in literature (Daly et al., 2008; Bales et al., 2018; Carolyn and Safeeq, 2018). After the initial QA/QC, missing data will be gap filled, and flagged, using a combination of the nearest and best correlated neighbor(s), linear interpolation, and normal ratio methods. The earlier work completed by UC on the WSN demonstrated that low frequency and short duration gaps can be filled using linear interpolation. However, when data from the multiple sensors are missing for a relatively long duration, normal ratio and regression-based methods are better suited for maintaining the data homogeneity. For metadata, the UC team will make full use of existing and emerging standards for documenting and sharing environmental data. Time series data collected by this project will be processed using Metavist and Water Markup Language (WaterML) format where possible.

Metavist, a metadata editor for the Federal Geographic Data Committee (FGDC), is a useful tool for developing metadata document that is compliant with the Biological Data Profile (BDP) metadata standard, which works for nearly any type of data. WaterML 2.0 is being developed through the Hydrology Domain Working Group of the Open Geospatial Consortium (OGC) and the World Meteorological Organization. Using these accepted standards for data interfaces and format encodings will ensure that the collected data is interoperable with existing data repositories such as USFS Research Data Archive, California Data Exchange Center (CDEC), Consortium of Universities for the Advancement of Hydrologic Science, Inc. Hydrologic Information System (CUAHSI-HIS), and Data Observation Network for Earth (DataONE), as well as other standards-compliant data systems.

Figure 7. Conceptual Illustration of Data Dashboard for Data Visualization and Drought Planning



Task 2b: Develop a communication platform (the Operations Management Dashboard)
Building on the datasets and analysis generated during this project, the UC team will develop a web portal specifically designed to visualize and access spatial and temporal datasets for the American River Basin. The current ARHO data dashboard is not active and limited in coverage and scope in terms of data display and retrieval (http://glaser.berkeley.edu/wsn/). Taking advantage of data processing protocols and methods developed by the UC team and available open-source tools, the online dashboard portal will be housed on a web server focused on supporting drought resilience and planning, which will be located at EDWA in Placerville. The overall configuration of the dashboard is based on a client-server architecture (Fig. 7) and consists of one data (data management), one logic (model/code management), and one presentation (user interface) tier. On the server, a backend tier retrieves and stores data in raw and processed formats. The middle tier coordinates between database and user interface through a series of process commands. A presentation tier exposes the logic tier through a user interface translating tasks and results in easy to understand format (both tabular and graphical). For the data dashboard, the UC team notes that much of the needed capability already exists; specifically, UC has previously developed server components to interface the wireless sensor network and to be able to retrieve and display data by node/parameter. This proposal incorporates and builds on this prior work, emphasizing three areas for additional development: 1) capabilities for performing data QA/QC and metadata development, 2) development of a data analysis component incorporating current and historical observational data, and 3) a user friendly interface for visualizing and extracting geospatial and time series data.

Task 2 Deliverables:

- Pilot version of the Operations Management Dashboard
- Version 1.0 of the Operations Management Dashboard

1.3.3 Task 3: Facilitate Stakeholder Working Group Input and Determine Next Steps for Program Expansion

Task 3 supports the coordination and facilitation of the stakeholder Working Group whose investment in the design and development of the dashboard is essential to a project outcome of value and utility. This task includes convening those stakeholders who have already expressed interest in the project in letters of support (Appendix A) as well as additional identified public and private local, state and federal agencies and individuals interested in utilization of the data for improved water management, forecasting and hydrologic modeling purposes. This task also supports the analysis and identification of further action needed to add new and complete hardening of the remaining necessary instrument clusters in the ARB, and associated outreach and education to share project outcomes with interested stakeholders.

Table 2. Stakeholder Working Group – Anticipated Participants

Organization	Stakeholder Primary Interest		
	ARB Water Management	**Forecasting**	**Hydro & Climate Modeling**
El Dorado Water Agency	X	X	X
El Dorado Irrigation District	X	X	
Georgetown Divide Public Utility District	X	X	
Placer County Water Agency	X	X	X
Sacramento Municipal Utility District	X	X	
El Dorado County Resource Conservation District		X	X
Regional Water Authority		X	X
Sierra Nevada Conservancy		X	X
State Water Resources Control Board		X	X
California Department of Water Resources		X	X
United States Forest Service, Eldorado National Forest		X	X
United States Forest Service, Tahoe National Forest		X	X
California Nevada River Forecasting Center (NOAA)		X	X
U.S Bureau of Reclamation	X	X	X
University of California		X	X

Task 3a: Coordination and Facilitation of the Stakeholder Working Group

Task 3a will engage stakeholders in actively developing and customizing the online dashboard. There will be four structured workshops where the stakeholder Working Group will have the opportunity to share their information interests with the UC dashboard developers. Key information that will be solicited during these workshops include: 1) the types and nature of uses of the data, and 2) data and display needs to assist with data use and decision-making. This Working Group input will be used for building the scripting and initial user interface. Once the

pilot dashboard is developed, two additional workshops will be held for training and obtaining feedback on the draft dashboard.

Task 3b: Identify Remaining Instrument Clusters to Harden

Task 3b will include tracking, capturing and reflecting input from the stakeholder Working Group regarding data and information needs for specific user purposes. This information will help determine which additional wireless sensor clusters in the ARB to prioritize for upgrades and hardening, where new stations should be installed, and future phases of the project that should be dedicated to dashboard refinements. This subtask may include up to two stakeholder Working Group visits to existing or potential WSN locations within the ARB. EDWA anticipates that stakeholder Working Group meetings will result in the identification of data gaps and needs within the ARB that the next phase of the project can address.

Task 3c: Explore expansion of ARB network to other watersheds in the Sierra

This project is being undertaken on the premise that it is a model of value not just in the American River Basin, but transferable into other river basins of the Sierra and possibly into the Lahontan Basin. Utilization of this technology will create the opportunity for more informed and nuanced drought and other water management decisions, and more accurate hydrologic and hydroclimatic models. As such, EDWA is committed to sharing information about the project and its results with other potentially interested stakeholders charged with water management throughout the Sierra Nevada. Sharing this information will involve correspondence with water managers and agencies in other parts of the Sierra Nevada, and will also include at least two presentations about the project and its anticipated benefits at regional or state-wide conferences (e.g. Mountain Counties Water Resources Association, Tahoe Central Sierra Initiative, Association of California Water Agencies)

Task 3 Deliverables:

- Four (4) workshops with the stakeholder Working Group to design and refine the Dashboard
- Two (2) workshops with the stakeholder Working Group to educate, and obtain feedback regarding the pilot Dashboard
- Identification and confirmation of additional sensors to harden and new locations to install WSNs within the ARB
- At least two (2) presentations about the project and its anticipated benefits at regional and/or state-wide conferences such as the Mid-Pacific Water Users Conference.

1.3.4 Task 4: Project Management and Reclamation Reporting (ongoing)

Task 4 encompasses the project management, coordination and Reclamation reporting requirements associated with this project. It consists of two subtasks.

Task 4a: Project Oversight and Coordination

EDWA will act as the project coordinator and administrator, overseeing contracting, budgets, schedule and milestones. In this capacity, EDWA will help to coordinate and gather feedback from UC Merced and consultants as the sensors are upgraded and the dashboard developed. In its role as project manager and coordinator, EDWA will regularly schedule meetings with the management team for the project, and will also assist with planning, scheduling, coordinating and hosting

stakeholder Working Group meetings, mediating project challenges, and providing overall general project direction and recommendations.

Task 4b: Reclamation Reporting

EDWA will complete the financial, interim and final performance report requirements as specified in the FOA. This will include semi-annual interim performance reports and financial reports, and a final performance report. The interim performance reports will be submitted at least twice per year and provide the information specified in the FOA including an update on milestone accomplishments and schedule and an explanation for any discrepancies. In addition, EDWA will submit a final performance report at the end of the grant period covering: whether the project objectives and goals were met, benefits achieved by the project, how the project improves long-term resiliency to drought, how the project demonstrates collaboration, and photographs documenting the project.

Task 4 Deliverables:

- Finalized contracts with UC Merced and contractors
- Coordinated check-in calls with the project team
- Financial Report and Interim Performance Reports #1, #2 and #3
- Final Report

1.4 Performance Measures

The overarching project goal is to enable users to improve their water management, forecasting and modeling with accurate, reliable, spatially representative, and organized continuous stream data (data not currently available). This outcome requires both functional and reliable field sensors and a dashboard that cleans, sorts, analyzes, and displays data in a format of high utility to those interested in using it. The success of this outcome will be measured by the project's utility and value.

In particular, EDWA and the project team will examine:

1. How and whether the dashboard is informing hydroclimatic modeling as part of the American River Basin Study
2. Whether and in what ways the data is used to calibrate drought period snowpack water content and stream flow forecasting by the California Nevada River Forecasting Center (NOAA)
3. Whether and in what ways the data informs the State Water Resources Control Board (SWRCB) and Department of Water Resources (DWR) for water planning and drought tracking purposes
4. Whether and how the project becomes a data source for water managers charged with on-the-ground water and drought management within the American River Basin
5. The extent to which there is increased confidence and accuracy in water supply forecasting and predictive modeling as evidenced by improved water allocation estimates.

During droughts, accurate data on water availability is critical to management and planning. Increased accuracy and confidence in datacan make many thousands of acre feet of more water available, and forecast earlier, in each water year. Use of the dashboard to improve the accuracy and efficiency of meteorological forecasting and hydroclimatic modeling establishes the foundation necessary to improve water management.

1.5 Evaluation Criteria

1.5.1 Evaluation Criterion A – Project Benefits (40 points)

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

The snowpack of the Sierra Nevada acts as the state's largest reservoir and is estimated to account for around 35% of California's useable water supply, which is about 15 million acre-feet of runoff during the spring and summer.[1] Of this, some 2.7 million acre-feet originates in the ARB, of which approximately 40%[2] (or just more than one million acre feet) is calculated to originate from snowmelt runoff. Currently, decisions regarding management of water originating in the Sierra Nevada rely on runoff forecasts based on data from ground measurements including continuous snow-pillow and snow-depth sensor measurements, monthly manual snow surveys, precipitation gauges and river gauges. These methods are neither sufficient, timely, nor accurate. Snow sensors (snow pillows) are sparsely placed in the mountains compared to the spatial scale of each watershed, and measurements are generally not representative of physiographic features required to capture spatial variability of snow depth and snow water equivalent (SWE) at the site or basin scale. In addition, predictive runoff models are based on historical data, data becoming increasingly less relevant in this period of rapid climate change. SWE forecasts based on data collected from existing sensors and precipitation gauges are known to underestimate snowpack by as much as 30%.[3]

This project addresses these information limitations and uncertainties: it brings next-generation hydrologic science and monitoring in the form of real-time, spatially distributed measurements of key variables including: soil moisture, air/soil temperature, snow depth, and air relative humidity, blends them with remote imaging (LIDAR) and makes the data immediately available via satellite to a centralized server. The result is a wide suite of independent, real-time data that provides a critical upgrade in improving confidence in the accuracy of forecasting and in predictive modeling, which is especially critical during droughts. Improved forecasts and models also increase in importance as the demand for water increases while the snowpack in the Sierra Nevada decreases. The information gained from this project will improve the information available for day to day decision-making related to water allocations, reservoir operations, environmental flow determinations, hydropower generation and improving the accuracy of hydroclimatic models for the region and State. These forecasts and models are used by water agencies, farmers, cities, hydroelectric facility operators, and regulators who make decisions about reservoir and in-stream flow releases, determine the onset of drought, project the severity of a drought, and appropriate mitigation and response actions to a drought. Even small percentage increases in accuracy and increased confidence in that accuracy can have substantial impacts on water-allocation/release decisions and associated impacts to in-stream flows downstream. Improved data is critical

[1] Department of Water Resources. 2010. California's Cooperative Snow Surveys Program by Chief Hydrologist, Maurice Roos. Available at: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.616.4238&rep=rep1&type=pdf

[2] Livneh, Ben, et al. "A spatially comprehensive, hydrometeorological data set for Mexico, the US, and Southern Canada 1950–2013." Scientific data 2.1 (2015): 1-12.

[3] Pelak, N., Safeeq, M., and Conklin, M., 2020. Improving snow water equivalent simulations in an alpine basin using blended gauge precipitation and snow pillow measurements. In preparation.

information for improving water management and efficiency during droughts: it creates the opportunity to ensure the most efficient use of the increasingly limited water available.

While this project would only upgrade two of the existing 12 wireless sensor clusters in the ARB, it would result in the development of an online dashboard with the capacity to receive information from all 12 and future ARHO clusters, laying the most critical piece of the groundwork to ensure the data collected by the WSN is useable by resource managers. In addition, this project (by bringing together the group of stakeholders that looks to and relies on this data for water management, forecasting and modeling) will ensure that both: 1) the dashboard will have value and utility to local, regional, state and federal users invested in the data, and 2) that the next phase of the project will include locating new and upgrading existing sensors based on both the physiographic science of sensor placement and the actual and practical information requests and requirements from data users. Already, data users contacted as part of this grant application have indicated micro-regions where they would like more data for improved forecasting and management purposes. Finally, the two sensor clusters that will be upgraded with this project would begin immediately transmitting data through the online dashboard by the end of 2022. This data can be immediately used by individuals and agencies tracking those areas (headwaters of the South Fork) of the watershed.

- *Will the project make additional water supplies available?*

This project, involving upgrades to two of the 12 sensors in the existing WSN, will increase the forecast reliability and availability of up to 18,000 acre-feet of snow water runoff per year. This estimate considers the limited accuracy of current snow measurement technology (e.g., snow pillows and heated precipitation gages) relative to the total average annual acre-feet of snowmelt runoff from the two sub-watersheds where the Robbs Saddle and Alpha WSNs are located (sub-watershed defined based on USGS 12-digit hydrologic unit codes). Existing field data instrumentation and associated models underreport snowpack in the Sierra by as much as 30%.[4] We estimate that approximately 60,000 average annual acre-feet of water originate from snowmelt in these two sub-watersheds (calculated based on the percent area of the ARB above 5,500 feet in elevation that these two watersheds represent, which is 6%). Accordingly, a 30% margin of error for 60,000 acre-feet is 18,000 acre-feet of water. In the context of El Dorado County water use, 18,000 acre feet of water is about half of the water delivered to customers by the water purveyors (in El Dorado County) in one year (a total of approximately 36,000 acre-feet based on purveyor-specific urban water management plans in 2015). Using Folsom Reservoir as context, 18,000 acre feet of water is close to nearly 4% of the 500,000 acre-feet of water provided from Folsom Reservoir for irrigation and municipal and industrial uses each year.[5] Eighteen thousand (18,000) acre-feet also represents about 1,300 cubic feet per second of additional flow that could be released to the Lower American River from Folsom Reservoir for a full 7 days during a critical drought outmigration period for salmonid fry.

- *Will the project improve the management of water supplies?*

The permanent wireless sensor clusters and dashboard will supply current, day-to-day, spatially representative and analyzed data on watershed climate and snowpack conditions that will better

[4] Ibid

[5] U.S Bureau of Reclamation. 2017 (May). Mid-Pacific Region, Folsom Dam Division, Central Valley Project. Fact Sheet. Available at: https://www.usbr.gov/mp/mpr-news/docs/factsheets/folsom-dam-reservoir-powerplant.pdf

support management decisions for local, regional, and Sacramento River water system operations. Given that more than 1 million acre-feet of water are estimated to originate from snowpack in the ARB on average in each year, substantial increases in the accuracy of forecast models using the improved technology and real-time data will significantly improve the accuracy and reliability of water supply management for downstream uses. Decisions that will be better informed by access to the real time, organized data available via the dashboard include:

- Upper elevation reservoir storage and releases (based on the real-time and improved snowmelt runoff forecasts).
- Drought monitoring and forecasting between regularly scheduled snow surveys, including snowpack depletion indicators (using the daily and spatially representative climate data, including dashboard displays of water supply conditions relative to historical averages).
- Minimum instream flow forecasting and flow maintenance for environmental resources including fisheries management and instream recreation (e.g., rafting and kayaking).
- Hydroelectric generation, electrical grid, and other electrical generation resource scheduling, dispatch, and load management.
- Water rights planning, allocation, and diversion forecasting and management (based on improved accuracy of Sierra snowpack water supply conditions).

The data collected will be immediately helpful for both basin runoff forecasts and for the development of time series hydrology for planning models. For the ongoing American River Basin Study, the improved data from this grant will better inform projections of future water supply and demand, including an assessment of risks to water supplies under uncertain future climate conditions. For planning purposes, this information will be used for the development and refinement of climate change hydrology. Specifically, the Variable Infiltration Capacity (VIC) Model is often paired with global circulation models (GCMs) to develop climate change time series hydrology as input to reservoir operations simulation models. Before the VIC model can be used for the development of climate change hydrology, it must first be calibrated to historic stream flow records using time series meteorological data like precipitation, air temperature and wind speed. Once the VIC model is calibrated, meteorological data developed by downscaling the output from the GCMs can be used to develop climate change hydrology. Some of the research-grade ARHO WSN instrument clusters already collect data to support this process. In addition, the grant will complement a separate grant for the ARHO awarded to the UC Merced Sierra Nevada Research Institute via a FY 2019 WaterSMART Applied Science Grant (*Defining the rain-snow transition in the Northern Sierra Nevada*) that will study the rain/snow transition zone migration associated with climate change.

- *Will the project have benefits to fish, wildlife, or the environment?*

The project is expected to have long-term direct and indirect benefits to the environment by providing resource managers for the ARB, Folsom Reservoir operators, and the state with improved understanding of the watershed. This knowledge will translate to improved water management decisions for fish, wildlife and the environment, including those associated with the Coordinated Operations Agreement between the Central Valley Project and State Water Project.

• *Metering/Water Measurement Projects.*
During the initial research time period for the ARHO (i.e., 2008 to 2018), the durability, accuracy, and reliability of the sensors were tested – including by comparing the data collected by the WSN to operational snow-depth sensors (snow pillows). As summarized in the abstract of a 2017 peer-reviewed journal article evaluating the ARHO,[6] the network reduces hydrologic uncertainty in at least three ways: 1) Redundant measurements improve estimation of lapse rates for air and dew-point temperature. 2) Distributed measurements capture local variability and constrained uncertainty in air and dew-point temperature, snow accumulation, and derived hydrologic attributes important for modeling and prediction. 3) The distributed relative-humidity measurements offer a unique capability to monitor upper-basin patterns in dew-point temperature and characterize elevation gradient of water vapor-pressure deficit across steep, variable topography. In addition, the testing concluded that the WSN was robust for cold, wet and windy conditions in the basin.[7] Further, a recent article published in the Journal of Hydrometeorology testifies to the ability of the sensors to better define the rain-snow transition elevation for storm events.[8] Finally, the instrumentation associated with the ARHO WSN has since been used in the Feather River Watershed where there are permanent WSN clusters used by Pacific Gas & Electric Company (PG&E) to improve snowpack forecasting for hydropower generation purposes.

Summary of Project Benefits

This project provides better data in a format that reflects the interest and needs of data users. This project directly benefits and/or supports:

- Availability of up to 18,000 acre-feet of additional snowmelt runoff to downstream water users during droughts.
- Provision of real-time, accurate data for day to day decision-making related to water allocations, reservoir operations, hydropower generation, and environmental flow determinations.
- Improved accuracy of hydroclimatic models for the region and State.
- Development of a comprehensive and accessible set of watershed data shared among stakeholders.
- Development of a shared regional understanding of near and long-term water availability.
- Increased alignment between State water regulators (SWRCB and DWR) and local water purveyors who have historically (including during the 2012-2016 drought) disagreed on drought severity.
- Improved water management decisions for fish, wildlife and the environment, including those associated with the Coordinated Operations Agreement between the Central Valley Project and State Water Project.

[6] Zhang, Z., S. D. Glaser, R. C. Bales, M. Conklin, R. Rice, and D. G. Marks (2017). Technical report: *The design and evaluation of a basin-scale wireless sensor network for mountain hydrology*, Water Resour. Res., 53, 4487–4498, doi:10.1002/ 2016WR019619.
[7] Ibid
[8] Cui Guotao; Bales, Roger; Rice, Robert; Anderson, Michael; Avanzi, Francsco; Harsough, Peter; Conklin, Martha. 2020: Detecting rain-snow-transition elevations in mountain basins using wireless-sensor networks. Journal of Hydrometerology, July 16, 2020. Available at: https://escholarship.org/uc/item/69s488kq

From a water management and drought perspective, the sensors will improve the confidence and certainty with which local (e.g., upstream reservoir managers and ARB Water Forum Agreement members), State, and federal water managers can predict droughts, assist with anticipating the onset and magnitudes of droughts, and better inform water and land management drought mitigation strategies. In addition, the shared information (provided by dashboard) regarding snowpack and water supply has the potential to reduce conflict/increase alignment between State water regulators (SWRCB and DWR) and local water purveyors who have historically (including during the 2012-2016 drought) disagreed on drought severity and necessary mitigation actions. An improved understanding of ARB water supply and the effect of warming global temperatures on the snowpack also will improve drought response and preparation by helping water and land managers identify and prioritize the most effective water storage and conservation strategies, whether that involves building new water storage facilities, completing meadow restoration projects, or organizing and prioritizing forest and headwaters management activities.

1.5.2 Evaluation Criterion B – Drought Planning and Preparedness (15 points)

- *Describe how your proposed drought resiliency project is supported by an existing drought plan.*

EDWA is presently preparing (through Reclamation's Fiscal Year 2018 Drought Contingency Planning program) a Regional Drought Contingency Plan (RDCP) for the Upper American River Basin. Developing the RDCP is a collaborative effort among the El Dorado Water Agency and local water purveyors including El Dorado Irrigation District (EID), Georgetown Divide Public Utility District (GDPUD), Grizzly Flats Community Services District (GFCSD) and the City of Placerville. A first and priority element identified as part of the RDCP collaboration is to establish a regional process for monitoring near and long-term water availability, and for developing a framework for predicting the probability of future drought conditions. This includes creating comprehensive sets of data that may be shared among stakeholders to create a regional understanding of near and long-term water availability, and to predict future drought probability. This project provides a direct and actionable means for achieving this desired outcome.

Development of an intelligent hydroclimatic information system for improved water and power management in the ARB was identified as priority project in the 2018 American River Basin Integrated Regional Water Management Plan Update prepared by the Regional Water Authority. In addition, the American River Basin Study (underway) is modeling how climate change may impact water supply, water quality and critical habitat areas within the American River Basin. As detailed above in the response to Criterion A, Project Benefits (1.6.1), the data collected through this Reclamation drought resiliency project will be immediately helpful for both basin runoff forecasts and for the development of time series hydrology for planning models that are part of the American River Basin Study. Besides these two planning processes, this proposed drought resiliency project is aligned with goals in the California Water Plan 2018 Update and the California Water Action Plan. The 2018 Update of the California Water Plan includes, as one of its six goals: *to support real-time decision-making, adaptive management and long-term planning, and to make accessing State water and ecological datasets easily accessible on open-water-data platforms.*

• *Describe existing or potential drought conditions in the project area.*
As evidenced in the paleoclimate record and as experienced in the historic record, long-term and severe droughts are a fundamental feature of the climate in California.[9,10] Paleoclimate information, especially, is a reminder that there is the potential for longer and more severe droughts than existing water institutions and infrastructure were designed to manage. The stress on managed and unmanaged water systems resulting from drought in the region has been tested multiple times since 1900, most recently in the drought of 2012-2016. That drought, the most severe in California recorded history, and significant in its severity even in the context of paleoclimate records,[11] included the four driest consecutive years of statewide precipitation on record and the lowest ever recorded snowpack in California in 2015, just 5% of normal.

The frequency and severity of such droughts in California is expected to increase due to changing hydrologic conditions associated with a warming climate. Climate change projections for California predict increased summer temperatures, which could increase water demand despite improved water use efficiency measures, contribute to loss of soil moisture, and exacerbate other impacts of drought. In addition, climate models predict a greater proportion of precipitation falling as rain rather than snow, and earlier snowmelt due to overall increased temperatures throughout the winter and spring. For example, the midpoint of Sierra Nevada snowmelt runoff has historically occurred in May, but multiple models estimate that, within the next 50 years, midpoint snowmelt surface runoff will occur earlier by a month or more.[12,13,14,15] A project undertaken by UCLA's Center for Climate Science used the latest-generation of global climate models (those which underlie the fifth climate change assessment report by the Intergovernmental Panel on Climate Change) and a hybrid downscaling approach – involving both dynamical and statistical downscaling – to answer questions about the likely impacts of climate change on Sierra Nevada snowpack. The project's findings, released in April 2018, describe a 64 percent decrease in average

[9] California Department of Water Resources. 2015. *California's Most Significant Droughts: Comparing Historical and Recent Conditions*. Chapter 2: Hydroclimate Background on Drought in California. pp. 19-38. [Website]. Viewed online at: https://water.ca.gov/LegacyFiles/waterconditions/docs/a9237_CalSignficantDroughts_v10_int.pdf

[10] Recent reconstructions of streamflow for the Sacramento, San Joaquin and Klamath River highlight multiple severe 10-year dry periods dating back to 900AD. (Ibid)

[11] In a report published in Geophysical Research Letters in December of 2014 the authors, using tree ring data, identified the 2012-2014 period as the most severe drought in the last 1,200 years, with single year (2014) and accumulated soil moisture deficits worse than any previous continuous span of dry years. Griffin, D. and K. J. Anchukaitis. 2014. How unusual is the 2012-2014 California drought? Geophysical Research Letters, Vol 41(24). Accessible at: https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2014GL062433

[12] Huning, L.S. and A. AghaKouchak. 2018. Mountain snowpack response to different levels of warming. Proceeding of the National Academy of Sciences, Vol 115(43), pp. 10932-10937. Accessible at: https://www.pnas.org/content/115/43/10932

[13] Schwartz, M., Hall, A., Sun, F., Walton, D., and N. Berg. 2017. Significant and Inevitable End-of-Twenty-First-Century Advances in Surface Runoff Timing in California's Sierra Nevada. Journal of Hydrometeorology, Vol 18. 3 pp. 181-3197. Accessible at: https://doi.org/10.1175/JHM-D-16-0257.1

[14] Reich, KD, N Berg, DB Walton, M Schwartz, F Sun, X Huang, and A Hall, 2018: "Climate Change" California's Water Future." UCLA Center for Climate Science. April 2018. Accessible at: https://www.ioes.ucla.edu/project/climate-change-sierra-nevada/

[15] Dettinger, M.D., Cayan, D.R., Meyer, M.K., and A.E. Jeton. 2004. Simulated Hydrologic Responses to Climate Variations and Change in the Merced, Carson, and American River Basins, Sierra Nevada, California, 1900-2099. Climatic Change, Vol 62 (1-3), 283-317 pp. Accessible at: https://doi.org/10.1023/B:CLIM.0000013683.13346.4f

springtime Sierra snowpack volume by the end of the 21st century and a 7 percent rise in average spring Sierra temperatures under a "Business as Usual" greenhouse gas emissions scenario.[16]

Overall, the managed and unmanaged water systems of El Dorado County, like those of most of California, are highly vulnerable to drought. This vulnerability is exacerbated by the reliance of water purveyors on surface water due to the lack of groundwater as a supplemental water source on the western slope of the Sierra Nevada; future vulnerabilities are further magnified by climate-change induced projections of dramatically reduced snowpack, earlier spring runoff, and the associated reduction in runoff during the summer and fall.

1.5.3 Evaluation Criterion C – Severity of Actual or Potential Drought Impacts to be addressed by the Project (15 points)

• *Describe the severity of the impacts that will be addressed by this project.*
The 2012-2016 drought had a dramatic impact to the American River Basin. These impacts included the following:

- Central Valley Project water allocations to American River contractors (including EID and PCWA that maintain contracts for 7,550 and 35,000 acre feet of water, respectively) were reduced by 25% in 2013, by 50% in 2014, and by 75% in 2015.
- Key reservoirs, including Jenkinson Lake, Caples Lake, Silver Lake, Stumpy Meadows, Hell Hole, French Meadows and others, regularly dropped to levels below historical monthly capacity averages for multiple months throughout the drought period.
- Folsom Reservoir fell to a historic low storage level of 135,561 acre-feet in December 2015, 14 percent of its maximum storage capacity, threatening the water supply to more than one million people in the lower American River Basin.
- EID (Main system and Strawberry system) and GDPUD both declared Stage 2 drought emergencies beginning between February and April 2014 through the end of the winter 2016. The declarations mandated or requested water conservation measures, such as reducing consumption by 30% and restricting landscape irrigation to once-per week.
- The State Water Resources Control Board (SWRCB) ordered curtailment of post-1914 water rights in May 2014.
- In-stream flows for fish were reduced beginning in the winter 2014 as part of EID's Stage 2 drought emergency declaration. Under the declaration, EID was relieved from maintaining fish flow requirements from several of its alpine reservoirs (Lake Aloha, Caples Lake, Silver Lake, and Echo Lake) as well as from Jenkinson Lake.
- The drought conditions and resulting bark beetle infestations that caused pervasive tree mortality across the Central and Southern Sierra Nevada Mountains (with some 129 million dead trees as of May 2016) also impacted the Eldorado National Forest where some 200,000 dead trees were documented in a May 2016 overflight of the forest.

These impacts testify to the stress drought has incurred on the landscape and communities of the American River Basin, and to downstream users and ecosystems. Better management, enabled by

[16] Reich, K.D., Berg, N., Walton, D.B., Schwartz, M., Sun, F., Huang, S., and A. Hall, 2018. Climate Change in the Sierra Nevada: California's Water Future. UCLA Center for Climate Science. The Regents of the University of California. [Website]. Viewed online at: https://www.ioes.ucla.edu/project/climate-change-sierra-nevada/

improved information, would mean ensuring the ARB's limited water supply can go further to meet local, regional and state water uses, especially during times of drought.

1.5.4 Evaluation Criterion D – Project Implementation (10 points)

The project would be implemented over an approximately two-year timeframe. In August of 2021, the UC Merced Team will begin to assemble the upgrades to the remote sensing equipment, and initiate development of the programming to support the online dashboard. Early in 2022, EDWA will convene the first stakeholder Working Group meeting, bringing together all the entities (including all those who submitted letters of support) to share their data and technical needs and requests with the UC Merced and UC Agriculture and Natural Resources Department team. The stakeholder Working Group will hold three additional meetings as the dashboard is developed to provide input and feedback on various design elements and utility, and then meet an additional two times to learn to use and to test the pilot version of the dashboard. Included below is an estimated schedule of work, with a timeline for each stage of work, broken down by task and month, and including major milestones (see Figure 8 and Table 3).

Figure 8. Project Schedule

Task	2021					2022												2023								
	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S
1: Harden and Upgrade Selected Instrument Clusters	Assemble sensors off-site										Complete in-field upgrades			Monitor sensors and adjust				Final on-site refinements								
2: Develop Operations Management Dashboard	Develop programing to clean the data and transmit it to a designated server					Build Operations Management Dasboard										Launch Pilot Dashboard		Refine Dashboard					Launch V. 1.0			
3: Facilitate Working Group Input and Determine Next Steps for Program Expansion		WG #1			WG #2			WG #3					WG #4				WG #5		WG #6			Presentation #1		Presentation #2			
4. Project Management and Reclamation Reporting						Interim Report #1						Interim Report #2						Interim Report #3							Final Report	

Table 3. List of Milestones (Chronologically)

No.	Milestone	Date	
1	Finalized contracts with UC Merced and Consultants	Aug 2021	
2	Complete off-site assembly of wireless sensor nodes	Dec 2021	
3	**Complete installation of two 10-node wireless sensor networks and telemetry connection to data server**	Jun-Sep 2022	**2021-2022**
4	Four (4) workshops with the stakeholder Working Group to design and refine the Dashboard	Sep 2021-Oct 2022	
5	Reclamation Financial Report and Interim Perf. Report #1	Jan 2022	
6	Monitor newly upgraded sensors	Jul 2022-Dec 2022	
7	Reclamation Financial Report and Interim Perf. Report #2	Jul 2022	
8	**Launch pilot version of the Operations Management Dashboard**	Nov 2022	
9	Two (2) workshops with the stakeholder Working Group to educate, and obtain feedback regarding the pilot Dashboard	Nov 2022 – Jan 2023	
10	Reclamation Financial Report and Interim Perf. Report #3	Jan 2023	
11	Identification and confirmation of additional sensors to harden	Feb 2023	**2023**
12	Complete final in-field refinements of the two wireless sensor networks	Jan 2023-Apr 2023	
13	At least two (2) presentations about the project and its anticipated benefits at regional and/or state-wide conference	Mar 2023-Jul 2023	
14	**Launch version 1.0 of the Operations Management Dashboard**	Jun 2023	
15	Reclamation Final Report	Aug 2023	

- *Describe any permits that will be required, along with the process for obtaining such permits.*

Existing instrument clusters within the ARHO WSN are located within either the Tahoe National Forest (TNF) or the Eldorado National Forest (ENF). The existing research grade clusters were installed with special use permits from the U.S. Forest Service (USFS). UC Merced holds a special use permit from the TNF and ENF for the network installations and is currently working with USFS on issuing a new special use permit to cover the existing sites and to expand to new sites. Based on conversations with personnel at both forests (TNF and ENF), UC Merced understands that as long as it, or other public entity, retains ownership and management responsibility for maintaining the instrumentation, then no additional fees would be required.

- *Identify and describe any engineering or design work performed specifically in support of the proposed project.*

Implementation of the project requires the engineering and programming work associated with assembling the upgraded sensors, installing the upgrades, and developing the programing to clean and transmit the data and building the hardware and software for the communications platform, the Operations Management Dashboard.

- *Describe any new policies or administrative actions required to implement the project. Describe how the environmental compliance estimate was developed.*

The project would not require any new policies or administrative actions. The project would not trigger review under the California Environmental Quality Act (CEQA) or National Environmental Policy Act (NEPA) and would not require any additional permits. Therefore, there is no anticipated budget required for environmental compliance.

1.5.5 Evaluation Criterion E – Nexus to Reclamation (10 points)

Overall, the project impacts Reclamation in that it will provide water managers in the American River Basin with more accurate and real-time information to predict water availability for any

given day, week and month, and to better understand the hydrologic conditions experienced in any given water year type, particularly during drought conditions. This is expected to have positive impacts on Folsom Reservoir water management, with the intention of more efficient use of available water such that many thousands more acre-feet of water are available during droughts for existing water rights holders, for instream ecosystem benefits, and for Reclamation's Central Valley Project. Further, the improved data is expected to enable Reclamation to more accurately and timely determine, and therefore forecast future, Central Valley Project (Folsom Unit) water supply conditions and water contractor allocations.

1.5.6 Evaluation Criterion F – Department of the Interior Priorities (10 points)

The project supports multiple Department of the Interior Priorities. The project:

1) Utilizes science (through new technology and data management) to identify best practices to manage land and water resources and adapt to changes in the environment.
2) Expands the lines of communication (via the stakeholder Working Group) among local, regional, state, academic, and federal entities including water purveyors (ARB water purveyors and Reclamation), regulatory and planning agencies (DWR and SWRCB), conservation organizations (El Dorado County Resource Conservation District) and land managers (U.S. Forest Service and El Dorado County).
3) Supports the White House Public/Private Partnership Initiative to modernize U.S. infrastructure.

In addition, the project is a legacy project. The infrastructure installed and the associated online dashboard are planned to remain in place transmitting important and useful data for decades. This project will be key in tracking climate-induced changes to the snowpack of the Sierra Nevada over the next century.

2.0 PROJECT BUDGET

2.1 Funding Plan and Letters of Commitment

The Water Agency is acting as the lead applicant for Reclamation funding and will serve as the lead project manager for this project. EDWA is the trusted, county-wide leader on water-resource issues, representing the long-term interest of the community, purveyors and residents through a dedicated team of professionals that are responsive and accountable to the public they serve.

• *Describe how the non-Federal share of project costs will be obtained.*
All of the non-Federal cash match ($189,616) for the project will be provided by EDWA. EDWA is committed and capable of funding the required cash match. The remainder of the non-Federal cost share is composed of in-kind hours committed by EDWA staff ($73,082), and by grant application partners ($52,600) who recognize the value of the project to their operations and have committed to participating in the stakeholder Working Group to provide input and feedback on the parameters of the data collected, on the reliability and accuracy of the data collected, and on the design of the platform that will host and display the data collected. The stakeholder Working Group may expand to include additional partners; however, the time of additional participating entities has not been factored into the non-Federal match of project costs required for this application.

• *Please identify the sources of the non-Federal cost share contribution for the project*
The following non-Federal agencies and organizations have committed cash or in-kind funding to support the project:

1. $262,699 from the El Dorado Water Agency
2. $5,000 from the Mountain Counties Water Resources Association
3. $10,000 from the Sacramento Municipal Utility District
4. $4,000 from the Georgetown Divide Public Utility District
5. $6,800 from the El Dorado Irrigation District
6. $4,800 from the El Dorado County Resource Conservation District
7. $16,000 from the Department of Water Resources
8. $6,000 from the State Water Resources Control Board.

The budget proposal does not include any project costs that have been or may be incurred prior to the award.

2.2 Budget Proposal

The budget proposal summary is provided in the tables below and is described in a narrative format below.

Table 4. Total Project Cost

FUNDING SOURCES	AMOUNT
Non Federal Entities	
Costs to be reimbursed with the requested Federal funding	$300,000
Costs to be paid by the applicant	$262,699
Value of third-party contributions	$52,600
TOTAL PROJECT COST	**$615,299**

Table 5. Summary of Non-Federal and Federal Funding Sources

Funding Source	Amount
Non Federal Entities	
Local	
El Dorado Water Agency (cash)	$189,616
El Dorado Water Agency (in-kind)*	$73,083
Mountain Counties Water Resource Association (in-kind)*	$5,000
Sacramento Municipal Utility District (in-kind)*	$10,000
Georgetown Divide Public Utility District (in-kind)*	$4,000
El Dorado Irrigation District (in-kind)*	$6,800
El Dorado County Resource Conservation District (in-kind)*	$4,800
State	
Department of Water Resources (in kind)*	$16,000
State Water Resources Control Board (in kind)*	$6,000
Non-Federal Subtotal	**$315,299**
Other Federal Entities	
CA-NV River Forecasting Center (in kind)*	$2,500
Other Federal Subtotal	**$2,500**
REQUESTED RECLAMATION FUNDING	**$300,000.00**
TOTAL STUDY FUNDING	**$615,299**

*In-kind contributions are noted with an asterisk (*).

Table 6. Budget Proposal

BUDGET ITEM DESCRIPTION	COMPUTATION			Local Funding	USBR Funding	TOTAL COST
	$/Unit	Unit	Qty			
TASK 1: Harden Data Sensors						
Salaries and Wages						
Professor, Rob Rice	$12,905	Month	0.75		$9,679	$9,679
Project Scientist, Peter Hartsough	$6,065	Month	4		$24,259	$24,259
Field Tech, TBA	$4,308	Month	4		$17,233	$17,233
Undergraduate Student, TBA	$15	hour	1733		$26,000	$26,000
Fringe Benefits						
Professor, Rob Rice	$645	Month	0.75		$484	$484
Project Scientist, Peter Hartsough	$2,844	Month	4		$11,377	$11,377
Field Tech, TBA	$2,021	Month	4		$8,082	$8,082
Undergraduate Student, TBA	$0.8	hour	1733		$1,387	$1,387
Travel						
Field Travel	$23,290		1		$23,290	$23,290
Equipment						
Wireless Sensor Network	$48,451	per cluster	2	$96,902		$96,902
Supplies and Materials						
Incidental	$1,500		1		$1,500	$1,500
Total Direct Charges				**$96,902**	**$123,291**	**$220,193**
Indirect Costs (@ 55% for UCM and 26% for ANR, less equipment)	$60,575		1		$60,575	$60,575

TOTAL COSTS FOR TASK 1: Harden Data Sensors				**$96,902**	**$183,867**	**$280,769**
TASK 2: Build Operations Mgmt. Dashboard						
Salaries and Wages						
Data Analyst, TBA	$6,047	Month	9	$31,938	$22,481	$54,419
Safeeq Khan (Lead PI)	$8,458	Month	0.75		$6,344	$6,344
Fringe Benefits						
Data Analyst (X Meng, UCM)	$3,474	month	9		$31,268	$31,268
Safeeq Khan (Lead PI)	$3,873	Month	0.75		$2,905	$2,905
Travel						
Workshop Travel	$1,360		1		$1,360	$1,360
Equipment						
Data Server	$12,176		1	$12,176		$12,176
Supplies and Materials						
Computer	$1,500		1		$1,500	$1,500
Total Direct Charges				**$44,114**	**$65,857**	**$109,971**
Indirect Costs (@ 55% for UCM and 26% for ANR, less equipment)	$50,276		1		$50,276	$50,276
TOTAL COSTS FOR TASK 2: Build Operations Mgmt. Dashboard				**$44,114**	**$116,133**	**$160,247**
TASK 3: Facilitate Stakeholder Working Group Input and Determine Next Steps for Program Expansion						
Salaries and Wages						
El Dorado Water Agency, General Manager, Kenneth Payne	$96	hour	100	$9,615		$9,615
El Dorado Water Agency, Business Services Officer	$55	hour	40	$2,200		$2,200
EDWA Contract Staff - Principal Director	$90	hour	80	$7,200		$7,200
EDWA Contract Staff - Sn. Planner	$36	hour	110	$3,960		$3,960
Mountain Counties Water Resource Association	$125	hour	40	$5,000		$5,000
Sacramento Municipal Utilities District	$100	hour	100	$10,000		$10,000
Georgetown Divide PUD Water Resources Manager	$83	hour	40	$3,320		$3,320
El Dorado Irrigation District, Director of Engineering	$170	hour	40	$6,800		$6,800
El Dorado RCD	$80	hour	60	$4,800		$4,800
CA Dept. of Water Resources, State Climatologist	$200	hour	80	$16,000		$16,000
CA State Water Board Senior Enviro. Scientist	$34	hour	60	$2,040		$2,040
Fringe Benefits						
El Dorado Water Agency, General Manager, Kenneth Payne	$20	hour	100	$2,004		$2,004
El Dorado Water Agency, Business Services Officer	$23	hour	40	$926		$926
EDWA Contract Staff - Principal Director	$106	hour	80	$8,480		$8,480
EDWA Contract Staff - Sn. Planner	$112	hour	110	$12,320		$12,320
Mountain Counties Water Resource Association		hour		$0		$0

Sacramento Municipal Utilities District		hour		$0		$0
Georgetown Divide PUD Water Resources Manager	$17	hour	40	$680		$680
El Dorado Irrigation District, Director of Engineering		hour		$0		$0
El Dorado RCD		hour		$0		$0
CA Dept. of Water Resources, State Climatologist		hour		$0		$0
CA State Water Board Senior Enviro. Scientist	$66	hour	60	$3,960		$3,960
Travel						
Workshop Travel	$1,500.0		1	$1,500		$1,500
Supplies and Materials						
Workshop Supplies	$1,000		1	$1,000		$1,000
Printing	$500		1	$500		$500
Consultant/Facilitator						
Jeffrey K. Meyer, Principal Water Resources Engineer	$200	hour	212	$42,400		$42,400
William Slightam, Owner, Senior Hydrographer	$100	hour	32	$3,200		$3,200
Total Direct Charges				**$147,905**	**$0**	**$147,905**
Indirect Costs				$0		$0
TOTAL COSTS FOR TASK 3:				**$147,905**	**$0**	**$147,905**
TASK 4: Project Management and Reclamation Reporting (ongoing)						
Salaries and Wages						
El Dorado Water Agency, General Manager, Kenneth Payne	$96	hour	10	$962		$962
El Dorado Water Agency, Business Services Officer	$50	hour	90	$4,491		$4,491
EDWA Contract Staff - Sn. Planner	$36	hour	84	$3,024		$3,024
EDWA Contract Staff - Proj. Mgm	$34	hour	64	$2,176		$2,176
Fringe Benefits						
El Dorado Water Agency, General Manager, Kenneth Payne	$20	hour	10	$200		$200
El Dorado Water Agency, Business Services Officer	$23	hour	90	$2,084		$2,084
EDWA Contract Staff - Sn. Planner	$112	hour	84	$9,408		$9,408
EDWA Contract Staff - Proj. Mgm	$63	hour	64	$4,032		$4,032
Total Direct Charges				**$26,377**	**$0**	**$26,377**
Indirect Costs				$0		$0
TOTAL COSTS FOR TASK 4:				**$26,377**	**$0**	**$26,377**
TOTAL PROJECT COSTS				**$315,299**	**$300,000**	**$615,299**

2.3 Budget Narrative

2.3.1 Salaries and Wages

Salaries and wages are inclusive of the time required by EDWA staff and contract staff, by UC Merced employees, and by staff hours committed by partners. All salary and wage estimates were based on current wages as provided by each participating entity and, as much as possible, rates were expressed in terms of salary and fringe. For a few of the partners who committed in-kind hours, anticipated hour contributions were not broken into salary and fringe, however the budget spreadsheet expresses the total in-kind value of their contribution in the amount specified in their support letter (attached as Appendix A). The UC Agriculture and Natural Resources Approved Proposal Package (Appendix C) includes a detailed break-down of anticipated hours by personnel (section, Budget Justification) and an overview of the key personnel, including Safeeq Khan (Lead PI), who will be leading Tasks 1 and 2.

EDWA key staff and contract staff are as follows:

Project Manager, Kenneth Payne, General Manager, El Dorado Water Agency: Mr. Payne will act as the overall director of the project, contributing a total of 110 hours, mostly under Task 3. Mr. Payne anticipates attending most or all of the stakeholder Working Group meetings and providing strategic guidance and direction to the consultant team and other staff on the project. His in-kind contribution also includes time preparing for and presenting about the project at two regional or statewide conferences.

Tami Scowcroft, Business Services Officer, El Dorado Water Agency: Ms. Scowcroft will act as the manager for the funding agreement for Reclamation. She will serve in the lead role for Reclamation reporting (Task 4) and will assist with coordination of the consultant hired to complete Task 3. Ms. Scowcroft is also designated hours to assist with stakeholder Working Group meetings to support Mr. Payne, coordinate meetings, and follow-up on action items on behalf of EDWA.

Rick Lind, Project Director, El Dorado Water Agency Contract Staff: Mr. Rick Lind will work with Mr. Payne and the consultant team hired for Task 3 to plan and prepare for the stakeholder Working Group meetings, to coordinate and collaborate with stakeholder partners, and to complete outreach on behalf of EDWA regarding the project. Mr. Lind brings his UC Davis water resources graduate degree and 40 years of water and power experience in the Sierra Nevada to the project and will work closely with Mr. Payne to determine best available strategies for completion of the ARHO WSN in the ARB and to look at approaches to expand the program into other Sierra Nevada Watersheds.

Patricia Sussman, Senior Planner, El Dorado Water Agency Contract Staff: Ms. Patricia Sussman brings her graduate degree in planning and 10 years of project management and deliverable development experience to the team. She will work with EDWA and the consultant team to prepare for and follow-up from stakeholder Working Group meetings (Task 3), and will also play a leading role in assisting EDWA with Reclamation reporting requirements and overall contract and project management (Task 4).

2.3.2 Fringe Benefits

Fringe benefits for EDWA full time permanent employees and their families include medical insurance, vision insurance, dental insurance, retirement contributions, workers compensation, and a limited life insurance policy in some instances. The value of hourly fringe benefit will vary by the employee. Fringe rate calculations for other agencies and organizations and for EDWA contract employees vary by the agency/organization, but generally include some health benefits and retirement contributions at minimum. The actual calculation for the hourly fringe benefit rate for each assigned personnel is shown in the detailed Budget Proposal Summary table above.

2.3.3 Travel

Field travel for Tasks 1 and Task 2 are a component of the UC Agriculture and Natural Resources Approved Proposal Package (see section, Budget Justification) and include estimated costs for travel to the installation sites, rental trucks and food and lodging. For Task 2, travel costs cover estimated costs associated with traveling to and attending stakeholder Working Groups meetings. Travel for Task 3 includes $1,500 in travel costs for EDWA staff and contract staff to attend stakeholder Working Group meetings.

2.3.4 Equipment

Equipment costs are associated the purchase of two wireless sensor clusters, telemetry equipment, and dedicated server. The cost estimate is described in the UC Agriculture and Natural Resources Approved Proposal Package (see section, Budget Justification).

2.3.5 Materials and Supplies

Materials and supplies for Tasks 1 and 2 include incidental costs, such as printing, and the purchase of a computer (to build online Operations Management Database on). The total budget for materials and supplies for Tasks 1 and 2 is $3,000. Materials and supplies for Task 3 cover costs associated with supporting facilitation of stakeholder Working Group meetings, including printing costs for handouts and other materials. The total budget for materials and supplies for Task 3 is estimated at $1,500.

2.3.6 Contractual

The total cost estimate includes costs associated with contracting for facilitation of the stakeholder Working Group (Task 3). The majority of hours and costs for contractual work under this task would be for the services of Jeffery Meyer, Project Manager and Partner at Western Hydrologics, L.L.P. Mr. Meyer has 27 years of experience in environmental engineering and water resources management. His experience includes hydrology development, stream flow gaging, runoff forecasting, water rights analysis, model application development, long term planning, short term planning using position analysis, alternatives evaluation, operations rules development, hydroelectric system evaluation and computer-aided dispute resolutions. Currently, Mr. Meyer is assisting with the calibration of runoff forecasts for use with forecasting operations models used to support power scheduling and hydro-economic modeling in the ARB.

Contractual costs for Task 3 also include the services of the William Slightam, owner of Western Hydrologic Systems. Mr. Slightam was asked to participate in the project because of his more than 24 years of stream flow measurement, snow survey and weather station installation experience to the project. He specializes in stream flow gage installation, flow measurements, data collection,

calibration, and maintenance. In addition, he has worked collaboratively with the California Department of Water Resources to assess snowpack by performing snow surveys. Although Mr. Slightam has installed both flow gages and weather stations in the coastal regions, most of his work is in the Sierra Nevada. Through his many years of experience, he has developed installation techniques and equipment that survive the winter snow storms, high flow events and even wildfire. Mr. Slightam accesses the data sites by truck, snowmobile, all-terrain vehicles, skis and helicopter.

Budget details for Mr. Meyer and Mr. Slightam are expressed in the table below. The budget estimate for their services is inclusive of direct costs they may incur associated with the project.

		Hourly Billing Rate	Task 3A Hours	Task 3B Hours	Task 3C Hours	TASK 3: Project Planning and Expansion SUBTOTAL	**TOTAL ESTIMATED PROJECT COSTS**
Entity							
Western Hydrologics	Jeffrey K. Meyer, Principal Water Resources Engineer	$200.00	120.00	32.00	60.00	$ 42,400.00	$ 42,400.00
Western Hydrologic Systems	William Slightam, Owner, Senior Hydrographer	$100.00		32.00		$ 3,200.00	$ 3,200.00
	Total Labor		*120.00*	*64.00*	*60.00*	*244.00*	244.00
			$ 24,000.00	*$ 9,600.00*	*$ 12,000.00*	*$ 45,600.00*	$ 45,600.00
	Total Direct Expenses		*$ -*		*$ -*	*$ -*	$ -
	Total Estimated Project Cost		$ 24,000.00	$ 9,600.00	$ 12,000.00	**$ 45,600.00**	**$ 45,600.00**

2.3.7 Third-Party In-Kind Contributions

Third-party in-kind contributions total $52,600 and are composed of hours committed by partnering agencies to participate as members of the stakeholder Working Group. Partners have committed between 40 and 100 hours for participation in up to six stakeholder Working Group meetings. Hour commitments are reflected in the Budget Proposal (Table 6) and are aligned with the commitment described in each partnering agency's letter of support (Appendix A).

2.3.8 Environmental and Regulatory Compliance Costs

No environmental or regulatory compliance costs are anticipated as part of the budget.

2.3.9 Other Expenses

There are no other expenses anticipated as part of the project.

2.3.10 Indirect Costs

Indirect costs for UC Merced are 55% and applicable to Task 1 and Task 2.

2.3.11 Total Costs

The total design, construction, and administrative cost for the project is estimated at $615,299, inclusive of Federal and non-federal cost share dollars and in-kind contributions.

3.0 ENVIRONMENTAL AND CULTURAL RESOURCES COMPLIANCE

- *Will the proposed project impact the surrounding environment (e.g., soil [dust], air, water [quality and quantity], animal habitat)?*

The proposed project will have no impacts that trigger any environmental resource compliance or new permitting requirements.

- *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?*

The two instrument cluster identified for upgrading are located within National Forest land that is host to several Federal and State listed species, however, the project, involving hardening existing remote wireless sensor instruments, will have no direct impacts to any species.

- *Are there wetlands or other surface waters inside the project boundaries that potentially fall under CWA jurisdiction as "Waters of the United States?"*

No. The sensors proposed for upgrade are not located within wetlands or surface waters.

- *When was the water delivery system constructed?*

Not applicable to this application.

- *Will the proposed project result in any modification of or effects to, individual features of an irrigation system (e.g., headgates, canals, or flumes)?*

No. This application does not involve irrigation systems.

- *Are any buildings, structures, or features in the irrigation district listed or eligible for listing on the National Register of Historic Places?*

No. This application does not involve irrigation systems and does not involve changes to any existing building, structures or features.

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

The project does not involve activities that would disturb any archeological sites. The project involves upgrading existing remote wireless sensor instrumentation already permitted under a special use permit from the Eldorado and Tahoe National Forests.

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

No. The project will provide improved hydrologic and hydroclimate information to local, state and federal agencies and the public.

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

No. The project is not located within or near tribal lands and would not impact access to the landscape.

- *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. The project, involving upgrading existing data gathering instrumentation, does not have the potential to contribute to the introduction or spread of any invasive species.

4.0 REQUIRED PERMITS OR APPROVALS

EDWA anticipates no new permits or fees would be applied to the project. Instrument clusters are located within either the Tahoe National Forest (TNF) or the Eldorado National Forest (ENF). The existing research grade clusters were installed with special use permits from USFS. UC Merced holds a special use permit from the TNF and ENF for the network installations and is currently working with USFS on issuing a new special use permit to cover the existing sites and to expand to new sites. Based on conversations with personnel at both forests (TNF and ENF), UC Merced understands that as long as it, or other public entity, retains ownership and management responsibility for maintaining the instrumentation, then no additional fees would be required.

5.0 EXISTING DROUGHT CONTINGENCY PLAN

EDWA has been awarded Reclamation cost share funding through Reclamation's Fiscal Year 2018 Drought Contingency Planning program to develop a Regional Drought Contingency Plan for the upper American River Basin. This plan is under development with a completed plan anticipated in 2021. There is no existing drought contingency plan for the upper American River Basin.

6.0 LETTERS OF SUPPORT

Appendix A includes 10 letters of support received to date for the process, including seven (7) letters committing a total of 420 hours valued at $52,600 to participate in stakeholder Working Group meetings and to assist with development and review of the online Operations Management Dashboard. A letter of support from each of the following agencies and organizations is included in Appendix A:

1) California Department of Water Resources
2) El Dorado Irrigation District
3) El Dorado Resource Conservation District
4) Georgetown Divide Public Utility District
5) Mountain Counties Water Resources Association
6) National Oceanic and Atmospheric Administration
7) Sacramento Municipal Utility District
8) Sierra Nevada Conservancy
9) State Water Resources Control Board
10) Tahoe National Forest

7.0 OFFICIAL RESOLUTION

Appendix B is the Draft Resolution that will be presented to the EDWA Board of Directors at their regular meeting on August 12, 2020. The letter describes EDWA Board of Directors support of this application and EDWA's partnership with Reclamation. The approved Resolution will be provided to Reclamation before the end of August 2020.

Appendix A: Letters of Support from Stakeholder Partners

Letters included:

1) California Department of Water Resources
2) El Dorado Irrigation District
3) El Dorado Resource Conservation District
4) Georgetown Divide Public Utility District
5) Mountain Counties Water Resources Association
6) National Oceanic and Atmospheric Administration
7) Sacramento Municipal Utility District
8) Sierra Nevada Conservancy
9) State Water Resources Control Board
10) Tahoe National Forest

June 15, 2020

Kenneth V. Payne, P.E.
General Manager
El Dorado County Water Agency
4330 Golden Center Drive, Suite C
Placerville, California 95667

Subject: Letter of Support Regarding El Dorado County Water Agency Application for WaterSmart Grant with U. S. Bureau of Reclamation – An Intelligent Hydroclimatic Information System for Water and Power Management in the American River Basin

Dear Mr. Payne:

As recently discussed with your staff, the Department of Water Resources (DWR) supports your Agency's efforts to improve the accuracy, reliability, and accessibility of real-time data on water supply conditions in the American River Basin. Your proposed collaboration with UC Merced to upgrade the American River Hydrologic Observatory (ARHO) will assist a wide range of federal and state water managers, hydropower producers, and local water purveyors, as well as resource agencies, in assessing water supply conditions in the Sierra Nevada. Better information is needed for more efficient water system operations and better decision-making for instream flow management.

Upgrading the existing UC Merced ARHO network and developing a real-time, online data tool also will greatly improve our ability to monitor climatic water conditions and project water supplies, especially in times of drought. Our recent challenges from the 2012 through 2016 drought highlight the need for readily accessible, real-time data for a variety of resource management uses. We envision this project to be valuable for a wide variety of uses, public and private – including analysis of and preparation for future drought scenarios – that will greatly improve our long-term resource management capabilities.

We understand that your Agency is the lead grant applicant for the proposed project and that you will be seeking input from DWR and other data users to design the online tool. We are committed to participate as a member of the project's working group for development of the online tool. This will include providing input and feedback on the parameters of the data collected, on the reliability and accuracy of the data collected, and on the design and platform that will host and display the data collected. As an advisory committee member, DWR will commit a minimum of 80 staff hours over the course of the two-year period of this grant, totaling approximately $16,000 of in-kind match. The cost-share will be in place for the duration of the project. There are no other constraints or contingencies associated with this commitment.

If you have questions regarding our support of this grant application project, please feel free to contact me directly at (916) 574-2830.

Sincerely

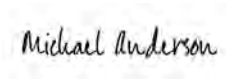
Michael Anderson
Michael Anderson
State Climatologist

Certificate Of Completion

Envelope Id: 4D17A50CD4B14FECA46B168CBB77E7D5
Status: Completed
Subject: Please DocuSign: Commitment Letter Template -DWR 6.15.2020.docx
Source Envelope:
Document Pages: 1
Signatures: 1
Envelope Originator:
Certificate Pages: 2
Initials: 0
Michael Anderson
AutoNav: Disabled
1416 9th Street
EnvelopeId Stamping: Disabled
Sacramento, CA 95814
Time Zone: (UTC-08:00) Pacific Time (US & Canada)
Michael.L.Anderson@water.ca.gov
IP Address: 73.41.82.88

Record Tracking

Status: Original
7/27/2020 4:17:32 PM
Holder: Michael Anderson
Michael.L.Anderson@water.ca.gov
Location: DocuSign
Security Appliance Status: Connected
Pool: StateLocal
Storage Appliance Status: Connected
Pool: Department of Water Resources
Location: DocuSign

Signer Events	Signature	Timestamp
Michael Anderson michael.l.anderson@water.ca.gov Department of Water Resources Security Level: Email, Account Authentication (None)	 Signature Adoption: Pre-selected Style Using IP Address: 73.41.82.88	Sent: 7/27/2020 4:17:59 PM Viewed: 7/27/2020 4:18:07 PM Signed: 7/27/2020 4:18:33 PM Freeform Signing

Electronic Record and Signature Disclosure:
Not Offered via DocuSign

In Person Signer Events	Signature	Timestamp

Editor Delivery Events	Status	Timestamp

Agent Delivery Events	Status	Timestamp

Intermediary Delivery Events	Status	Timestamp

Certified Delivery Events	Status	Timestamp

Carbon Copy Events	Status	Timestamp
Michael Anderson Michael.l.anderson@water.ca.gov Department of Water Resources Security Level: Email, Account Authentication (None)	COPIED	Sent: 7/27/2020 4:18:34 PM Resent: 7/27/2020 4:18:35 PM Viewed: 7/27/2020 4:19:02 PM

Electronic Record and Signature Disclosure:
Not Offered via DocuSign

Witness Events	Signature	Timestamp

Notary Events	Signature	Timestamp

Envelope Summary Events	Status	Timestamps
Envelope Sent	Hashed/Encrypted	7/27/2020 4:18:34 PM
Certified Delivered	Security Checked	7/27/2020 4:18:07 PM
Signing Complete	Security Checked	7/27/2020 4:18:34 PM

Envelope Summary Events	Status	Timestamps
Completed	Security Checked	7/27/2020 4:18:34 PM

Payment Events	Status	Timestamps

El Dorado Irrigation District

Letter No.: EEO2020-0746

VIA E-MAIL

June 24, 2020

Kenneth V. Payne, P.E.
General Manager
4330 Golden Center Drive, Suite C
Placerville, CA 95667
ken.payne@edcgov.us

Subject: Support for An Intelligent Hydroclimatic Information System for Water and Power Management in the American River Basin

Dear Mr. Payne:

On behalf of the El Dorado Irrigation District (EID), I am writing to confirm our commitment and support of An Intelligent Hydroclimatic Information System for Water and Power Management in the American River Basin, a project that would be supported by a grant from the U.S. Bureau of Reclamation as a Drought Resiliency Project under its WaterSMART Drought Response Program.

We understand that El Dorado County Water Agency (EDCWA) is acting as the lead grant applicant for the proposed project, and that the project involves operationalizing the existing research-based American River Basin wireless sensor network (American River Hydrologic Observatory - ARHO) from a research-grade network to a permanent, reliable network that collects and processes real-time hydroclimatic information (e.g. snow depth, temperature, insolation, soil moisture, humidity and other parameters) for use by a wide variety of local, state and federal agencies and organizations in the public, private and academic sectors. EID views the Intelligent Hydroclimatic Information System as a project that will produce accurate and reliable high resolution data for EID water and power management, especially in time of drought.

To support the project and ensure its outcome is of real value to water purveyors in the American River Basin, EID is committed to participate as an active member of the project's advisory committee. As an advisory committee member, we understand we will be requested to provide input and feedback on the parameters of the data collected, on the reliability and accuracy of the data collected, and on the design and platform that will host and display the data collected. We understand participating as an advisory committee member will require a minimum of 40 staff hours over the course of the two-year period of this grant, totaling approximately $6,800. of in-kind match. The cost-share is immediately available and will be in place for the duration of the project. There are no other constraints or contingencies associated with this commitment.

If you have any questions feel free to contact me at bmueller@eid.org or by phone 530-642-4029.

Sincerely,

Brian Mueller, P.E.
Director of Engineering

BM:lv

cc: Kristen Hunter, Biologist/Natural Resource Analyst (via e-mail)
EN2 Resources, Inc.
kristenhunter@en2resources.com

July 20, 2020

Kenneth V. Payne, P.E.
General Manager
El Dorado County Water Agency
4330 Golden Center Drive, Suite C
Cameron Park, California 95667

Subject: El Dorado County Resource Conservation District Commitment to El Dorado County Water Agency Regarding U. S. Bureau of Reclamation Grant Application – An Intelligent Hydroclimatic Information System for Water and Power Management in the American River Basin

Dear Mr. Payne:

This follows my discussions with your staff regarding El Dorado County Resource Conservation District's (RCD) commitment and support to the County Water Agency regarding An Intelligent Hydroclimatic Information System for Water and Power Management in the American River Basin, a project that would be supported by a grant from the U.S. Bureau of Reclamation as a Drought Resiliency Project under its WaterSMART Drought Response Program.

The El Dorado County RCD is actively working with County farmers and private timber managers on use and interpretation of water supply data as it relates to water and drought management. However, there is limited real-time data availability for County water users. Upgrading the existing UC Merced American River Hydrologic Observatory network and developing a real-time, online water data tool that is accessible to all members of the public would greatly improve the understanding and ability of landowners to efficiently manage, and the RCD to advise, on reat-time water conditions, especially in times of drought.

We understand that the County Water Agency is acting as the lead grant applicant for the proposed project. El Dorado County RCD is committed to participate as an active member of the project's advisory committee, and also to serve as an information conduit to private land managers to disseminate the accessibility, utility, and interpretation of the ARHO data.

As a member of the proposed advisory committee for the development of the online tool, we understand that we will be requested to provide input and feedback on the parameters of the data collected, on the reliability and accuracy of the data collected, and on the design and platform that will host and display the data collected. As an advisory committee member, El Dorado County RCD staff will commit a minimum of 60 staff hours over the course of the two-year period of this grant, totaling approximately $4,800.00 of in-kind match. The cost-share will be in place for the duration of the project. There are no other constraints or contingencies associated with this commitment.

If you have questions regarding our support of this grant application project, please feel free to contact me directly on (530) 295-0120.

Sincerely

Mark A. Egbert, District Manager
El Dorado County & Georgetown Divide Resource Conservation Districts
100 Forni Road, Suite A. Placerville, CA 95667
Mark.Egbert@ca.usda.gov

June 15, 2020

Kenneth V. Payne, P.E.
General Manager
El Dorado County Water Agency
4330 Golden Center Drive, Suite C
Placerville, California 95667

Subject: Support of El Dorado County Water Agency Grant Application to U. S. Bureau of Reclamation – An Intelligent Hydroclimatic Information System for Water and Power Management in the American River Basin

Dear Mr. Payne:

This letter expresses Georgetown Divide Public Utility District's (GDPUD) support of the above referenced El Dorado County Water Agency (EDCWA) grant application to the U. S. Bureau of Reclamation (Reclamation). This project would be a Drought Resiliency Project funded under Reclamation's WaterSMART Drought Response Program. Upgrading the American River Hydrologic Observatory (ARHO) will supply important information that could be used to improve management of GDPUD's Stumpy Meadows Reservoir and water distribution system.

GDPUD foresees substantial value in upgrading the existing UC Merced wireless sensor stations (ARHO) from a research-grade network to a real-time data reporting network. The upgraded network, along with the proposed Online Dashboard Tool, would help improve the accuracy, timeliness, and accessibility of snowpack water storage and runoff projection data. GDPUD expects the upgraded network also will greatly improve the accuracy, efficiency, and coordination of water management operations throughout the American River Basin.

EDCWA is acting as the lead grant applicant for the proposed project and GDPUD will participate as an active member of the project's advisory committee. As an advisory committee member, we understand that we will be requested to provide input and feedback on the parameters of the data collected, on the reliability and accuracy of the data collected, and on the design and platform that will host and display the data collected. As an advisory committee member, GDPUD will commit a minimum of 40 staff hours over the course of the two-year period of this grant, totaling approximately $4,000 of in-kind match. The cost-share will be in place for the duration of the project. There are no other constraints or contingencies associated with this commitment.

Sincerely,

Jeff Nelso

Jeff Nelson
Interim General Manager

Mountain Counties
WATER RESOURCES ASSOCIATION

www.mountaincountieswater.com

June 19, 2020

Sent via electronic transmission

Kenneth V. Payne, P.E.
General Manager
El Dorado County Water Agency
4330 Golden Center Dr, Suite C
Placerville, CA 95667

Subject: Commitment for El Dorado County Water Agency Grant Application to U. S. Bureau of Reclamation – An Intelligent Hydroclimatic Information System for Water and Power Management in the American River Basin

Dear Mr. Payne:

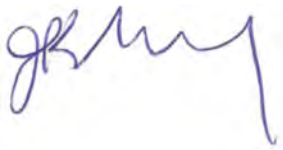
I am writing to express Mountain Counties Water Resources Association's (MCWRA) commitment and support of An Intelligent Hydroclimatic Information System for Water and Power Management in the American River Basin, a project that would be supported by a grant from the U.S. Bureau of Reclamation as a Drought Resiliency Project under its WaterSMART Drought Response Program.

We understand that El Dorado County Water Agency (EDCWA) is acting as the lead grant applicant for the proposed project, and that the project involves upgrading existing UC Merced wireless sensor stations (American River Hydrologic Observatory - ARHO) from a research-grade network to a permanent, reliable network. The upgraded network, along with the proposed Online Dashboard Tool, would serve as a model for improving the accuracy, timeliness, and water manager accessibility of Sierra Nevada snowpack water storage and runoff projection data. We also understand that the upgraded network will greatly improve the accuracy and efficiency of water management operations throughout the American River Basin.

MCWRA is committed to participate as an active member of the project's advisory committee, and also to serve as an information conduit to disseminate the design, value, and transferability of the ARHO upgraded network to other river basins throughout the Sierra

Nevada. As an advisory committee member, we understand that we will be requested to provide input and feedback on the parameters of the data collected, on the reliability and accuracy of the data collected, and on the design and platform that will host and display the data collected. As an advisory committee member, MCWRA staff will commit a minimum of 40 staff hours over the course of the two-year period of this grant, totaling approximately $5,000 of in-kind match. The cost-share will be in place for the duration of the project. There are no other constraints or contingencies associated with this commitment.

Sincerely,



John Kingsbury
Executive Director
Mountain Counties Water Resources Association

cc: Board of Directors, Mountain Counties Water Resources Association

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Weather Service
3310 El Camino Avenue, ste 227
Sacramento, CA 95821-6373

June 18, 2020

Kenneth V. Payne, P.E.
General Manager
El Dorado County Water Agency
4330 Golden Center Drive, Suite C
Placerville, CA 95667

Subject: Support for An Intelligent Hydroclimatic Information System for Water and Power Management in the American River Basin

Dear Mr. Payne:

On behalf of the California-Nevada River Forecasting Center (CNFRC) I am writing to confirm our commitment and support of An Intelligent Hydroclimatic Information System for Water and Power Management in the American River Basin, a project that would be supported by a grant from the U.S. Bureau of Reclamation (USBR) as a Drought Resiliency Project under USBR's WaterSMART Drought Response Program. The CNFRC forecasts runoff in the American Basin as part of its mission to protect life and property and to support water resources management.

We understand that El Dorado County Water Agency (EDCWA) is acting as the lead grant applicant for this proposed project, and that the project involves operationalizing the existing research-based American River Basin wireless sensor network (American River Hydrologic Observatory - ARHO) from a research-grade network to a permanent, reliable network that collects and processes real-time hydroclimatic information (e.g. snow depth, temperature, insolation, soil moisture, humidity and other parameters) for use by a wide variety of local, state and federal agencies and organizations in the public, private and academic sectors. CNFRC recognizes the need for more detailed, reliable and accurate hydroclimate data for more accurate hydrologic modeling.

To support the project and ensure its outcome is of value, CNFRC is committed to participating as an active member of the project's advisory committee. If you have any questions or need additional information, please feel free to contact me at 916-281-6519 or at peter.fickenscher@noaa.gov

Sincerely,

Peter Fickenscher
Service Coordination Hydrologist
California-Nevada River Forecast Center

SMUD®

July 27, 2020

Kenneth V. Payne, P.E.
General Manager
El Dorado Water Agency
4330 Golden Center Drive, Suite C
Cameron Park, California 95667

Subject: SMUD Support of El Dorado Water Agency Grant Application for an Intelligent Hydroclimatic Information System to Improve the Accuracy of Water Supply Forecasting in the American River Basin

Dear Mr. Payne:

This letter confirms Sacramento Municipal Utility District's (SMUD) support for the El Dorado Water Agency's (EDWA) proposed collaboration with UC Merced, UC Berkeley, and the UC Division of Agriculture and Natural Resources on the subject grant application. The purpose of the project is to increase the accuracy of snowpack water supply forecasting and to create an online dashboard tool to report real-time snow water content and other hydroclimatic data that are critical to drought monitoring and forecast, flood forecast, and hydropower operations. Entitled "An Intelligent Hydroclimatic Information System for Water and Power Management in the American River Basin", the project would be partially funded by a 50 percent match grant from the U.S. Bureau of Reclamation (USBR) as a Drought Resiliency Project under USBR's WaterSMART Drought Response Program.

The project involves upgrading the existing American River Basin wireless sensor network (American River Hydrologic Observatory - ARHO) from a research-grade network to a permanent, reliable network that collects, processes, and reports real-time hydroclimatic information (e.g. snow depth, temperature, insolation, soil moisture, humidity and other parameters) for use by a wide variety of local, state and federal water managers, hydroelectric operators, and other organizations in the public, private and academic sectors.

SMUD views the upgrading of the ARHO and the creation of the online dashboard tool as a project that will produce more accurate and more reliable, high resolution data for improved water and power management, especially in times of drought. This will greatly benefit managers striving to improve runoff forecasts of Upper American River Basin water supplies, including lower American River water purveyors and the Central Valley Project (CVP) operators. Importantly, it will also support improved management of downstream (Lower American River, Sacramento River, and Sacramento-San Joaquin

SMUD Hydro Operations & Maintenance | 3995 Old Carson Rd. | Pollock Pines, CA 95726-1500 | 530-644-2013 | smud.org

Delta) environmental flows through the CVP/State Water Project coordinated operations.

This project is identified as a top priority project in the Regional Water Authority's 2018 Integrated Regional Water Management Plan. We understand that EDWA would host and maintain the server for the online tool and sensor network and seek future grant cost-sharing to expand the network sensors throughout the upper American River Basin.

To help ensure that the project meets water manager data needs in the American River Basin, SMUD looks forward to participating as an active member of the project's stakeholder working group. As an interested stakeholder, SMUD will attend coordination meetings and supply input and feedback on the parameters of the data collected, and on the design of the platform that will host and display the data collected. As part of our commitment, we estimate that SMUD staff will contribute approximately 100 hours of time to coordination and planning meetings, review of online data dashboard tool design, and long-term planning for expansion of the ARHO network. This represents approximately $10,000 of in-kind match toward the EDWA's grant application commitment.

We appreciate EDWA's initiative to partner with us and others to improve Upper American River Basin water supply data availability and management. We look forward to the opportunity of supporting you in this effort.

Sincerely,

Tim Talbert
Manager, Hydro Generation Assets

SIERRA NEVADA
CONSERVANCY

AUBURN OFFICE
11521 Blocker Drive, Ste. 205
Auburn, CA 95603
p (530)823-4670 f (530)823-4665

July 29, 2020

Mr. Darion Mayhorn
U.S. Bureau of Reclamation
Policy and Administration
PO Box 25007
Denver, CO 90225

RE: Letter of Support Regarding El Dorado Water Agency Application for WaterSmart Grant with U. S. Bureau of Reclamation – An Intelligent Hydroclimatic Information System for Water and Power Management in the American River Basin

Dear Mr. Mayhorn and others at the U.S. Bureau of Reclamation:

The El Dorado Water Agency (EDWA) is applying to the U.S. Bureau of Reclamation's WaterSMART program to partner with the University of California (UC) Berkeley, UC Merced, and the UC Division of Agricultural and Natural Resources to upgrade the existing research-grade American River Hydrologic Observatory (ARHO) network. The ARHO originated with researchers at UC Merced, with whom the Sierra Nevada Conservancy (SNC) has strong working relationships. The SNC fully supports UC Merced's efforts and EDWA's proposal to transform the network into a permanent, real-time, and publicly accessible source of hydroclimatic data that will serve water managers and researchers in the American River Basin, a primary source water area of the U.S. Bureau of Reclamation's Central Valley Project (CVP).

The proposed enhancement of the ARHO network and its real-time availability will improve the accuracy of forecasts for both the timing and amounts of water yield from the Sierra Nevada snowpack. This will greatly benefit managers of Upper American River Basin water supplies, including the CVP. It will also improve management of downstream (Lower American River, Sacramento River, and Sacramento-San Joaquin Delta) environmental flows, benefitting both the CVP and State Water Project's coordinated operations.

The SNC sees an upgraded, permanent network and associated online data platform as a valuable component to improve water condition projections and supplies in times of drought. The more accurate and nuanced data provided by the network will greatly improve long-term climate change assessments and development of strategies for Sierra Nevada watersheds,

ecosystems, and communities – including analyses of, preparation for, and responses to future drought scenarios. Thank you for considering this important proposal.

Sincerely,

Angela Avery
Executive Officer

cc: Kenneth V. Payne, P.E.
General Manager
El Dorado County Water Agency
4330 Golden Center Drive, Suite C
Cameron Park, CA 95667

State Water Resources Control Board

TO: Kenneth V. Payne, P.E.
General Manager
El Dorado County Water Agency
4330 Golden Center Drive, Suite C
Cameron Park, California 95667

FROM: Greg Gearheart
Deputy Director
OFFICE OF INFORMATION MANAGEMENT AND ANALYSIS

DATE: July 20, 2020

SUBJECT: LETTER OF SUPPORT REGARDING EL DORADO COUNTY WATER AGENCY APPLICATION FOR WATERSMART GRANT WITH U.S. BUREAU OF RECLAMATION – AN INTELLIGENT HYDROCLIMATIC INFORMATION SYSTEM FOR WATER AND POWER MANAGEMENT IN THE AMERICAN RIVER BASIN.

The State Water Resources Control Board (SWRCB), Office of Information Management and Analysis (OIMA) supports your Agency's efforts to improve the accuracy, reliability, and accessibility of real-time data on water supply conditions in the American River Basin. The information pipeline that will be enhanced through this project will support better informed decisions by federal and state water managers, hydropower producers, and local water purveyors.

We support the proposed collaboration with UC Merced to upgrade the American River Hydrologic Observatory (ARHO) to improve water supply storage and runoff forecasting data availability for the upper American River Basin. Your project goal to ensure the data is more spatially representative, consistently formatted, and accessible is in alignment with the AB1755, Dodd. The Open and Transparent Water Data Act and SWRCB's Open Data Resolution (2018-0032). The data collected through this effort will inform projecting drought conditions and establishing minimum instream flows. We encourage the project to also coordinate with our agency and Department of Water Resources (DWR) efforts on AB1755 and SB 19, Dodd. Water resources: stream gages and connect with our federal U.S. Geological Survey (USGS) partners through the Streamflow Collaborative Workgroup.

We understand that you will be seeking input from SWRCB and other data users to design the online tool. We are committed to participate as a member of the project's advisory committee. This will include providing input and feedback on the parameters of the data collected, on the reliability and accuracy of the data collected, the design and platform that will host and display the data collected, and electronic format, frequency, and connectivity to public data portals. As an advisory committee member, SWRCB-OIMA will commit a minimum of 60 staff hours over the course of the two-year period of this grant, totaling approximately $6000 of in-kind match. The cost-share will be in place for the duration of the project. There are no other constraints or contingencies associated with this commitment.

If you have any questions regarding our support of this application project, please feel free to contact me directly at (916)341-5892.

Greg Gearheart
Deputy Director
Office of Information Management and Analysis
State Water Resources Control Board
1001 I Street
Sacramento, CA 95814

cc: Melissa Morris

United States Department of Agriculture | **Forest Service** | **Tahoe National Forest** | **22830 Foresthill Road**
Foresthill CA 95631
530-478-6254
530-367-2992 FAX

File Code: 2720
Date: 6/19/2020

Kenneth V. Payne, P.E.
General Manager
El Dorado County Water Agency
4330 Golden Center Drive, Suite C
Cameron Park, California 95667

Subject: El Dorado County Water Agency Request for Support Regarding Application for WaterSmart Grant with U. S. Bureau of Reclamation – An Intelligent Hydroclimatic Information System for Water and Power Management in the American River Basin

Dear Mr. Payne:

This follows your Agency's request for a letter of support regarding your application for a grant to the U. S. Bureau of Reclamation for a project entitled "An Intelligent Hydroclimatic Information System for Water and Power Management in the American River Basin." We understand the application is being submitted as a Drought Resiliency Project under Reclamation's WaterSMART Drought Response Grant Program.

UC Merced holds a Tahoe National Forest special use permit for the existing American River Hydrologic Observatory (ARHO) network installations. We are currently working with UC Merced on issuing a new special use permit to cover these sites and expansion to new sites. If grant is approved, the existing UC Merced permit would need to be amended or a new permit issued to reflect the proposed changes in layout, type, construction, housing, and operation of the instrument sensors.

We recognize that upgrading the existing UC Merced ARHO network and developing a real-time, online data tool that is accessible to the USFS, water managers and purveyors, and other resource managers, as well as members of the public, would greatly improve our ability to monitor climatic water conditions and manage water supplies, especially in times of drought. Our recent challenges from the 2012 through 2016 drought in the American River Basin highlighted the need for more accessible, real-time data for a variety of resource management uses, and we envision this project to be a valuable day-to-day tool that will greatly improve our water and other resource management capabilities.

If you have questions regarding our support of this grant application project, please feel free to contact American River Ranger District Public Services Officer Mary Sullivan at (530) 367-2224, or mary.sullivan2@usda.gov.

Sincerely,

MICHAEL J. WOODBRIDGE
District Ranger

Appendix B: DRAFT El Dorado Water Agency Board of Directors Resolution

DRAFT RESOLUTION No. WA-X-2020

of the Board of Directors of the

El Dorado Water Agency

A RESOLUTION OF THE BOARD OF DIRECTORS OF THE EL DORADO WATER AGENCY AUTHORIZING AN APPLICATION FOR FUNDING ASSISTANCE THROUGH THE BUREAU OF RECLAMATIONS WATERSMART DROUGHT RESPONSE PROGRAM: DROUGHT RESILIENCY PROJECTS FOR FISCAL YEAR 2021

WHEREAS, the El Dorado Water Agency recognizes the County's vulnerability to drought and the potential increase in frequency, duration and intensity of future drought events; and

WHEREAS, the U.S. Bureau of Reclamation ("Reclamation") has implemented the WaterSMART Program to leverage Federal and non-Federal funding to support stakeholder efforts to stretch scare water supplies and avoid conflicts over water; and

WHEREAS, Reclamation has solicited proposals from organizations with water or power delivery authority for a new round of grant funding under the Fiscal Year 2021 (WaterSMART) Drought Response Program: Drought Resiliency Projects) for which applications for Fiscal Year 2021 were due on or before August 5, 2020; and

WHEREAS, the Board of Directors of El Dorado Water Agency ("EDWA") has identified itself as an eligible applicant under Reclamation's WaterSMART Drought Resiliency Projects Program; and

WHEREAS, UC Merced and UC Berkeley have established a research-scale American River Hydrologic Observatory (ARHO) wireless sensor network (WSN) for purposes of water supply monitoring and forecasting in the American River Basin that needs to be upgraded to become a real-time source of detailed, reliable and accurate hydroclimatic data for County water purveyors and users; and

WHEREAS, EDWA is pursuing grant funding assistance under the WaterSMART Drought Response Program: Drought Resiliency Projects in an amount of $300,000 to upgrade identified sensors in the network and develop an online program and communications platform that water managers and other local, state, and federal agencies can use to display and download the real-time data.

NOW, THEREFORE, BE IT RESOLVED by the Board of Directors as follows:

1) The Board finds that the proposed project will serve both the mission of EDWA and satisfy the goals of the WaterSMART Program and, on that basis, supports staff's submittal of the financial assistance application to Reclamation.
2) EDWA, with its grant application partners, is capable of funding the minimum 50-percent cost share required to obtain grant funding under the WaterSMART Drought Resiliency Projects Program. A detailed breakdown of the project costs is included with the application.
3) The Board hereby ratifies the action of its General Manager, or his designee, of EDWA in applying for financial assistance from Reclamation's WaterSMART Program as part of a regional drought

resiliency effort and authorizes the General Manager or his designee to execute any related documents, including a cooperative financial assistance agreement with Reclamation.

4) The General Manager and staff are directed to take all other actions necessary to secure funding for the Project under the WaterSMART Drought Resiliency Projects Program, including working with Reclamation to meet established deadlines for entering into a cooperative financial assistance agreement.

PASSED AND ADOPTED BY THE Board of Directors of the El Dorado Water Agency at a regular meeting of said Board, held on August 12, 2020, by the following vote of said Board:

Ayes:

Noes:

Abstain:

Absent:

Attest By:

Appendix C: University of California Agriculture and Natural Resources Approved Proposal Package

University of California
Agriculture and Natural Resources

Contracts and Grants

ANR Office of Contracts and Grants
2801 Second Street
Davis, CA 95618
(530) 750-1276 office
(530) 756-1148 fax
ktrose@ucanr.edu
http://ucanr.org/contractsandgrants

June 16, 2020

Kenneth Payne
El Dorado County Water Agency
4330 Golden Center Drive
Placerville, CA 956677

RE: Letter of Commitment

Dear Mr. Payne,

On behalf of The Regents of the University of California – Agriculture and Natural Resources, attached is our proposal entitled "An Intelligent Hydroclimatic Information System for Water and Power Management in the American River Basin" with a projected start date of January 1, 2021 and a requested two year budget of $440,938. We are pleased to confirm our commitment to serve as a subcontractor to The El Dorado County Water Agency in support of this proposal under the Bureau of Reclamation WaterSMART Drought Response Program: Drought Resiliency Projects solicitation. Our Principal Investigator is Dr. Safeeq Khan, Assistant Cooperative Extension Specialist, Water and Watershed Sciences.

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 Kendra Rose at ktrose@ucanr.edu or by phone at (530) 750-1276. Correspondence may be sent to the attention of Kendra Rose, University of California, Agriculture and Natural Resources, Office of Contracts & Grants, 2801 Second Street, Davis, CA 95618.

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,

Kendra Rose
Contracts and Grants Officer

An Intelligent Hydroclimatic Information System for Water and Power Management in the American River Basin

PI: Safeeq Khan

Scope of Work

Task 1: Upgrade (Harden) Selected Instrument Clusters

Task 1 will involve hardening and upgrading the existing wireless nodes and base stations at two of the five sensor clusters in the American River basin (Table 1). Each of the two wireless sensor clusters consist of ten measurement nodes, and a base station which stores and transmits the data.

This task will support two technical managers, one experienced in-field sensor technician, and a total of six (four during the summer and two during the academic year) undergraduate students from the University of California, Merced.

Table 1. Five wireless cluster sites (two will be considered in this round) in the American River basin identified for hardening and upgrading hardware.

	Elevation, m/ft	Location
Robbs Saddle	1799/5900	SF American
Dolly/Rice	1829/6400	MF American
Van Vleck	2025/6642	SF American
Alpha	2290/7511	SF American
Caples Lake	2439/8000	SF American

Hardening and upgrading the sensors and base stations will involve the following tasks at each of the two wireless clusters in the American River basin.

- The existing aluminum pipes at the 10 sensor nodes within each of the five clusters will be replaced with larger diameter and thicker walled material to decrease the likely of bending/breaking due to snow loads (Figure 1).
- A sub-set of nodes at each cluster will be pulled into a tighter cluster to improve communication performance in the local network, without sacrificing data quality.
- Problematic nodes in each sensor cluster will be removed from emplacements and re -located within the network.
- All nodes will be attached (e.g. bolted) to steel u-channel supports which will be set in concrete.
- Plastic weather-proof enclosures, which house the electronics for each node will be replaced with stronger metal enclosures.
- All electronics will be updated with the latest versions/firmware.

Figure 1. Wireless sensor node in the Feather River basin that is hardened.

- All sensors, temperature/relative humidity, snow depth sensors, and soil moisture will be updated, calibrated, or replaced.
- Flexible metal conduit, which protect external sensor wires, will be replaced with rigid PVC.
- Base communication stations will be rebuilt with stronger material and raised up to accommodate heavier and deeper winter snowpacks (Figure 2).
- The communication systems at the base stations will be updated from problematic cellular or commercial satellite to the NOAA GOES system. This will allow for more reliable data transfer from the wireless cluster to the end users.

Figure 2. Base station in the Feather River basin that is hardened with upgraded hardware and communications.

The wireless sensor nodes will be assembled, in-part, at University of California, Davis, and driven to the field sites for final installation. All sensors and data logging systems will be tested in the lab. The system is designed to function autonomously throughout the winter using solar panels and Li-ion batteries and deliver data to a centrally located server.

During the first winter of operation, periodic site visits may be required to make final adjustments, and other necessary maintenance. Finally, during summer 2022, all wireless sensor clusters will be surveyed to ensure future reliability.

Task 1 Deliverables:

- *Two 10-node wireless sensor network installed and operations.*
- *Telemetry connection to data server*

Task 2: Develop Operations Management Dashboard

Task 2a: Develop programing to clean the data and transmit it to a designated server

This task will support automation of data quality assurance (QA) and quality control (QC) and preparing metadata following before final reporting and public access. We will apply the QA/QC method for range checking, negative and extreme value check, low and high frequency cyclic and random noise, instrument noise etc. following the established procedure as described in literature (Daly et al., 2008; Bales et al., 2018; Carolyn and Safeeq, 2018). After the initial QA/QC, missing data will be gap filled, and flagged, using a combination of the nearest and best correlated neighbor(s), linear interpolation, and normal ratio methods. Our earlier work shows that low frequency and short duration gaps can be filled using linear interpolation. However, when data from the multiple sensors are missing for a relatively long duration, normal ratio and regression-based methods are better suited for maintaining the data homogeneity. For metadata, will make full use of existing and emerging standards for documenting and sharing environmental data. Time series data collected by this project will processed using Metavist and Water Markup

Language (WaterML) format where possible. Metavist, a metadata editor for the Federal Geographic Data Committee (FGDC), is a useful tool for developing metadata document that is compliant with the Biological Data Profile (BDP) metadata standard, which works for nearly any type of data. WaterML 2.0 is being developed through the Hydrology Domain Working Group of the Open Geospatial Consortium (OGC) and the World Meteorological Organization. By using these accepted standards for data interfaces and format encodings, we will ensure that our data are interoperable with existing data repositories such as USFS Research Data Archive, California Data Exchange Center (CDEC), Consortium of Universities for the Advancement of Hydrologic Science, Inc. Hydrologic Information System (CUAHSI-HIS), and Data Observation Network for Earth (DataONE), as well as other standards-compliant data systems.
Deliverables:

Task 2b: Develop a communication platform (the Operations Management Dashboard)

Building on the datasets and analysis generated during this project, we will develop a web portal specifically designed to visualize and access spatial and temporal datasets for the American River Basin. Our current data dashboard is not active and limited in coverage and scope in terms of data display and retrieval (http://glaser.berkeley.edu/wsn/). Taking advantage of data processing protocols and methods developed within our team, and available open-source tools, the data dashboard portal will be housed on a web server focused on supporting drought resilience and planning. The overall configuration of our dashboard is based on a client-server architecture (Fig. 3) and consists of one data (data management), one logic (model/code management), and one presentation (user interface) tier. On the server, a backend tier retrieves and stores data in raw and processed formats. The middle tier coordinates between database and user interface through a series of process commands. A presentation tier exposes the logic tier through a user interface translating tasks and results in easy to understand format (both tabular and graphical). For the data dashboard, we note that much of the needed capability already exists; specifically, we have previously developed server components to interface the wireless sensor network and be able to retrieve and display data by node/parameter. This proposal incorporates and builds on this prior work, emphasizing three areas for additional development: 1) capabilities for performing data QA/QC and metadata development, 2)

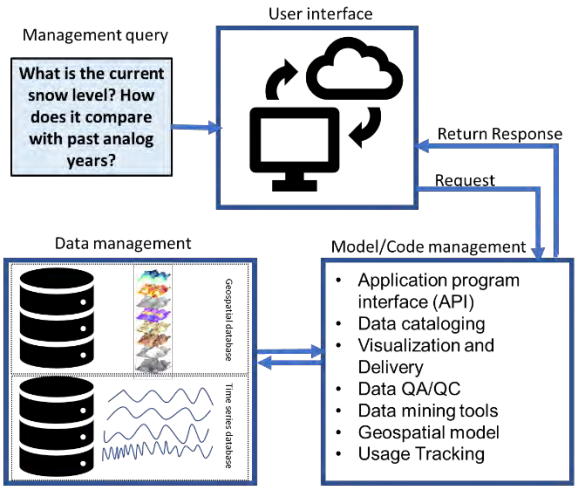


Figure 3. A conceptual illustration of data dashboard for data visualization and drought planning.

development of a data analysis component incorporating current and historical observational data, and 3) a user-friendly interface for visualizing and extracting geospatial and time series data.

Task 2c: Pilot the Operations Management Dashboard with the Working Group of platform users (ARB water purveyors and representatives from DWR and SWRCB)

Task 2c will engage stakeholders in actively developing and customizing the data dashboard based on their feedback and inputs. There will be four structured workshops dedicated for seeking clientele input on: 1) types and nature of decisions; 2) data needs for making those decision making. These inputs will be used for building the scripting and initial user interface. After the first draft, we will host one additional workshop for training and obtaining feedback on the draft dashboard.

Task 2 Deliverables:

- Four (4) workshops with Dashboard users and land managers to design and refine the Dashboard
- One workshop with Dashboard users to educate, and obtain feedback regarding the pilot Dashboard
- Pilot version of the Operations Management Dashboard

An Intelligent Hydroclimatic Information System for Water and Power Management in the American River Basin

PI: Safeeq Khan

Budget Summary

BUDGET ITEM DESCRIPTION	COMPUTATION			EDCWA Funding	USBR Funding	TOTAL COST
	$/Unit	Unit	Quantity			
TASK 1: Harden Data Sensors						
Salaries and Wages						
Professor, Rob Rice (UCM)	$12,905.3	Month	0.75		$9,679	$9,679
Project Scientist, Peter Hartsough (UCM)	$6,064.8	Month	4		$24,259	$24,259
Field Tech, TBA (UCM)	$4,308.3	Month	4		$17,233	$17,233
Undergraduate Student, TBA (UCM)	$15.0	Hour	1733		$26,000	$26,000
Fringe Benefits						
Professor, Rob Rice (UCM)	$645.3	Month	0.75		$484	$484
Project Scientist, Peter Hartsough (UCM)	$2,844.3	Month	4		$11,377	$11,377
Field Tech, TBA (UCM)	$2,020.5	Month	4		$8,082	$8,082
Undergraduate Student, TBA (UCM)	$0.8	Hour	1733		$1,300	$1,300
Travel						
Field Travel (ANR)	$23,299.0		1		$23,299	$23,299
Equipment						
Wireless Sensor Network	$48,451.0	per cluster	2	$96,902		$96,902
Supplies and Materials						
Incidental (ANR)	$1,500.0		1		$1,500	$1,500
Contractual/Construction						
Consultant/Facilitator						
Consultant		Hour				
Other						
Total Direct Charges				**$96,902.00**	**$123,212.95**	**$220,115**
Indirect Costs (@ 55% for UCM and 26% for ANR, less equipment)	$60,575.4		1		$60,575	$60,575
TOTAL COSTS FOR TASK 1: Harden Data Sensors						**$280,690**
TASK 2: Build Operations Mgmt. Dashboard						
Salaries and Wages						
Data Analyst, (X Meng, UCM)	$6,046.56	Month	9	$31,860	$22,559.00	$54,419
Safeeq Khan (Lead PI, ANR)	$8,458.00	Month	0.75		$6,343.50	$6,344
Fringe Benefits						
Data Analyst, (X Meng, UCM)	$3,474.22	Month	9		$31,268.00	$31,268
Safeeq Khan (Lead PI, ANR)	$3,873	Month	0.75		$2,905.00	$2,905
Travel						
Workshop Travel (ANR)	$1,360		1		$1,360	$1,360
Equipment						
Data Server (ANR)	$12,176		1	$12,176		$12,176
Supplies and Materials						
Computer	$1,500		1		$1,500	$1,500
Contractual/Construction						
Consultant/Facilitator						
Consultant		hour				
Other						
Total Direct Charges				**$44,036**	**$65,936**	**$109,972**
Indirect Costs (@ 55% for UCM and 26% for ANR, less equipment)	$50,276.00		1		$50,276	$50,276
TOTAL COSTS FOR TASK 2: Build Operations Mgmt. Dashboard						**$160,248**
TOTAL PROJECT COSTS						**440,938**

Budget Labor Detail

	Hourly Billing Rate	Task 1A Hours	TASK 1: Harden Data Sensors SUBTOTAL	Task 2A Hours	Task 2B Hours	Task 2C Hours	TASK 2: Build Operations Mgmt. Dashboard SUBTOTAL	TOTAL ESTIMATED PROJECT COSTS
Entity								
Dr. Rice	$84.69	120.00	$ 10,163.00				$ -	$ 10,163
Pete Hartsough	$55.68	640.00	$ 35,636.00				$ -	$ 35,636
UG (TBA)	$15.75	1733.33	$ 27,299.95				$ -	$ 27,300
Safeeq Khan	$77.07		$ -	48.00	48.00	24.00	$ 9,248.50	$ 9,249
Data Analyst (X Meng)	$59.50		$ -	160.00	1120.00	160.00	$ 85,687.00	$ 85,687
Field Tech (TBA)	$39.55	640.00	$ 25,315.00				$ -	$ 25,315
			$ -				$ -	$ -
			$ -				$ -	$ -
Total Labor		*3133.33*	*3133.33*	*208.00*	*1168.00*	*184.00*	*1560.00*	$ 4,693
		$ 98,413.95	*98413.95*	*$ 13,220.18*	*$ 70,344.84*	*$ 11,370.48*	*$ 94,935.50*	$ 193,349
Direct Expenses								
Support Costs (supplies, printing, postage, etc.)		$ 1,500.00	$ 1,500.00		$ 1,500.00		$ 1,500.00	$ 3,000
Equipment		$ 96,902.00	$ 96,902.00		$ 12,176.00		$ 12,176.00	$ 109,078
Transportation (mileage)		$ 23,299.00	$ 23,299.00		$ 1,360.00		$ 1,360.00	$ 24,659
Other Costs (IDC)		$ 60,575.41	$ 60,575.41		$ 50,276.00		$ 50,276.00	$ 110,851
Total Direct Expenses		*$ 182,276.41*	*$ 182,276.41*	*$ -*	*$ 65,312.00*	*$ -*	*$ 65,312.00*	$ 247,588
Total Estimated Project Cost		$ 280,690.36	**$ 280,690.36**	$ 13,220.18	$ 135,656.84	$ 11,370.48	**$ 160,247.50**	**$ 440,938**

Budget Justification

Note: The proposed work will be managed by UC ANR but a portion of the work will be performed at UC Merced campus through a sub-award ($285,358) to PI Khan who holds a joint PI status.

Task 1 - ($280,690)

A. Senior Personnel ($10,163)

Co-PI-Rice: Dr. Rice will have primary responsibility for overseeing the field installation, including purchasing and fabrication associate with Task 1. Funds are requested to support 0.5 months summer salary in year 1 and 0.25 months in year 2. Total funds requested: $9,679 Salary + $484 benefits @5%= ***$10,163***

B. Other Personnel ($88,251)

Funds are requested, 2 months per year for two years, to support Peter Hartsough, who will be responsible for leading the field campaign and work with undergraduate students and field tech in completing the task 1. Total funds requested: $24,259 Salary + $11,377 benefits @46.9%= ***$35,636***

Funds are requested to support one field technician for 4 months during year 1 for leading the fabrication. The field tech will work with Peter Hartsough and Bob Rice. Total funds requested: $17,233 Salary + $8,082 benefits @46.9% = ***$25,315***

Funds are requested to support four undergraduate students during the summer (2 months, 1.0 FTE) and 2 under graduate for 2 months (0.5 FTE) during academic year for year 1. Undergraduate students will assist with the field installation, which includes transportation and pouring concrete. Total funds requested: $26,000 Salary + $1,300 benefits @5% = ***$27,300***

C. Travel ($23,299)

Funds for domestic travel to the field sites are requested in the amount of $17,296 in year 1 and 6,003 for year 2. The breakdown of expenses are as follows:

Transportation							
Year 1							
	# of people	rate/wk	# of Vehicles	total rate/wk	# of weeks		**Total**
*Rental Trucks	6	197.36	3	592.08	6		3552.48
**Rental Trucl	2	197.36	1	197.36	4		789.44
						Total year 1	**4341.92**
Year 2							
***Rental Tru	2	198	2	396	5		1980
						Total year 2	**1980**
					Total Transportation		**6321.92**
*Rental truck rates are based on UC Merced TAPs rates. Field instalations will cover 3 mos over the period June 15 - September 15, 2020							
**Field installations will cover 2 mos over the period September 15 - November 15, 2020 (wx permitting)							
***Rental truck rates are based on UC Merced TAPs rates. Transportation covers winter and summer 2021 site visits.							
Food and Lodging							
Year 1							
	# of people	rate/day	Total food/day	total food/wk	# of weeks		
*Food	6	49.50	297	1485	6		8910
*Food and Loc	2	168.50	337	1011	4		4044
						Total year 1	**12954**
Year 2							
*Food and Loc	2	168.50	337	1011	3		3033
*Food	2	49.50	99	495	2		990
						Total year 2	**4023**
					Total food and lodging		**16977**
					Total Travel Year 1		**17295.92**
					Total Travel Year 2		**6003**
*Food based on GSA rates for S. Lake Tahoe (El Droado County) - 2020						**Total Travel**	**23298.92**

D. Equipment ($96,902)

*Funds are requested to purchase 2 clusters, 10 node each, of wireless sensor network as described under task 1. See Appendix (A) for itemized cost. Total cost = **96,902** @48,450.98 per cluster.*

E. Other Direct Costs

Materials and Supplies ($1,500)

Materials and supplies support are requested in the amount of $1,500 for miscellaneous expenses such as costs associated with acquiring special land use permit, printing, site licensing etc.

Indirect Costs ($60,575)

Per the solicitation guidelines for this program, the Federally negotiated indirect rate of 55% (for work performed at UC Merced campus) and 26% (for worked performed at UC ANR campus) were used. UC Merced Task 1 Total Direct Costs $98,414 x 55% = $54,128 indirect costs. UC ANR Modified Total Direct Costs (excludes equipment) $24,799 x 26% = $6,447 indirect costs.

Task 2 ($160,248)

A. Senior Personnel ($9,249)

PI-Safeeq: Dr. Safeeq will have primary responsibility for managing overall project, advise and mentor project personnel. Funds are requested to support 0.75 months summer salary, 0.5 months in year 1 and 0.25 months in year 2. Total funds requested: $6,342 Salary + $2,905

*benefits @44.7%= **$9,249***

B. Other Personnel ($85,687)

*Funds are requested to support data analyst @0.45FTE per year for two years. Data analyst will work under the supervision of the lead PI and will be responsible for doing the data QA/QC, develop metadata as described under Task 2a, and develop dashboard as described in the project description (Task 2b). Total funds requested: $54,419 Salary + $31,268 benefits @54.9% = **$85,687***

C. Travel ($1,360)

Funds for domestic travel to attend stakeholder workshops related to data dashboard.

D. Equipment ($*12,176*)

Funds are requested to for purchasing a PowerEdge T640 Tower Server for the dashboard.

E. Other Direct Costs

Materials and Supplies ($1,500)

Materials and supplies support are requested in the amount of $1,500 for a laptop to be used by the data analyst.

Indirect Costs ($50,276)

Per the solicitation guidelines for this program, the Federally negotiated indirect rate of 55% (for work performed at UC Merced campus) and 26% (for worked performed at UC ANR campus) were used. UC Merced Task 2 Total Direct Costs $85,687 x 55% = $47,128 indirect costs. UC ANR Modified Total Direct Costs (excludes equipment) $12,107 x 26% = $3,148 indirect costs.

Total Requested (Task 1 + Task 2): $440,938

Appendix (A)

10 sensor stations, 1 manager, 10 repeaters

A: Wireless Sensor Node

Parts::ItemName	arts::UnitCo	rts::OrderU	::OrderUnit	FabQty	c_Cost	or::Vendor	r::VendorIt	arts::Website
Aluminum Pipe Sch 80, 1.5-	$ 155.20	1	ea	10	$ 1,552.00	metalsdepc	T311480	https://ww different vendor
Aluminum Pipe Sch 40, 1.5-	$ 50.02	1	ea	10	$ 500.20	metalsdepc	T3114	https://ww different vendor
Concrete, bag	$ 4.68	1	ea	2	$ 9.36	Local Hardware Store		
Battery, 11.1V Li-Ion (9 AH)	$ 122.50	1	ea	10	$ 1,225.00	batteryspac	3642	http://www.batteryspace.com/Li-ion-Battery-Module-11.1V-9Ah-99.9-Wh-9A-rate-with-wire.aspx
Bushing, Small	$ 4.90	50	ea	10	$ 0.98	Allied Elect	SB-2	http://www.alliedelec.com/search/productdetail.aspx?SKU=70208808
Soil Moisture Sensor	$ 110.00	1	ea	22	$ 2,420.00	Meter	Teros 10	http://www.decagon.com
Cable, 18 AWG (Gray)	$ 390.01	1000	Ft	130	$ 50.70	Digikey	C0454-100(	http://www.digikey.com/product-detail/en/C0454.41.10/C0454-1000-ND/307347
SD Card, 1GB	$ 19.40	1	ea	10	$ 194.00	Digikey	AF1GSDI-0E	http://www.digikey.com/product-detail/en/AF1GSDI-5ACXX/AF1GSDI-5ACXX-ND/3770372
Radiation Shield	$ 100.00	1	ea	10	$ 1,000.00	EME Systen	DV7714/A	email sales@emesystems.com
Temp/RH	$ 125.00	1	ea	10	$ 1,250.00	EME Systen	SHT15DV	email sales@emesystems.com
Liquid Tight Conduit, 3/4" r	$ 323.00	100	ft	100	$ 323.00	Grainger	5YH57	http://www.grainger.com/product/LIQUATITE-Conduit-5YH57
Enclosure, Node	$ 70.08	1	ea	10	$ 700.80	enclosureh	VJ1008HWF	http://www.enclosurehub.com/productcart/pc/viewPrd.asp?idproduct=17724&idcategory=1254
Node Base Plate	$ 35.00	1	ea	10	$ 350.00	Waters Eng	43560	waters.engineering@att.net
Antenna Cable- NM to RPSM	$ 22.25	1	ea	10	$ 222.50	L-com	CA-NMNMA	http://www.l-com.com/coaxial-rp-sma-plug-to-n-male-pigtail-10-ft-195-series
Antenna Mounting Bracket	$ -	1	ea	10	$ -	L-com	5200225	included w/antenna
Antenna, 4 dBi	$ 39.60	1	ea	10	$ 396.00	L-com	HGV-2404(	http://www.l-com.com/wireless-antenna-24-ghz-6-dbi-omnidirectional-antenna-n-female-connector
Zipties, 8.5"	$ 3.50	50	pk	50	$ 3.50	McMaster-(	7130K104	http://www.mcmaster.com/#7130k104
Bolt, for 1.25-in pipe	$ 6.29	10	pk	20	$ 12.58	McMaster-(	91286A171	http://www.mcmaster.com/#91286A171
Flat Washer, 5/16-in	$ 5.52	50	pk	40	$ 4.42	McMaster-(	98180A120	http://www.mcmaster.com/#98180A120
Hoseclamp, No 32	$ 10.03	10	pk	30	$ 30.09	McMaster-(	5416K19	https://www.mcmaster.com/#5416k19/
Lock Washer, 5/16-in	$ 7.51	100	pk	20	$ 1.50	McMaster-(	92147A030	http://www.mcmaster.com/#92147A030
Nut, 5/16-in	$ 10.02	100	ea	20	$ 2.00	McMaster-(	93827A219	http://www.mcmaster.com/#93827A219
Set Screw	$ 5.86	100	pk	40	$ 2.34	McMaster-(	92470A192	http://www.mcmaster.com/#92470a192
Temp/RH U-Bolt	$ 3.24	1	ea	20	$ 64.80	McMaster-(	8896T106	http://www.mcmaster.com/#8896T106
Washer, Set Screw	$ 3.89	100	pk	10	$ 0.39	McMaster-(	96659A103	http://www.mcmaster.com/#96659a103
Right-Angle Conduit Fitting,	$ 10.50	1	ea	10	$ 105.00	McMaster-(	7119k22	http://www.mcmaster.com/#7119k22/
Machine Screw, 8-32	$ 4.58	100	pk	40	$ 1.83	McMaster-(	90272A193	http://www.mcmaster.com/#90272A193
Lock Washer, Stand-off	$ 2.40	100	pk	40	$ 0.96	McMaster-(	91114A009	http://www.mcmaster.com/#91114A009
Nut, Stand-off	$ 1.49	100	pk	40	$ 0.60	McMaster-(	90480A009	http://www.mcmaster.com/#90480A009
O-Ring, PG-7 Plug	$ 7.76	50	pk	10	$ 1.55	McMaster-(	9396K24	http://www.mcmaster.com/#9396k24
Straight Conduit Fitting, 3/4	$ 5.03	1	ea	10	$ 50.30	McMaster-(	7119K13	http://www.mcmaster.com/#7119k13
Strut Channel, Node	$ 90.95	15	8-in length	20	$ 121.27	McMaster-(	33085T47	http://www.mcmaster.com/#33085t47/=pdogs3
Strut Clamp, 1.25-in	$ 1.23	1	ea	20	$ 24.60	McMaster-(	3115T84	https://www.mcmaster.com/#3115t84/
Strut Washer, Large	$ 3.65	100	pk	40	$ 1.46	McMaster-(	91090A120	http://www.mcmaster.com/#91090a120
Strut Washer, Small	$ 2.19	100	pk	40	$ 0.88	McMaster-(	90108A411	http://www.mcmaster.com/#90108a411
Strut Screw (1/4-20 x 5/8")	$ 7.70	50	ea	40	$ 6.16	McMaster-(	91772A539	https://www.mcmaster.com/#91772A539
Strut Lock Nut, 1/4-20	$ 4.42	50	ea	40	$ 3.54	McMaster-(	91831A029	https://www.mcmaster.com/#91831A029
O-Ring, 3/4" Conduit	$ 6.56	10	pk	10	$ 6.56	McMaster-(	1182N214	http://www.mcmaster.com/#1182n214
PVC Conduit - 1/2" (10 ft le	$ 3.66	1	ea	10	$ 36.60	McMaster-(	7912K1	https://www.mcmaster.com/#7912K1
PVC male adapter - 1/2"	$ 0.22	1	ea	10	$ 2.20	McMaster-(	7945K31	https://www.mcmaster.com/#7945K31
Reducing washer - 1 to 1/2"	$ 2.29	10	pk	10	$ 2.29	McMaster-(	7513K372	https://www.mcmaster.com/#7513K372
Conduit Locknut	$ 2.55	10	pk	10	$ 2.55	McMaster-(	7513K241	https://www.mcmaster.com/#7513K241
PVC Conduit Junction, 1/2"	$ 2.58	1	ea	10	$ 25.80	Home Depo	R5133663	http://www.homedepot.com/p/1-2-in-Type-LB-Conduit-Body-R5133663/202043487
PVC 45 Degree Elbow - 1/2"	$ 0.61	1	ea	20	$ 12.20	Home Depo	UA7ADB-CT	http://www.homedepot.com/p/1-2-in-45-Degree-Sch-40-PVC-Standard-Radius-Elbow-UA7ADB-CTN/100144599
PVC female adapter - 1/2"	$ 0.27	1	ea	10	$ 2.70	McMaster-(	7945K21	https://www.mcmaster.com/#7945K21
Charge Controller	$ 75.00	1	ea	12	$ 900.00	Metronome	N/A	NA
NuRail, 1.25 x 1.25 in	$ 26.07	1	ea	10	$ 260.70	McMaster-(	4698T64	https://www.mcmaster.com/#4698T125
Solar Panel Bracket, 10 W	$ 47.00	1	ea	10	$ 470.00	mrsoloar.c	RAC-M-530	http://www.mrsolar.com/solartech-rac-m530-side-of-pole-mount/
Solar Panel, 15 W	$ 22.35	1	ea	10	$ 223.50	ACO Solar	HY015-12P	https://www.acosolar.com/acopower-15w-solar-panel-hy015-12p-off-grid-poly-silver-frame
Temp/RH Saddle	$ 2.99	2	pk	20	$ 29.90	Solid Signa	DS-2002	http://www.solidsignal.com/pview.asp?p=ds-2002&d=winegard-ds-2002-u-bolt-kit---up-to-2-mast-(ds-2002)&sku=61579810177
U-channel, 6-ft	$ 17.90	1	ea	10	$ 179.00	Traffic Safe	11900401	http://www.tssco.com/
Desiccant bag, 1/2 unit	$ 19.93	75	pk	10	$ 2.66	McMaster-(	2139K77	https://www.mcmaster.com/#2139K77
Judd Depth Sensor	$ 650.00	1	ea	10	$ 6,500.00	Judd Comm	N/A	http://www.juddcom.com
Neo Mote	$ 650.00	1	ea	10	$ 6,500.00	Metronome	N/A	NA
Neo Mote case	$ 250.00	1	ea	10	$ 2,500.00	Metronome	N/A	NA
Sum (Node)					**$ 28,290.96**			

B: Signal Repeater (Hopper)								
Aluminum Pipe Sch 80, 1.25	$ 138.20	1	ea	10	$ 1,382.00	metalsdepc	T311480	https://www.metalsdepot.com/products/alum2.phtml?page=pipe&LimAcc=%20&aident=#p364
Bolt, for 1.25-in pipe	$ 6.29	10	pk	20	$ 12.58	McMaster-I	91286A171	http://www.mcmaster.com/#91286A171
Flat Washer, 5/16-in	$ 5.52	50	pk	40	$ 4.42	McMaster-I	98180A120	http://www.mcmaster.com/#98180A120
Lock Washer, 5/16-in	$ 7.51	100	pk	20	$ 1.50	McMaster-I	92147A030	http://www.mcmaster.com/#92147A030
Nut, 5/16-in	$ 10.02	100	ea	20	$ 2.00	McMaster-I	93827A219	http://www.mcmaster.com/#93827A219
U-channel, 6-ft	$ 17.90	1	ea	10	$ 179.00	Traffic Safe	11900401	http://www.tssco.com/
Battery, 3.6V	$ 15.15	1	ea	10	$ 151.50	AA Portable	2049	http://www.batteryspace.com/primarylithiumthionylchloridebatterydsize36v19aher34615saftlsh20super-energyden
Mounting Plate, Repeater	$ 13.00	1	ea	10	$ 130.00	Apostu Ma	N/A	N/A
Enclosure, Repeater	$ 23.93	1	ea	10	$ 239.30	enclosureh	N4X-FG-06(	http://www.enclosurehub.com/productcart/pc/viewPrd.asp?idproduct=13709&idcategory=971#details
Antenna, 4 dbi	$ 36.92	1	ea	10	$ 369.20	L-com	HGV-2404U	http://www.l-com.com/wireless-antenna-24-ghz-4-dbi-omnidirectional-antenna-n-female-connector
Antenna Pigtail	$ 8.81	1	ea	10	$ 88.10	L-com	CA-MMNM(	http://www.l-com.com/item.aspx?id=22586#.UJRHlcXA-NA
Locknut, Repeater Enclosur	$ 5.92	100	ea	40	$ 2.37	McMaster-I	91831A009	http://www.mcmaster.com/#91831a009
Screw, Repeater Enclosure	$ 10.45	100	ea	40	$ 4.18	McMaster-I	91772A199	http://www.mcmaster.com/#91772a199
Repeater Board	$ 225.00	1	ea	10	$ 2,250.00	Metronome	N/A	NA
Repeater Mounting Kit	$ 2.99	2	pk	10	$ 14.95	Solid Signa	DS-2002	http://www.solidsignal.com/pview.asp?p=ds-2002&d=winegard-ds-2002-u-bolt-kit---up-to-2-mast-(ds-2002)&sku=61
Sum (Repeater)					**$ 4,831.10**			
C: Telemetry - GOES								
GOES transmitter	########	1	ea	1	$ 2,495.00	CSI	tx321	
GOES antenna	$ 600.00	1	ea	1	$ 600.00	CSI	25316	
GOES antenna cable	$ 68.00	1	ea	1	$ 68.00	CSI	COAXNTN	
GOES antenna cable length	$ 2.04	1	ft	15	$ 30.60	CSI	-L	
surge protector kit, n to n	$ 215.00	1	ea	1	$ 215.00	CSI	31329	
28dBi GPS Antenna	$ 88.00	1	ea	1	$ 88.00	CSI	17992	
GPS antenna cable, n to tnc	$ 65.00	1	ea	1	$ 65.00	CSI	COAX3NT	
GPS antenna cable length (:	$ 0.79	1	ft	15	$ 11.85	CSI	-L	
gps surge protector kit	$ 250.00	1	ea	1	$ 250.00	CSI	31326	
gps antenna mounting pipe	$ 14.00	1	ea	1	$ 14.00	CSI	7623	
gps antenna mounting brac	$ 32.00	1	ea	1	$ 32.00	CSI	CM220	
Sum (Telemetry)					**$ 3,869.45**			
D: Base Station								
Parts::ItemName	**arts::UnitCorts::OrderU**	**::OrderUnit**		**FabQty**	**c_Cost**	**or::Vendorl**	**::VendorIte**	**arts::Website**
Charge Controller	$ 83.90	1	ea	1	$ 83.90	ACO Solar	PS-15M	https://www.acosolar.com/morningstar-s-prostar-ps-15m
Temp Sensor (Charge contro	$ 28.50	1	ea	1	$ 28.50	ACO Solar	RTS	n/a
150 watt solar panel	$ 199.99	1	ea	1	$ 199.99	renogy.com	RNG-150D	https://www.renogy.com/renogy-150-watt-12-volt-monocrystalline-solar-panel/
150 watt solar panel brack	$ 79.99	1	ea	1	$ 79.99	renogy.com	MTS-SP100	https://www.renogy.com/renogy-single-side-27-4in-pole-mount-support-for-solar-panel/
Galvanized Pipe, 2.5-in, 3-f	$ 100.00	21	ft	1	$ 4.76	Bakersfield	Pipe	
Grounding strap	$ 2.35	10	ft	1	$ 0.24	Grainger	4NCC5	http://www.grainger.com/product/DMC-Hanging-Strap-4NCC5?s_pp=false
Wire, 10 AWG (Green)	$ 35.55	100	ft	6	$ 2.13	Grainger	4WYZ2	http://www.grainger.com/product/SOUTHWIRE-COMPANY-Wire-4WYZ2?s_pp=false
Cable, 16 AWG (Gray)	$ 283.00	1000	ft	15	$ 4.25	Grainger	4DPJ6	http://www.grainger.com/search?searchQuery=4DPJ6
Wire, 14 AWG (Black)	$ 23.07	100	ft	2	$ 0.46	Grainger	4WZC4	http://www.grainger.com/product/SOUTHWIRE-COMPANY-Wire-4WZC4?s_pp=false
Wire, 14 AWG (Red)	$ 23.07	100	ft	2	$ 0.46	Grainger	4WZC6	http://www.grainger.com/product/SOUTHWIRE-COMPANY-Wire-4WZC6?s_pp=false
Wire, 4 AWG (Black)	$ 47.00	25	ft	3	$ 5.64	Grainger	6X776	http://www.grainger.com/product/CAROL-Cable-6X776?s_pp=false
Ground Rod	$ 14.98	1	ea	1	$ 14.98	Grainger	2KXL7	http://www.grainger.com/product/ERITECH-Ground-Rod-2KXL7?s_pp=false
Ground Rod Clamp	$ 28.60	5	pk	1	$ 5.72	Grainger	22A961	http://www.grainger.com/product/BURNDY-Ground-Rod-Clamp-22A961?s_pp=false
Job Box	$ 199.00	1	ea	1	$ 199.00	Home Depo	2032-OS	http://www.homedepot.com/p/RIDGID-32-in-x-19-in-Portable-Storage-Chest-2032-OS/100189569
Antenna, 6 dBi	$ 43.08	1	ea	1	$ 43.08	L-com	HGV-2406(	http://www.l-com.com/wireless-antenna-24-ghz-6-dbi-omnidirectional-antenna-n-female-connector
Antenna Cable	$ 15.75	1	ea	1	$ 15.75	L-com	CA-NMNMA	http://www.l-com.com/item.aspx?id=22607
Antenna Cable	$ 15.75	1	ea	1	$ 15.75	L-com	CA-NMNMA	http://www.l-com.com/item.aspx?id=22607
Antenna Mounting Bracket	$ -	1	ea	1	$ -	L-com	5200225	not online
Lightning Protector	$ 39.61	1	ea	2	$ 79.22	L-com	AL6-NMNFB	http://www.l-com.com/surge-protector-n-male-to-n-female-bulkhead-0-6-ghz-90v-lightning-protector
Concrete, bag	$ 4.68	1	ea	5	$ 23.40	Local Hardware Store		
Bolt, 1/4-in SS	$ 6.52	50	pk	1	$ 0.13	McMaster-I	92240A544	http://www.mcmaster.com/#92240a544/=pu2s0j
Bolt, for 2.5-in pipe	$ 8.40	10	ea	2	$ 1.68	McMaster-I	91286A177	http://www.mcmaster.com/#91286a177
Flat Washer, 1/4-in SS	$ 5.88	50	pk	2	$ 0.24	McMaster-I	93852A102	http://www.mcmaster.com/#93852a102/=pu2vmu
Flat Washer, 5/16-in	$ 5.52	50	pk	4	$ 0.44	McMaster-I	98180A120	http://www.mcmaster.com/#98180A120
Galvanized Pipe Coupler, 2	$ 15.57	1	ea	1	$ 15.57	McMaster-I	4638K119	http://www.mcmaster.com/#4638k119/=pngnet
Galvanized Pipe, 2-in, 10-ft	$ 74.88	1	ea	1	$ 74.88	McMaster-I	7307K26	http://www.mcmaster.com/#7307k26/=pnguah
Galvanized Pipe, 2-in, 5-ft	$ 42.85	1	ea	1	$ 42.85	McMaster-I	7307K16	http://www.mcmaster.com/#7307k16/=pngu7a
Lock Washer, 5/16-in	$ 7.51	100	pk	2	$ 0.15	McMaster-I	92147A030	http://www.mcmaster.com/#92147A030
Nut, 5/16-in	$ 9.74	100	ea	2	$ 0.19	McMaster-I	93827A219	http://www.mcmaster.com/#93827A219
Aluminum Pipe, 1-in, 2ft	$ 8.92	1	ea	1	$ 8.92	metalsdepc	T31	https://www.metalsdepot.com/products/alum2.phtml?page=pipe&LimAcc=%20&aident=#p363
Aluminum Pipe, 1-in, 6ft	$ 24.76	1	ea	1	$ 24.76	metalsdepc	T31	https://www.metalsdepot.com/products/alum2.phtml?page=pipe&LimAcc=%20&aident=#p363
Bolt, 1/4-in SS	$ 6.52	50	pk	1	$ 0.13	McMaster-I	92240A544	http://www.mcmaster.com/#92240a544/=pu2s0j
Grounding Lug (Offset)	$ 1.90	1	ea	1	$ 1.90	McMaster-I	6923K32	http://www.mcmaster.com/#6923k32/=pskt1t
Grounding Lug (Straight)	$ 2.04	1	ea	1	$ 2.04	McMaster-I	6923K62	http://www.mcmaster.com/#6923k62/=pskrx2
Nut, 1/4-in SS	$ 3.85	100	pk	1	$ 0.04	McMaster-I	91845A029	http://www.mcmaster.com/#91845a029/=pu2tqo
Strut Channel, Base Sta	$ 10.70	1	ea	2	$ 21.40	McMaster-I	33085T93	https://www.mcmaster.com/#33085t93/
Strut Clamp, 2-in	$ 1.48	1	ea	2	$ 2.96	McMaster-I	3115T86	http://www.mcmaster.com/#3115t86/=pdnr1d
Hose clamp, No 24	$ 8.09	10	pk	4	$ 3.24	McMaster-I	5388K28	http://www.mcmaster.com/#5388k28/=pngtxw
Terminal Connector	$ 7.69	50	pk	10	$ 1.54	McMaster-I	7113K92	http://www.mcmaster.com/#7113k92/=pclzqb
Right-Angle Conduit Fitting,	$ 3.46	1	ea	2	$ 6.92	McMaster-I	7119K81	http://www.mcmaster.com/#7119k81/=pd6wl8
Cable Gland, 2 wire	$ 4.33	1	ea	1	$ 4.33	McMaster-I	7807K33	https://www.mcmaster.com/#7807K33
Straight Conduit Fitting, 3/8	$ 1.75	1	ea	1	$ 1.75	McMaster-I	7119K71	http://www.mcmaster.com/#7119k71
PVC Conduit - 1/2" (10 ft le	$ 3.66	1	ea	1	$ 3.66	McMaster-I	7912K1	https://www.mcmaster.com/#7912K1
PVC male adapter - 1/2"	$ 0.22	1	ea	1	$ 0.22	McMaster-I	7945K31	https://www.mcmaster.com/#7945K31
Reducing washer - 1 to 1/2	$ 2.29	10	pk	1	$ 0.23	McMaster-I	7513K372	https://www.mcmaster.com/#7513K372
Conduit Locknut	$ 2.55	10	pk	1	$ 0.26	McMaster-I	7513K241	https://www.mcmaster.com/#7513K241
PVC Conduit Junction, 1/2"	$ 2.58	1	ea	1	$ 2.58	Home Depo	R5133663	http://www.homedepot.com/p/1-2-in-Type-LB-Conduit-Body-R5133663/202043487
PVC 45 Degree Elbow - 1/2"	$ 0.61	1	ea	2	$ 1.22	Home Depo	UA7ADB-CT	http://www.homedepot.com/p/1-2-in-45-Degree-Sch-40-PVC-Standard-Radius-Elbow-UA7ADB-CTN/100144599
PVC female adapter - 1/2"	$ 0.27	1	ea	1	$ 0.27	McMaster-I	7945K21	https://www.mcmaster.com/#7945K21
Terminal Block	$ 1.74	1	ea	1	$ 1.74	McMaster-I	7618K614	http://www.mcmaster.com/#7618K614
NuRail, 1 x 1 in	$ 18.86	1	ea	2	$ 37.72	McMaster-I	4698T64	https://www.mcmaster.com/#4698T64
Battery 12V SLA, 100 AH	$ 200.00	1	ea	2	$ 400.00	renogy.com		
Desiccant bag, 1 unit	$ 19.00	50	pk	2	$ 0.76	McMaster-I	2139K78	https://www.mcmaster.com/#2139K78
Enclosure, Base Station	$ 97.44	1	ea	1	$ 97.44	enclosureh	VVJ1412HW	http://www.enclosurehub.com/productcart/pc/viewPrd.asp?idproduct=17726&idcategory=1254
Backing Plate, Base Sta	$ 11.23	1	ea	1	$ 11.23	enclosureh	VMP1412A	http://www.enclosurehub.com/productcart/pc/viewPrd.asp?idproduct=17683
Manager	########	1	ea	1	$ 1,650.00	Metronome	N/A	N/A
Sum (Base Station)					**$ 3,230.60**			
TOTAL (A+B+C+D)					**$ 40,222.11**			
Engineering					$ 2,000.00			
Contingency					$ 1,000.00			
Estimated tax (@ 8%)					$ 3,217.77			
and Handling (@ 5%)					$ 2,011.11			
GRAND TOTAL					**$ 48,450.98**			

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Education:

PhD	2010	Natural Resources and Environmental Management	University of Hawaii-Manoa
M. Tech	2005	Agricultural Engineering	Indian Institute of Technology Kharagpur
B. Tech	2003	Agricultural Engineering	CSA University of Agriculture & Technology

Employment History:

2019-	Assistant Cooperative Extension Specialist	University of California Agriculture and Natural Resources
2015-	Assistant Adjunct Professor	University of California- Merced
2014-2019	Assistant Research Scientist, University of California- Merced	University of California- Merced
2010-2014	Postdoctoral Research Associate	Oregon State University
2006-2010	Research/Teaching Associate	University of Hawaii-Manoa
2005-2006	Design and Sales Engineer	Jain Irrigation Systems Ltd.,
2003-2005	Research fellow	Indian Institute of Technology Kharagpur

Activities:

Professional Activities:

- Associate Editor, Hydrological Processes Journal
- *Organized Conference, Workshop and Field Day:*

2019 Participated as a resource speaker for the California Water Education headwater tour of the American River Basin.

2018 Participated as a resource speaker for the California Water Education headwater tour of the American River Basin.

2017 Participated as a speaker for the southern Sierra headwaters tour presented by Southern Sierra Critical Zone Observatory, UC Water, & USDA Forest Service Pacific Southwest Research Station.

2017 Co-organized and participated as a speaker for the Kings River Experimental Watersheds tour by the Sierra Pacific Industries and other stakeholders.

2016 Represented Kings River experimental watersheds as a speaker during joint USFS R5 and USFS PSW California Tree mortality tour of the Southern Sierra Nevada.

2014 Member of the Organizing Committee for the 5thAnnual Pacific Northwest Climate Science Conference, Seattle, Washington, September 9-10, 2014.

2013 Member of the Organizing Committee for the 4thAnnual Pacific Northwest Climate Science Conference, Portland, Oregon, September 5-6, 2013.

2010 Controlling the nonpoint source pollution at the source: Performance of Piligrass, California, and Ahuawa in reducing nutrients and sediments, Honolulu, Hawai'i.

2007 Workshop on "Modeling water flow and contaminant transport in soils and groundwater using the HYDRUS software packages", Honolulu, Hawai'i, November 12- 13 2007.

2007 Member of the Local Organizing Committee for Soil Moisture Sensing Technology Conference, Honolulu, Hawai'i, March 19-21, 2007.

- *Broader Education*

2017 Featured in an education video "Water in the Balance", jointly produced by UC Water and UC Merced.

Grants Received:

INFEWS/T1: Sustaining California's food production through integrated water and energy management, 2018-2022 ($2.5 million), USDA NIFA.

Headwaters to groundwater: Resources in a changing climate, 2018-2021 ($500K), University of California Office of President.

Monitoring and Evaluating Hydrologic Impacts of Forest Restoration in the Headwaters of American River Basin, 2018-2020 ($175K), The Nature Conservancy.

Streamflow Enhancement Research for the French Meadow Watershed Restoration Project, 2018-2021 ($788K), California Wildlife Conservation Board.

Forests and Water in Changing Climate: The Role of Forest Management in Keeping the Balance, 2015-2020 ($230K), USDA Forest Service.

Teaching Experience:

ENVE-110 Hydrology and climate; 2016, 2017, 2018; Basics of the hydrological cycle and the global climate system. Fundamentals of surface and subsurface hydrology, hydrometeorology, precipitation, evapotranspiration, statistical and probabilistic methods, unit hydrograph and flood routing.

Honors and Awards:

2016 Editors' citation for excellence in refereeing for the Eos Transactions, American Geophysical Union, 2017.

University of Hawaii at Manoa, Graduate Student Organization travel award, 2009.

Dr. Perry Phillip award for best PhD research presentation (poster), 2009.

Award for best student presentation (oral) at Hawaii Soil Moisture Sensing Technology Conference, 2007.

The Graduate Aptitude Test in Engineering (GATE) fellowship award by the Ministry of Human Resources and Development, Government of India, 2003-2005.

High School Merit Scholarship from the Department of Secondary Education Government, Uttar Pradesh, India, 1993-1997.

Publications (past 4 years):

Haig, S. M., Murphy, S. P., Matthews, J. H., Arismendi, I., and Safeeq, M., 2019. Climate-Altered Wetlands Challenge Waterbird Use and Migratory Connectivity in Arid Landscapes. Scientific reports, 9(1), 4666.

Flitcroft, R., Lewis, S., Arismendi, I., Davis, C., Giannico, G., Penaluna, B., Santelmann, M., Safeeq, M. and Snyder, J., 2019. Using expressed behaviour of coho salmon (Oncorhynchus kisutch) to evaluate the vulnerability of upriver migrants under future hydrological regimes: Management implications and conservation planning. Aquatic Conservation: Marine and Freshwater Ecosystems, 29(7), pp.1083-1094.

Fan, Y., Clark, M., Lawrence, D. M., Swenson, S., Band, L. E., Brantley, S. L., Brooks, P. D., Dietrich, W. E., Flores, A., Grant, G., Kirchner, J. W., Mackay, D. S., McDonnell, J. J., Milly, P. C. D., Sullivan, P. L., Tague, C., Ajami, H., Chaney, N., Hartmann, A., Hazenberg, P., McNamara, J., Pelletier, J., Perket, J., Rouholahnejad-Freund, E., Wagener, T., Zeng, X., Beighley, E., Buzan, J., Huang, M., Livneh, B., Mohanty, B. P., Nijssen, B., Safeeq, M., Shen, C., van Verseveld, W., Volk, J., and Yamazaki, D., 2019. Hillslope hydrology in global change research and Earth system modeling. Water Resources Research, 55(2), 1737-1772.

Visser, A., Thaw, M., Deinhart, A., Bibby, R., Safeeq, M., Conklin, M., Esser, B. and Van der Velde, Y., 2019. Cosmogenic Isotopes Unravel the Hydrochronology and Water Storage Dynamics of the Southern Sierra Critical Zone. *Water Resources Research*, *55*(2), pp.1429-1450.

Bales, R.C., Goulden, M.L., Hunsaker, C.T., Conklin, M.H., Hartsough, P.C., O'Geen, A.T., Hopmans, J.W. and Safeeq, M., 2018. Mechanisms controlling the impact of multi-year drought on mountain hydrology. *Scientific reports*, *8*(1), p.690.

O'Geen, A.T., Safeeq, M., Wagenbrenner, J., Stacy, E., Hartsough, P., Devine, S., Tian, Z., Ferrell, R., Goulden, M., Hopmans, J.W. and Bales, R., 2018. Southern Sierra Critical Zone Observatory and Kings River Experimental Watersheds: A synthesis of measurements, new insights, and future directions. *Vadose Zone Journal*, *17*(1).

Bales, R., Stacy, E., Safeeq, M., Meng, X., Meadows, M., Oroza, C., Conklin, M., Glaser, S. and Wagenbrenner, J., 2018. Spatially distributed water-balance and meteorological data from the rain–snow transition, southern Sierra Nevada, California. *Earth System Science Data. 10 (4): 1795-1805*, *10*(4), pp.1795-1805.

Black, B.A., van der Sleen, P., Di Lorenzo, E., Griffin, D., Sydeman, W.J., Dunham, J.B., Rykaczewski, R.R., García-Reyes, M., Safeeq, M., Arismendi, I. and Bograd, S.J., 2018. Rising synchrony controls western North American ecosystems. *Global change biology*, *24*(6), pp.2305-2314.

Clifton, C.F., Day, K.T., Luce, C.H., Grant, G.E., Safeeq, M., Halofsky, J.E. and Staab, B.P., 2018. Effects of climate change on hydrology and water resources in the Blue Mountains, Oregon, USA. *Climate Services*, *10*, pp.9-19.

Klos, P.Z., Goulden, M.L., Riebe, C.S., Tague, C.L., O'Geen, A.T., Flinchum, B.A., Safeeq, M., Conklin, M.H., Hart, S.C., Berhe, A.A. and Hartsough, P.C., 2018. Subsurface plant-accessible water in mountain ecosystems with a Mediterranean climate. *Wiley Interdisciplinary Reviews: Water*, *5*(3), p.e1277.

Danner, A.G., Safeeq, M., Grant, G.E., Wickham, C., Tullos, D. and Santelmann, M.V., 2017. Scenario-Based and Scenario-Neutral Assessment of Climate Change Impacts on Operational Performance of a Multipurpose Reservoir. JAWRA, 53(6), pp.1467-1482.

Saksa, P., Safeeq, M. and Dymond, S., 2017. Recent Patterns in Climate, Vegetation, and Forest Water Use in California Montane Watersheds. Forests, 8(8), p.278.

Flitcroft, R.L., Lewis, S.L., Arismendi, I., LovellFord, R., Santelmann, M.V., Safeeq, M. and Grant, G., 2016. Linking hydroclimate to fish phenology and habitat use with ichthyographs. *PloS one*, *11*(12), p.e0168831.

Safeeq, M. and Hunsaker, C.T., 2016. Characterizing runoff and water yield for headwater catchments in the southern Sierra Nevada. JAWRA, 52(6), pp.1327-1346.

Cooper, M., A., Nolin, and M. Safeeq, 2016. Testing the Recent Snow Drought as an Analog for Climate Warming Sensitivity of Cascades Snowpacks. *Environmental Research Letters 11(8)*, doi:10.1088/1748-9326/11/8/084009.

Safeeq, M., and A. Fares, 2016. Groundwater and Surface Water Interactions in Relation to Natural and Anthropogenic Landuse Changes. *In* Emerging Issues in Groundwater Resources, pp. 289-326. DOI: 10.1007/978-3-319-32008-3_11.

Fares, A., M. Safeeq, R. Awal, S. Fares, and A. Dogan, 2016. Temperature and Probe-to-Probe Variability Effects on the Performance of Capacitance Soil Moisture Sensors in an Oxisol. *Vadose Zone Journal 15(3),* doi: 10.2136/vzj2015.07.0098.

Safeeq, M., S. Shukla, I. Arismendi, G. Grant, and A. Nolin, 2016. Influence of Winter Season Climate Variability on Snow-Precipitation Ratio in the Western U.S*. International Journal of Climatology, 36(9) 3175–3190*.

Safeeq, M., G. Grant, S.L. Lewis, and B. Staab, 2015. Predicting Landscape Sensitivity to Present and Future Floods in the Pacific Northwest, USA. Hydrological Processes*,* 29 (26) 5337–5353.

Penaluna, B.E, et al., 2015. Local Variability Explains Vulnerability of Trout Populations to Land Use and Climate Change. *Plos One*, 10(8): e0135334. doi: 10.1371/journal.pone.0135334.

Shukla, S., M. Safeeq, A. AghaKouchak, K. Guan, and C. Funk, 2015. Temperature Impacts on the Water Year 2014 Drought in California. Geophysical Research Letters, 42(11) 4384–4393