Lawrence Livermore National Laboratory

# Improved Recharge Monitoring for Enhanced Conjunctive Management of Ground and Surface Water

21 April 2021

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## 1.1 Executive Summary

This proposal is submitted on 21 April 2021 by Lawrence Livermore National Laboratory (LLNL, a category B applicant, located in Livermore, Alameda County, California) to the "WaterSMART: Applied Science Grants" funding opportunity (R21AS00289) in partnership and with the agreement of the Omochumne-Hartnell Water District (OHWD, a category A entity), a water district located in Elk Grove, Sacramento County, California.

Omochumne-Hartnell Water District (OHWD) is committed to effective water resource management strategies to protect its member's interests and the Cosumnes River. Reduced summer flows have limited the use of riparian diversion and OHWD is exploring the conjunctive use of ground and surface water to meet the future water needs. To that end, OHWD has invested in an on-farm groundwater recharge project that successfully applied Cosumnes river water for recharge in January 2021 as pilot study, and will be expanded starting Winter 2022. **Lawrence Livermore National Laboratory** (LLNL), in partnership with OHWD, UC Davis (UCD), and Larry Walker Associates (LWA), **proposes a Type 3 project to improve monitoring of infiltration and groundwater recharge and provide real-time data accessibility to inform OHWD water management decisions.** Specifically, this project will develop a numerical flow model to simulate unsaturated and saturated conditions, perform geophysical surveys, incorporate electrical conductivity and soil moisture sensors into an online dashboard for data sharing, perform isotopic source attribution, and improve estimates for river recharge potential. This new information will directly aid OHWD in the coordinated management of both surface and groundwater systems and guide the expansion of on-farm recharge infrastructure projects. This project will provide key information to Projects and Managements Actions which are under consideration in the development of the Groundwater Sustainability Plans for both the Cosumnes and South American Subbasin.

This project will start in January 2022 with a duration of 2 years and a completion date of 31 December 2023. The project location is not a federal facility. Work will be performed at a federally funded research and development center (LLNL).

## 1.2 Technical Project Description

### 1.2.1 Water Supply Reliability and Climate Change

As our climate warms, the snowpack that delivers 73% of river water to California[1] will decrease by 64% and melt 2-4 months earlier.[2] Historical changes have already led to a decline of riparian diversions and a greater reliance on groundwater within the OHWD management area. Because water infrastructure was not designed for these dramatic changes, new solutions are needed to capture and store river water for summer irrigation demand.[3] Managed aquifer recharge on agricultural land as a component of conjunctive management of ground and surface water is by far the most cost-effective solution to this challenge.[4, 5] Especially because agricultural water use has depleted Central Valley aquifers. During the 2012-2016 drought, more than 2,000 domestic wells failed because water levels decreased below the intake point.[6].

Recent studies suggest that there is sufficient unmanaged surface water physically available to mitigate long-term groundwater overdraft in the Central Valley [7] Agricultural managed aquifer recharge can increase both groundwater availability and seasonal baseflow.[8] The fact that the

California Department of Water Resources is actively investigating the possibility of using flood waters for managed aquifer recharge (Flood-MAR) in several basins as a climate adaptation and drought mitigation strategy[9] is an example of how surface water and groundwater need to be managed conjunctively.

The rivers and streams that flow from the Sierra Nevada have always provided an important source of recharge water to groundwater aquifers of the Central Valley. As the development of groundwater resources increased to meet agricultural and municipal demands in the Central Valley, the interaction between rivers and underlying aquifers changed. In many cases, this interaction between river and aquifer is poorly understood—and the Cosumnes River is no exception.

As a recent LLNL study showed, river recharge, identified by a lighter stable isotope signature, represents 47 ± 4% of modern groundwater in the San Joaquin Valley (recharged after 1950) but only 26 ± 4% of premodern groundwater (recharged before 1950).[10] This implies that the importance of river water recharge in the San Joaquin valley has nearly doubled and is likely the result of a 40% increase in total recharge, caused by river water irrigation return flows and increased stream depletion and river recharge due to groundwater pumping.

What is known is that the Cosumnes River and other local waterways are critical sources of recharge water to the aquifer underlying south Sacramento County and the northern San Joaquin County. Water budget models estimate that river recharge accounts for 50% of all recharge in the Cosumnes basin. Yet groundwater and river water are still largely managed separately. Conjunctive use and recharge projects proved to be efficient means to achieve this objective in many parts of California. The California Department of Water Resources defines Conjunctive Use as: [11]

*"The coordinated and planned management of both surface and groundwater systems in order to maximize the efficient use of the resource; that is, the planned and managed operation of a groundwater basin and a surface water storage system combined through a coordinated conveyance infrastructure. Water is stored in the groundwater basin for later and planned use by intentionally recharging the basin during years of above-average water supply."*

### 1.2.2 Monitoring Recharge

To inform water resource management decisions for conjunctive use, the groundwater benefits of river water applied to (agricultural) land need to be accurately quantified. One of the key challenges is precisely estimating recharge rates and flow velocities in the unsaturated zone. As these metrics control the delay of water table responses, they are necessary to set realistic expectations for the timescales of beneficial impacts on the groundwater system. Several case studies have reported high groundwater recharge efficiencies on alfalfa with minimal crop damage.[12] To gain trust and acceptance of these practices, real-time sensor data can provide live information and enable land managers to respond to current conditions during the application of water on agricultural land.

### 1.2.3 Project Objectives and Stakeholder Questions

The objectives of this project are to improve monitoring of infiltration and groundwater recharge and provide real-time data accessibility to inform water management decisions at OHWD recharge project sites. Specifically, this project will perform geophysical surveys, install new monitoring wells, incorporate electrical conductivity and soil moisture sensors into an online dashboard for data sharing, perform isotopic source attribution, and improve estimates for river recharge potential. This new information will directly aid OHWD in the coordinated management of both surface and groundwater systems and guide the expansion of on-farm recharge infrastructure projects. One of the specific questions related to the OHWD recharge projects (described below) is whether recharge will be benefitting the South American or the Cosumnes groundwater subbasins. Benefits to both basins are likely and the distribution of benefits is one of the major unknowns for the draft groundwater sustainability plans. In addition to local interest, the Flood-Managed Aquifer Recharge (Flood-MAR) group at the California Department of Water Resources (DWR) are particularly interested in answering the following questions:

- How are recharge benefits partitioned between the Cosumnes subbasin, the South American subbasin, and the Cosumnes River?
- How quickly does infiltrating surface water recharge the groundwater system? What is the role of perched aquifers on this process?
- What proportion of recharge exfiltrates back to the Cosumnes River downstream of the recharge sites? When and where does this occur? How does this benefit in-stream ecosystems?
- Do recharge efforts impact groundwater quality?
- How do recharge efforts benefit fish habitat in the river? Specifically, do recharge efforts measurably (1) increase the duration of flowing conditions in the river and/or (2) decrease surface water temperatures in the river?
- How can we use information collected at these sites to better characterize future locations for groundwater recharge?

## 1.3 Project Location

### 1.3.1 Omochumne-Hartnell Water District (OHWD)

Omochumne-Hartnell Water District was established in 1953 and has historically purchased and managed supplemental water from the Central Valley Project for the benefit of District agricultural users adjacent to the Cosumnes River and Deer Creek (Figure 1).[13] In recent years, however, the number of riparian diverters has decreased. Four flashboard dams that historically supported diversions are now maintained and operated by the District to increase the wetted perimeter of the river to affect greater groundwater recharge. The District is committed to working with the Southeast Sacramento County Agricultural Water Authority to develop an effective management strategy that protects its member's interests, the resources of the Cosumnes River, and meets the future water needs of the region. OHWD has continued to develop and create new projects that will enhance the water supply for its landowners and the region. These projects include conjuctive use projects such as groundwater recharge and Cosumnes River flow augmentation to increase fish flows in the river and dam improvement projects(Figure 3).

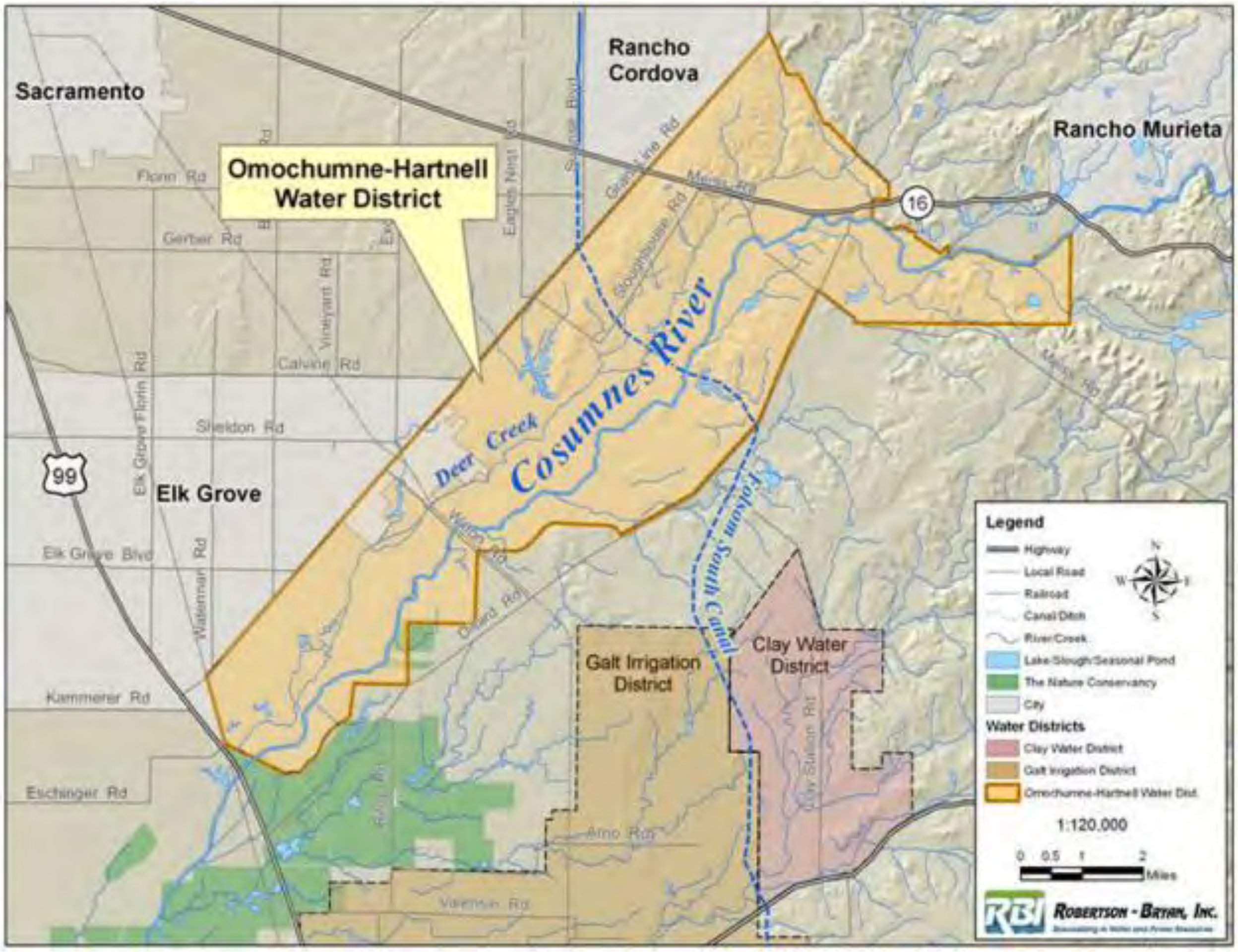


**Figure 1: Map of the Omochumne-Hartnell Water District.**

### 1.3.2 Cosumnes River

The Cosumnes River is the major source of surface flow to the south area with an average annual flow of 312,000 acre-feet per year and is a major source of groundwater recharge for the underlying basins. Flows on the Cosumnes River are unregulated and result primarily from winter storms and seasonal snowmelt. Approximately 16 percent of the watershed lies above the typical snow-level elevation of 5,000 feet. Consequently, only a small portion of the upper reaches of the watershed receives significant snowfall; and the flow regime of the river is influenced primarily by rainfall.

### 1.3.3 South American and Cosumnes Groundwater Subbasins

OHWD covers part of the South American Subbasin to the north of the Cosumnes River and the Cosumnes Subbasin to the south of the Cosumnes River. DWR estimates that the total groundwater storage capacity of the entire Cosumnes sub-basin is 6 million acre-feet based on 1967 and 1974 data.[14] This estimate is based on a surface area of 281,000 acres, an aquifer thickness above the Mehrten formation of 290 feet (20- to 310-foot depths), and an average specific yield of 7.4 percent.[15] In the last four decades, groundwater levels in wells outside the influence of the Cosumnes River have generally declined between 10 and 50 feet. Declines have been most severe in the Cosumnes subbasin whereas the South American subbasin has shown stabilization of water levels in most recent years.

Recharge to the groundwater aquifer is derived from four major components (Table 1):

- deep percolation of precipitation
- deep percolation of the non-consumptive use portion of applied irrigation water
- seepage from streams
- subsurface inflow from surrounding areas

During the dry years of 2000–2004, it is estimated that the South Basin aquifer storage lost an average of 11,900 acre-feet of water annually due to drought conditions.

Annual precipitation in the South Basin ranges from approximately 15 inches at the western edge to about 22 inches in the east.[14] Winter storms between November and March account for about 80 percent of the annual precipitation in the basin. A comparison of historical flows in the Cosumnes River between the USGS gauges at Michigan Bar and McConnell indicates that the river loses flow in its lower reaches. This loss is attributable to seepage to the groundwater aquifer, evaporation, and evapotranspiration. UC Davis have concluded that there is a hydraulic disconnection between the regional aquifer and the streams in the South Basin[16] classifying the river as a "losing stream"—meaning the river serves as a source of recharge to the underlying groundwater aquifer.

**Table 1: Summary of modeled groundwater balance in the South Basin**

| **Inflow (acre-feet)** | **1980-2004** | | **2000-2004** | |
|---|---|---|---|---|
| Infiltration (rainfall and irrigation) | +59,500 | | +48,400 | |
| Seepage from streams | +60,200 | | +52,300 | |
| Sub surface inflow from adjacent basins | +37,300 | | +33,000 | |
| Subtotal | | +157,000 | | +133,700 |
| **Outflow (acre-feet)** | | | | |
| Groundwater withdrawals | -154,400 | | -145,600 | |
| Subtotal | | -154,400 | | -145,600 |
| **Change in groundwater storage** | | **+2,600** | | **-11,900** |

Groundwater supports nearly 95 percent of all water demands in the South Sacramento County Groundwater Basin (South Basin). Irrigated Agriculture demands 132,100 acre-feet (af), 125,300 af of which is met by groundwater pumping, 2,700 af by reclaimed water and 4,100 af by surface water. Surface water supplies a small portion—only 5 percent of the total water supply—of the South Basin's annual water demand. Due to the strong seasonality of Cosumnes River flows, only a smaller volume of water is available for use during the irrigation season. Landowners along the Cosumnes River have riparian water rights and historically riparian users have received imported water from the Central Valley Project, purchased by Omochumne-Hartnell Water District. Current riparian diversions within the Planning Area are estimated to be 100 acre-feet annually.

The Sustainable Groundwater Management Act (SGMA) was passed in 2014 to protect groundwater from depletion and overuse. Under this law, groundwater users in the Cosumnes Subbasin can help shape how this vital resource is used - everything from defining what constitutes sustainable groundwater usage to determining what steps local agencies will take to ensure there is balance between long-term supply and use. There are seven GSAs in the Cosumnes Subbasin (Figure 2).[17] Together they form the Cosumnes Subbasin SGMA Working Group, which meets monthly to work on the development of a groundwater sustainability plan (GSP). The district area north of the Cosumnes River is part of the South American Subbasin where 5 Groundwater Sustainability Agencies are working collaboratively to develop the Groundwater Sustainability Plan.

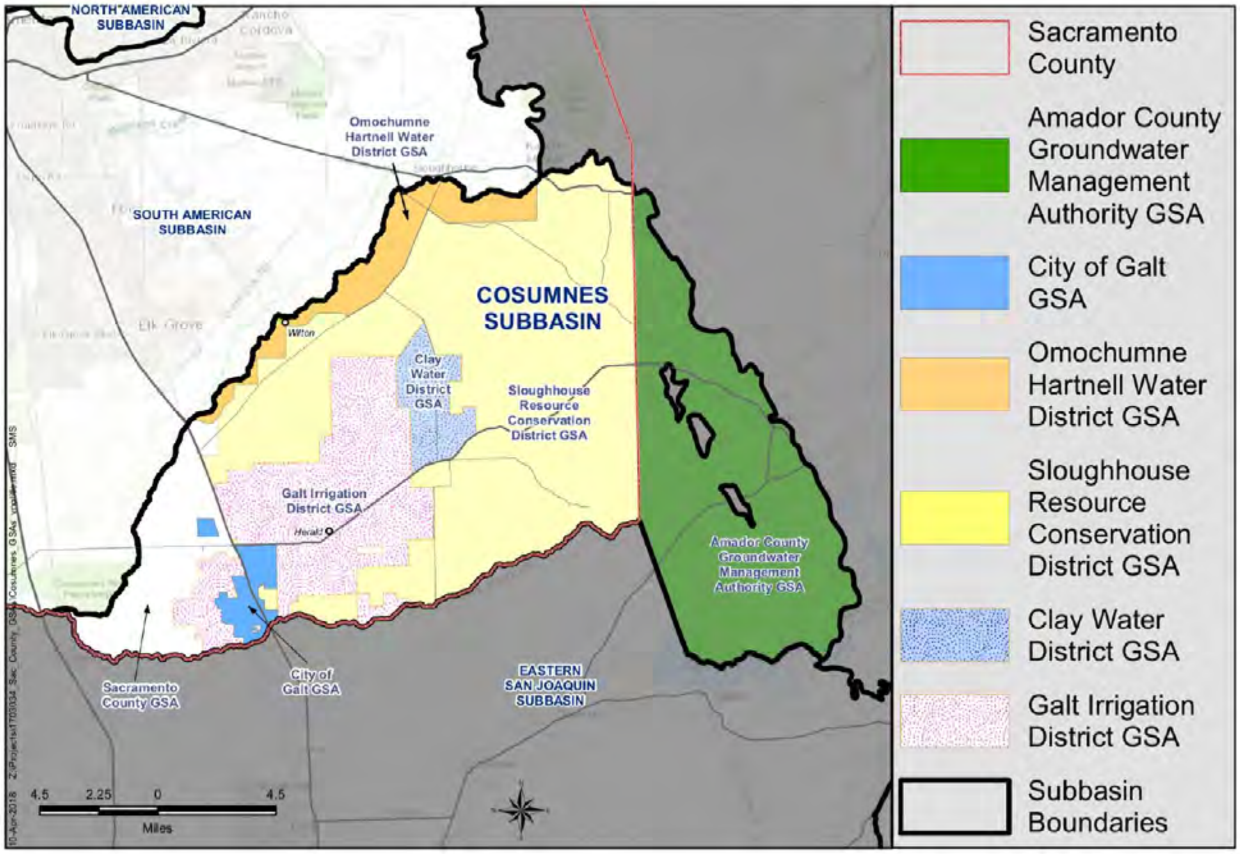


**Figure 2: Map of Groundwater Sustainability Agencies in the Cosumnes Subbasin**

### 1.3.4 OHWD Recharge Projects

Over the years of groundwater pumping have lowered groundwater levels thus effecting the flow in the Cosumnes River. New recharge projects are intended to increase groundwater recharge adjacent to and under the Cosumnes River, allowing the groundwater level to be raised to historic levels that will reconnect with, and thereby allow, the Cosumnes River to run for longer periods during the spring and summer and begin flowing earlier in the fall. These multi-stakeholder projects were conceived by OHWD with support from external organizations (e.g. SAFCA and the Nature Conservancy) and permitting by the State of California Department of Water Resources and Department of Fish and Wildlife.

By increasing water levels in the Cosumnes River Groundwater Subbasin, OHWD reduces the pumping cost for their customers. The higher the water level, the less energy it takes to pump the groundwater and the more efficient the District's pumps become. Instead of building new pipelines or canals to deliver surface water, the District will be utilizing the groundwater basin to transport and store water. By improving groundwater levels, OHWD can also improve the flow in the river which helps improve fish migration. A collaboration with the Sacramento Area Flood Control Agency is also looking into options to increase the amount of water available for recharge through use of Folsom South Canal.

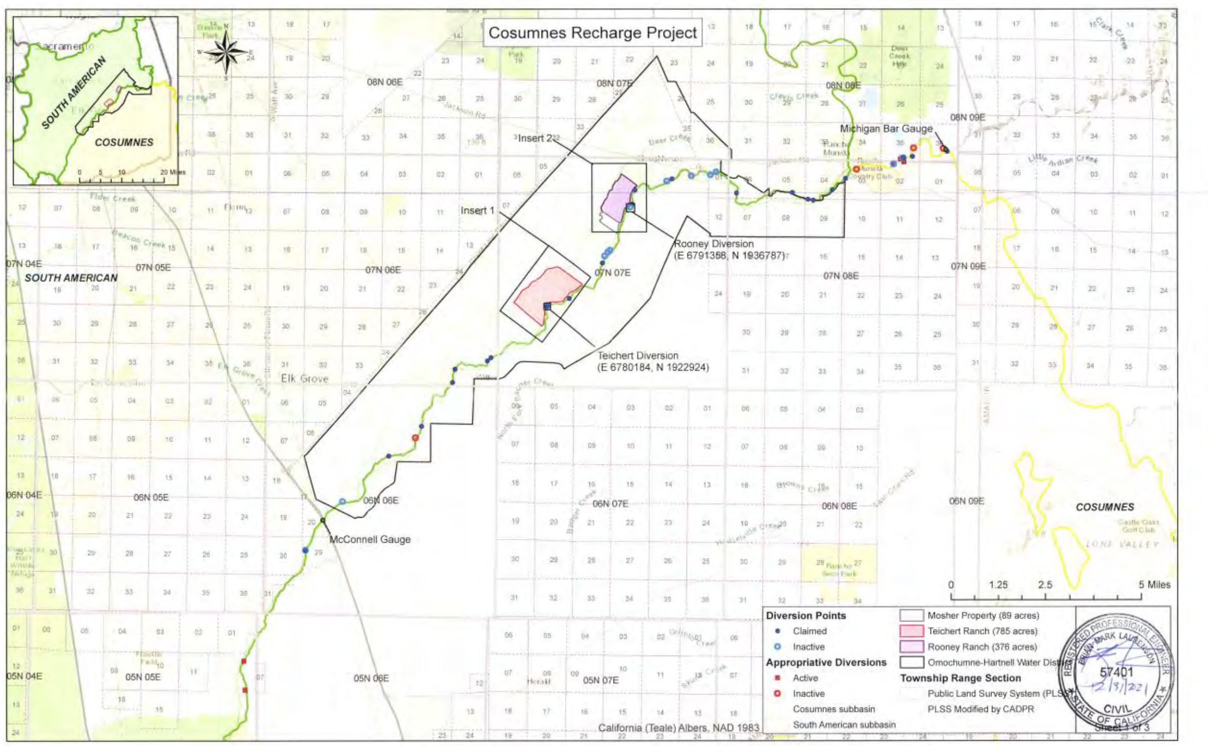


**Figure 3: Map of the Omochumne-Hartnell Water District with location of the recharge sites where diversions have been installed and a temporary permit for diversion has been issued.**

### 1.3.4.1 In River Dam Operations - Water Recharge and Surface Supplies

OHWD operates three removable dams along the Cosumnes River. These dams are used to hold water in the river during the late spring time to help recharge the ground water and allow some onstream user to pump riparian water rights from the river.

These dams are constructed to be temporary and are removed during the winter and times when fish migration may occur. Several of the dams have fish ladder to allow the fish to migrate pass the dams and provide safe passage for the fish during the crucial times of the year.

Figure 4: Flashboards installed on the Blodgett Dam.

Flashboards installed on the Blodgett Dam (Figure 4) are primarily used to increase the depth of water stored behind the dam during periods of drought. Previous work in four dams along the river was conducted to improve flow passage conditions to support salmon spawning and migration during low flow conditions. However, the ongoing maintenance necessary to keep the dams functional is both time consuming and costly.

Recharge potential is important to consider in the design and cost of Blodgett Dam maintenance. The presence of the dam and installation of flashboards for several months of the year is expected to be advantageous for recharge by increasing the head. Alternatively, recharge potential could increase with a larger wetted area resulting from dam removal.

Currently, streamflow measurements on the lower Cosumnes River are limited to a single USGS stream gage at Michigan Bar. Additional streamflow measurements at proposed gage locations downstream of Michigan Bar are proposed to provide estimates of stream gains and losses along the river, and to provide important validation data for modeling efforts. Stream gages will be placed strategically to leverage the existing groundwater network, so that stage data from gages will also be used in conjunction with head data in wells to evaluate the extent, direction, and timing of gaining and losing conditions along the river. Stream gage installation will be coordinated with the Cosumnes Coalition, and instrumentation will be equipped with telemetry to be included in the existing monitoring network.

#### 1.3.4.2 On-Farm Recharge Project

OHWD has been awarded a grant through the Integrated Regional Water Management program of DWR to develop a groundwater recharge project in the South America groundwater subbasin (north of the Cosumnes River) to improve groundwater levels and provide for conjunctive use in the region. This project uses two existing diversion points on the Cosumnes River to flood dormant agricultural fields between the months of December and March when streamflow is high, excess water is available, and irrigation is not needed.

Over a 10-year period, the project will use two existing diversion points on the Cosumnes River to flood dormant agricultural fields in the off-irrigation season between the months of December and March when streamflow is high and excess water is available. The proposed Project will divert a minimum of approximately 4,000 acre-feet per year (AFY) of water in 'normal' years to recharge the groundwater aquifer. The system will be designed to divert and recharge up to 6,000 AFY during 'wet' periods when sufficient diversion water is available in the river, using two existing pump houses and pipelines, and installation of two additional pump houses and a conveyance system.

The Project is located in central Sacramento County, central California. The Project site is located south of Route 16 and directly west of the Cosumnes River. Two field sites lie between Deer Creek and the Cosumnes River, near the Folsom South Canal of Wilton, CA.

Field Site 1 – Teichert Ranch: A 785-acre property is currently cultivated with grape vines; vine rows run northeast to southwest, roughly parallel to the river (Figure 5). New removable pipes, approximately 9,300 feet in length, have been installed parallel to the irrigation pipeline along the south edge of the property with mainline shut off valve to isolate the existing irrigation pump from the future pump for conveyance of recharge water. Four 18-inch overflow valves have been installed along the conveyance system at each roadway to supply water to the southeast end of the recharge field; water will gravity-flow across the natural NW aspect of field.

**Figure 5: Construction at the on-farm recharge site.**

Field Site 2 – Rooney Ranch: A 376-acre property currently cultivated with grapevines; vine rows run northeast to southwest, roughly parallel to the river. An existing river diversion with 12-inch pipe through the levee and a non-operational pump system is located at the site and will be rehabilitated. New pipe sized to convey the ultimate future capacity of 8,350 cfs, 5,883 feet in length, will be installed along the south edge of the property. A new variable speed pump capable of supplying 3,465 gpm to the fields is required for implementing the on-farm recharge project to its full potential. The conveyance of water from the pump along the levee edge of the field will be sized for the ultimate future capacity of 8,350 gpm.

The on-farm recharge project has been the subject of research conducted by UC Davis and UC Water to study the interactions between surface water and groundwater in the Cosumnes watershed. A recent multi-campus research initiative (funded by the UC Office of the President) to study the connection between headwaters and groundwater included the Cosumnes as one of the watersheds under investigation. Researchers from UC Davis continue to monitor the project utilizing real-time sensors and sample collection.

A precipitation gage equipped with telemetry records quarterly precipitation totals at the field. Six monitoring wells have been installed and screened at a depth of 70 ft (10 ft screen). These wells are equipped with automated level loggers that transmit daily groundwater levels to the dashboard. Two of the wells are equipped with sensors for temperature and electrical conductivity. These wells have been sampled repeatedly for water quality parameters and isotopic tracers, including stable isotopes of hydrogen and oxygen of water, tritium-helium groundwater age, and noble gas recharge temperatures. Suction cups are installed in the soil profile and sampled for nutrient analyses in the unsaturated zone. Ten meter deep soil cores were collected in 2019 and analyzed for texture and water content by UC Davis and for stable isotopic composition by LLNL. Soil isotope profiles show distinctly different sources of water in the shallow top soil, converging to a mix of sources at greater depths.

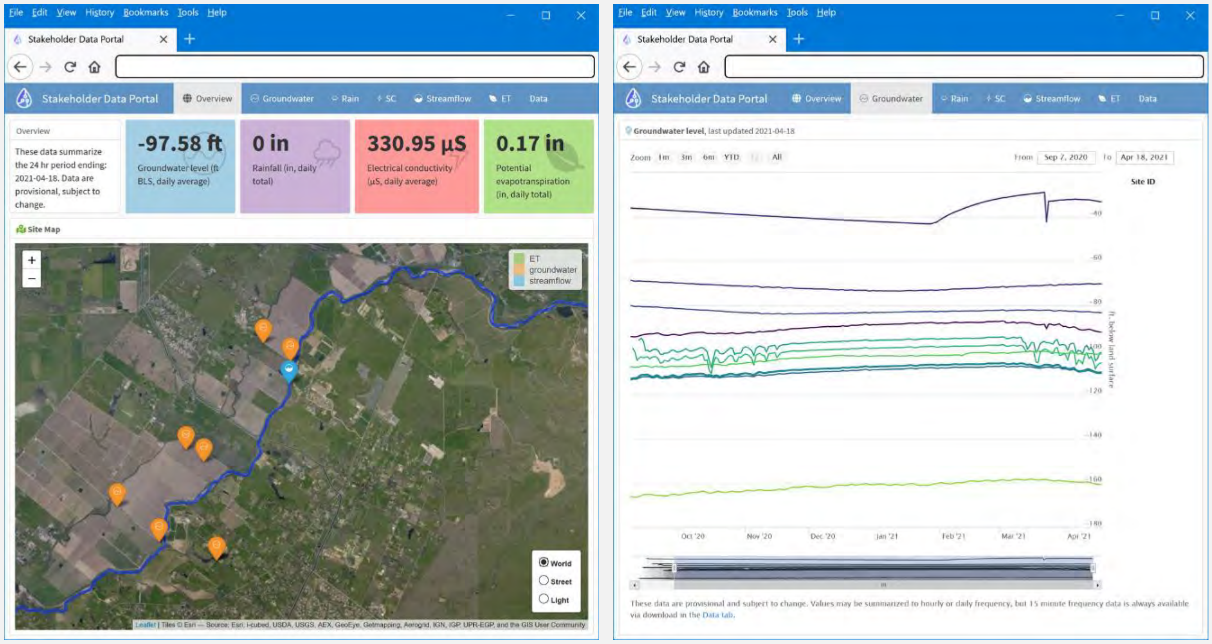


**Figure 6: Screenshots of the Stakeholder Data Portal.**

To estimate hydrological processes, we are proposing to instrument all sites with a suite of soil moisture sensors, water level loggers (already installed through the previous IWRM grant) and flow meters to estimate the amount of surface water applied for recharge and the infiltration and percolation of water to the groundwater table. For the replicated plot studies, recharge amounts are likely too small to see a response in the groundwater table or nitrate concentration of the underlying groundwater. Hence, to monitor groundwater response, efforts will focus on large-scale, large-volume experiments on private landowner fields where several hundred or thousands of acre-feet of water can be applied.

The (near) real-time data is transmitted to the Stakeholder Data Portal (Figure 6) that is accessible to stakeholders with login credentials. The data portal includes a map view of the monitoring locations as well as several data-stream graphs for groundwater, rain, streamflow, and ET. OHWD aims to utilize the Stakeholder Data Portal in the future to track the sustainability criteria defined in the groundwater sustainability plans for the basin.

In 2021, the on-farm recharge project became active for the first time (Figure 7). Between 29 January and 3 February, 13 million gallons of Cosumnes River water were pumped onto a 400-acre vineyard field. Additional permits and pumps are in place to expand the recharge period and amount of flooding in 2022.


**Figure 7: Flooded vineyard next to the Cosumnes River.**

## 1.4 Evaluation Criteria

### 1.4.1 Evaluation Criterion A — Benefits to Water Supply Reliability

Water supply for OHWD stakeholders is challenged by two compounding factors: decline in riparian diversions due to lower summer flows and decline in groundwater water levels due to increased reliance on groundwater. This leads to reduced reliability of water delivery to customers, shortfalls during drought and uncertainties in water availability. Drought exacerbates these challenges, especially "snow droughts" that result in a smaller snow pack do to a combined effect of reduced precipitation and warmer temperatures. For the undammed Cosumnes, this results in rain-driven early winter peak flows when irrigation demand is low and low base flows when irrigation demand is high.

South Basin Groundwater Management Plan (SBGMP) provides a framework under which all users of the aquifer can move toward a commonly held set of goals and objectives concerning groundwater use and protection. The goals and objectives focus on managing and monitoring the basin to benefit all groundwater users in the basin. The SBGMP discusses four goals and related Basin Management Objectives (BMOs) based on feedback from basin stakeholders to help achieve groundwater basin goals. Our project addresses GOAL 1: Maintain Long-term Reliable Groundwater Supplies. In the SBGMP, four scenarios were explored to address Goal 1: The fourth scenario, a combination of In-lieu Recharge and Direct Recharge, utilizes available surface water supplies in lieu of pumping groundwater and directly recharge groundwater. This scenario provided the greatest increase to groundwater storage and the spatial distribution of water elevations when compared to the other management scenarios.

Our project will address the water management issues identified above by conducting applied science tasks to develop new information streams for OHWD to guide their water delivery decisions and sustainable groundwater management. The project will directly contribute to several water management objectives. Primarily, the information will enhance the conjunctive use of ground and surface water in the basin, by providing detailed and accurate estimates of infiltration rates through the unsaturated zone at a site dedicated to on-farm recharge. This information will enable OHWD to better quantify the role of conjunctive use in the sustainable management of the basin. This in turn will lead to greater water supply reliability and more accurate management of water deliveries, as better quantification of recharge increases the ability to maintain or raise water levels in the basin. Furthermore, higher groundwater levels will mitigate the severity of drought and drought management activities, promote overall watershed health as the groundwater and Cosumnes River get reconnected. Specific to the soil moisture sensor data-streams that will become available to OHWD and the vineyard operator, this will lead to a greater irrigation efficiency and conservation of water resources.

Overall project benefits are difficult to quantify in terms of water savings. Qualitatively, project results will reduce uncertainty considerably in managing the water resources sustainably. The on-farm recharge project is expected to pump 1,000 acre-feet from the Cosumnes River annually. This amount is 10% of the estimated water budget deficit during the 2002-2004 drought years. This one project alone systematically raises recharge in the groundwater basin by 2%. The potential for additional increases in groundwater recharge via streambed infiltration at Blodgett Dam is one of the key project results. Furthermore, it is expected that better soil moisture information leads to reduced irrigation and additional water savings. Fundamentally, accurate monitoring of the on-farm and in-river recharge rates enables precisely planning expanded recharge initiatives.

The monitoring and data collection activities proposed for this project complement and build on ongoing research funded by the University of California Office of the President Laboratory Fees program. The Lab Fees research was aimed at investigating the connection between headwaters and groundwater resources in a changing climate. Complementary expertise at LLNL and UC Davis on groundwater and surface water monitoring tracing led to a deep understanding of the challenges quantifying recharge through a deep unsaturated zone. To address this fundamental research question, LLNL has submitted a proposal to fund a new project aimed at enhancing our understanding of unsaturated zone flow via advanced numerical modeling. If funded, this modeling research will complement our ability to quantify recharge at the on-farm project site. Simultaneously, monitoring efforts in data collection proposed for this project will provide additional constraints to the numerical model.

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

Long-term lowering groundwater levels can have adverse impacts on all groundwater users, ranging from increased energy costs and water quality degradation to the need to deepen existing wells or even develop new wells. Therefore, it is important to maintain or enhance groundwater elevations in the basin so that groundwater will continue to be a reliable, safe, efficient, and cost-effective water supply. The stakeholders in the basin are committed to investigating and pursuing conjunctive use opportunities within the South Basin area to achieve this. This entails seeking and obtaining permanent and/or temporary surface water supplies and identification of recharge, and in-stream and off-stream storage sites. Furthermore, the stakeholders aim to implement GMP's monitoring program components by collection, analysis and assimilation of water levels and quality data and development and maintenance of a data base system. Data are needed to understand conditions within the Basin, evaluate trends, facilitate the implementation of management actions, and evaluate their effectiveness.

Our project directly addresses these needs. It will result in an improved data dashboard that will be immediately available for OHWD to guide on-farm flooding management decisions. Information on the sources of water in the unsaturated zone will be readily applicable at the end of the spring for guiding diversion decisions next year. The workflow will provide a blueprint for water resource managers across the West to implement efficient monitoring network and data telemetry systems for new and expanded recharge infrastructure projects.

The need for this project was formulated in the South Basin Groundwater Management Plan[18] (SBGMP) by the South Area Water Council, in which OHWD is a participant, together with the County of Sacrament, multiple other water districts, community service districts, and municipal utility districts, and other stakeholders. In the SBGMP, groundwater recharge from local rivers and streams was identified as the key technical issue important to a comprehensive understanding of local groundwater conditions.

While it is known is that the Cosumnes River and other local waterways are critical sources of recharge water to the aquifer underlying south Sacramento County and the northern San Joaquin County, this interaction between river and aquifer is poorly understood. Much of the current understanding is based on research conducted by UC Davis. The SBGMP notes that it is important that additional information be collected on the rate of groundwater recharge from the Cosumnes River and Dry Creek, as well as the lesser creeks, to develop a more comprehensive understanding of the groundwater basin.

Basin Management Objectives (BMO) were proposed based on feedback from the stakeholders to achieve the goals of the SBGMP. To achieve the goal of maintaining long-term reliable groundwater supplies, the first BMO is to understand the groundwater dynamics of the basin. The SBGMP notes that the complexity of flow within aquifers requires extensive data and detailed modeling to answer development questions. Actions to be pursued to reach this objective include maintaining a consistent long-term monitoring network and identifying areas that are contributing significant natural recharge in the basin.

In order to reach the second BMO (to maintain or enhance groundwater elevations to meet the long-term needs of groundwater users within the Groundwater Management Area) the governing body will (1) investigate and pursue conjunctive use opportunities within the South Basin area, (2) seek and obtain permanent and/or temporary surface water supplies, and (3) identify recharge, and in-stream and off-stream storage sites.

Under the Sustainable Groundwater Management Act (SGMA), OHWD has formed a Groundwater Sustainability Agency for the district's area. The GSA has joined six other GSAs to jointly submit the Cosumnes Subasin's GSP (CSGSP) to CA Dept. of Water Resources by Jan. 2022. The CSGSP identifies similar key technical issues, goals, objectives, and actions as the SBGMP. Considering the draft status of the CSGSP, we've refrained from including specific language of the GSP in this proposal.

The results of your project will inform water resource management actions and decisions by OHWD immediately upon completion of the project tasks that add new data-streams (e.g. electrical conductivity, soil moisture) to the online dashboard. The results of the geophysical surveys, Blodgett dam recharge potential calculations, and source water attribution tasks will inform OHWD upon completion. The final product of our project, an integration of all project results, will be available upon completion of the project.

While project data-streams are not transferrable to other users and locations, the project workflow will provide a blueprint for water resource managers across the West to implement efficient monitoring network and data telemetry systems for new and expanded recharge infrastructure projects.

This project has been developed in close communication between project partners from the start. LLNL as lead institution will ensure that the project beneficiary (OHWD) is continuously involved in planning and implementation of project tasks via monthly project meetings with all participants.

### 1.4.3 Evaluation Criterion C — Project Implementation

#### 1.4.3.1 Approach and Methodology

Our project approach includes multiple distinct components aimed better quantifying the recharge on the on-farm recharge project site and through the Cosumnes riverbed, making that data available in near real-time via a web database and portal, integrating the newly gathered data with existing information into a project report, all in close communication and coordination with project partners, external stakeholders, and the water resources management community in California and the West.

Our project employs several demonstrated scientific methodologies to gather new data and information. Methodologies applied to the on-farm recharge project location include geophysics, monitoring wells installation, installation of online sensors for electrical conductivity and soil moisture, isotopic tracing of water sources. Stream recharge quantification includes installation of additional stream gages and new quantification of recharge potential using field observations and numerical modeling.

Surface-based and down-hole geophysical methods are a potentially fast and cost-effective ways to investigate groundwater aquifer systems and recharge pathways. Two geophysical methods used in groundwater exploration studies are electrical resistivity surveying[19] and down-hole nuclear magnetic resonance[20] (NMR) logging. Electrical resistivity (ER) methods are ideal for using differences in conductivity to identify the elevation of the water table and to determine the location of freshwater-saturated coarse sediment (more resistive) and clay layers (less resistive), and NMR can assess porosity, water content, water content and estimates of permeability in boreholes.

Soil moisture sensors with real-time telemetry (e.g. Meter Group, GS3 sensors[21]) are currently the industry standard. Soil moisture sensors are based on the changing dielectric properties of soil with changing water content. They are crucial to understand water movement in the soil and provide key information to understanding the delayed response of groundwater levels. Real-time telemetry removes the necessity of periodically downloading data from the site and enables the user to be notified of failing sensors.

Source water identification using isotopes is a demonstrated technique applied across California by researchers at LLNL and other institutions. The isotopic ratios of hydrogen ($^{2}H/^{1}H$) and oxygen ($^{18}O/^{16}O$) in water vary predictably in precipitation with elevation and distance inland to orographic and continental rainout processes. As a result, rivers originating at higher elevations have distinct signatures that can be used to distinguish water sources.[10] The oxygen isotopic ratios of local precipitation ($\delta^{18}O$ = -7 ‰) and Cosumnes River water ($\delta^{18}O$ = -9.5 ‰), originating from a mean watershed elevation of 1,000 m, are sufficiently different that mixing ratios can easily be established with a typical measurement precision of 0.2 ‰. Soil cores will be analyzed by Isotope Ratio Infrared Spectroscopy using a Picarro L-2130i instrument using a high sample throughput method developed by co-investigator Oerter,[22] involving equilibration of soil water with dry air in an air-tight sample enclosure for three days.

A MODFLOW groundwater flow model of the lower Cosumnes River and surrounding area was developed by UC Davis researchers with LWA support to investigate impacts of managed aquifer recharge and levee removal on groundwater recharge. The heterogeneous subsurface is populated using Transition Probability Geo-Statistics (TProGS) to reconstruct a realistic subsurface model domain using the probabilities of transitioning from one sediment class to another over fixed distances. This technique was developed at UC Davis[23, 24] and has become the industry standard for flow and transport modeling in a heterogeneous subsurface. This model will be used first to explore effects of Blodgett Dam redesign on groundwater recharge, and then upscaled to better understand recharge in the entire area, and to include a more thorough representation of unsaturated flow and transport in both the saturated and unsaturated zone. The new field observation of water conditions (moisture content, water tension) in the unsaturated zone, of chemical concentrations, and of cropping system status (plant growth, nitrogen uptake, etc.) will be compared to simulated results and used to calibrate the models. Dr. Foglia's group will apply a variety of sensitivity analyses and calibration methods, spanning both local and global techniques. Local gradient-based methods (such as the methods developed in PEST and UCODE [25, 26] will be applied first to develop extensive sensitivity analysis, to provide a preliminary understanding of the importance of the parameters, the amount of information provided by the available observation data and their role in the calibration process, and to evaluate future data needs and data gaps. We plan to use different types of data, related to both water quantity and water quality: the importance of using different types of data for calibration of complex hydrological system models has been largely proven (e.g., Ginn et al., 2009[27], Rasa et al., 2013[28]), but not yet exploited for an experiment similar to the one suggested here. We expect the extensive calibration will yield an increased reliability of the model and of the system set up.

#### 1.4.3.2 Work Plan

Our project plan includes five tasks: Communication and Coordination (A), On-Farm Recharge Monitoring and Modeling (B), River Recharge Monitoring and Modeling (D), Data Infrastructure Development and Maintenance (E), and Data Integration and Reporting (E). The activities for each task are described in detail below and will be executed by project partners according to the quarterly project schedule (Table 2).

<u>Task A: Communication and Coordination</u> includes all communication and coordination between project partners, external stakeholders and the water resources management community. Monthly project meetings will keep all project partners informed of project progress and results. LLNL, LWA, and/or UCD shall represent the partnership at monthly OHWD board meetings to provide updates on project progress. Quarterly meetings will be established to coordinate Groundwater Sustainability Plan development efforts between the South American and Cosumnes subbasins. Meetings will facilitate sharing of data, methodology, and scientific findings to improve understanding of the local hydrology, as well as to ensure GSP compliance.

<u>Task B: On-Farm Recharge Monitoring</u> is aimed at enhancing monitoring of the on-farm recharge project.

We will use combination of electrical resistivity surveying methods at land surface immediately within and adjacent to the recharge sites as well as down-hole NMR in each existing monitoring well. Both methods will lead to an improved understanding of surface geologic heterogeneity and potential coarse-texture recharge pathways. Results would help fill data gaps in the groundwater model and provide additional calibration points for the model in areas with fewer lithologic well data.

We will install additional sensors to monitor electrical conductivity in groundwater wells on the recharge project site. Electrical conductivity is a tracer that, together with the temperature, can provide information on flow velocities and directions. Temperature is currently being collected continuously at two existing wells. The goal is to be able to identify if the water that is being recharged is coming from Deer Creek or from the Cosumnes River.

New soil moisture sensor profiles will be installed near four existing monitoring wells on the Teichert field of the on-farm recharge project. The profile will consist of sensors at 10, 25, 50, and 100 cm depth below the surface. Sensors will be connected to a datalogger with telemetry components that will enable near real-time data transfer to the web database. Power will be derived from existing solar panels and batteries at the monitoring well locations feeding the existing level, temperature, and conductivity sensors. Colocation of soil moisture sensors and monitoring wells will aid the interpretation of near-vertical water flow in the unsaturated zone.

We will sample 4 monitoring and 4 irrigation wells for isotopic analyses before and after the flood season to detect the arrival of river water. We will sample soil profiles (0-3m depth) before and after flooding events for analysis of $^{18}O/^{16}O$ and $^{2}H/^{1}H$ isotopic ratios. Analyses will be performed using the high-throughput membrane inlet laser spectroscopy methods developed by LLNL staff (Oerter).[22] This isotopic data in combination with soil moisture sensor data will enable us to trace the transport of applied water through the unsaturated zone and support the calibration of the unsaturated zone model.

Task C: River Recharge Monitoring and Modeling is aimed at improving the understanding of recharge through the Cosumnes riverbed.

Streamflow measurements on the lower Cosumnes River are limited to a. A new streamflow gage at the location of the on-farm recharge proejct, in addition to the USGS stream gage at Michigan Bar gage provides estimates of stream gains and losses along the river, and provides important validation data for modeling efforts. This stream gages was placed strategically to leverage the existing groundwater network, so that stage data from gages will also be used in conjunction with head data in wells to evaluate the extent, direction, and timing of gaining and losing conditions along the river. We will perform additional rating curve measurements to calibrate the stream gage and integrate the data into the hydrological modeling.

We will explore the potential recharge benefit of the Blodgett Dam under alterative design parameters. We will conduct a detailed survey of the flashboard dam and surrounding streambed to quantify recharge area associated with a water depth using a Trimble SX10 Scanning Total Station with Controller and the Trimble Real Works Advanced (TRW) Software. Field and GIS-based calculations will provide maximum, minimum, and mean water depths upstream of the flashboard dam based on field measurements and corresponding maximum, minimum and mean wetted perimeter based on cross sectional survey or DEM with geospatial software. New estimates of the recharge potential of Blodgett Dam will be calculated based on simulated scenarios of streamflow based on historical data. The model will then be upgraded to simulate the larger recharge area, to include saturated and unsaturated flow, and the transport component.

Task D: Data Infrastructure and Maintenance will enhance the availability of (near) real-time monitoring data from the OHWD recharge projects and wells across the groundwater basins.

We will continue development of the web database that informs OHWD of active sensors at the On-Farm Recharge Project site. The proposed enhancements by Larry Walker Associates will present all the data collected within the area, including precipitation, evapotranspiration, surface water, and all the continuous groundwater monitoring related data to be shared with all or selected groups of stakeholders. Particular effort will be placed on (1) ensuring portability of data collected and stored within the web-database for transfer GSP data management systems (DMSs), and (2) ensuring the privacy of data, where necessary. Improvements on the data portal will be focused on sustainability metrics defined in the groundwater sustainability plan derived from the level measurements.

Additional resources are reserved to maintain monitoring instrumentation that is deployed throughout the South American and Cosumnes subbasins to ensure that collected data are accurate and complete. Expenses include replacement sensors or telemetry components, solar panels or batteries, or other necessary components to maintain a reliable data stream to the Web Database.

Task E: Data Integration and Reporting includes the integration of existing and newly collected data to summarize the project results in a technical report for OHWD and the water resources management community in the West. Task E includes estimated hours for compliance with reporting requirements, including the final financial and performance reports.

### 1.4.3.3 Project Schedule

The task-level project schedule is presented in the table below on a quarterly basis. Work will be performed on tasks A, B, and D continuously throughout the project duration. Milestones and products listed in Table 3 provide more detail on the estimated completion time of sub-tasks. Sampling and isotopic analysis for source attribution is focused on Q1 and Q2 of each project year (indicated by an asterisk in the table below).

**Table 2: Task Level Project Schedule**

| **Task** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Year | 2022 | | | | 2023 | | | |
| Month | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 |
| **A. Communication and Coordination** | | | | | | | | |
| **B. On-Farm Recharge Monitoring and Modeling** | * | * | | | * | * | | |
| **C. River Recharge Monitoring and Modeling** | | | | | | | | |
| **D. Data Infrastructure and Maintenance** | | | | | | | | |
| **E. Data Integration and Reporting** | | | | | | | | |

### 1.4.3.4 Products

The products that our project will deliver (listed in the table below) include geophysical surveys, data-streams, laboratory analyses, recharge calculations, and a final project report.

**Table 3: Project Products**

| Product | Description | Date |
|---|---|---|
| A.1 | Project updates recorded in the OHWD board meeting minutes | Monthly |
| B.1 | Interpretation of geophysical survey of near-subsurface at recharge site | 6/30/2022 |
| B.3 | Data-streams of electrical conductivity | Starting 6/30/2022 |
| B.4 | Data-streams of soil moisture | Starting 3/31/2022 |
| B.5 | Isotopic analysis of groundwater and soil profiles | Annually, January and April |
| C.1 | Online data stream of newly installed stream gages | Starting 9/30/2022 |
| C.2 | Blodgett dam recharge potential quantification | 3/31/2022 |
| D.1 | Enhanced web database | 12/31/2022 |
| D.2 | Live data streams from all sensors | Continuous |
| E.1 | Final Project Report | 12/31/2022 |

#### 1.4.3.5 Staff

Our project team, described below, is capable of proceeding with the proposed project immediately upon entering into a financial assistance agreement.

**Ate Visser, PhD** (*Lawrence Livermore National Laboratory*) is a research scientist in the Environmental Isotope Systems group and an expert in utilizing isotopes to trace the source, recharge mechanism, and travel times of water. He has led multiple sponsored projects for the California and regional Waterboards in collaboration with academic partners and in close communication with stakeholders. He has co-supervised UCD students in his lab at LLNL, co-authoring multiple recent student publications.

**Erik Oerter, PhD** (*Lawrence Livermore National Laboratory*) is a research scientist in the Environmental Isotope Systems group and an expert in stable isotope ratio infrared spectroscopy and developing new hydrological tracer techniques for soil water analysis. He has co-supervised UCD students in his lab at LLNL for the benefit of integrated water resources projects.

**Michael Wackman** *(Omochumne-Hartnell Water District)* is general manager at OHWD and the driving force behind the OHWD recharge projects. He previously initiated a research program in partnership with UC Water to study the interactions between surface water and groundwater in the Cosumnes watershed to identify ways to enhance recharge and is the driving force behind the OHWD on-farm recharge project.

**Prof. Laura Foglia, PhD** *(Larry Walker Associates, University of California – Davis)* is an Adjunct Associate Professor at UC Davis and Associate Engineer with Larry Walker Associates. Her research focuses on understanding integrated groundwater/surface water systems at local and macro-scale. Her emphasis is on model calibration and uncertainty analysis applied to different watersheds and different water management problems, from ecohydrological problems to optimization of conjunctive use of surface water/groundwater. She has been involved in research in the Cosumnes field site since more than five years and she is working with OHWD on the groundwater recharge project.

**Helen Dahlke, PhD** *(University of California – Davis)* is an Associate Professor in Physical Hydrology at the Department of Land, Air and Water Resources. Her main research interest is to improve mechanistic understanding of flow and transport processes in agricultural landscapes in California, studying water and biogeochemical cycles through ground-based measurements, stochastic analysis and numerical modeling to advance our predictive ability and to support planning and resource management decisions.

### 1.4.4 Evaluation Criterion D — Dissemination of Results

Project results will be communicated to project partners via monthly project meetings. LLNL, LWA, and/or UCD shall represent the partnership at monthly OHWD board meetings to provide updates on project progress. Quarterly meetings will be established to coordinate Groundwater Sustainability Plan development efforts between the South American and Cosumnes subbasins. Meetings will facilitate sharing of data, methodology, and scientific findings to improve understanding of the local hydrology, as well as to ensure GSP compliance. Communication and coordination is organized in a dedicated project task.

Project partners commit to participate in at least one Reclamation-sponsored webinar to disseminate deliverables and discuss ways to apply deliverables to management questions. In addition, project partners are actively engaged in the Flood-MAR Network organized by the California Department of Water Resources. We will use this platform to inform the MAR community of the proposed project and keep them up to date with project results. Key results will be presented at informal Lunch-MAR webinars organized by the network.

The final project report, prepared by LLNL will be made publicly available via the Department of Energy Office of Scientific and Technical Information (OSTI, osti.gov). The technical report will include a clear presentation of the project goals, approach, and results to enable water agencies across the Western US to benefit from the expertise, with an emphasis on how the results of the monitoring were incorporated in OHWD recharge decisions.

This project, and its participants, all share the primary goal of better understanding needs and perspectives of stakeholders in order to provide relevant tools and information related to a sustainable water resource in California. This information must be clearly understood by various stakeholder groups to build a collective knowledge base among water resource clientele and to formulate sound policies. Our efforts will integrate field demonstration sites with modeling in order to demonstrate relevant and systems-based outcomes associated with adoption of management practices. In addition, we will actively engage selected practitioners (growers), trainers (UC Cooperative Extension advisors), and decision makers (state agency staff) in the interpretation of results in order to ensure practicality and applicability of the proposed research-based management guidelines.

# 2 Project Budget

## 2.1 Funding Plan and Letters of Funding Commitment

LLNL proposes a total project budget of $400,000. LLNL requests to be reimbursed for $200,000 of the total project costs by the Bureau of Reclamation. Omochumne-Hartnell Water District, a Category A project partner, commits to make $40,000 available to project participants at the time the project has been selected for funding by Bureau of Reclamation. The Moore Foundation supports the project by providing a third-party in-kind contribution of $160,000 for work performed by the University of California – Davis as detailed in the budget narrative.

Letters of Participation and Funding Commitment are attached to this application. OHWD funding will be made available on the condition to perform the work described in the submitted proposal.

## 2.2 Budget Proposal

Table 4 summarizes the total project costs and value of third-party contributions.

**Table 4: Total Project Cost Table**

| SOURCE | AMOUNT |
|---|---|
| Costs to be reimbursed with the requested Federal funding | $ 200,000 |
| Costs to be paid by the applicant | $ 0 |
| Value of third-party contributions | $ 200,000 |
| **TOTAL PROJECT COST** | **$ 400,000** |

The budget breakdown in Salaries and Wages, Fringe Benefits, Supplies and Materials, Contractual, Third-Party In-Kind Contributions, and Indirect Costs are provided in Table 5. The UC Davis In-Kind Contribution Direct Costs provided by the Moore Foundation (denoted with a plus) includes the UC Davis Salaries and Wages and Fringe Benefits (denoted with an asterisk).

**Table 5: Overall Project Budget Proposal**

| BUDGET ITEM DESCRIPTION | COMPUTATION | | Quantity Type | TOTAL COST |
|---|---|---|---|---|
| | $/Unit | Quantity | | |
| **Salaries and Wages** | | | | |
| ***Senior/Key Personnel*** | | | | |
| Ate Visser (LLNL) | | 2.5 | months | $ 28,603 |
| Eric Oerter (LLNL) | | 0.6 | months | $ 6,823 |
| Helen Dahlke (UC Davis)* | $ 132,252 | 0.5 | months | $ 4,595 |
| Laura Foglia (UC Davis)* | $ 78,100 | 0.6 | months | $ 3,392 |
| ***Other Personnel*** | | | ***months*** | |
| Postdoctoral researcher 1 (UC Davis)* | $ 35,466 | 12 | months | $ 35,466 |
| Postdoctoral researcher 2 (UC Davis)* | $ 35,466 | 12 | months | $ 35,466 |
| Postdoctoral researcher 3 (UC Davis)* | $ 35,466 | 12 | months | $ 35,466 |
| **Fringe Benefits** | | | | |
| ***Senior/Key Personnel*** | | | | |

| BUDGET ITEM DESCRIPTION | COMPUTATION | | Quantity Type | TOTAL COST |
|---|---|---|---|---|
| | $/Unit | Quantity | | |
| Ate Visser (LLNL) | | | | $ 17,971 |
| Eric Oerter (LLNL) | | | | $ 4,287 |
| Helen Dahlke (UC Davis)* | | | | $ 446 |
| Laura Foglia (UC Davis)* | | | | $ 1,346 |
| ***Other Personnel*** | | | | |
| Postdoctoral researchers (UC Davis)* | | | | $ 26,047 |
| **Supplies and Materials** | | | | |
| Laboratory Consumables | $3,256 | 1 | assorted | $3,256 |
| **Contractual/Construction** | | | | |
| Larry Walker Associates | $60,000 | 1 | contract | $60,000 |
| **Third-Party In-Kind Contributions** | | | | |
| Moore Foundation (UC Davis)+ | | | | $142,223 |
| Omochumne Hartnell Water District | | | | $40,000 |
| **Travel** | | | | |
| LLNL to OHWD project site | $100 | 8 | trip | $800 |
| **TOTAL DIRECT COSTS** | | | | **$ 303,962** |
| Indirect Costs | | | | |
| Combined LLNL Burdens | 63% | $ 122,826 | | $ 78,261 |
| Combined UC Davis Burdens | 12.5% | $ 142,223 | | $ 17,777 |
| **TOTAL ESTIMATED PROJECT COSTS** | | | | **$400,000** |

## 2.3 Budget Narrative

The total project budget provided above includes all costs estimated to be incurred during the execution of the project tasks described in the project plan. The total project budget components will be discussed in this Budget Narrative at the level of the project tasks. Dr. Ate Visser (LLNL) will serve as project manager. Senior/Key Personnel include Dr. Erik Oerter (LLNL), Prof. Laura Foglia (UC Davis) and Prof. Helen Dahlke (UC Davis). Three postdocs at UC Davis will contribute to this project. Additional staff from Larry Walker Associates working on this project under subcontract is listed under the Contractual section of the budget narrative.

### 2.3.1 Salaries and Wages

Table 6 provides the salaries and wages, estimated effort (months), and base salary (annual) for all personnel. Salary rates are equal for all tasks. Table below provides the breakdown of the estimated project effort to the task level for senior/key personnel and other personnel.

**Table 6: Task Level Effort Breakdown**

| Task | A | B | C | D | E |
|---|---|---|---|---|---|
| ***Senior/Key Personnel*** | | | | | |
| Ate Visser (LLNL) | 0.3 | 1.2 | - | - | 0.9 |
| Eric Oerter (LLNL) | - | 0.6 | - | - | - |
| Helen Dahlke (UC Davis) | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 |
| Laura Foglia (UC Davis) | 0.3 | 0.1 | - | 0.1 | 0.1 |

| Task | A | B | C | D | E |
|---|---|---|---|---|---|
| ***Other Personnel*** | | | | | |
| Postdoc 1 | 1 | 11 | - | - | - |
| Postdoc 2 | 1 | - | 11 | - | - |
| Postdoc 3 | 1 | - | - | 6 | 5 |

Visser will devote 0.3 months to Task A for 24 monthly meetings during the two years of the project and additional hours for ad hoc meetings with stakeholders or externally interested parties. Visser will devote 1.2 months to Task B for laboratory analysis of well samples and data interpretation. Visser will devote 0.1 months to Task D for the to guide the development of the Stakeholder Data Dashboard. Visser will devote 0.9 months to Task E for integrating and analyzing new and existing data streams and leading the writing of the final technical project report. This includes 0.3 months for compliance with reporting requirements, including the final financial and performance reports.

Oerter will devote 0.6 months to Task B for the analysis and interpretation of soil isotope profiles in conjunction with other data sources.

Dahlke will devote 0.1 months to Task A for ad hoc meetings with project participants and stakeholders. Dahlke will devote 0.1 months to Task B to guide the modeling of the on-farm recharge. Dahlke will devote 0.1 months to Task C to guid modeling and analysis of the potential recharge benefit of the Blodgett Dam. Dahlke will devote 0.2 months to Task E for integrating and writing of the final technical project report.

Foglia will devote 0.3 months to Task A for 24 monthly meetings during the two years of the project and additional hours for ad hoc meetings with stakeholders or externally interested parties. Foglia will devote 0.1 months to Task B for the interpretation of geophysics, guidance on soil moisture sensor installation, and other monitoring activities. Foglia will devote 0.1 months to Task D for the to guide the development of the Stakeholder Data Dashboard. Foglia will devote 0.1 months to Task E for integrating and writing of the final technical project report.

Postdoctoral researcher 1 will devote 1 month to Task A for monthly meetings, coordinating communications between project participants and stakeholders. Postdoctoral researcher 1 will devote 11 months to Task B for modeling the unsaturated zone at the on-farm recharge site and integrating results with observations.

Postdoctoral researcher 2 will devote 1 month to Task A for monthly meetings, coordinating communications between project participants and stakeholders. Postdoctoral researcher 2 will devote 11 months to Task C for simulating scenarios of streamflow based on historical data to calculate new estimates of the recharge potential of Blodgett Dam.

Postdoctoral researcher 3 will devote 1 month to Task A for monthly meetings, coordinating communications between project participants and stakeholders. Postdoctoral researcher 2 will devote 6 months to Task D to integrate model results with the Stakeholder Data Dashboard to provide stakeholders will actionable information. Postdoctoral researcher 3 will devote 5 months to Task E for writing modeling and data results chapters of the final technical project report.

### 2.3.2 Fringe Benefits

**Payroll Burden** costs are incurred for employee fringe benefits.  Includes accrued vacation cost, sick leave and holidays taken, court and miscellaneous leave with pay, employer retirement contributions (pension and 401K), employer health plan contributions, Medicare, Social Security, workman's compensation insurance, unemployment insurance, and Variable Compensation Plan (VCP), which includes Strategic Performance Bonus (SPB) and Individual Performance Bonus

### 2.3.3 Travel

The budget includes $800 for travel from LLNL to the on-farm recharge site, based on a 90-mile one-way distance and the federal privately owned vehicle mileage reimbursement rate (0.56 $/mile).

### 2.3.4 Equipment

No equipment will be purchased for this project.

### 2.3.5 Materials and Supplies

The budget includes $3,256 for laboratory supplies at LLNL. The materials that will be purchased are not attractive, capital or controlled. Materials include laboratory consumables (mylar bags, needles, gaskets, etc.). Procurements can include ad-hoc procurement of materials needed for repairs of analytical instruments (e.g., filaments, gages). The estimated cost of materials and supplies is based on incurred costs for projects with similar number of analyses.

### 2.3.6 Contractual

Larry Walker Associates will be contracted to perform several tasks of this project. The total value of the contracted work is estimated at $100,000, based on the following task-level breakdown.

LWA will be tasked with installing soil moisture sensor profiles with four sensors at four locations near the existing monitoring wells. The cost estimate for this task is $30,000. LWA will procure 16 soil moisture sensors (Meter Group, GS3) with supporting materials (estimated $1,400 each) and spend 40 hours to install by LWA staff ($191/hr, $7,640 total).

LWA will be tasked with installing new electrical conductivity and temperature loggers in four monitoring wells. The cost estimate of this task is $5,000. LWA will procure 4 DTS loggers with supporting materials (estimated $295 each) and spend 20 hours to install ($191/hr, $3,820 total).

LWA will be tasked with incorporating new data streams into the Stakeholder Data Dashboard and improving the user interface. The cost estimate for this task is $50,000, based on 262 hours of technician time ($191/hr).

LWA will be tasked with contributing to the final report in close communication with project stakeholders and other groundwater sustainability agencies in the region. The cost estimate for this task is $15,000, based on 55 hours of effort by associate staff.

### 2.3.7 Third-Party In-Kind Contributions

A Third-Party In-Kind Contribution of $160,000 by the Moore Foundation consists of work performed by UC Davis. The Third-Party In-Kind Contribution breakdown in Salaries and Wages, Fringe Benefits, Supplies and Materials, and Indirect Costs is provided in Table 7.

**Table 7: Third-Party In-Kind Contribution Cost Details**

| BUDGET ITEM DESCRIPTION | COMPUTATION | | Quantity Type | TOTAL COST |
|---|---|---|---|---|
| | $/Unit | Quantity | | |
| **Salaries and Wages** | | | | |
| ***Senior/Key Personnel*** | | | | |
| Helen Dahlke (UC Davis) | $ 132,252 | 0.5 | months | $ 4,595 |

| BUDGET ITEM DESCRIPTION | COMPUTATION | | Quantity Type | TOTAL COST |
|---|---|---|---|---|
| | $/Unit | Quantity | | |
| Laura Foglia (UC Davis) | $ 78,100 | 0.6 | months | $ 3,392 |
| ***Other Personnel*** | | | ***months*** | |
| Postdoctoral researcher 1 | $ 35,466 | 12 | months | $ 35,466 |
| Postdoctoral researcher 2 | $ 35,466 | 12 | months | $ 35,466 |
| Postdoctoral researcher 3 | $ 35,466 | 12 | months | $ 35,466 |
| **Fringe Benefits** | | | | |
| ***Senior/Key Personnel*** | | | | |
| Helen Dahlke (UC Davis) | | | | $ 446 |
| Laura Foglia (UC Davis) | | | | $ 1,346 |
| ***Other Personnel*** | | | | |
| Postdoctoral researchers (UC Davis) | | | | $ 26,047 |
| **Contractual** | | | | |
| Larry Walker Associates (OHWD) | | | | $ 40,000 |
| **TOTAL DIRECT COSTS** | | | | **$182,223** |
| Indirect Costs | | | | |
| Combined UC Davis Burdens | 12.5% | $ 142,223 | | $ 17,777 |
| **TOTAL IN-KIND CONTRIBUTION** | | | | **$ 200,000** |

Table 7 provides the salaries and wages, estimated effort (months), and base salary (annual) for the Moore Foundation in-kind contribution of personnel. Salary rates are equal for all tasks. The breakdown of the estimated project effort to the task level for UC Davis senior/key personnel and other personnel was provided in Table 6.

### 2.3.8 Description of LLNL Burdens

#### 2.3.8.1 General and Administrative Costs:

**General & Administrative (G&A)** costs are incurred for the general management and administration of the Laboratory as a whole such as Executive Management, CFO (Budget, Finance, Accounting, and Matrixed Financial Services), Internal Audit & Ethics, Legal, Prime Contract Management Office, and Procurement. Other G&A activities include external relations & communications, staff relations, human resources, integrated performance and pay administration/workforce management (non-programmatic), LDRD Program Office administration, outreach (pipeline and education including STEM educational programs, teacher development, and university relations), Special Employees activities (limited to individuals classified as Post Doc who may charge some of their effort in support of general institutional activities), and technical activities in accordance with the Statement of Policy on Technical Activities.

#### 2.3.8.2 Overhead Costs:

**Program Management Charge (PMC) – PAD** costs are incurred for managing and administering programs within a Principal Directorate. There are six program PMCs.

**Computations (COMP):** includes COMP program management and technical activities (i.e. sponsor engagement)

**Engineering (ENG):** includes ENG program management and technical activities (i.e. sponsor engagement)

**Global Security (GS):** includes GS program management, program development, PAD office operations, and technical activities (i.e. sponsor engagement)

**National Ignition Facility (NIF):** includes NIF program management, program development, PAD office operations, and technical activities (i.e. sponsor engagement)

**Physical and Life Sciences (PLS):** includes PLS program management and technical activities (i.e. sponsor engagement)

**Weapons and Complex Integration (WCI):** includes WCI program management, program development, PAD office operations, and technical activities (i.e. sponsor engagement)

**Institutional Strategic Support** costs are incurred for technical activities, including sponsor engagement, and program development associated with supporting LLNL initiatives and priorities that are multi programmatic and having cross directorate benefit; strategic studies and analyses related to LLNL missions or in support of decisions to be made by executive and national leadership; maintaining a knowledgeable workforce on emerging national security issues; liaison with NNSA, DOD, and other sponsors in the nuclear security arena; institutional investments that provide capability sustainment to develop and maintain the intellectual base that have lab wide or cross directorate benefit; and investments in LLNL's core competencies and mission challenges that benefit multiple customers. Other activities include offsite institutional assignments and oversight.

A core competency is an area of special capability or signature expertise in which LLNL is a recognized national leader and is viewed as critical to maintain for the foreseeable future because of the Laboratory's enduring mission responsibilities. Core competencies include: bioscience and bioengineering; earth and atmospheric science; high-energy-density science; high-performance computing, simulation, and data science; lasers and optical science and technology; advanced materials and manufacturing; nuclear, chemical, and isotopic science and technology.

Mission challenge areas address urgent national security needs for which LLNL has special S&T strengths to pursue innovative ideas for breakthroughs that will make a difference. Mission challenge areas include: nuclear weapons science; high explosive physics, chemistry and materials science; nuclear threat reduction; chemical and biological countermeasures; directed energy; forensic science; space security; cybersecurity and cyber-physical resilience; Quantum Science & Technology; and energy and resource security.

**Site Support** costs are necessary for the management, maintenance, and upgrades of the general purpose facilities and property, and for the provision of basic infrastructure services and safety on site. Activities include, but are not limited to, computer support, networks, telecommunications, information technology management and services, health services, environmental protection, hazards control, site emergency preparedness, facilities management, facilities maintenance, roads and grounds maintenance, fire protection services, environmental safety & health compliance, shipping, receiving, mail services, taxi services, and print & digital media (P&DM provides site wide supported copy services). The pool also includes technical activities (i.e. general purpose laboratory/institutional scientific infrastructure), indirect funded capital equipment (e.g. Institutional General Purpose Equipment (IGPE)), and indirect funded minor construction projects that benefit multiple programs or are institutional in nature. Infrastructure activities that are in support of multiple programs and are not direct funded, are charged to the indirect site support pool. Infrastructure activities that are in support of a single direct program are charged directly to that program. Infrastructure activities that are in support of multiple programs identified as a high mission risk by a sponsor, may be direct funded by that sponsor and charged direct. Infrastructure activities meeting the line item threshold are required to be funded as a Congressional line item and charged direct. On-site security activities are charged direct to DOE and are not included in the pool.

#### 2.3.8.3 Other:

**Laboratory Directed Research and Development (LDRD)** is an assessment annually approved by the Department of Energy (DOE) that funds research and development work selected by the Laboratory's Director or designee.

**Safeguards and Security Charge (S&S) rate** is utilized as a mechanism to offset LLNL direct funded S&S, Cyber Security (CS), and Hazardous Waste Charge (HWC) costs. Each of the 3 direct funded efforts calculate their contribution to the consolidated S&S pool by their respective ratio of non-DOE Strategic Partnership Projects (SPP) labor costs divided by total direct labor and LDRD labor costs multiplied by their applicable direct funded base. The S&S costs are in accordance with NNSA's guidance on the recovery of S&S costs from SPP customers and consistent with the FY10 Energy and Water Appropriations ACT and the CS costs are in accordance with NNSA's November 15, 2013 guidance on the recovery of Cyber Security costs. Direct security activities applicable to non-DOE SPP include security and protection, protective forces, physical and technical security, information security, personnel security, and security program operations and planning. Direct security activities not applicable to SPP include nuclear materials control and accountability. Direct cyber security activities applicable to SPP include access control, risk management, threat definition, maintenance, network defense, contingency planning, and incident response. Direct security activities not applicable to non-DOE SPP include classified network operations, classified federal telecommunication system, and secure fax equipment.

**Management Fee** is paid to LLNS, LLC for oversight and management of the Laboratory. There are two Management Fee rates:

**DOE/NNSA fee** rate is applied to DOE/Integrated Contractor/NNSA costs, except for where fee is specifically excluded by contract. Maximum available fee is established in the contract and consists of a fixed and performance incentive portion. The fee rate will be allocated to the total cost base of DOE/NNSA work effort, excluding Laboratory Directed Research and Development (LDRD), projects funded by Residual Net Licensing income (royalties), Task Assignment Statements (TAS), the DOE equivalent to IPA assignments), ASC and Russian pass through procurements, and Integrated Contractor Order (ICO) procurements.

**Reimbursable Work fee** rate is applied to non-DOE reimbursable work costs, including DOD, DHS, and CRADAs. LLNL's senior management can waive fee from non-DOE reimbursable work at their discretion. Maximum available fee is established by NNSA based on estimated SPP volume prior to the commencement of each fiscal year. Non-DOE Fee will be allocated to the total cost base of non-DOE reimbursable work effort. Non-DOE Fee will not be applied to work for which fee has been waived by LLNL senior management, or IPAs.

**DOE Federal Administrative Charge (FAC)** represents an allocation of DOE's depreciation and administrative costs (according to full cost recovery provisions outlined in the DOE Order 522.1 – Pricing of Departmental Materials and Services) to non-DOE funded projects. FAC is allocated on total costs, including all overhead costs and G&A. FAC is applied to non-DOE funded projects unless an exemption applies. DOE supplies the FAC rate.

# 3 Environmental and cultural resources compliance (as applicable to the project)

- The proposed project will impact the surrounding environment (i.e., soil). Agricultural soil will be disturbed for the installation of soil moisture sensors. Given the agricultural nature of the soil, the impact will be minimal.
- The applicant is not 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.
- No wetlands or other surface waters exist inside the project boundaries that potentially fall under CWA jurisdiction as "Waters of the United States.".
- The date of the original construction of the water delivery system is unknown. New pumps have been installed in 2018.
- The proposed project will not result in any modification of or effects to, individual features of an irrigation system (e.g., headgates, canals, or flumes).
- No buildings, structures, or features in the irrigation district are listed or eligible for listing on the National Register of Historic Places
- No known archeological sites are in the proposed project area.
- The proposed project will not have a disproportionately high and adverse effect on low income or minority populations.
- The proposed project will not limit access to and ceremonial use of Indian sacred sites or result in other impacts on tribal lands.
- The proposed project will not contribute to the introduction, continued existence, or spread of noxious weeds or non-native invasive species known to occur in the area.

# 4 Required permits or approvals

Permits or approvals are not required for the tasks proposed for this project.

# 5 Letters of support for the project and letters of participation

Letters of participation, funding commitment, support, and third-party in-kind contributions are attached as Appendices at the end of the proposal.

Appendix 1: Letter of Participation and Funding Commitment from OHWD

Appendix 2: Letter of Support and Third-Party In-Kind Contribution from the Moore Foundation

# 6 Official resolution

The official resolution will be submitted to SHA-DRO-FAFOA@usbr.gov within 30 days after the application deadline.

# 7 Unique Entity Identifier and System for Award Management

SAM registration will be completed within 30 days after the application deadline.

# 8 References


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# 9 Appendices

Appendix 1: Letter of Participation and Funding Commitment from OHWD

Appendix 2: Letter of Support and Third-Party In-Kind Contribution from the Moore Foundation

Appendix 1: Letter of Participation and Funding Commitment from OHWD

*Omochumne Hartnell Water District*

**O H W D**

*Kurt A Kautz*
*CHAIRMAN*

*Mark Stetars*
*VICE CHAIRMAN*

*Mark Wilson*
*TREASURE*

*Ken Mitchell*
*DIRECTOR*

*Paul Hensleigh*
*DIRECTOR*

*Michael Wackman*
*GENERAL MANAGER*

*Shasta Burns*
*BOARD SECRETARY*

Bureau of Reclamation
Financial Assistance Support Section
Attn: Applied Science NOFO
P.O. Box 25007, MS 84-27133
Denver, CO 80225

April 21, 2021

Subject: Letter of Project Participation and Funding

Dear Sir/Madam,

With this letter, Omochumne-Hartnell Water District (OHWD, a Category A entity) agrees to the submittal and content of the proposal prepared by Lawrence Livermore National Laboratory (LLNL, a Category B applicant) to the "WaterSMART: Applied Science Grants" funding opportunity (R21AS00289) with the title "Improved Recharge Monitoring for Enhanced Conjunctive Management of Ground and Surface Water". OHWD is a water district located in Sacramento County, California, and as such, a category A entity as defined in section C.1 of the Notice of Funding Opportunity.

OHWD will provide non-federal cost-share for this project in the amount of $40,000. The funds are currently available to OHWD and do not depend on pending funding requests. OHWD will coordinate the project activities closely with the lead applicant (LLNL) and other project participants and subcontractors (University of California – Davis; Larry Walker Associates). Project coordination shall take place during monthly project meetings with representatives of all participating organizations. LLNL, UCD, or LWA shall be welcome to present project progress and results at OHWD monthly board meetings which are open to the public.

Technical activities coordinated between OHWD and the project partners include the location and depth of new soil moisture sensors, the presentation of new data-streams on the enhanced water information dashboard, and the interpretation of project results in terms of water resource management objectives of OHWD and the groundwater sustainability plans relevant to the OHWD management area. The on-farm recharge project led by OHWD and monitored within this project is one particular area of coordination between OHWD and project partners. OHWD will timely inform LLNL,

*Phone: 916-682-5958*
*Street Address: 8970 Elk Grove Blvd, Elk Grove, CA 95624*
*Mailing Address: P.O. Box 211, Wilton, CA 95693-0211*
*Email:info@ohwd.org*

LWA, and UCD of planned water diversions from the Cosumnes River for groundwater recharge, to enable adequate pre-event sampling and preparation.

Thank you,

Mike Wackman

General Manager

*Phone: 916-682-5958*
*Street Address: 8970 Elk Grove Blvd, Elk Grove, CA 95624*
*Mailing Address: P.O. Box 211, Wilton, CA 95693-0211*
*Email:info@ohwd.org*

Appendix 2: Letter of Support and Third-Party In-Kind Contribution from the Moore Foundation

GORDON AND BETTY MOORE FOUNDATION

1661 Page Mill Road
Palo Alto, CA 94304
650.213.3000
moore.org

To: Bureau of Reclamation – WaterSMART Applied Science Program

RE: Commitment of cost-sharing support to the project proposal, "Improved Recharge Monitoring for Enhanced Conjunctive Management of Ground and Surface Water"

I am pleased to support the WaterSMART proposal titled "Improved Recharge Monitoring for Enhanced Conjunctive Management of Ground and Surface Water" that is being proposed by Lawrence Livermore National Laboratory and the University of California, Davis in collaboration with Omochumne-Hartnell Water District (OHWD).

The proposed project aims to improve monitoring of infiltration and groundwater recharge and provide real-time data accessibility to inform OHWD water management decisions. Specifically, this project will develop a numerical flow model to simulate unsaturated and saturated conditions in the recharge fields, collect geophysical and isotopic data for improved estimation of recharge potential, and incorporate field collected well and vadose zone sensor data into an online dashboard for data sharing with stakeholders.

The Gordon and Betty Moore Foundation will support the project over the 2021-2022 period by providing an in-kind contribution of $160,000 to the project from an active grant titled "Developing science-based approaches to managed agricultural groundwater recharge in California's Central Valley" for which Dr. Helen Dahlke is the lead PI.

We believe the proposed research is a great opportunity to further the adoption of conjunctive use practices such as on-farm groundwater recharge for improved management of groundwater resources in California. We hope that the WaterSMART program will support this proposal.

Sincerely,

Dusan Pejakovic, PhD
Program Director, Science
dusan.pejakovic@moore.org
650-213-3065

**Attachment to the SF-424, Section 16, Congressional Districts**

| City | County | State | Congressional District |
|---|---|---|---|
| Livermore | Alameda | CA | CA-015 |
| Wilton | Sacramento | CA | CA-007 |
| Davis | Yolo | CA | CA-003 |