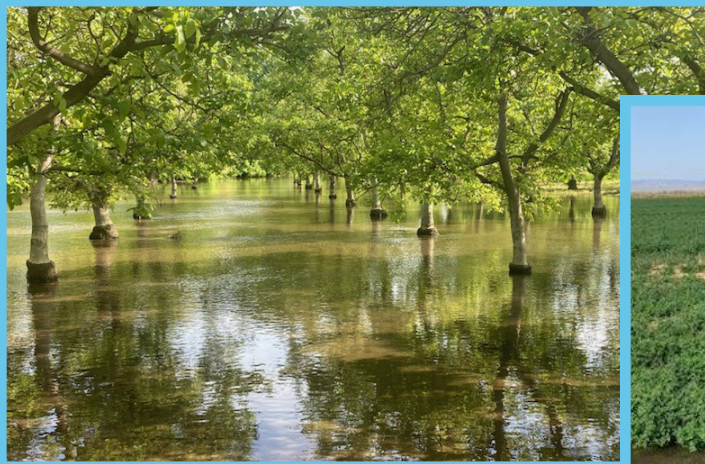


ON-FARM RECHARGE METHODS MANUAL

A Summary of Strategies and Challenges



PREPARED BY SUSTAINABLE CONSERVATION
FUNDED BY THE DEPARTMENT OF WATER RESOURCES

SEPTEMBER 2026

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1. INTRODUCTION

Under the Sustainable Groundwater Management Act (SGMA), groundwater sustainability agencies (GSAs) have been charged with developing and implementing groundwater sustainability plans (GSPs) that guide how to meet their subbasin's sustainability goals.

On-farm recharge is one of several key tools identified in GSPs to improve groundwater sustainability by applying excess surface water on farm fields to recharge aquifers. Successful GSP implementation will depend on the leadership of GSAs and the participation of numerous growers to use high flows for aquifer recharge in wet years.

This document gathers observed results and lessons learned from over a decade of Sustainable Conservation working directly with growers and irrigation districts to implement on-farm recharge. There are a limited number of scientific research studies documenting the potential and challenges of on-farm recharge. This report summarizes what is known from in-field practice while more extensive scientific studies can be completed. Its purpose is to provide practical information about on-farm recharge from growers to growers. The intended audiences are growers interested in on-farm recharge, as well as technical assistance providers such as resource conservation districts, crop advisors, and non-profit organizations.

2. WHY CONDUCT ON-FARM RECHARGE?

There are numerous potential benefits associated with on-farm recharge:

Improve Groundwater Sustainability

High surface water flows can create opportunities for recharging the root zone and the local groundwater basin, which can raise groundwater levels and reduce pumping costs. On-farm recharge can be strategically located to help protect or improve the quality of local drinking water supplies in communities that are dependent on groundwater.

Reduce Flood Risk

The planned diversion of stormwater onto fields can reduce flood risk in nearby areas. If recharge is planned on a large scale, there may be opportunities to reduce flood risk at a regional level.

Support Groundwater-Dependent Habitat

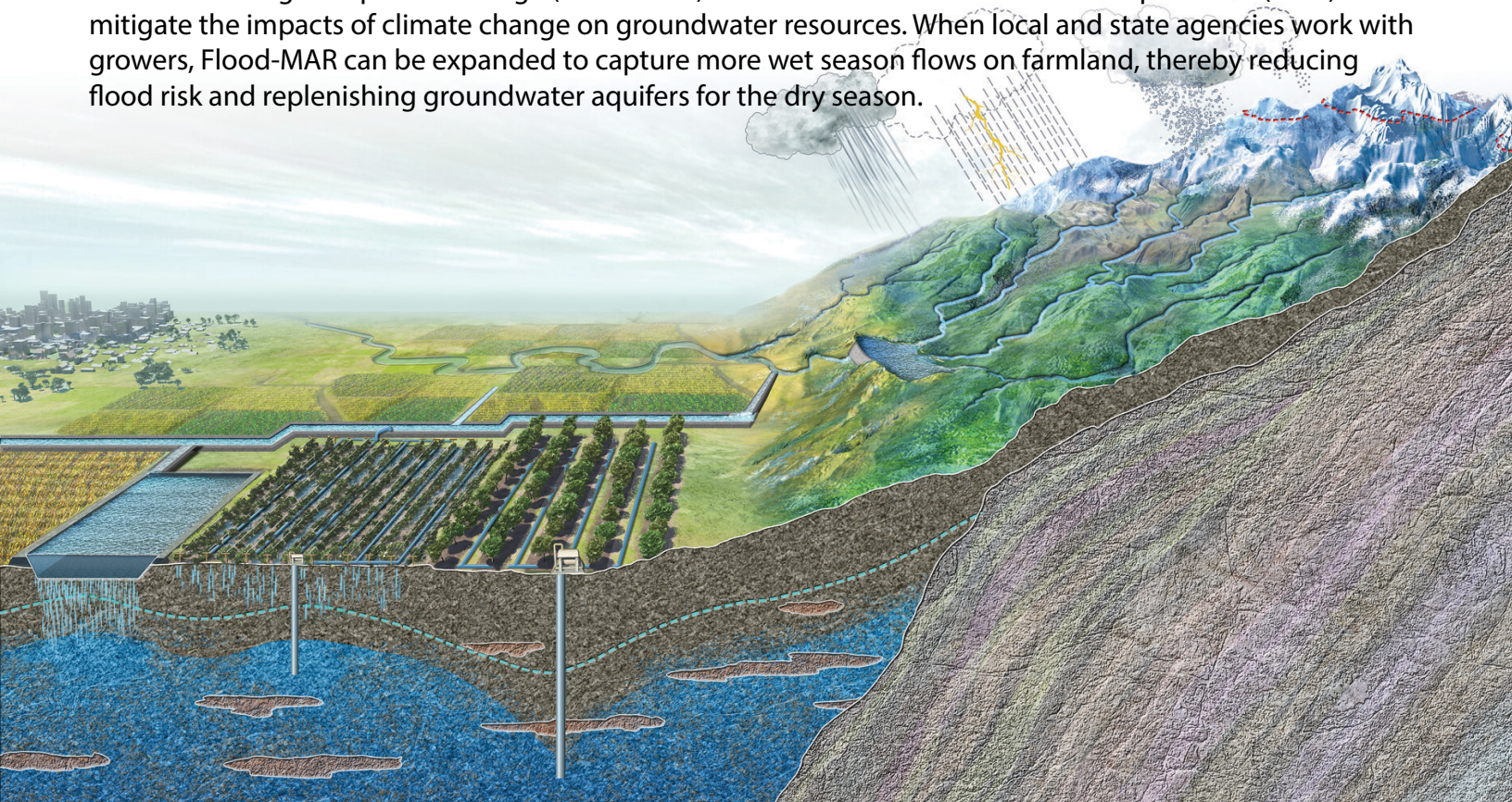
On-farm recharge in specific locations can help to support ecosystems that rely on groundwater, by raising groundwater levels and by contributing to base flows in streams over time.

Sustain a Farming Economy and Preserve Working Lands

Recharging groundwater when surface water supplies are available can help the farming community adapt to a changing climate that includes increasing frequency and severity of floods and drought.

It is important to note that on-farm recharge alone will not address all groundwater overdraft challenges facing many California basins and subbasins. In many areas, pumping curtailment and land repurposing will be needed to achieve sustainable groundwater management and secure the future of farming and the communities it supports.

The [San Joaquin Basin Flood-MAR Watershed Studies](#) released by DWR in 2025 evaluated the opportunity for Flood-Managed Aquifer Recharge (Flood-MAR) and Forecast-Informed Reservoir Operations (FIRO) to mitigate the impacts of climate change on groundwater resources. When local and state agencies work with growers, Flood-MAR can be expanded to capture more wet season flows on farmland, thereby reducing flood risk and replenishing groundwater aquifers for the dry season.





3. PREPARING FOR ON-FARM RECHARGE

Evaluate Local/Regional Recharge Opportunities

Groundwater sustainability agencies are composed of one or more local public agencies (e.g., irrigation districts, county governments) that are responsible for water supply, water management, or land use decisions within a groundwater basin. GSAs develop and implement groundwater sustainability plans to manage groundwater in a basin, using either a single GSP or multiple, coordinated GSPs.

The Sustainable Groundwater Management Act (SGMA) requires GSAs to consider the interests of all beneficial uses and users of groundwater and to encourage the active involvement of diverse social, cultural, and economic segments of the population within the groundwater basin prior to and during the development and implementation of the GSP.

The GSAs set the stage for local and regional recharge projects and programs through development of projects and management actions in their GSP(s). Landowner participation in these efforts may be self-directed engagement with their GSA or water provider, participation in agency-led public meetings or committees, or submitting formal letters of interest.

Does the district or GSA have (or intend to have) a recharge program?

YES	NO
How does a grower participate in the program? What are the conditions to participate? What incentives, funding, credits, or other assistance are available to support growers participating in on-farm recharge? (See Section 8: Financial Aspects of On-Farm Recharge) How does the program plan to measure recharge at the farm level and at a district/sub-basin scale? Is the program willing to invest in more infrastructure to support on-farm recharge?	What would it take to start an on-farm recharge program? How can growers support on-farm recharge programs?

Does the district or GSA have water rights to provide water for recharge?

YES	NO
What is the predicted volume, timing, and place of use for available recharge water? Does the district manage water when there is a local threat of flood conditions? Are there any water quality issues (site-specific or regional) that growers need to be aware of before implementing on-farm recharge? (See Water Quality section below)	Does the district or GSA plan to pursue new or modified water rights or assist growers with this process?

Water Rights

In any recharge project or program, the first order of business is to understand water rights.

For growers within water districts, the easiest path forward is to work within the local district's existing water rights and authorities to divert surface water for recharge purposes. Existing water rights may need to be modified for purpose or place of use to accommodate district- or GSA-scale recharge programs. New temporary or permanent water rights may be needed for diversions outside of the irrigation season (i.e., winter) to maximize use of high flows for groundwater recharge. A streamlined water rights process is available for GSAs or local agencies pursuing permanent and temporary water rights for diverting high winter flows for recharge. The process can be accessed at the State Water Board's [Permits for Groundwater Recharge website](#).

Growers not served by a water district and fully dependent on groundwater may be able to work with a local district or neighboring water right holder to deliver water for either direct or in-lieu recharge (i.e., using surface water for irrigation in lieu of groundwater). Existing water right conditions set the timing and location of where a district or water right holder can divert and deliver water for irrigation or recharge. Growers outside of districts could apply for temporary or permanent water rights to surface water for recharge on their own or working with other growers; however, due to the intense and expensive application process, it is more likely that water rights would be pursued by a local water agency.

Site Suitability

Conveyance and Infrastructure

Adequate surface water conveyance to the parcel or field is critical for on-farm recharge. Typical turnouts from canals and ditches and pipeline capacities range from 3 to 15 cubic feet per second (cfs). Floodwater may be available for short time periods and rich in suspended sediments, so properties with flood irrigation infrastructure are better suited for on-farm recharge using floodwaters than those exclusively

using micro-sprinkler and drip irrigation. The rate of flow, size of field, and soil infiltration rate will help determine the area to be targeted for recharge because it may not always be possible or practical to flood the entire field at the same time.

If a field is not currently served by surface water, additional investment in permanent or temporary infrastructure would be required, some of which may be subsidized by local, state, or federal funding (see **Section 8: Financial Aspects of Recharge**).



A Note on Flood Conditions and Flood Emergencies

Local and state leadership recognize the need to simplify water rights permitting for using high flows to maximize recharge during threat of flood conditions. In March 2023, the governor issued an executive order (EO) that allowed floodwater resulting from winter storms to be diverted for recharge outside of the water rights process when certain conditions were met.

This EO represented a shift in how floodwater is managed for groundwater recharge in California. Subsequently in July 2023, Senate Bill 122 - based on the EO - was approved and codified as Water Code §1242.1, which allows diversion of floodflows for groundwater recharge without a water right when flood conditions are present and a local flood management agency makes a public notification. There are limitations on when, where, and how floodflows can be diverted to reduce impacts on groundwater quality and local ecosystems, and diversions must be reported to the State Water Board. Because there is no water right associated with these flood diversions, rechargers do not have the right to extract the water later, but recharged water may be allocated through local GSA processes. For more information, visit the State Water Board's [Flood Recharge Diversion](#) page.



Soil and Geologic Suitability

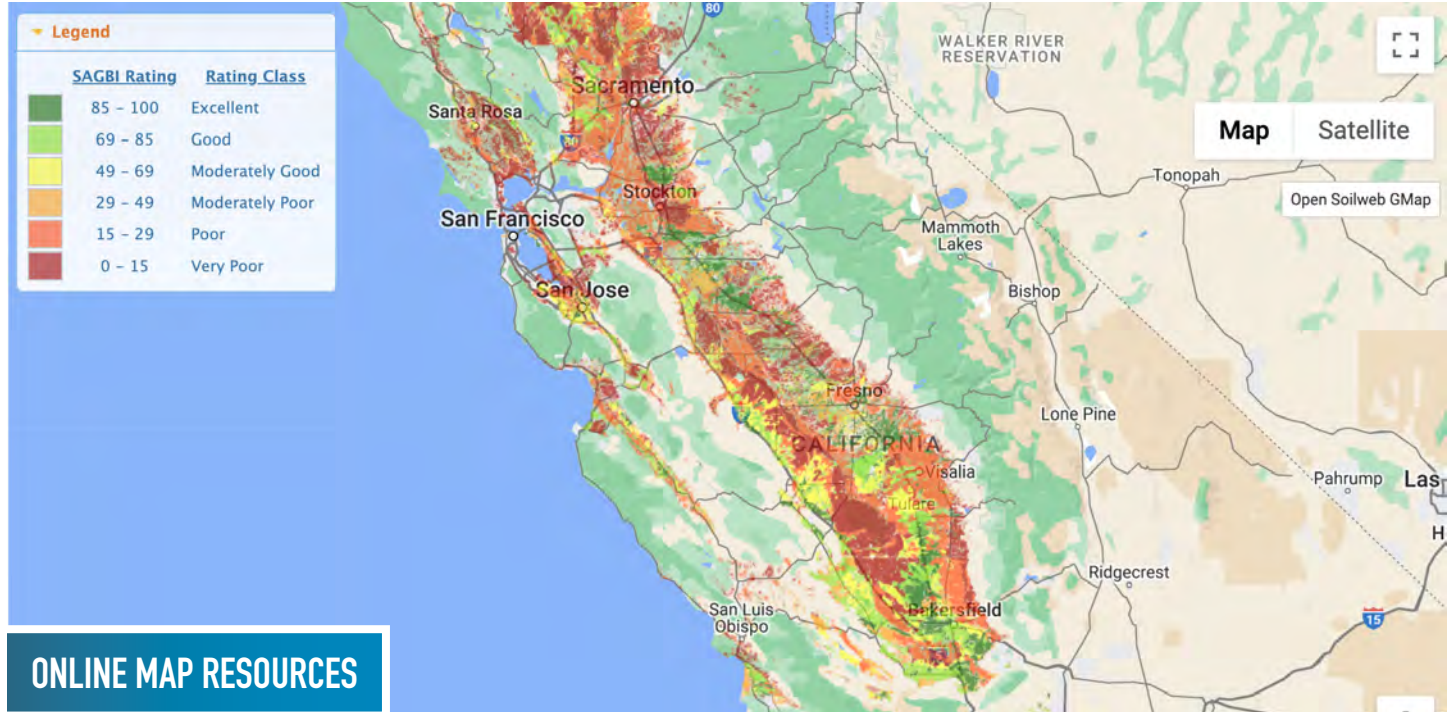
Understanding the underlying hydrogeology below the root zone is key to anticipating the flow and ultimate effect of recharge on local groundwater conditions. The movement of water through soil is complex and highly localized. Recharged water will generally find preferential pathways to the aquifer instead of infiltrating uniformly across the field. Sites with sandy streaks or coarse soils tend to be the best suited for on-farm recharge because of high water infiltration rates. High infiltration rates are most desirable for a recharge field as soil does not remain saturated for long and field inundation is less likely to cause harm to permanent crops.

Understanding Hydrogeology

The vadose zone is the unsaturated layer of soil between the root zone and the water table. It is an important factor controlling water movement from the land surface to the aquifer and strongly affects the rate of infiltration. Sandy loam, loamy sand, and sand textures are generally preferred for planned recharge activities because of potential for higher infiltration and percolation rates as compared to heavier silt and clay soil types.

There are numerous clay and silt layers that affect the speed and flow direction of groundwater. Most notably, a geologic feature called the Corcoran Clay, which is a remnant of an ancient lakebed that extends 4,000 square miles, covers most of the lower San Joaquin Valley (see figure below). This largely impermeable layer ranges from 50 to 120 feet thick and varies from 50 to 800 feet beneath the ground surface. When planning recharge in areas over Corcoran Clay, it is important to understand that recharged water will only affect the aquifer above the clay layer, unless there are perforations in the clay. In other words, wells that pull water from below the clay layer will not benefit from on-farm recharge that may be occurring right next to the wellhead.





ONLINE MAP RESOURCES

Online map resources to determine site suitability

Sites where water has a difficult time moving into the soil or runs into a hardpan layer as it percolates will be of limited use for replenishing aquifers. To identify sites with the best conditions for recharge, researchers at the University of California at Davis created the [Soil Agricultural Groundwater Banking Index \(SAGBI\)](#). SAGBI is a suitability index for groundwater recharge on agricultural land, which rates soil types on five major factors that are critical to successful recharge on crop land: deep percolation to 5 feet, root zone residence time, topography, chemical limitations, and soil surface conditions. SAGBI classifies soils into six major categories ranging from Excellent to Very Poor based on suitability for recharge. Note that the SAGBI classifications are useful at a regional scale but may not reflect on-the-ground knowledge of site conditions nor reflect recent land management practices that could have an influence on percolation potential. For example, a recently levelled field that has been deep-ripped may be more suitable for recharge than is reflected in the SAGBI rankings.

Land IQ, a California-based company that specializes in earth sciences, developed a [Groundwater Recharge Suitability Index \(RSI\)](#), an online resource that provides growers with another look at site recharge suitability by evaluating SAGBI along with the depth to groundwater and depth to the Corcoran Clay layer. The Land IQ RSI was calculated for the entire Central Valley and the ratings mirror the SAGBI categories of Excellent, Good, Moderately Good, Moderately Poor and Poor for recharge.

The [SGMA Data Viewer](#) hosts a broad collection of datasets that relate to groundwater and its management in California. SAGBI, AEM survey data, and other evaluation methods for recharge suitability (Aquifer Recharge Potential (ARP) maps, and Stanford's FastPath analysis) are available to explore in the "Basin Characterization" section of the SGMA Data Viewer.

AEM and tTEM Surveys

Airborne Electromagnetic (AEM) and Towed Transient Electromagnetic (tTEM) Surveys

The California Department of Water Resources (DWR) conducted statewide [airborne electromagnetic \(AEM\) surveys](#) to improve the understanding of groundwater aquifer structures. Data were collected in a rectangular grid pattern across 95 groundwater basins with lines spaced

approximately 2 miles by 8 miles apart ([Dlubac et al., 2024](#)). Data is available to the public in the [SGMA Data Viewer](#).

During an AEM survey, a helicopter tows electronic equipment that sends signals into the ground. A receiver mounted on the helicopter measures the electromagnetic response of the subsurface materials, providing a visual representation of soil composition to bedrock and the depth to groundwater. The resulting information will improve the understanding of large-scale aquifer structures across the state's groundwater basins to help identify areas ideally suited for groundwater recharge. In tandem with this effort, DWR and other entities such as universities and local districts, are conducting towed transient electromagnetic (tTEM) surveys that provide higher resolution data at the field scale to supplement the AEM data.

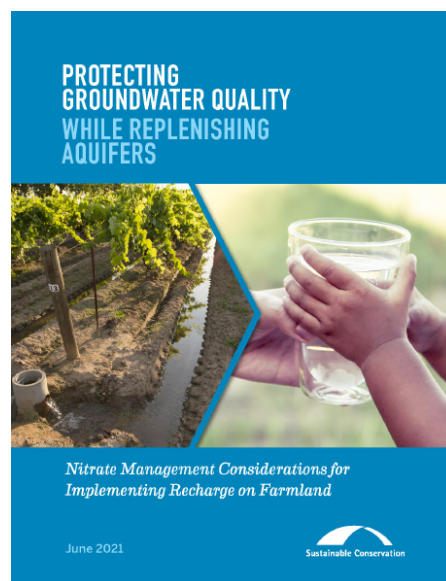
Water Quality

An important consideration when selecting a field for on-farm recharge is the potential impact on groundwater quality. When planned and managed correctly, recharge could improve groundwater quality by diluting contaminated groundwater. However, recharge can mobilize constituents in the soil that may degrade water quality.

Ideally, a recharge practitioner would apply clean surface water onto a field or recharge basin where the soil does not contain substantial legacy nutrients or other hazardous constituents that can leach into groundwater. Nitrate, a form of nitrogen (N) commonly found in agricultural soils as a byproduct of fertilization, moves easily with water and is found in wells across California, where it becomes a health hazard to humans. Agricultural fields that contain substantial residual or legacy N in soils include those where high N-input crops or crops that leave high amounts of N-rich residues are grown and land that has received frequent or habitual applications of animal manure. These fields should not be used for recharge. The "[Assessment Mapping Tool for Water Quality and Recharge](#)" provides information on physical, chemical, and site-specific factors that influence water quality outcomes during MAR vary across the landscape. For guidance on using this map tool, refer to the [Methodology for the Assessment Mapping Tool for Water Quality and Recharge](#). Recharging on active farmland requires careful management of nutrients, pesticides, and other agrochemical inputs to avoid leaching of constituents to the shared groundwater supply. At a minimum, the grower should follow all manufacturer

recommendations and legal restrictions for agrochemical application, particularly the required wait periods, before applying water to fields. Growers should be aware that the State of California has designated some pesticides as highly leachable, and [recharge is not permitted within 6 months of using these products](#).

One technique to protect water quality and reduce leaching of nitrate and other constituents into an aquifer is to concentrate multiple applications of large amounts of recharge water to a limited number of fields that use appropriate agrochemical management, rather than recharging large areas less intensively or rotating on-farm recharge fields annually.



For further detail about how on-farm recharge can be used to effectively protect or improve groundwater quality with regard to nitrate, see Sustainable Conservation's [Water Quality Guidance](#).

Look up a farm's risk of nitrate leaching using the [Nitrogen Leaching Hazard Index tool](#). Soil scientists and agronomists from UC Davis and the Natural Resources Conservation Service (NRCS) developed the Nitrogen Leaching Hazard Index to provide information to farmers about groundwater nitrogen contamination potential in their fields and suggest voluntary management practices. The index combines soil, crop, and irrigation information to assign an overall hazard score, and management practices are suggested when hazards are identified. Select the crop, soil type (there is a lookup function), and choose "Surface Irrigation" to approximate recharge flooding events. Indicate whether the field is deep ripped, which can impact infiltration and percolation of water.

Nitrogen Leaching Hazard Index

The Nitrogen Leaching Hazard Index was developed to provide information to farmers interested in voluntary management practices that reduce nitrogen contamination potential in groundwater. The index works with an overlay of soil, crop, and irrigation information. Based on the three components, an overall potential hazard number is assigned and management practices are suggested where necessary. [Show more...](#)

FIND YOUR HAZARD INDEX NUMBER:

Crop: Select: ↕

Soil: Select: ↕

LOOK UP YOUR SOIL TYPE ▾

[OPEN SOILWEB GMAP](#) Open the SoilWeb GMap application in a new browser tab, where you can explore soil data using an interactive map.

[USE MY LOCATION](#) Look up soil data at your current location using your browser's geolocation feature. For best results, use a device with GPS capability and be sure to enable it.

Irrigation: Select: ↕

Deep Rip: None ↕

[FIND YOUR INDEX NUMBER](#)

4. RECHARGE ON PERENNIAL CROPS

Perennial crop fields may be suitable for on-farm recharge, especially those crops that are dormant in winter. The tolerance to on-farm recharge conditions will vary by crop type, variety, rootstock, soil type, timing of water application, and a wide array of environmental conditions. Deciduous tree and vine crops are generally more tolerant of root zone saturation during dormancy up to bud-break. Once out of dormancy, these crops are sensitive to long-term root zone saturation. There is ongoing research to better understand maximum thresholds of different crops' tolerance to inundation and root zone saturation during on-farm recharge activities.

A model developed by the California Department of Water Resources ([Flores-López et al., 2025](#)) calculates the amount and frequency of water application for recharge that a crop can tolerate based on soil texture. The model assumes that recharge water is applied for five consecutive days, limiting the applied amount to keep the root zone saturation below 75% to protect crop health. These five days are followed by several days of no water application to allow time for the soil to dry before applying water again. Crop-specific recharge application guidelines to protect crop health based on the model's output [can be found here](#). Currently, guide sheets are available for [almonds](#), [pistachios](#), [walnuts](#), [vineyards](#), [alfalfa](#), [pasture](#), and [annual crops](#).

As a general rule, growers should consider on-farm recharge timing in relation to crop cultural development and stages of growth to avoid plant health problems. A grower's knowledge of soil infiltration rates and the ability to anticipate the timing of tree and vine development and growth stages that may be more sensitive to saturated soils, such as flower or fruit initiation, will be invaluable guides to planning on-farm recharge. In-field observations are critical to managing a recharge event and should outweigh any model predictions when making decisions about turning recharge water on and off for any specific field. Some growers have successfully conducted recharge after dormancy, typically on sandy soils that drain very quickly. Each crop and soil type will have different factors that require a tailored recharge application method and close field monitoring.

Practitioners of on-farm recharge generally use methods similar to flood irrigation. Water application methods specific to on-farm recharge include focusing water on sandy fields with high percolation rates and limiting the length of time that orchards and vines are saturated. See **Section 7** for methods to prepare fields and manage water during on-farm recharge, and for discussion of alternative irrigation methods.



Grapevines

Grapevines are generally tolerant of on-farm recharge during the dormant season up to the time of buds setting. They do not have high nitrogen demand, so the risk of nitrate leaching during recharge is minimized.

Recharge on grapevines typically takes place after harvest when surplus water is available. Growers often target on-farm recharge to fields with lower value varieties to minimize potential economic losses if recharge compromises crop health or productivity. The soil types on which grape growers conduct recharge vary from heavier silty loams to very sandy soils.

Pioneering growers have experimented with on-farm recharge on grapevines beyond the dormant season as shown in the photo above. Growers on very sandy, well drained soils applied water during the dormant season and into May, past bud-break. In some cases, recharge in those vineyards occurred into July. Although in-season recharge was successful, these growers ultimately preferred conducting on-farm recharge during the dormant season because of concerns about nutrient leaching and plant stress in the spring, and increased risks of powdery mildew resulting from higher humidity levels that can occur during on-farm recharge in warm weather.

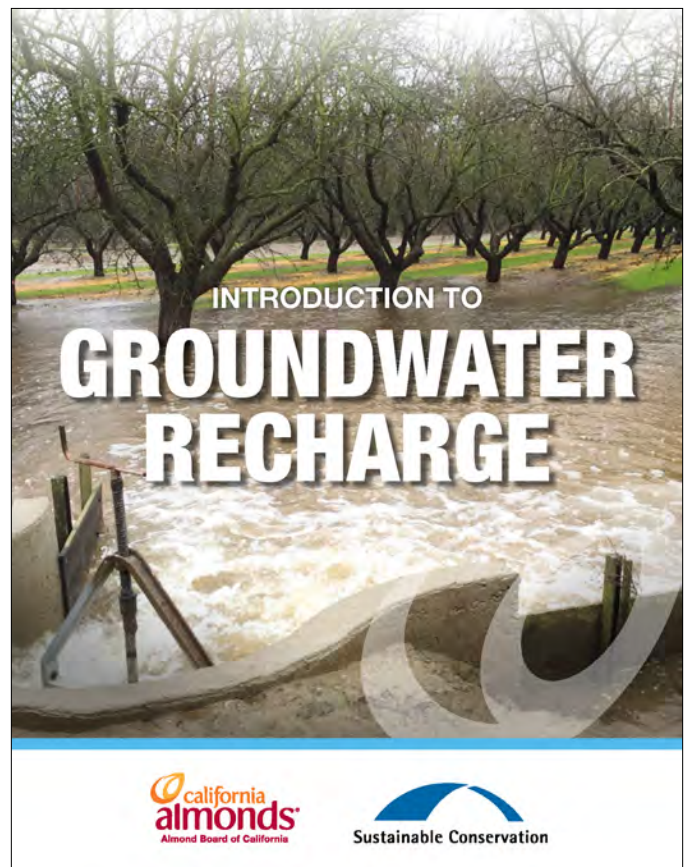
Some vineyards on slopes or heavier soils may not be able to use flood irrigation for recharge. For alternative recharge methods that may be appropriate for these sites, refer to **Section 6, Other Types of Recharge**, or to [A Groundwater Recharge Guide for Vineyards](#), a new resource that provides a complete overview of vineyard-specific methods and best practices for recharge. A companion worksheet within the Guide leads growers through a set of questions to outline a recharge plan customized for their vineyard.



Almonds

On-farm recharge in almond orchards has been evaluated by a number of growers and researchers. There is growing consensus that recharge can be conducted on almond orchards during the dormant season when trees have lowered metabolic rates and can tolerate soil saturation. Because of the trend toward more frequent but smaller application of nutrients, on-farm recharge should be avoided during the growing season to limit the risk of leaching these nutrients into the groundwater. Growers interested in on-farm recharge should preserve flood irrigation infrastructure for orchards converted to micro irrigation.

The Almond Board of California published an in-depth [Introduction to Groundwater Recharge](#) that reviews in detail some of the considerations specific to conducting recharge on almond fields.





Pistachios

Pistachios are grown on heavier clay or saline soils, which are considered less suitable for more salt-sensitive tree crops like almonds. Heavier clay soils have a lower infiltration rate and thus are less suitable for on-farm recharge. However, excess water applications are known to reduce soil salinity by leaching salts past the root zone, and many growers view this as an important side benefit of groundwater recharge. Reduced flow rates, surge irrigation, or shorter duration of recharge water applications can help adjust for lower infiltration rates and make recharge successful on heavier soils. Infiltration could be improved by deep ripping or gypsum application prior to planting, or a field might have sandy streaks where recharge water could be concentrated. Current research is exploring the use of cover crops in pistachio orchards to improve infiltration and recharge outcomes. Several pistachio orchards participating in this research appear as case studies in the **Appendix**.

Newly planted pistachio orchards typically use drip or micro sprinkler irrigation, but some orchards

have maintained flood irrigation systems that facilitate on-farm recharge. Irrigation systems can be retrofitted for flooding by bypassing drip or sprinkler lines with temporary pipelines for flood irrigation.

Ongoing research will improve our understanding of the tolerance of pistachios for planned recharge events during both the dormant and growing seasons. Tree crops generally are more sensitive to root zone saturation when temperatures rise in the spring, the crop is actively transpiring, and higher microbial activity reduces oxygen content in soil water. Natural flooding events suggest that pistachios may have a relatively high tolerance for recharge when carefully managed.



Walnuts

Walnut orchards have a longer dormancy period than almonds. The prime on-farm recharge opportunity for walnuts to avoid plant health issues is generally from November to early May, depending on the timing of the bud break. Some walnut varieties can be more sensitive to excess water in the root zone than others. For example, Paradox rootstock generally shows higher resistance to plant health issues like phytophthora root rot under flood conditions compared to black walnut rootstock. Caution is advised to consider current rootstock conditions and susceptibility to root rot diseases such as those caused by phytophthora species before proceeding with recharge, regardless of the type of perennial nut or fruit tree crop targeted for on-farm recharge.

Alfalfa

Alfalfa is a perennial legume primarily grown for feeding livestock or used as a cover crop and soil conditioner. Alfalfa is harvested March through October, and a typical alfalfa season in the Central Valley can yield seven to eight cuts of hay per year. On-farm recharge can be applied during the plant's semi-dormancy season from October through February.

Additionally, there could be recharge opportunities during the growing season, which would require careful timing of water applications to avoid plant development problems or delays in harvest because of soil and plant moisture.



5. RECHARGE ON ANNUAL CROPS AND OTHER LAND USES

Fallow Fields

Growers often choose to allow fields to lie fallow in the time between removing and replanting an orchard or vineyard, which reduces water demand on the parcel and reduces risk of certain soil diseases to carry over to the new crop (i.e., replant disease).

Fallow fields are readily adapted for on-farm recharge, especially if they are equipped with flood irrigation valves and water conveyance. Fallow fields can be inundated at any time of the year when water is available.

Annual Crops

On-farm recharge can be conducted on annual crop fields during periods when a crop is not being cultivated, such as after harvest. In some instances, a crop buyout or temporary or seasonal land fallowing program may incentivize on-farm recharge in fields that usually grow annual crops.

Crops intended for fresh market human consumption should not be growing in the field when recharge takes place, to reduce the risk of waterborne disease. Recharge on annual crop fields may erode beddings intended for the following season. In that case, additional water control structures like berms may be needed to slow down or direct recharge water.

When recharge occurs on fields normally planted with row crops, recharge events need to be carefully timed with agricultural practices. Pesticides and nutrients applied late in the growing season may persist in the soil and risk leaching into groundwater. Sufficient dry-down periods after recharge will be needed to allow off-season field work like tillage, bed-shaping, and weed control.



18-acre on-farm recharge basin
Madera County

Basins

Recharge basins are typically shallow excavated basins in non-crop areas of a farm which are dedicated to accepting recharge water as an alternative to flooding crop fields. Growers may want to devote portions of their fields to recharge basins for various reasons, such as reducing their overall irrigated acreage under groundwater allocations, retiring sandy areas where it is difficult to grow crops, or simply building overall groundwater resilience.

Basins need to be designed correctly to be safe and effective. Growers can reference general guidance on how to build a basin from the NRCS's [Conservation Practice Standard 815](#) Groundwater Recharge Basin or Trench. Basins can be designed to incorporate features like variable bottom depths to provide habitat for migrating shorebirds and waterfowl, or shoreline and upland vegetation for pollinator species. Growers interested in ecologically beneficial recharge basins can reference the Environmental Defense Fund's [Building Multibenefit Recharge Basins](#) brochure. The [Ecological Recharge Basins Case Study report](#) describes three case studies of ecologically beneficial basins, and more detailed guidance will be available in early 2027.

Basins can accept water at any time of year and may be especially valuable during late spring snowmelt, when many crops are in full swing and cannot accept additional water. Because there are no agronomic inputs in a basin and because high volumes of water are percolated in a relatively small footprint of land, there are fewer water quality concerns when recharging in a basin. Various types of funds exist for growers to create basins on their property (see **Section 8, Financial Aspects of On-Farm Recharge**).

Alternative Recharge Locations

Growers may want to consider focusing recharge on portions of their land that are not currently in agricultural production, such as unlined ditches and ephemeral streams. These areas have advantages similar to basins, as they can accept water at any time of year and they do not pose any water quality risk or conflict with agricultural practices. Growers should work with their local district to discuss options for recharge water deliveries to these sites.



Two adjacent orchards, with bare ground (left) and with winter cover crops (right), after receiving $\frac{3}{4}$ " rain in January 2023. Grower reports water was drained within hours in cover-cropped orchard compared to days in bare-ground orchard. Photos courtesy of Donny Hicks.

Cover Crops

The interactions between sustainable farm practices such as recharge and cover cropping are a growing area of research. The impacts of cover crops on the agricultural water cycle are influenced by local climate, soil type, context of cover crop usage, and management strategies. Growers report decreased runoff and improved infiltration in fields with cover crops because of the greater number of roots in the soil, which reduces surface sealing, improves soil structure, and can increase soil organic matter. Fields with cover crops also show improved water use efficiency; some growers have been able to delay the first irrigation or irrigate less frequently in the summer months because the cover crops increase capture and retention of precipitation and applied water.

Research in California, summarized in the document "[Cover Cropping in the SGMA Era](#)", supports these grower observations. Cover crops increase infiltration of water by at least 40% and reduce surface runoff by 40-80%, depending on conditions. Cover crops increase overall evapotranspiration by only 0.7 - 1.2 inches of water compared with bare ground fields, because they greatly reduce evaporation from the soil surface.

Non-legume winter cover crops, such as triticale or cereal rye, have been shown to scavenge excess nitrate-nitrogen in the upper soil horizons and can reduce nitrate leaching by more than 50% (Cover Cropping in the SGMA Era, 2024). These types of cover crops grown prior to on-farm recharge may provide a valuable service in protecting groundwater quality from nitrate leaching. Nutrient scavenging potential is correlated with cover crop biomass, so if flooding for recharge takes place before the cover crop matures, leaching of nutrients could still take place.

Although most cover crop species can tolerate intermittent flooding, a cover crop may not thrive or survive if it is inundated for an extended period. This may or may not be acceptable to the grower, depending on the grower's objectives with the cover crop. More research is needed to understand the combined effects of recharge and cover crops on nutrient leaching and soil health, and the best ways to manage the two practices together.

For further details about managing cover crops to maximize water cycle benefits on the farm, see the publication [Cover Cropping in Water Scarce Environments](#), developed by Sustainable Conservation in partnership with Community Alliance with Family Farmers (CAFF), NRCS, and UC Davis.

The publication [Cover Cropping in the SGMA Era](#) summarizes research outcomes in California related to cover crops and water use, compiled by a large group of experts convened by Sustainable Conservation.

In 2026, Sustainable Conservation [released in-depth guidance for water-wise cover crop strategies](#) in three distinct cropping systems in the Central Valley.

Sustainable Conservation has collected [links to cover crop information and tools for species selection and management](#), all relevant to California and the Western US.

6. OTHER TYPES OF RECHARGE

Subsurface Recharge

Unsaturated Zone and Aquifer Storage and Recovery Wells

Unsaturated zone wells are gravity-fed excavated pits or shallow wells lined with perforated casing and backfilled with gravel or stone. Also known as “dry wells”, these are different from Aquifer Storage and Recovery (ASR) wells, which inject large volumes of pressurized water into deeper aquifers.



PHOTO BY R. M. GAILEY, CONSULTING HYDROGEOLOGIST PC.

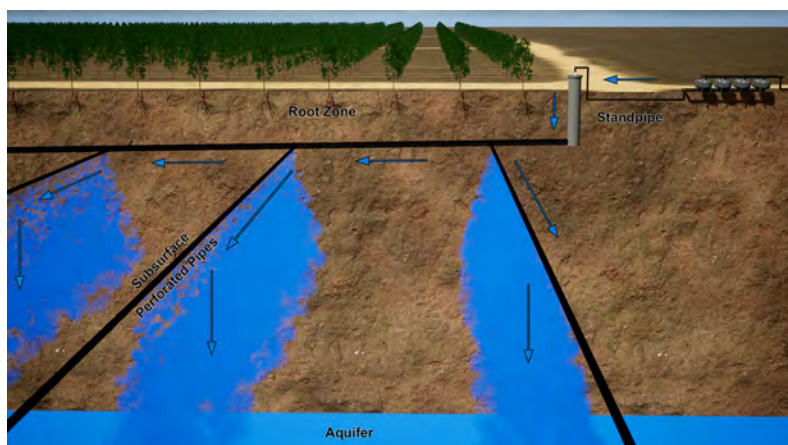
Unsaturated zone wells penetrate layers of clay soils that have poor infiltration rates, allowing for rapid infiltration of recharged water into more permeable soils deeper underground. They could be used to bypass constituents in the root zone that would be leached during an on-farm recharge event.

Extra care must be taken to use clean source water to avoid unintentional contamination of the underlying aquifer. Growers should check with the [Regional Water Quality Control Board](#) in their area to understand any water quality or permitting requirements if they are interested in dry well recharge.

Reverse Tile Drains

Conventional tile drain systems are installed to drain water from the crop root zone in fields with a high water table to prevent low-oxygen conditions for crop roots. Tile drainage can be found in the Sacramento Valley, Tulare Basin, and Imperial Valley production areas of California. The adaptation of “reverse tile drains” instead applies excess water below the root zone into areas with over-drafted aquifers for the express purpose of recharge. Subsurface groundwater recharge using tile drains was introduced to the San Joaquin Valley in 2017.

A key benefit of the reverse tile drain system is that it does not saturate roots, allowing water application during the growing season. It separates field management needs, such as nutrient or pest management, from the availability of water and timing of recharge.



The cost of installation can be a drawback, as these systems require significantly higher capital expenses compared to other forms of on-farm recharge.

Growers who are interested in a reverse tile drain system must install tile drains and pipelines prior to planting a field. This system should be considered when planting a new orchard or vineyard or replacing an existing one. **Case Study 2** in the **Appendix** profiles a reverse tile drain system installed on a Fresno State University experimental farm.

SCHEMATIC COURTESY OF LIDCO, INC.

7. PRACTICAL METHODS TO PREPARE FIELDS AND MANAGE WATER DURING ON-FARM RECHARGE

Infrastructure

Fields with existing flood irrigation infrastructure are best suited to on-farm recharge. Drip and sprinkler systems typically apply water at low rates and often cannot achieve the volume and intensity of water application necessary for recharge.

For fields where flood irrigation is possible, the grower will need to have temporary or permanent infrastructure, including:

- **pumps** to move water from the source to the field
- **conveyance** such as pipes to move water to various parts of the field
- **flow meters** or some other system to measure amounts of water applied

Fields that are set up with both flood and drip irrigation can adapt to the increasing frequency and intensity of droughts and floods. The grower can use efficient drip irrigation during dry periods and use flood irrigation for on-farm recharge in wet periods when surface water is available.

For fields where flood irrigation is not feasible, recharge of some sort may still be possible. Some growers are experimenting with modifying their drip and sprinkler systems to apply greater volumes of water, by opening the ends of driplines or bypassing drip and sprinkler lines with temporary flood irrigation pipelines. Others are trying “deep pre-irrigation” by running their unmodified low-flow system around the clock in the winter or early spring when water is available. These methods may not achieve volumes of recharge comparable to flooding, but they fill the soil profile with water and may enable growers to delay or skip early irrigation events. Tradeoffs include additional power and labor costs to run pressurized irrigation systems in the off-season. Refer to **Case Studies 8 and 9** in the Appendix of this manual for examples of growers using drip and micro-sprinkler systems for recharge.





Preparing Fields for On-Farm Recharge

On-farm recharge can be thought of as flood irrigation in the off-season, with large amounts of water applied to achieve maximum infiltration. Berms installed at intervals within furrows or in the alleys between permanent crop rows help to slow horizontal movement of recharge water, enhance infiltration and percolation, and prevent runoff of water at the end of the field.

Trees planted on berms are ideally suited to on-farm recharge because the berms help keep the root system above water saturation levels.

If a field intended for recharge is managed as bare ground and soil crusting or low infiltration is a problem, tilling the soil between rows can break up soil crusts and increase infiltration of recharge water. Tilling must be done carefully to avoid damage to permanent crop roots. Tillage can also mobilize fine silt that clogs soil pores and make recharge less effective overall. Alternatively, gypsum can be applied prior to recharge events to prevent soil crusting and maintain higher infiltration rates.

As stated before, cover crops improve water infiltration into the soil by preventing the surface sealing or crusting. They reduce evaporation from the soil surface and can improve water storage capacity in the soil by building organic matter over time. Growers that recharge on fields with cover crops report faster infiltration and less ponding of water.

Managing Water During Recharge

Growers use traditional flood irrigation management strategies for recharge water applications, with the goal of keeping water on the field to maximize infiltration and minimize runoff losses.

Alternate row irrigation is the flooding of alternate rows or furrows while leaving every other row dry, which prevents crop roots from being completely saturated during recharge and avoids lowered oxygen levels. Alternate row irrigation may be useful for crops sensitive to flooding and may be an option for recharge during the growing season.

Surge irrigation applies water in intermittent pulses rather than continuously. It is used to improve distribution uniformity along the length of a field or a furrow.

Duration of water application is important. Growers reported applying water for five to seven days followed by a rest period for infiltration and percolation beyond the root zone. Growers with very sandy soils or sandy streaks in heavier soils reported being able to apply recharge water continuously during the dormant period because water was fully infiltrated before reaching the end of the field. Refer to the [Guidance for Protecting Crop Health During On-Farm Recharge](#) for more detailed information on duration and volume of recharge water application appropriate for different soil types and crops.

Temperature is important when considering the duration of soil saturation. Soil oxygen levels critical for root respiration vary with temperature and soil biotic activity. Growers have reported that trees are more tolerant of saturation in winter when average soil and air temperatures are lower than in spring. Research is needed to better understand the dynamics of temperature, oxygen levels, and their influence on tree health during recharge.

Maintenance and Monitoring

Areas around flood irrigation valves need to be monitored for erosion. Berms should be monitored and repaired to ensure uniform distribution of water.

As water is applied for recharge, infiltration should be monitored in the field. Growers should make real-time decisions about turning water on and off based on observed infiltration rates, how quickly water advances across the field, and evidence of runoff or erosion resulting from the recharge application.



LOW-RATE APPROACH TO ON-FARM RECHARGE

Growers might use a low rate of recharge water application to avoid ponding of water in the field and reduce the length of time that the root zone is saturated. Water applied will fully infiltrate before flow reaches the end of the row. This approach is useful for soils that have a lower infiltration rate, or when recharge is done during the growing season.



HIGH-RATE APPROACH TO ON-FARM RECHARGE

Growers using a higher rate of water application apply enough water to pond up to berm level. Water should not fully saturate the crown, nor should it cover the scion union of grafted trees, which may increase the risk of introducing pathogens into the trunk. This approach will maximize benefit to the aquifer and is best for soils with high infiltration rates and water application during crop dormancy or fallow periods.



8. FINANCIAL ASPECTS OF OFR

Cost

The cost of installing the infrastructure needed for moving water onto the field will depend on the location of the field relative to the water source and any existing infrastructure. If permanent irrigation infrastructure is not available nor desired, temporary structures may be required to pump and spread the required volume of water needed for recharge. Temporary structures can be installed at relatively lower cost than permanent pipelines.

At least one person is needed to activate and monitor recharge activities on the ground. When enrolled in an incentive program, growers may be expected to record data, such as pumping start and stop dates and times, flow capacity of the pump, date-stamped photos of the recharge events, and other observations such as depth and duration of ponding.

The cost of water for on-farm recharge varies considerably, depending on the availability of surface water supplies and district incentive programs. Water for recharge can sometimes be available at a highly discounted rate or even free, depending on a district's recharge policies (see **Incentives** section below). In some cases, the district can help the grower with the electricity costs of running pumps for recharge. Even when growers pay the full cost for recharge water, the expense can be offset if the district offers credits on

grower water bills or an increased allocation for groundwater pumping in return for on-farm recharge efforts.

The following cost estimates for water and labor are based on the data collected in our case studies. The cost of recharge water, which in some cases was discounted, ranged from \$0 to \$118 per acre-foot, with an average cost of \$25 per acre-foot. Energy costs ranged from approximately \$5 to \$60 per acre-foot, with the average being \$35 per acre-foot. Labor costs, which included labor conducted during recharge and preparation of the field prior to recharge, varied across individual case studies and by recharge type, as presented in the table below. For more details, read the **Case Studies** at the end of this document.

Recharge type	Average labor cost (\$)	Average labor cost (\$ per acre)	Average labor cost (\$ per acre-foot)
Micro-irrigation	2,416	79	46
Flood irrigation	1,350	48	33
Basin*	187	113	10
Reverse tile drain**	10	5	3

* The basin cost presented here is from a single case study on a 1.65-acre basin.

** The reverse tile drain system has a one-time installation cost of \$6,000.

Incentives

Locally-led On-Farm Recharge Incentive Programs

Many irrigation districts have on-farm recharge incentive programs for their growers, ranging from a robust groundwater crediting program to offering discounted or free water, as mentioned above. Sustainable Conservation has produced [Groundwater Recharge Incentives and Strategies](#), documenting incentives for groundwater recharge employed across California. Growers should contact their local irrigation district or GSA for details about incentives that may be available for on-farm recharge in their area.

Natural Resources Conservation Service Financial Assistance

In 2023, the Natural Resources Conservation Service (NRCS) piloted a recharge program in a few areas of the Central Valley that helped growers offset infrastructure and management costs associated with recharge. In addition to receiving financial assistance for constructing a recharge basin or applying on-farm recharge water to cropland, growers could simultaneously apply for other Environmental Quality Initiative Program (EQIP) practices that help offset costs with upgrading infrastructure and water conveyance. Once the pilot phase is complete, EQIP funding for recharge practices may be more widely available for growers in California. Growers should contact their [local NRCS Service Center](#) for current information.

Statewide Programs

Several [state grant programs](#) can be used to support groundwater recharge for the purpose of groundwater sustainability, or to implement recharge projects that deliver co-benefits such as improving groundwater supply for communities, reducing flood risk, and sustaining groundwater-dependent ecosystems. State

funding is typically directed through irrigation districts or GSAs who enroll growers into local programs. Statewide programs such as [LandFlex](#) and the [Multibenefit Land Repurposing Program](#) pay growers to temporarily fallow or permanently repurpose irrigated fields. Fields enrolled in these programs could also provide suitable recharge areas. Growers should ask their local irrigation district or GSA about programs that may be available in their area.

A Note on Measuring and Reporting

If a grower is engaged in an on-farm recharge program with incentives, it is important to be able to measure the amount of water applied during recharge events. Some irrigation districts already have meters in place at turnouts. Bills from irrigation districts can help to determine how much water was applied to individual fields or small clusters of fields. Additionally, the design capacity of a turnout, along with the duration of the recharge event, can help to estimate the amount of water applied.

9. INFORMATION AND GUIDANCE

[GroundwaterRecharge.org](#)

At this site, Sustainable Conservation presents groundwater recharge strategy and implementation resources for growers, GSAs and water districts. It includes:

- The Groundwater Recharge Assessment Tool (GRAT) Viewer, a mapping tool for recharge suitability information available to the public;
- Summaries of and links to DWR's San Joaquin Watershed Studies;
- A StoryMap illustrating practical strategies to manage and broaden recharge benefits for communities, ecosystems, agriculture, and flood risk reduction; and
- The "Recharge for..." pages, which include MAR strategy and implementation information tailored to different audiences, including growers, water districts or GSAs, community members, ecosystem managers, and policymakers.

[Introduction to Groundwater Recharge](#), Almond Board of California

This guide is targeted to California almond growers to help evaluate their options for conducting groundwater recharge, by describing factors to consider and primary recharge methods available. The information provided in this guide is based on a combination of current scientific knowledge and growers' experiences.

[Flood-MAR Hub](#)

The Flood-MAR Hub is a one-stop shop for all things related to Flood Managed Aquifer Recharge (Flood-MAR). This site is managed by the Flood-MAR Network and showcases on-the-ground recharge projects, research, guidance, tools and more. The reader can also join the Flood-MAR Network list-serve to keep updated on statewide efforts to increase the pace and scale of groundwater recharge in California, including a growing body of webinars on various topics related to Flood-MAR.

Groundwater Exchange, a project of the California Data Library

The Groundwater Exchange is a central, collaborative, and publicly accessible online resource center connecting water managers, water users, and community members with tools and resources to support the design and implementation of effective Groundwater Sustainability Plans under California's Sustainable Groundwater Management Act.

Grower Networks

There are several organizations throughout California representing various agricultural industries. These organizations provide resources to growers, allowing them to learn from industry experts and from each other, and they often work to promote sustainable farming practices. Sustainable Conservation has worked with several of these groups, including the [Almond Board of California](#), [American Pistachio Growers](#), and [California Sustainable Winegrowing Alliance](#), to develop recharge-focused guidance materials for growers in an effort to scale up on-farm recharge. Growers who engage with these groups can learn from supportive grower networks with experience in groundwater recharge.

10. ACKNOWLEDGEMENTS

Sustainable Conservation would like to thank the following people and agencies for providing valuable information that helps to inform the content in this document. The views expressed in this document are those of the authors and do not necessarily represent the views of the individuals and organizations listed below.

This report was prepared by Sustainable Conservation through funding provided by the California Department of Water Resources.

Case Studies in pistachio orchards were made possible by funding from the American Pistachio Growers (APG) Sustainability Committee, a Specialty Crop Block Grant (SCBG) from the United States Department of Agriculture, and other private funders. Sustainable Conservation and APG began on-farm recharge pilot projects with support from private funders in 2024; in 2025, the cover crop treatment was added to the pilot farms through the SCBG. Partners in the SCBG project investigating the interactions of cover crops with groundwater recharge include APG, Sustainable Conservation, and California State University-Fresno. The study is expected to end in 2027. The results from these pilot projects will inform on-farm recharge guidance for pistachio growers through case studies highlighted here, as well as through workshops and field day demonstrations.

We acknowledge the growers cooperating in the Case Studies presented here for their willingness to open their farms to us, and devote their own resources and many hours of effort to pioneer on-farm recharge practices: Al Costa, Arlen Thomas, Christine and Erich Gemperle, Don Cameron, Eric Harcksen, Eric Spycher, Karun Samran, Russel and Matt Efrid, Gurdial Grewal, Jimi Valov, Justin Wylie, Robert Wilmott (CSU-Fresno University Agricultural Lab), Phillip Cunha, Staci Buttermore, Matthew and Brian Watte, and Matthew Young.

Daniel deGraaf, deGraaf Engineering, Inc.

Dina Nolan, Madera Irrigation District

Jennifer Spaletta, North San Joaquin Water Conservation District

Jesse Roseman, formerly with the Almond Board of California

Ladi Asgill, former Sustainable Conservation agronomist

Wendy Rash, formerly with the Natural Resources Conservation Service, USDA

Wes Miller, Turlock Irrigation District

11. APPENDIX: CASE STUDIES

Case Study	Producer	Crop/Land Use	Recharge Type	Recharge Year(s)	Page
1	Costa	Grapes	Flood	2023-2026	29
2	CSU-Fresno	Almonds	Subsurface	2024	34
3	Grewal	Almond	Flood	2025-2026	38
4	Grewal	Peach	Flood	2025-2026	43
5	Grewal	Micro basin	Basin	2025-2026	47
6	Grewal	Pistachio	Flood	2025-2026	51
7	Valov	Pistachio	Flood	2025-2026	57
8	Wylie	Pistachio	Micro-Sprinkler	2025-2026	63
9	Samran	Pistachio	Double-Line Drip	2025-2026	68
10	Cunha	Pistachio	Flood	2025-2026	74
11	Buttermore	Pistachio	Flood	2024	79
12	Watte	Pistachio	Flood	2025-2026	84
13	Young	Extended Fallow	Flood	2024	88
14	Gemperle *	Almonds	Flood	2022-2023	93
15	Harcksen *	Almonds	Flood	2022-2023	96
16	Spycher *	Almonds	Flood	2022-2023	99
17	Samran *	Almonds	Flood	2022-2023	102
18	Costa *	Grapes	Flood	2018, 2019, 2022	105
19	Thomas *	Almonds	Flood	2016	116
20	Efird *	Grapes	Flood	2018	122
21	Cameron *	Almonds	Flood	2017	128
22	Cameron *	Grapes	Flood	2017	133
23	Cameron *	Recharge basin	Basin	2023	139

* Case studies are unchanged from the previous version of the Recharge Methods Manual, published in 2023.



On-farm recharge on Al Costa's vineyard

PROJECT DESCRIPTION

Al Costa is a wine grape grower in San Joaquin County who has participated in on-farm recharge since 2018. Mr. Costa diverts surface water available from his local water district to flood irrigate 23 acres of grapes from October through March (see tables below for more information). His recharge site is very sandy, allowing the application of large volumes of water without harm to his crops. He also has the benefit of working with the North San Joaquin Water Conservation District (NSJWCD), which is very supportive of recharge efforts.

Mr. Costa's main objective is to support the efforts of the NSJWCD's Groundwater Sustainability Agency (GSA) to replenish groundwater in the Eastern San Joaquin Subbasin, which spans the San Joaquin, Stanislaus, and Calaveras counties. This case study includes salinity observations from the 2022-23 wet year. Growers throughout the Central Valley have commented on the excessive salt buildup in the soil root zone, citing the increasing drought in California as the cause, and noting the resulting reduced yields and quality of crops. The observations in this case study show salinity dilution from recharge. Many growers refer to this dilution as an immediate benefit from on-farm recharge for their crop health, growth, and development.

The on-farm recharge effort at the vineyard is a prime example of what can be achieved when different entities, such as farm communities, local irrigation districts, and Groundwater Sustainability Agencies, collaborate with the common goal of replenishing groundwater. The accomplishments of Mr. Costa and the recharge benefits observed at his farm are an important reminder that grower participation is critical to achieving Sustainable Groundwater Management Act (SGMA) goals. Incentivized on-farm recharge programs encourage grower participation because many growers need financial support to cover the costs (e.g., infrastructure and electricity) required to conduct recharge. Growers would like to see an expansion of incentive programs in the San Joaquin and Sacramento Valleys.

Field Description

CATEGORY	DETAILS
Acres	23
Type of crop	Grapes (Zinfandel) on Freedom rootstock
Age of crop	34 years
Average root depth	6-7 feet
Irrigation infrastructure	Single dripline tape per plant row

Hydrogeology

CATEGORY	DETAILS
Soil texture	Sandy loam
Land IQ recharge suitability rating	Moderately Good
SAGBI rating	Good to Excellent
Restrictive layers	None
Depth to groundwater	75-80 feet

Water Supply

CATEGORY	DETAILS
Source of water	North San Joaquin Water Conservation District (NSJWCD)
Maximum diversion rate	10 cubic feet per second
Method of diversion	Water was pumped from the Mokelumne River into an underground conveyance pipe that leads to the vineyard
Cost of water	NSJWCD did not charge Mr. Costa for the recharge water. NSJWCD paid for the electricity to pump the water from the Mokelumne River and for the infrastructure to convey the water to the vineyard recharge pilot site.

Soil Health

CATEGORY	DETAILS
Compost	None
Cover crops	Native or natural plant cover between plant lines
Other amendments	Periodically, based on need, Mr. Costa applied gypsum at a rate of approximately 20 pounds per acre with minimum tillage

On-Farm Recharge Logistics

CATEGORY	DETAILS
Type of recharge	Flood irrigation
Field preparation and management during recharge	A 12-inch berm was installed at the outer perimeter of the recharge field site, and an inflatable gated pipeline was placed on the west side of the field for flooding each row. Water was conveyed through an underground pipe for approximately 1,500 feet before entering a distribution pipe with risers at the ends of the multiple rows on the field's west side where the inflatable, gated flood pipe was connected. The water that was pumped into the rows rapidly infiltrated before reaching the end of the field, which was approximately 1,000 feet from west to east.
Nutrient management (excludes compost)	Fertilizer was not applied during the dormancy period from late November to early April.
Average inundation height	3-4 inches
Duration of inundation	See Recharge Events table below
Time to dry down after each inundation period	1 day
Labor costs	Total labor cost: \$1,862 (98 person-hours at \$19 per hour)

Recharge Events

Year	Dates of recharge ^A	Duration (days)	Field Size ^A (acres)	Water applied ^A (total AF)	Water applied ^A (AF/acre)	ET _c ^B (ft)	Net water recharged ^C (total AF)	Net water recharged ^C (AF/acre)
2018	10/5 – 11/5	32	13.7	237	17.3	0.26	232.73	16.99
2019	10/4 – 10/17	14	23	295.39	12.84	0.14	291.53	12.68
	10/21 – 10/27	7						
	11/16 – 11/30	15						
2022	12/9 – 12/31	23	23	223.47	9.72	0.01	223.15	9.7
2023 - 2024	12/14 – 12/22	9	23	589.47	25.63	0.07	587.67	25.55
	1/8, 1/10, 1/12, 1/14, 1/16, 1/18	6						
	1/26 – 1/30, 2/1	6						
	2/5, 2/8, 2/10, 2/12, 2/15, 2/18, 2/20, 2/22, 2/24, 2/26, 2/28, 3/1, 3/3, 3/5, 3/7, 3/9, 3/11, 3/13	18						
2024 - 2025	10/17 – 10/20	4	23	249.69	10.86	0.05	248.23	10.79
	10/24 – 11/6	14						
	12/17 – 12/22	6						
	1/1 – 1/10	10						
2025 - 2026	12/30 – 3/15	61	23	441.77	19.21	0.83	418.86	19.09

A: Dates of recharge, field size, and water applied sourced from grower.

B: Crop evapotranspiration (ET_c) value sourced from CIMIS station #s 70, 71, and 80.

C: Net water recharged = water applied (AF) - 1.2 * ET_c (feet) * acres

Changes in Field Conditions

CATEGORY	DETAILS
Diseases and weeds	Mr. Costa conducted routine powdery mildew and bunch rot prevention sprays and did not notice any increase in disease activity.
Salinity	In 2018 and 2019, soil salinity measurements showed soil salinity higher in the top 46 inches of soil before recharging compared to post-recharge, indicating that recharge moved salts or diluted the salts into a lower depth in the root zone.
Changes to field practices	None

GROWER'S EXPERIENCE

Mr. Costa noted that it was extremely hard to get irrigation water across the field. The field contains some very sandy streaks, and the grape vines tended to be less developed at the end of furrows because of low soil moisture retention in sandy soil. Mr. Costa believes his field could receive a lot more water if it is available and if he has continued access to local incentive assistance funding to help offset electrical bills for pumping. Mr. Costa thinks the immediate benefit of on-farm recharge is reduction in soil salinity, which promotes a healthier plant. He wants to recharge to replenish overdrafted basins to meet SGMA goals and to help ensure the continuation of agricultural production for future generations.



Fresno State University Agricultural Lab



Case Study 2

Method: Shallow Subsurface Artificial Groundwater Recharge, or Reverse Tile Drainage, on Almond Orchard
Location: Fresno County



Left: Robert Wilmott (orchard manager) looking over the reverse tile drain system on Fresno State almond field. Right: Filter and pipeline delivery for the system.

PROJECT DESCRIPTION

California State University, Fresno (Fresno State) has a reverse tile drain system to conduct shallow subsurface artificial groundwater recharge (SSAGR) on two acres of an almond orchard. In conventional tile drain systems, water is drained from the rootzone in fields with a high-water table to alleviate low oxygen conditions caused by waterlogging, which can harm crops. Reverse tile drains use a similar system of perforated pipe to apply excess water below the rootzone to recharge groundwater aquifers. This allows water to be applied during the growing season, while avoiding plant health issues due to flood conditions that would saturate the roots.

Fresno State's SSAGR system was installed by LIDCO Inc. in 2020. It was initially used for research but now functions as an educational resource for local farmers and has become part of Fresno State's recharge program. The system integrates well with current farm operations, requires minimal management and maintenance, and has great potential to scale recharge without taking land out of production. Anyone looking to invest in a SSAGR system should install it before crop planting, because the installation of the perforated pipeline requires trenching 8 to 15 feet deep to lay the pipe. According to LIDCO Inc., the one-time installation cost can range from \$3,000 to \$12,000 per acre based on water flow or delivery capacity, and soil type or texture, which influences the water percolation rate below the reverse tile system.

Field Description

CATEGORY	DETAILS
Acres	2
Type of crop	Almonds (Nonpareil) on Nemaguard rootstock
Age of crop	5 years
Average root depth	2 feet
Irrigation infrastructure	Dual dripline irrigation system for each plant line. The reverse tile drainage system was installed at an 8-foot depth on a 2-acre portion of the field before it was planted with 2-3-foot-tall almond transplants.

Hydrogeology

CATEGORY	DETAILS
Soil texture	Fine sandy loam
Land IQ recharge suitability rating	Ranging from Moderately Good to Moderately Poor as depth increases
SAGBI rating	Moderately Good
Restrictive layers	Corcoran Clay layer lies in the subsurface at about 200-800 feet
Depth to groundwater	80-90 feet

Water Supply

CATEGORY	DETAILS
Source of water	Fresno Irrigation District (FID)
Maximum diversion rate	6-7 cubic feet per second
Method of diversion	FID turnout gate
Cost of water and system installation	Current irrigation season cost: \$35.60 per acre-foot One-time initial installation cost: \$6,000

Soil Health

CATEGORY	DETAILS
Compost	None
Cover crops	Yes, native grass and weeds
Other amendments	None

Subsurface Recharge Logistics

CATEGORY	DETAILS
Type of recharge	Reverse tile drain or SSAGR
Field preparation and management during recharge	Preparation involved initial installation of plumbing and earth work. Very little maintenance was needed. Meters were used for monitoring soil moisture levels.
Duration of recharge	39 days with an average of 8 hours each day
Maximum potential flow rate through SSR system	~28,800 gallons per 8 hours of flooding
Labor costs	~\$10 per SSAGR event (Estimated 0.5 hours at \$20 per hour to turn open and close valves at the start and finish of the SSAGR application and check that the system was operating properly)

Recharge Events

Year	Dates of recharge ^A	Duration (days)	Field size ^A (acres)	Water applied ^A (total AF)	ET _c ^B (ft)	Net water recharged ^C (AF per acre)
2024	5/31 – 7/8	39	2	3.35	N/A due to subsurface water application	1.68

A: Dates of recharge, field size, and water applied sourced from the farm manager.

B: Crop evapotranspiration (ET_c)

C: Net water recharged = water applied (AF) - 1.2 * ET_c (feet) * acres. Water applied and water recharged are the same in this case study because the use of the subsurface irrigation system means there is no evapotranspiration.

Changes in Field Conditions

CATEGORY	DETAILS
Diseases and weeds	N/A
Salinity	N/A
Changes to field practices	None

GROWER’S EXPERIENCE

Robert Wilmott, orchard manager for Fresno State's University Agricultural Lab, explained that Fresno State wanted to incorporate the SSAGR into the experimental farm to help offset the university's groundwater usage. Because the system was designed for recharging, it cannot be used to irrigate crops. One potential drawback of the SSAGR is clogging: fine particles can enter the system and reduce water flow. To help combat clogging and biological growth, Fresno State filtered the water before introducing it into the SSAGR system. The university has not observed any clogging or biological growth issues in its system to date.

The system's recharge capacity far exceeds what was achieved in 2024, when Fresno State was limited by a 60-gallon-per-minute delivery system. Mr. Wilmott is now interested in upgrading the pumping and water filtration capacity. He hopes to demonstrate how this sustainable water practice can benefit the county and surrounding community, and that similar practices might become common on farms throughout the Central Valley.



Gurdial Grewal of Grewal Brothers Farming (GBF)

Crop: Almonds

Location: Madera County



Left: On-farm recharge on almond orchard with cover crops.
Right: On-farm recharge on almond orchard without cover crops (natural weed growth).

PROJECT DESCRIPTION

Grewal Brothers Farming (GBF) purchased their farm parcel in 1991 in Madera, a region facing significant challenges as groundwater levels drop, land subsides, and wells in surrounding areas go dry. Gurdial Grewal of GBF manages a micro recharge basin and grows peaches, grapes, almonds, plums, and pistachios.

Gurdial Grewal's roots in American agriculture began with his father, Atma Singh Grewal, who immigrated from India to the U.S. in 1959. Mr. Grewal works with his brothers, Bob and Ranbir, to farm over 1,000 acres of crops. "We raise nine varieties of peaches and four grape varieties, nine kinds of almonds, three kinds of pistachios, along with a plum orchard," said Mr. Grewal. Mr. Grewal notes that diversified cropping systems promote valuable opportunities that have allowed him to implement sustainable practices such as on-farm recharge, whole orchard recycling, cover cropping, compost amendments, and low-till or no-till field operations.



Discovered accidentally while making irrigation system repairs, Gurdial Grewal showcases a large daikon root (turnip family) that grew after two years of previous cover crop planting on a different almond field.

The Grewal brothers feel all farmers and landowners in Madera County and elsewhere in the Central Valley who can recharge should do so whenever surface water is available to replenish the groundwater aquifers to help meet the Sustainable Groundwater Management Act (SGMA) goals.

One of the many crops grown by GBF is almonds. Mr. Grewal has planted cover crops on the almond fields and has seen benefits from cover cropping, such as increased pore space in the soil and contribution of carbon, nitrogen, and other nutrients to the soil from the cover crop biomass. This case study highlights Mr. Grewal's experience conducting on-farm recharge on 40 acres of almonds with cover crops. GBF and Mr. Grewal are currently implementing on-farm recharge whenever possible.

Field Description

CATEGORY	DETAILS
Acres	40
Type of crop	Almonds (Butte & Padre) on Nemaguard rootstock
Age of crop	15 years
Average root depth	3-4 feet
Irrigation infrastructure	Flood with optional single line drip irrigation system

Hydrogeology

CATEGORY	DETAILS
Soil texture	Madera loam
Land IQ recharge suitability rating	Moderately Good
SAGBI rating	Moderately Good
Restrictive layers	None known in this field, but soil in this region often includes an abrupt boundary with an increase of at least 15% clay within the subsoil preventing rapid infiltration. This lateral clay layering is random and inconsistently found in the soil profile at different depths ranging from 10 feet to 150 feet.
Depth to groundwater	Approximately 270 feet

Water Supply

CATEGORY	DETAILS
Source of water	Madera Irrigation District
Maximum diversion rate	5 cubic feet per second
Method of diversion	Madera Irrigation District turnout
Cost of water	Winter 2026 cost (discounted): \$10 per acre-foot Current irrigation season cost: \$110 per acre-foot
Cost of energy	\$760.32 (\$18.66 per acre-foot)

Soil Health

CATEGORY	DETAILS
Compost	None for the past two years
Cover crops	The “Nitro Builder” cover crop mix was sourced from Weaver Seed and planted in early November 2025. The mix includes canola, Braco white mustard, common yellow mustard, and daikon radish applied at 8-12 pounds per acre.
Other amendments	Nitrogen, phosphorus, and potassium fertilizers applied as needed for the crop, and trace minerals added to foliar sprays

On-Farm Recharge Logistics

CATEGORY	DETAILS
Type of recharge	Flood irrigation
Field preparation and management during recharge	The topsoil was disced 4-6 inches deep to prepare for cover crops. No soil preparation was done on the field without cover crops. The cover crop was mowed on 02/26/2026 when it reached 10 inches in height. The cover crops were terminated on 03/15/2026 by mowing and discing 3-4 inches into the topsoil.
Nutrient management (excludes compost)	No fertilizer added since July 2025 harvest
Average inundation height	6-8 inches
Duration of inundation	11 days
Time to dry down after each inundation period	3-4 days
Labor costs	Total labor cost: \$1,175 (44 person-hours at \$26.71 per hour)

Recharge Events

Year	Dates of recharge ^A	Duration (days)	Field size ^A (acres)	Water applied ^A (total AF)	Water applied ^A (AF per acre)	ET _c ^B (ft)	Net water recharged ^C (total AF)	Net water recharged ^C (AF per acre)
2026	1/26 – 2/5	11	40	40.75	1.02	0.06	37.91	0.95

A: Dates of recharge, field size, and water applied sourced from grower.

B: Crop evapotranspiration (ET_c) value sourced from CIMIS station #80.

C: Net water recharged = water applied (AF) - 1.2 * ET_c (feet) * acres

Changes in Field Conditions

CATEGORY	DETAILS
Diseases and weeds	No disease, some extra weed growth due to excess water
Salinity	Not measured
Changes to field practices	None

GROWER'S EXPERIENCE

CATEGORY	DETAILS
Advantages and disadvantages of recharge	Mr. Grewal stated that the main advantage of recharge was getting water back into the aquifers, and good soil moisture in the 3 to 5-foot soil profile after recharge.
Advantages and disadvantages of cover cropping	Mr. Grewal observed that planting cover crops created pore space in the soil profile and allowed him to add nitrogen (in the form of green manure), carbon, and other minerals back into the soil. Mr. Grewal noted the extra work required for planting cover crops and working the residues back into the soil but stated that it was well worth the additional work.
Benefits and challenges of combining recharge and cover cropping	Mr. Grewal did not see any benefits but expects to see soil health benefits once the cover crop biodegrades or becomes integrated into the soil and nutrients are available to the trees.
What is needed to scale on-farm recharge on the grower's farm and in their water district or basin?	Mr. Grewal believes that recharge water should be available for longer so that farmers can make multiple area recharge applications. He adds that farmers need help paying for recharge water because the practice adds costs but does not add profit to the farming system.
Attitude toward on-farm recharge	Mr. Grewal believes on-farm recharge is very good for recharging aquifers, and everyone should participate.

Gurdial Grewal of Grewal Brothers Farming (GBF)



Crop: Peaches

Location: Madera County



Left: Pre-recharge fall pruning on peach orchard.
Right: Peach orchard during recharge.

PROJECT DESCRIPTION

Grewal Brothers Farming (GBF) purchased their farm parcel in 1991 in Madera, a region facing significant challenges as groundwater levels drop, land subsides, and wells in surrounding areas go dry. Gurdial Grewal of GBF manages a micro recharge basin and grows peaches, grapes, almonds, plums, and pistachios.

Mr. Grewal has conducted on-farm recharge on 10 acres of peach orchards using flood irrigation over the past 10 years. The orchard's soils are primarily Madera loam and are rated moderately good for recharging, although some areas of standing water have been observed. GBF has added compost and planted cover crops on many of their fields where they have had issues with standing water, as well as on fields that have very sandy streaks of Tujunga soil to retain nutrients and water in the root zone. Cover cropping can accomplish both by opening the ground to take the water into the root zone and by keeping water in the root zone of the plants with the biomass of the cover crop in the ground.

See *Gurdial Grewal's almond orchard case study* for more background information on GBF.



Field Description

CATEGORY	DETAILS
Acres	10
Type of crop	Peaches (Stanislaus scion wood) on Nemaguard rootstock
Age of crop	19 years
Average root depth	2-3 feet for most roots, some feeder roots as deep as 15-18 feet
Irrigation infrastructure	Dual-line dripline irrigation and flood irrigation system

Hydrogeology

CATEGORY	DETAILS
Soil texture	Madera loam
Land IQ recharge suitability rating	Moderately Good
SAGBI rating	Moderately Good
Restrictive layers	None known in this field, but soil in this region often includes an abrupt boundary with an increase of at least 15% clay within the subsoil preventing rapid infiltration. This lateral clay layering is random and inconsistently found in the soil profile at different depths ranging from 10 feet to 150 feet.
Depth to groundwater	Approximately 270 feet

Water Supply

CATEGORY	DETAILS
Source of water	Madera Irrigation District
Maximum diversion rate	5 cubic feet per second
Method of diversion	Madera Irrigation District turnout
Cost of water	Winter 2026 cost (discounted): \$10 per acre-foot Current irrigation season cost: \$110 per acre-foot

Soil Health

CATEGORY	DETAILS
Compost	None for the past two years
Cover crops	Cover crops were added to newly planted fields for the first 5 years. The “Nitro Builder” cover crop mix was sourced from Weaver Seed and planted in early November 2025. The mix includes canola, Braco white mustard, common yellow mustard, and daikon radish applied at 8-12 pounds per acre.
Other amendments	Soil and tissue tests done periodically and amendments added as needed

On-Farm Recharge Logistics

CATEGORY	DETAILS
Type of recharge	Flood irrigation
Field preparation and management during recharge	Before recharge, all riser valves on the flood system were checked and cleared of debris to ensure water could flow freely
Nutrient management (excludes compost)	No fertilizer applied after late June
Average inundation height	4-5 inches
Duration of inundation	11 days (Not all consecutive)
Time to dry down after each inundation period	3-4 days
Labor costs	Total labor cost: \$1,068 (40 person-hours at \$26.71 per hour)

Recharge Events

Year	Dates of recharge ^A	Duration (days)	Field size ^A (acres)	Water applied ^A (total AF)	Water applied ^A (AF per acre)	ET _c ^B (ft)	Net water recharged ^C (total AF)	Net water recharged ^C (AF per acre)
2026	1/22 – 2/1	11	10	24.97	2.5	0.05	24.37	2.44

A: Dates of recharge, field size, and water applied sourced from grower.

B: Crop evapotranspiration (ET_c) value sourced from CIMIS station #80.

C: Net water recharged = water applied (AF) - 1.2 * ET_c (feet) * acres

Changes in Field Conditions

CATEGORY	DETAILS
Diseases and weeds	No root disease issues, some additional weed growth
Salinity	Not measured
Changes to field practices	None

GROWER'S EXPERIENCE

Mr. Grewal has conducted on-farm recharge on peach orchards several times in the past 10 years with no adverse effects on plant health. GBF generally feels that peach trees grow better after winter flooding because it lowers the salinity levels in the crop's rootzone. Mr. Grewal encourages other peach orchard farmers to try on-farm recharge.

See Gurdial Grewal's almond orchard case study for more grower experience information.



Gurdial Grewal of Grewal Brothers Farming (GBF)



Method: Micro Recharge Basin

Location: Madera County



Managed aquifer recharge conducted on micro recharge basin.

PROJECT DESCRIPTION

Grewal Brothers Farming (GBF) has been conducting recharge using a 1.65-acre micro basin. This parcel of land is in Madera County, which is in a critically overdrafted and high-priority groundwater basin, as designated by the California Department of Water Resources (DWR) under the Sustainable Groundwater Management Act (SGMA). There were well-publicized programs in Madera to support on-farm recharge projects in 2022-2023, which Mr. Grewal participated in on other parcels (see case studies on almonds, peaches, and pistachios). For this project, Mr. Grewal took an alternative approach; rather than spread recharge water across farm fields, the water is concentrated in a dedicated basin.



Micro recharge basin at full capacity (3.5 acre-feet) at sunset (left) and midday (right).

The previous owner of this land had observed poor plant growth at the edge of one field and dug a hole 4-6 feet deep to investigate the soil. They found a super sandy streak of soil running through the field. Mr. Grewal decided to develop the hole into a groundwater recharge micro basin, and applied for funding from the Natural Resources Conservation Service (NRCS) Environmental Quality Incentives Program (EQIP) in 2023. Compared to recharge on farmland, excavated basins can hold more water and thus achieve a greater volume of recharge per acre. They also tend to be built on soils with high water transmission rates, and the water has a greater standing head or pressure to aid infiltration. In 2023, the project was approved and construction of pipelines and a pump to support the recharge began. The micro basin was completed for full operation by winter 2024.

See *Gurdial Grewal’s almond orchard case study* for more background information on GBF.

Field Description

CATEGORY	DETAILS
Acres	1.65
Average depth of pond	5 feet, 3.5 acre-feet capacity
Water conveyance infrastructure	Piping, valves, and pump for conveying water from district turnout to the micro basin

Hydrogeology

CATEGORY	DETAILS
Soil texture	Madera loam
Land IQ recharge suitability rating	Moderately Good
SAGBI rating	Moderately Good
Restrictive layers	None noted on this farm, but soil in this region often includes an abrupt boundary with an increase of at least 15% clay within the subsoil preventing rapid infiltration. This lateral clay layering is random and inconsistently found in the soil profile at different depths ranging from 10 feet to 150 feet.
Depth to groundwater	Approximately 270 feet

Water Supply

CATEGORY	DETAILS
Source of water	Madera Irrigation District
Maximum diversion rate	5 cubic feet per second
Method of diversion	Madera Irrigation District turnout
Cost of water	Winter 2026 cost (discounted): \$10 per acre-foot Current irrigation season cost: \$110 per acre-foot

Recharge Logistics

CATEGORY	DETAILS
Type of recharge	Micro basin
Site preparation and management during recharge	Removed excess debris from the pond (e.g., weeds, fine soil sediment) before filling with water
Average inundation height	4-5 feet
Duration of inundation	7 days (Not all consecutive)
Time to dry down after each inundation period	48 hours
Labor costs	Total labor cost during recharge events: \$186.97 (7 person-hours at \$26.71 per hour)

Recharge Events

Year	Dates of recharge	Duration ^A (days)	Field size (acres)	Water applied ^A (total AF)	Water applied (AF per acre) ^A	ET _c ^B (ft)	Net water recharged (total AF) ^C	Net water recharged ^C (AF per acre)
2026	1/22 – 2/1	4	3.5	18.33	5.24	0.03	18.22	5.21
	1/28 – 1/30	3						

A: Dates of recharge, field size, and water applied sourced from grower.

B: Crop evapotranspiration (ET_c) value sourced from CIMIS station #80.

C: Net water recharged = water applied (AF) - 1.2 * ET_c(feet) * acres

GROWER'S EXPERIENCE

GBF recognized the sandy streak in the soil of the nonproductive farmland as a great opportunity to implement recharge. It was an easy decision for GBF to target this sandy hole for recharging the aquifer to help meet SGMA goals in Madera subbasin. Mr. Grewal says the micro basin project is very easy to operate and maintain: "I open a couple of valves in the morning and return in the afternoon to check for leaks and the level of water in the micro basin." When approximately 11 acre-feet of water was applied to the empty micro basin, the height of the pond reached about 4.5 feet; at this point, Mr. Grewal stopped application. It usually takes about 3-4 days to fill the micro basin to this level. GBF plans to periodically continue recharging in the basin throughout the growing season with the goal of exceeding the 18.33 acre-feet achieved and recorded in 2026.



Gurdial Grewal of Grewal Brothers Farming (GBF)

Crop: Pistachios
Location: Madera County

PROJECT DESCRIPTION

Grewal Brothers Farming (GBF) conducted recharge on a 40-acre pistachio orchard via winter flood irrigation. The pistachio trees are planted on berms that elevate the tree rootstock 8-10 inches above the soil, and cover crops are planted between tree rows. Research suggests soil health practices like cover cropping can increase infiltration rates, thus improving the recharge benefits of on-farm recharge, and nutrient cycling. The field was prepared with furrows on either side of tree rows to allow more efficient water movement across the field and to increase water infiltration into soil. Mr. Grewal's efforts have been supported by a low-cost water incentive provided by Madera Irrigation District to use surface water to recharge the groundwater.

See *Gurdial Grewal's almond orchard case study* for more background information on GBF.

Note: Funding for this project was made possible by a grant/cooperative agreement from the U.S. Department of Agriculture (USDA) Agricultural Marketing Service. Its contents are solely the responsibility of the authors and do not necessarily represent the official views of the USDA.



Sustainable Conservation



Left: Recharge in pistachio orchard with cover crops. Right: Recharge in pistachio orchard with no cover crops (some native weed growth).



Left: Small furrows in the soil on both sides of the plant's berm. Right: Tractor going through cover cropped field with a blower clearing debris from the furrow to create a path for water. Mr. Grewal says this method of cover crop cultivation yields better water distribution, and the water flows from the shallow furrow into the cover crop and readily infiltrates the soil profile.

Field Description

CATEGORY	DETAILS
Acres	40
Type of crop	Pistachios (Kerman scion wood) on UCB-1 rootstock
Age of crop	12 years
Average root depth	10-12 feet
Irrigation infrastructure	Flood irrigation system, with underground mainlines and pop-up valves every 18 feet at the end of each plant line, and single line drip irrigation system



Hydrogeology

CATEGORY	DETAILS
Soil texture	Madera loam
Land IQ recharge suitability rating	Moderately Good
SAGBI rating	Moderately Good
Restrictive layers	None known in this field, but soil in this region often includes an abrupt boundary with an increase of at least 15% clay within the subsoil preventing rapid infiltration. This lateral clay layering is random and inconsistently found in the soil profile at different depths ranging from 10 feet to 150 feet.
Depth to groundwater	Approximately 270 feet

Water Supply

CATEGORY	DETAILS
Source of water	Madera Irrigation District
Maximum diversion rate	5 cubic feet per second
Method of diversion	Madera Irrigation District turnout
Cost of water	Winter 2026 cost (discounted): \$10 per acre-foot Current irrigation season cost: \$110 per acre-foot
Cost of energy	\$1,036.80 (\$8.93 per acre-foot)

Soil Health

CATEGORY	DETAILS
Compost	None
Cover crop	The “Nitro Builder” cover crop mix was sourced from Weaver Seed and planted in early November 2025. The mix includes canola, Braco white mustard, common yellow mustard, and daikon radish applied at 8-12 pounds per acre.
Other amendments	Applied nitrogen, phosphorus, and potassium fertilizer as needed

On-Farm Recharge Logistics

CATEGORY	DETAILS
Type of recharge	Flood irrigation
Field preparation and management during recharge	The flood irrigation system was checked to ensure that the pop-up valves cleared the soil surface and were not obstructed by debris. During the recharge event, 4-5 valves were opened at a time until the water depth reached 4-5 inches between the tree rows. Water was applied sequentially, 4-5 tree rows at a time, until the entire field was flooded. The soil was disced 4-6 inches deep to prepare for cover crops, which were planted on 11/06/2025. No soil preparation was done on the field without cover crops. On 02/26/2026, the cover crop had reached 10 inches in height, and it was mowed. The cover crops were terminated on 03/15/2026 by mowing followed by discing 3-4 inches into the topsoil.
Nutrient management (excludes compost)	No fertilizer applied since July 2025
Average inundation height	6-8 inches
Duration of inundation	8 days, 24 hours/day
Time to dry down after each inundation period	8-10 hours
Labor costs	Total labor cost: \$1,709 (64 person-hours at \$26.71 / hour, encumbered rate) Total labor cost if additional costs included (e.g., workers compensation, documentation of recharge event): \$1,728 - \$1,792 (64 person-hours at \$27-28 per hour)



Recharge Events

Year	Dates of recharge ^A	Duration (days)	Field size ^A (acres)	Water applied ^A (total AF)	Water applied ^A (AF per acre)	ET _c ^B (ft)	Net water recharged ^C (total AF)	Net water recharged ^C (AF per acre)
Non-cover crop field								
2026	1/29 – 2/5	8	20	55.67	2.78	0.05	54.55	2.73
Cover crop field								
2026	1/21 – 1/28	8	20	60.45	3.02	0.03	59.77	2.99

A: Dates of recharge, field size, and water applied sourced from grower.

B: Crop evapotranspiration (ET_c) value sourced from CIMIS station #80.

C: Net water recharged = water applied (AF) - 1.2 * ET_c(feet) * acres

Changes in Field Conditions

CATEGORY	DETAILS
Diseases and weeds	There were weeds that grew more aggressively under the wet conditions
Salinity	Within the top 48 inches of soil, average salinity levels after recharging were higher compared to pre-recharge salinity levels at greater depths, suggesting the salts moved down in the soil profile with recharge. Note that these results are preliminary and research is ongoing; final detailed results will be available in a 2027 report.
Changes to field practices	None

GROWER'S EXPERIENCE

Mr. Grewal noticed additional weed growth in the orchard. While the recharge project created additional work, Mr. Grewal indicated that the recharge benefits were worth it and on-farm recharge projects should be expanded via state programs like the Environmental Quality Incentives Program (EQIP). Since the wet winter of 2022-23, the local Natural Resources Conservation Service (NRCS) soil conservationist team has supported eligible applicants in Madera County to apply for this funding to cover their farm infrastructure needs and water cost to conduct on-farm recharge. Mr. Grewal said that the EQIP funding should be made available statewide to all landowners and farmers in CA.

There are ongoing efforts by Madera Irrigation District and Madera County to continue supporting the adoption of diversified farm practices for growers both inside and outside of the irrigation district service area. Mr. Grewal believes that true collaboration to scale recharge requires inclusion of pathways to conduct recharge for all landowners.

See Gurdial Grewal's almond orchard case study for more grower experience information.



Jimi Valov Jr. of Valov Brothers Farms

Crop: Pistachios
Location: Waukena, Tulare County



Left: Mr. Valov in the cover crop. Middle: recharge on non-cover cropped field. Right: recharge on the cover cropped field.

PROJECT DESCRIPTION

Jimi Valov Jr. is a pistachio farmer located in Waukena, Tulare County, an area that faces serious challenges associated with groundwater level decline, including land subsidence of up to 1 foot per year. Mr. Valov’s fields receive water from Tulare Irrigation District (TID), where there has been a surge in recharge engagement fueled by the implementation of county-wide groundwater pumping allocations for irrigated lands. The pumping allocations are a strong incentive for farmers to conduct on-farm recharge because growers receive credit toward their groundwater pumping allocation. Along with other growers in TID practicing recharge, Mr. Valov uses TID’s groundwater accounting platform to track his recharge credits and groundwater pumping allocations.

This case study highlights Mr. Valov's recharge on 53 acres of pistachios, half of which have cover crops. The results show the increased water infiltration and other benefits that can be achieved by implementing cover crops alongside groundwater recharge. Mr. Valov is a proponent of healthy soil practices and believes there needs to be more support and incentives for practices like cover cropping.

Field Description

CATEGORY	DETAILS
Acres	52.5 acres total – 26.5 acres with cover crop, 26 acres with no cover crop
Type of crop	Pistachios (Kerman scion wood) on UCB-1 rootstock
Age of crop	Non-cover crop field = 17 years, cover crop field = 13 years
Average root depth	9-11 feet
Irrigation infrastructure	Both fields have a turnout from the TID canal and a lift pump leading to a filtration system for a drip irrigation system. Both fields also have a flood irrigation system with underground mainlines and pop-up valves located every 4 plant lines.

Hydrogeology

CATEGORY	DETAILS
Soil texture	Fine sandy loam
Land IQ recharge suitability rating	Good
SAGBI rating	Good
Restrictive layers	Corcoran clay layer lies in the subsurface at about 200-800 feet
Depth to groundwater	Generally, between 136 feet (standing water level) to approximately 160 feet (pumping water level) at Valov's farm. However, the range can be 150-300 feet in surrounding areas.

Water Supply

CATEGORY	DETAILS
Source of water	Tulare Irrigation District (TID)
Maximum diversion rate	Non-cover crop field = 1.75 - 1.9 CFS, Cover crop field = 2.9 CFS
Method of diversion	TID turnout gate on district canal, with use of a lift pump
Cost of water	Winter 2026 cost (discounted): \$53 per acre-foot Current irrigation season cost: \$120-\$230 per acre-foot
Cost of energy	\$9,862.23 (\$59.23 per acre-foot)

Soil Health

CATEGORY	DETAILS
Compost	Non-cover crop field: 3 tons/acre of green compost
Cover crops	Seed mix included grasses, legumes, and flowering broadleaf species.
Other amendments	No tillage, no disking, no mowing (sheep grazing in 2026)

On-Farm Recharge Logistics

CATEGORY	DETAILS
Type of recharge	Flood irrigation
Field preparation and management during recharge	Small berms or checks were required in a few places to ensure water stayed on the field; this was needed to avoid flooding the road. These were done every fourth row in the non-cover crop field but not in the cover crop field. Recharge water was applied every 4-8 plant rows, (~0.5 - 1 acre) until water reached a 4-5-inch height, at which point water was shifted to the next 4-8 plant lines. This process was repeated until the entire field received water.
Nutrient management (excludes compost)	Urea Nitrogen 32% fertilizer was applied in the water for the non-cover crop field during the season as needed. Four applications of foliar sprays based on plant tissue analyses were applied in the cover crop field. The final fourth foliar spray with low-bi urea (water-soluble urea fertilizer with low biuret) was applied in winter 2025-26.
Average inundation height	5-6 inches
Duration of inundation	Non-cover crop field: average 8 days (not all consecutive), 8 hours/day Cover crop field: average 13 days, 8 hours/day
Time to dry down after each inundation period	6-7 days
Labor costs	Labor cost for recharge water management: \$1,050 (64 person-hours at \$16.40 / hour)

Recharge Events

Year	Dates of recharge ^A	Duration (days)	Field size ^A (acres)	Water applied ^A (total AF)	Water applied ^A (AF per acre)	ET _c ^B (ft)	Net water recharged ^C (total AF)	Net water recharged ^C (AF per acre)
Non-cover crop field								
2025	2/24 - 2/27	4	26	31.51	1.21	0.02	30.92	1.19
	3/4 - 3/5	2						
2026	1/12 - 1/17	6	26	24.43	0.94	0.03	23.66	0.97
	1/21 - 1/23	3	20					
Cover crop field								
2025	3/10 - 3/20	11	26.5	47.75	1.8	0.04	46.6	1.76
2026	1/11 - 1/24	14	26.5	62.83	2.37	0.04	61.56	2.32

A: Dates of recharge, field size, and water applied sourced from grower.

B: Crop evapotranspiration (ET_c) value sourced from CIMIS station #80.

C: Net water recharged = water applied (AF) - 1.2 * ET_c(feet) * acres

Changes in Field Conditions

CATEGORY	DETAILS
Diseases and weeds	No disease, typical weeds grew more aggressively with excess moisture
Salinity	Within the top 48 inches of soil, average salinity levels after recharging were higher compared to pre-recharge salinity levels at greater depths, suggesting the salts moved down in the soil profile with recharge. Note that these results are preliminary and research is ongoing; final detailed results will be available in a 2027 report.
Changes to field practices	No mowing or disking in 2026. In 2025, Mr. Valov used a mower to remove the cover crop. Sheep were introduced to graze the orchard floor in early March 2026, with the goal of grazing the cover crop down to a 6-inch height to stimulate plant growth. Sheep were moved each day to cover the entire field over a 10-day period.

GROWER'S EXPERIENCE

CATEGORY	DETAILS
Advantages and disadvantages of recharge	Mr. Valov noted several advantages of recharging including leaching salts, filling the soil profile with water, getting groundwater pumping credits, and replenishing the aquifers. Disadvantages include the potential risks to crop health depending on the time of year (e.g., flooding when temperatures are higher or over saturated when tree growth occurs), resulting in explosion of cover crop or weed pressure, and field management of logistical issues.
Advantages and disadvantages of cover cropping	Mr. Valov recognizes several benefits of cover cropping, including enhanced nutrient cycling and reduced plant stress. He is testing whether the nutrition profile of his crop is improved by using cover crops. The cover cropped field infiltrated more water per acre than the non-cover crop field. Mr. Valov and his irrigators observed water racing across the non-cover crop field compared to the slow-moving water in the cover crop field. In the non-cover crop field, the head of water was slowed by the checks or berms staged throughout the field. In the cover crop field, water was infiltrating faster than it could move across the entire length of the plant row. During the second year, the cover crop did a better job of outcompeting weeds. Mr. Valov also observed more grasses (especially after the termination of broadleaf weeds). Disadvantages include learning to manage the cover crop and cover crop evapotranspiration being charged against his groundwater allocation. Mr. Valov recognized potential problems that could arise from cover crops such as pest issues, water competition, high humidity in the orchard, and transition period problems.
Benefits and challenges of combining recharge and cover cropping	Mr. Valov points to increased soil water retention and infiltration as benefits of combining the practices. He believes growers must eventually do all soil health principles to reap the true benefits. He notes that while cover cropping can increase modeled evapotranspiration (ET), its adoption is often discouraged because Groundwater Sustainability Agencies (GSAs) use Open ET estimates to assess groundwater demand and may charge farmers for that additional ET, even when little or no additional groundwater is applied. As a result, growers implementing soil health practices like cover cropping may be

(Cont'd) Benefits and challenges of combining recharge and cover cropping	penalized rather than incentivized. Mr. Valov believes this approach does not fully account for the whole water system benefits of cover crops, including improved infiltration, greater soil water storage, reduced non-productive evaporation, moderated canopy temperatures, and more efficient use of available soil moisture. He believes GSAs should adopt a more comprehensive accounting framework that better reflects actual groundwater use. He believes GSAs need to truly incentivize cover cropping for growers to adopt it as a sustainable management and healthy soil practice.
What is needed to scale on-farm recharge on the grower's farm and in their water district or basin?	Mr. Valov shares that scaling on-farm recharge will require stronger GSA incentives, improved communications, and continued grower education through field days, demonstration projects, and peer-to-peer learning.
Attitude toward on-farm recharge	Mr. Valov finds it interesting that so much farmland was transitioned away from flood irrigation for irrigation efficiency, and now we are back to flood irrigation for on-farm recharge. He thinks that water allocations for individual water users, especially high-volume pumpers, are needed to reduce groundwater demand for agriculture to survive in the Central Valley.

Justin Wylie of Wylie Farms

Crop: Pistachios

Location: Madera County



PROJECT DESCRIPTION

Justin Wylie is a fifth-generation California farmer and ranch manager with Wylie Farms. "Farming is a family effort," he says, with his father, uncle, brother, and cousin all growing pistachios in the Central Valley. Mr. Wylie grows pistachios in the Madera groundwater subbasin, a region with intensive groundwater pumping and significant groundwater decline, resulting in wells going dry. Recharge on this farm and others in the region can help counteract these issues and promote longevity not only for farming, but for communities that rely on groundwater. There is interest in targeting recharge to locations like Mr. Wylie's that are near communities to improve their water supply.

Alongside conventional production, Mr. Wylie has been transitioning acreage to regenerative and organic management, with a strong focus on water stewardship, improving soil health, and the long-term resilience of California agriculture. His interest in on-farm recharge comes from a practical desire to help farms better manage water while strengthening the land for future generations. He has also engaged in approaches to restoring soil biology through irrigation, using certified organic products like MyLand microalgae and Living Water microbe injections for nutrient fertility.

This case study demonstrates the potential to conduct on-farm recharge with a micro-sprinkler irrigation system on 40 acres of pistachios. Mr. Wylie experienced some difficulties using this system, but he was still able to apply a similar amount of water as other pilots that recharged using flood systems.



Left: Single line micro sprinkler on pistachio orchard. Right: Micro sprinkler (red circle) and its water pattern (yellow circle), with an output of approximately 1 gallon per hour, on pistachio orchard.



Dripline micro sprinkler system hoses disconnected from the riser valves to apply more water per acre.

Field Description

CATEGORY	DETAILS
Acres	40
Type of crop	Pistachios
Age of crop	43 years
Average root depth	5-7 feet
Irrigation infrastructure	Water is pumped into a sand filtration system before being pressurized and pumped through the micro-sprinkler system to supply water to the trees.

Hydrogeology

CATEGORY	DETAILS
Soil texture	Madera loam with sandy clay loam subsurface
Land IQ recharge suitability rating	Good
SAGBI rating	Moderately Good
Restrictive layers	None
Depth to groundwater	250-300 feet

Water Supply

CATEGORY	DETAILS
Source of water	Madera Irrigation District
Maximum diversion rate	2.7 cubic feet per second
Method of diversion	Madera Irrigation District turnout
Cost of water	Winter 2026 cost (discounted): \$20 per acre-foot Current irrigation season cost: \$220 per acre-foot
Cost of energy	\$2,666.84 (\$59.80 per acre-foot)

Soil Health

CATEGORY	DETAILS
Compost	5-7 tons of 100% green compost, banded on top of the berm in early spring just before rainfall
Cover crops	Resident vegetation as ground cover crop year-round and mowed periodically to manageable heights between ~3-12 inches or less in the field. Mr. Wylie maintains full ground cover year-round on the plant line berms and middles of the field. Sheep grazing is done as needed.
Other amendments	The pistachio orchard is managed using a regenerative fertility program that combines foliar nutrition with targeted soil applications throughout the season. Nutrients are applied based on soil, tissue, and sap analyses, with an emphasis on feeding both the tree and the soil biology. The program relies heavily on organic and biologically derived inputs, including compost, fish hydrolysates, microbial products, humic substances, seaweed extracts, and naturally sourced mineral amendments, while supplementing with conventional nutrients only when needed to address documented deficiencies. The goal is to improve nutrient efficiency, build soil health, and support long-term orchard resilience rather than simply maximize short-term inputs.

On-Farm Recharge Logistics

CATEGORY	DETAILS
Type of recharge	Flood irrigation (using micro-sprinkler system)
Field preparation and management during recharge	The field did not require any land shaping to prepare for receiving water or to safely contain water on the field. Each plant line was checked for clogs in the micro-sprinkler system, opening drip line risers, checking the drip lines for problems, and closing the riser valves.
Nutrient management (excludes compost)	No nutrients applied through the irrigation system since July
Average inundation height	2-3 inches sporadic ponding at best, very uneven distribution
Duration of inundation	11 days, 24 hours per day (pump was never shut off)
Time to dry down after each inundation period	5-6 hours
Labor costs	Total labor cost: \$2,872 (160 person-hours at \$17.95 / hour)

Recharge Events

Year	Dates of recharge ^A	Duration (days)	Field size ^A (acres)	Water applied ^A (total AF)	Water applied ^A (AF per acre)	ET _c ^B (ft)	Net water recharged ^C (total AF)	Net water recharged ^C (AF per acre)
2026	1/21 – 1/31	11	40	44.6	1.12	0.05	42.64	1.07

A: Dates of recharge, field size, and water applied sourced from grower.

B: Crop evapotranspiration (ET_c) value sourced from CIMIS station #80.

C: Net water recharged = water applied (AF) - 1.2 * ET_c (feet) * acres

Changes in Field Conditions

CATEGORY	DETAILS
Diseases and weeds	No diseases, some additional weeds noticed
Salinity	Not measured
Changes to field practices	None

GROWER'S EXPERIENCE

Category	Details
Advantages and disadvantages of recharge	Mr. Wylie mentioned replenishing the depleting groundwater aquifer as a benefit of recharging. One difficulty he encountered was being able to deliver equal distribution of water across the field with micro sprinklers as opposed to flood irrigation.
Advantages and disadvantages of cover cropping	One big advantage of cover cropping that Mr. Wylie identified was increased carbon sequestration.
Benefits and challenges of combining recharge and cover cropping	Mr. Wylie identified several benefits of combining recharge and cover cropping, including increased water infiltration and improved water quality with cover crops.
What is needed to scale on-farm recharge on the grower's farm and in their water district or basin?	Mr. Wylie mentioned surface water availability as a need for scaling on-farm recharge, as well as recharge credits.
Attitude toward on-farm recharge	Mr. Wylie believes that all farmers with the capacity to conduct on-farm recharge should do so since the resulting groundwater replenishment supports the longevity of farming.



Karun Samran of Bapu Farming Company

Case Study 9

Crop: Pistachios

Location: Madera County



PROJECT DESCRIPTION

Karun Samran is a second-generation farmer of Bapu Farming Company (Bapu is a Punjabi term of endearment for an older male relative, like a grandfather), which was founded in 1988 as a family-owned wine grape vineyard in Madera. Mr. Samran graduated from UC Berkeley with an Economics degree, and he and his brother Arjun Samran are following in the farming footsteps of their father, Sohan Samran, who encouraged them to take on various responsibilities in the family company. The Samran family produces pistachios, almonds, wine grapes, and processing tomatoes in Madera, Fresno, and Kern Counties. Bapu Farming Company was officially established as an incorporated farming and management company in 1992. The almond processing arm, Bapu Almond Company, was officially established in 2015.

The San Joaquin Valley is a region that faces challenges related to excessive groundwater pumping and land subsidence, and local Groundwater Sustainability Plans (GSPs) include intensive groundwater management actions to combat these issues. Bapu Farming Company's recharge efforts have been supported by incentives provided by Madera Irrigation District, which provides surface water for winter recharge at a reduced cost to growers, and by the Natural Resources Conservation Service (NRCS) through the Environmental Quality Incentives Program (EQIP). NRCS EQIP funding helps cover farm infrastructure needs and management costs to conduct on-farm recharge for farmers in a limited region of the Central Valley.

Groundwater recharge began in earnest at Bapu Farming during the winter of 2019. Since then, Mr. Samran has been committed to adopting on-farm recharge as a sustainable farm practice, believing it should be standard practice that is conducted whenever excess surface water flows are available.

Mr. Samran says that coordination between local farmers and water managers paired with local, state, and federal incentives is crucial for on-farm recharge to become a scaled standard sustainable practice to support both meeting Sustainable Groundwater Management Act (SGMA) goals and the longevity of farming in the Central Valley.



Left: Recharge via a dripline system on pistachio orchard with cover crops. Right: Karun Samran at the Eastside Bypass in Madera County during his recharge efforts in wet winter 2022-23. One of the Samran's family pistachio fields is adjacent to Eastside Bypass.



Left: Cover crop in early stage of growth in pistachio orchard. Right: Cover crop established in pistachio orchard.

Field Description

CATEGORY	DETAILS
Acres	32
Type of crop	Pistachios
Age of crop	16 years
Average root depth	6-7 feet
Irrigation infrastructure	A lift pump moves water into the farm's sand filtration system. Water is then delivered to the orchard via a double-line drip system.

Hydrogeology

CATEGORY	DETAILS
Soil texture	Sandy loam to loam
Land IQ recharge suitability rating	Moderately Good
SAGBI rating	Good
Restrictive layers	None known on this field. Soil in this region often includes an abrupt boundary with an increase of at least 15% clay within the subsoil, preventing rapid infiltration.
Depth to groundwater	Approximately 250 feet

Water Supply

CATEGORY	DETAILS
Source of water	Madera Irrigation District
Maximum diversion rate	2.5 cubic feet per second
Method of diversion	Madera Irrigation District turnout
Cost of water	Winter 2026 cost (discounted): \$10 per acre-foot Current irrigation season cost: \$110 per acre-foot
Cost of energy	\$2,719.27 (\$33.25 per acre-foot)

Soil Health

CATEGORY	DETAILS
Compost	N/A
Cover crops	“Weed Suppressor Mix” (seed mixture including Winter Rye, Winter Lentil, Sunflower-Black oil, Spring Barley, Triticale-winter, Black Oats, Berseem Clover, Common Vetch, and Austrian winter peas) was planted at 56 pounds per acre via seed drill on 12/21/2025.
Other amendments	Spread gypsum, Tiger 90 sulfur, and lime wherever needed based on soil sampling data

On-Farm Recharge Logistics

CATEGORY	DETAILS
Type of recharge	Flood irrigation (using double-line drip system)
Field preparation and management during recharge	There were no land shaping or berms needed to control water movement because the field was leveled. During the 19-day period of water application, Mr. Samran conducted daily monitoring of the water system and movement of water throughout the field to ensure equal distribution. The field was disced to a depth of 5-6 inches on 11/15/2025 to prepare for cover crop seeding. Cover crop seed was planted via seed drill on 12/21/2025. Cover crop was mowed on 3/1/2026 when it reached 12 inches in height and was periodically mowed thereafter to keep it at about 2-3 inches high. Mr. Samran’s cover crop is still growing in July. He will start mowing it down at 3 feet to a manageable height of 6 inches. He will allow it to self-terminate (dry out) later in season but will do a final mow preharvest to ensure complete termination.
Nutrient management (excludes compost)	Nitrogen, phosphorus, potassium, and minor nutrients added as needed per soil and tissue analyses

On-Farm Recharge Logistics (continued)

Average inundation height	4-5 inches
Duration of inundation	19 days, 24 hours per day (pump was not turned off for the 19-day application period)
Time to dry down after each inundation period	6-8 hours
Labor costs	Total labor cost: \$2,728 (152 person-hours at \$17.95 / hour) (Cost assumption is based on the Wylie case study, a similar dripline system used for on-farm recharge)

Recharge Events

Year	Dates of recharge ^A	Duration (days)	Field size ^A (acres)	Water applied ^A (total AF)	Water applied ^A (AF per acre)	ET _c ^B (ft)	Net water recharged ^C (total AF)	Net water recharged ^C (AF per acre)
2026	1/16 - 2/5	19	32	81.78	2.56	0.08	78.55	2.45

A: Dates of recharge, field size, and water applied sourced from grower.

B: Crop evapotranspiration (ET_c) value sourced from CIMIS station #80.

C: Net water recharged = water applied (AF) - 1.2 * ET_c (feet) * acres

Changes in Field Conditions

CATEGORY	DETAILS
Diseases and weeds	No disease; Some new weed activity or growth in cover crop
Salinity	Within the top 48 inches of soil, average salinity levels after recharging were higher at greater depths, suggesting the salts moved down in the soil profile with recharge. Note that these results are preliminary and research is ongoing; final detailed results will be available in the year 2027 report.
Changes to field practices	None

GROWER'S EXPERIENCE

Category	Details
Advantages and disadvantages of recharge	Mr. Samran noted many advantages of on-farm recharge, including diluting salts in the root zone, replenishing the aquifer, and reducing flood risk. Mr. Samran's experience conducting on-farm recharge on both pistachio and almond orchards has allowed him to increase the volume of water he applies without apprehension about negative impacts to crop health. He has never experienced crop health issues due to recharging on his pistachio or almond trees.
Advantages and disadvantages of cover cropping	Mr. Samran observed that cover cropping provided green biomass for incorporation into the soil and aerated the soils, allowing for increased water infiltration.
Benefits and challenges of combining recharge and cover cropping	Benefits of cover cropping that Mr. Samran noted included enhancing water infiltration rates at the soil surface compared to non-cover crop fields. Challenges include logistics associated with timing field preparation and planting for the cover crop, and timing of surface water availability from the irrigation district. There were additional costs to the operation for recharging, including the seed drill, pre-plant discing, and periodic mowings to regulate the height below the orchard canopy.
What is needed to scale on-farm recharge on the grower's farm and in their water district or basin?	Mr. Samran shares that financial incentives are needed to scale on-farm recharge. For on-farm recharge to become standard practice, coordination between local farmers and water managers paired with local, state, and federal incentives is crucial. Mr. Samran says that more conveyance needs to be constructed to take full advantage of excess flows in wet winters and deliver water to areas that do not currently have access to surface water delivery systems.

Attitude toward on-farm recharge

Mr. Samran believes that on-farm recharge is a great practice that should become standard practice. Whenever excess surface water is available during winter months and late spring-summer months; he believes farmers and landowners have a responsibility to conduct groundwater recharge efforts. Additionally, when lands are fallow, such as for a short period between harvest and planting of annual crops, one may be able to safely conduct on-farm recharge.



Phillip Cunha of P Cunha Farms

Crop: Pistachios

Location: Waukena, Tulare County



PROJECT DESCRIPTION

Phillip Cunha is a pistachio farmer in the Waukena region in Tulare County, which has been identified as a major subsidence zone that has experienced up to 1 foot in ground level decline each year. He has both a dripline system, allowing him to irrigate efficiently, and a surface flood system, through which he can apply larger volumes of recharge water when surface water is available.

Mr. Cunha primarily conducted his recharge through the dripline system (approximately 95% of the water applied), and the remainder was applied using the flood system. This case study covers the recharge Mr. Cunha applied to his pistachio orchard, one half with cover crops and the other half with no cover crops and traditional tillage. Mr. Cunha conducted on-farm recharge with planted cover crops for the first time on his pistachio orchard in the winter of 2025-2026. The recharge conducted and its impacts on the cover crop and non-cover crop portions of the field were compared to demonstrate the impacts of cover crops on soil health and on-farm recharge outcomes. Mr. Cunha foresees that cover cropping practices and both flood and dripline systems in the same field will help make farming sustainable as growers aim to decrease their water usage and increase groundwater supply through on-farm recharge.



On-farm recharge on pistachio orchard without cover crops (some native weeds present).



On-farm recharge on pistachio orchard with cover crops.

Note: Funding for this project was made possible by a grant/cooperative agreement from the U.S. Department of Agriculture (USDA) Agricultural Marketing Service. Its contents are solely the responsibility of the authors and do not necessarily represent the official views of the USDA.

Field Description

CATEGORY	DETAILS
Acres	38
Type of crop	Pistachios (Kerman scion wood) on PG-1 rootstock
Age of crop	27 years
Average root depth	10 feet
Irrigation infrastructure	A flood system with pop-up valves connected to underground pipes, and a single line drip irrigation system.

Hydrogeology

CATEGORY	DETAILS
Soil texture	Fine sandy loam
Land IQ recharge suitability rating	Moderately Good
SAGBI rating	Moderately Good
Restrictive layers	Corcoran clay layer lies in the subsurface at about 200-800 feet.
Depth to groundwater	Generally, between 136 feet (standing water level) to approximately 160 feet (pumping water level) at Cunha's farm. However, the range can be 150-300 feet in some areas of Waukena.

Water Supply

CATEGORY	DETAILS
Source of water	Tulare Irrigation District (TID)
Maximum diversion rate	4.5 – 5.0 cubic feet per second
Method of diversion	TID turnout gate on district canal with use of a lift pump
Cost of water	Winter 2026 cost (discounted): \$53 per acre-foot Current irrigation season cost: \$120-\$230 per acre-foot
Cost of energy	\$2,433.06 (\$60.48 per acre-foot)

Soil Health

CATEGORY	DETAILS
Compost	None
Cover crops	Cover crops were planted on 12/23/2025
Other amendments	None in past 4 years

On-Farm Recharge Logistics

CATEGORY	DETAILS
Type of recharge	Flood irrigation
Field preparation and management during recharge	All recharge fields were disced about 6-8 inches deep on 12/22/2025 Cover crop seed was planted via seed drill on 12/23/2025
Nutrient management (excludes compost)	No nutrients applied since June 2025
Average inundation height	3-4 inches head height
Duration of inundation	21 days (not all consecutive) for 24 hours each day for drip line
Time to dry down after each inundation period	18-24 hours
Labor costs	Total labor cost: \$1,647 (92 person-hours at \$17.90 per hour)

Recharge Events

Year	Dates of recharge ^A	Duration (days)	Field size ^A (acres)	Water applied ^A (total AF)	Water applied ^A (AF per acre)	ET _c ^B (ft)	Net water recharged ^C (total AF)	Net water recharged ^C (AF per acre)
2026	1/8 - 1/20	13	38	40.23	1.06	0.1	35.63	0.94
	1/24 - 2/3	11						

A: Dates of recharge, field size, and water applied data are from the grower.

B: Crop evapotranspiration (ET_c) over the recharge dates, from CIMIS station #182.

C: Net water recharged = water applied (AF) - 1.2 * ET_c(feet) * acres

Changes in Field Conditions

CATEGORY	DETAILS
Diseases and weeds	No disease, some weed growth
Salinity	In the top 48 inches of the soil profile, average salinity levels after recharging were higher at greater depths, suggesting the salts moved down in the soil profile with recharge. Note that these results are preliminary and research is ongoing; final detailed results will be available in a 2027 report.
Changes to field practices	First time planting cover crop in field

GROWER'S EXPERIENCE

Category	Details
Advantages and disadvantages of recharge	Mr. Cunha noted that the wet profile before the season starts may help eliminate pests. The water can flood out rodents and insects like the navel orangeworm, and interrupt the life cycles of the insects. Mr. Cunha could see the moisture in the soil throughout the season as the cover crop did not die out. He mowed twice down to 1-2 inches for a manageable height, then allowed to die out naturally. One benefit that Mr. Cunha noted was the potential leaching of salt from the root zone. Mr. Cunha observed some pooling at the end of the orchard row but did not consider it negative since it was during the dormant season. The pooled water was also gone within 24 hours.
Advantages and disadvantages of cover cropping	This is the first year Mr. Cunha has used cover cropping. He anticipates increased organic matter and carbon sequestration in the soil resulting from cover crops. No disadvantages were noted, although Mr. Cunha has heard from other farmers who believe cover crops will increase insect pressure from lygus bugs.
Benefits and challenges of combining recharge and cover cropping	Mr. Cunha believes that the field had a higher water intake when recharge was done with cover cropping compared to previous years in which recharge was done without cover cropping! One challenge Mr. Cunha faced was that he did not own a seed drill and mower, and so had to pay an additional cost to rent one.
What is needed to scale on-farm recharge on the grower's farm and in their water district or basin?	Mr. Cunha says that more field days are needed for farmers, and they should include a demonstration, hands-on training, and lunch. Farmers need help paying for the adoption of on-farm recharge. The costs of electricity and water are large, and there are additional expenses, such as the seed drill that Mr. Cunha had to rent.
Attitude toward on-farm recharge	Mr. Cunha feels that on-farm recharge is necessary for the future. He believes this practice will help farming in the San Joaquin Valley persist into the future, and he likes the idea of recharging the aquifer in winter and using banked water to irrigate in the dry period of the growing season.

Staci Buttermore

Crop: Pistachios

Location: Orland, Glenn County



PROJECT DESCRIPTION

Staci Buttermore is a pistachio farmer in Glenn County. She is committed to conducting on-farm recharge to comply with the Sustainable Groundwater Management Act (SGMA) and replenish the State's depleted aquifers. Part of her motivation comes from wanting to preserve family farms and passing her orchard down to her kids. Ms. Buttermore's case study provides an example of on-farm recharge conducted later in the season, during the months of March and April. Her recharge events were made possible because of large atmospheric river events that occurred in early springtime, which caused reservoirs like Oroville and Shasta to release water sporadically to allow for more storage space. Orland-Artois Water District temporarily made this water available for growers to recharge at no cost until the start of the irrigation season, at which point the irrigation season price was set.



Left: Recharge efforts on pistachio orchard. **Right:** Staci Buttermore inspects pistachio nut development in her older Kerman variety, which matures later than some of the newer varieties of pistachio trees like Golden Hills.

Field Description

CATEGORY	DETAILS
Acres	27.5
Type of crop	Pistachios, Kerman scion wood on UCB-1 rootstock
Age of crop	43 years
Average root depth	About 15 feet
Irrigation infrastructure	Flood system



Hydrogeology

CATEGORY	DETAILS
Soil texture	Fine-loamy mix
Land IQ recharge suitability rating	Moderately Good
SAGBI rating	Good
Restrictive layers	None known
Depth to groundwater	Average 52 feet but can fluctuate when a large amount of pumping occurs

Water Supply

CATEGORY	DETAILS
Source of water	Orland-Artois Water District (OAWD)
Maximum diversion rate	4-5 cubic feet per second
Method of diversion	OAWD turnout
Cost of water	Winter 2026 cost (discounted): \$0 per acre-foot Current irrigation season cost: \$40 per acre-foot

Soil Health

CATEGORY	DETAILS
Compost	None
Cover crops	None
Other amendments	Conventional fertilizers for crop growth and development

On-Farm Recharge Logistics

CATEGORY	DETAILS
Type of recharge	Flood irrigation
Field preparation and management during recharge	No preparation was needed because the land already has flood irrigation set up. The field was divided into three smaller irrigation checks of 7.5 acres, 10 acres, and 10 acres for a total of 27.5 acres. Spreading the excess surface water flows simply involved opening and closing a series of riser valves on the underground irrigation mainline connected to the turnout to spread water evenly throughout the field.
Nutrient management (excludes compost)	No nutrient application since July 2023, prior to 2024 recharge event
Average inundation height	5-6 inches
Duration of inundation	3 days on each irrigation check (not consecutive)
Time to dry down after each inundation period	48-72 hours
Labor costs	Not reported

Recharge Events

Year	Dates of recharge ^A	Duration (days)	Field size ^A (acres)	Water applied ^A (total AF)	Water applied ^A (AF per acre)	ET _c ^B (ft)	Net water recharged ^C (total AF)	Net water recharged ^C (AF per acre)
2024	3/20, 4/18, 4/28	3	7.5	9.95	1.33	0.02	9.8	1.31
	3/21, 4/19, 4/29	3	10	11.23	1.12	0.02	11.01	1.1
	3/22, 4/20, 4/30	3	10	11.15	1.12	0.02	10.93	1.09

A: Dates of recharge, field size, and water applied sourced from growers.

B: Crop evapotranspiration (ET_c) value sourced from CIMIS station #222.

C: Net water recharged = water applied (AF) - 1.2 * ET_c(feet) * acres

Changes in Field Conditions

CATEGORY	DETAILS
Diseases and weeds	No disease, some extra weed growth
Salinity	Within the top 48 inches of soil, average salinity levels after recharging were higher compared to pre-recharge salinity levels at greater depths, suggesting the salts moved down in the soil profile with recharge. Note that these results are preliminary and research is ongoing; final detailed results will be available in a 2027 report.
Changes to field practices	No, farmer typically uses flood irrigation

GROWER'S EXPERIENCE

After conducting recharge, Ms. Buttermore noticed that several species of wildlife began to visit the farm. Deer, ducks, and turkeys were gathering to drink and rest in the ponding water across the pistachio orchard. Ms. Buttermore did not experience any soil or plant health problems because of the flooding. If more surface water had been available earlier in the winter season, she would have opted to apply more water. Ms. Buttermore wants to be a part of the solution to conserve California's groundwater. She would like to pass her farm down to her kids and believes that effort is needed to preserve family farms by adopting sustainable water practices.



Brian and Matthew Watte



Crop: Pistachios
Location: Tulare County

PROJECT DESCRIPTION

Brian and Matthew Watte are father and son and second and third generation pistachio farmers, respectively, in the Kaweah subbasin of Tulare County. This region has been identified as a priority basin and has experienced up to 1 foot in ground level decline per year because of regional groundwater extraction.

The Wattes have fields both with and without cover crops. They converted their orchard to dripline irrigation approximately 26 years ago and they maintained their flood irrigation system. The flood system allows them to conduct recharge whenever excess surface water flows are available, and they have recharged on and off during the winter for the past 24 years (~ 75% of the time to date). The Wattes’ decision to keep their flood system in place and add the dripline system allows them to balance the need for aquifer replenishment with the need for efficient irrigation to comply with the Sustainable Groundwater Management Act (SGMA) and ensure that sustainable farming irrigation practices help achieve water balance by 2042.



Left: Pistachio orchard without cover crops. Right: Pistachio orchard with cover crops.



Left: On-farm recharge on pistachio orchard without cover crops. Right: On-farm recharge on pistachio orchard with cover crops.

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Field Description

CATEGORY	DETAILS
Acres	196
Type of crop	Pistachios
Age of crop	24 years
Average root depth	12 feet
Irrigation infrastructure	Each field is equipped with a turnout, a lift pump feeding water into a 16-inch pipeline, and an underground flood system with 10-inch “Fresno Valves” which pop up every 5th-plant line.

Hydrogeology

CATEGORY	DETAILS
Soil texture	Fine sandy loam to loam
Restrictive layers	This area's soil texture is known to have some subsurface clay layering. A perched water table often forms from a depth of 48 to 72 inches between January and March, which can act like a seasonal hydraulic restriction.
Land IQ recharge suitability rating	Moderately Good
SAGBI rating	Moderately Good
Depth to groundwater	Approximately 185 feet below ground level

Water Supply

CATEGORY	DETAILS
Source of water	Tulare Irrigation District (TID)
Maximum diversion rate	4-4.5 cubic feet per second
Method of diversion	TID turnout
Cost of water	Winter 2026 cost (discounted): \$53 per acre-foot Current irrigation season cost: \$120-\$230 per acre-foot
Cost of energy (2026)	\$1,000 (\$4.66 per acre-foot)

Soil Health

CATEGORY	DETAILS
Compost	None
Cover crops	Yes
Other amendments	As needed per soil or tissue samples, typically twice per growing season

On-Farm Recharge Logistics

CATEGORY	DETAILS
Type of recharge	Flood irrigation
Field preparation and management during recharge	Berms between plant lines separate cover cropped and non-cover cropped fields, and an 18-inch perimeter border berm contains recharge water where low spots occur periodically in the field.
Nutrient management (excludes compost)	Last fertilizer injection into the dripline system applied in July 2025
Average inundation height	4-5 inches
Duration of inundation	Average 11 days at 8 hours/day
Time to dry down after each inundation period	2-3 days
Labor costs	Total labor cost: \$1,880 (96 person-hours at \$19.58 / hour)

Recharge Events

Year	Dates of recharge ^A	Duration (days)	Field size ^A (acres)	Water applied ^A (total AF)	Water applied ^A (AF per acre)	ET _c ^B (ft)	Net water recharged ^C (total AF)	Net water recharged ^C (AF per acre)
2025	3/8 - 3/14	7	40	72.82	1.82	0.02	71.76	1.79
2026	1/13 - 1/26	14	196	214.73	1.1	0.04	205.52	1.05

A: Dates of recharge, field size, and water applied sourced from growers.
B: Crop evapotranspiration (ET_c) value sourced from CIMIS station #80.
C: Net water recharged = water applied (AF) - 1.2 * ET_c (feet) * acres

Changes in Field Conditions

CATEGORY	DETAILS
Diseases and weeds	No disease, some extra weed growth
Salinity	Within the top 48 inches of soil, average salinity levels varied, with the highest salinity in the top few inches of soil. Salinity throughout the soil profile was generally lower after recharging. Note that these results are preliminary and research is ongoing; final detailed results will be available in a 2027 report.
Changes to field practices	Cover crops mowed and disced

GROWER'S EXPERIENCE

Category	Details
Advantages and disadvantages of recharge	The Wattes noted that building up the soil water profile and diluting concentrated salts in the root zone are important advantages of recharge for optimum plant growth and development.
Advantages and disadvantages of cover cropping	The Wattes identified building better soil structure and health and locking in soil moisture as advantages of cover crops. Cover crops add new costs and tasks to their farming system, which can be a disadvantage.
Benefits and challenges of combining recharge and cover cropping	The Wattes believe that recharge and cover cropping practices work well together. An identified challenge was being able to time their recharge implementation with weather events and managing that task along with other activities during that time of year (e.g., pruning, shredding, berm blowing, spraying pre-emergent herbicide).
What is needed to scale on-farm recharge on the grower's farm and in their water district or basin?	To scale on-farm recharge, the Wattes believe growers need more information about the benefits of recharge.
Attitude toward on-farm recharge	The Wattes feel great about on-farm recharge, noting that it has been a part of their program for the past 24 years.



Matthew Young

Crop: Fallow

Location: Stanislaus County



PROJECT DESCRIPTION

Matthew Young's 16-acre farm is located in a rural area of Stanislaus County within the Modesto subbasin, which is designated as a high-priority basin under the Sustainable Groundwater Management Act (SGMA). Rural properties in this area often rely on private individual wells, as is the case for Mr. Young's family. The farm is currently fallow land, and Mr. Young is working with Sustainable Conservation to develop a multi-benefit land repurposing concept for ecosystem conservation. The long-term vision involves converting the fallow land to native grassland with pollinator habitat and oak woodland. It also includes the transformation of a seasonal marsh into perennial features designed to improve soil health, promote carbon sequestration, and enhance wildlife habitat to increase biodiversity. Groundwater pumping is reduced on this property due to the lack of irrigated crops, and Mr. Young is conducting on-farm recharge whenever surface water is available. From late April 2024 to early November 2024, on-farm recharge was conducted for a duration of approximately 18 days (8-to-12-hour water applications). These recharge events are intended to demonstrate how small agricultural properties can be repurposed to provide ecological, hydrological, and community benefits while remaining consistent with the long-term goals of the Sustainable Groundwater Management Act (SGMA).



Left: Aerial image of the lower portion of the field. **Right:** Aerial image of the upper portion of the field with the turnout gate and marsh area labeled.



On-farm recharge across the native ground cover, which includes various weed species.



Farmer Matthew Young

Note: Funding for this project was made possible by a grant/cooperative agreement from the U.S. Department of Agriculture (USDA) Agricultural Marketing Service. Its contents are solely the responsibility of the authors and do not necessarily represent the official views of the USDA.



Field Description

CATEGORY	DETAILS
Acres	16
Type of crop	Fallow land with both grasses and broad-leafed resident vegetation
Age of crop	Ground has been fallowed for more than 10 years and was previously used to graze cattle.
Average root depth	18-48 inches
Irrigation infrastructure	Flood

Hydrogeology

CATEGORY	DETAILS
Soil texture	Fine-loamy, with subsoil layers containing silty clay
Land IQ recharge suitability rating	Moderately Good
SAGBI rating	Moderately Good
Restrictive layers	The San Joaquin sandy loam soil is often underlain by a compact silt layer that can act as a restricting horizon, in some cases cemented with lime to form a thin weak hardpan. The unconfined aquifer exists in deposits above the Corcoran Clay, which is 150-200 feet deep.
Depth to groundwater	~ 65 to 75 feet range from winter to summer months

Water Supply

CATEGORY	DETAILS
Source of water	Modesto Irrigation District
Maximum diversion rate	5 cubic feet per second
Method of diversion	Modesto Irrigation District turnout
Cost of water	\$53 per acre-foot

Soil Health

CATEGORY	DETAILS
Compost	Resident vegetation was incorporated into the soil with low tillage work (top 4-5 inches)
Cover crops	Diverse resident grasses and broad-leafed plants
Other amendments	None

On-Farm Recharge Logistics

CATEGORY	DETAILS
Type of recharge	Flood irrigation on fallow agricultural fields
Field preparation and management during recharge	Berms were created every 50 feet parallel with water flow, at the end of fields, and perpendicular every ~200 ft
Nutrient management (excludes compost)	None
Average inundation height	4-5 inches
Duration of inundation	18 days (not consecutive). Water flooded the field for approximately 8 hours until the 16 acres were completely flooded.
Time to dry down after each inundation period	5-7 days
Labor costs	Total labor cost: \$1,224 (72 person-hours at \$17/hour)

Recharge Events

Year	Dates of recharge ^A	Duration (days)	Field size ^A (acres)	Water applied ^A (total AF)	Water applied ^A (AF per acre)	ET _c ^B (ft)	Net water recharged ^C (total AF)	Net water recharged ^C (AF per acre)
2024	4/28, 5/13, 5/19, 6/7, 6/16, 6/30, 7/12, 7/13, 8/10, 8/24, 8/25, 9/9, 9/22, 10/12, 10/20, 11/3, 11/4, 11/5	18	16	72.2	4.51	0.17	68.94	4.31

A: Dates of recharge, field size, and water applied sourced from growers.

B: Crop evapotranspiration (ET_c) value sourced from CIMIS station #80.

C: Net water recharged = water applied (AF) - 1.2 * ET_c(feet) * acres

Changes in Field Conditions

CATEGORY	DETAILS
Diseases and weeds	No disease. Broad-leafed weeds and grasses had prolific growth in April, but in May the grass began to die back as temperatures increased. The second stand emerged in mid-June. In late October, the cool seasonal grasses began to germinate once again across the recharge field area.
Salinity	Not measured
Changes to field practices	None

GROWER'S EXPERIENCE

CATEGORY	DETAILS
Advantages and disadvantages of recharge	Mr. Young observed many species of waterfowl and other birds, snakes, dragonflies, and frogs using the recharge site. The longest recorded period that the water stood in the field was 4 days at the marsh area and 2 days elsewhere. On average, water stood for 1 day at the far north end of the field. One challenge Mr. Young faced was controlling the water across the field, wetting patterns, and a disagreement with a farm neighbor who was upset due to some apparent seepage into his pistachio field.
Advantages and disadvantages of cover cropping	Mr. Young noted that a true cover crop would help because cool season native grasses died back as soon as the temperatures increased in early May during recharge.
Attitude toward on-farm recharge	Mr. Young considers himself a sustainable agriculturalist because he is working to develop multi-benefit concepts for enhancing ecosystem benefits, in addition to replenishing groundwater levels near his farm. He understands farm longevity means sustainable farming practices that avoid groundwater overdraft or excessive pumping. He shares that San Joaquin Valley farmers and communities need to conserve and replenish as much water as possible by recharging using surface water and by using surface water for irrigation whenever it is available in lieu of groundwater.



Note: Case studies below are unchanged from the previous version of the Recharge Methods Manual, published in 2023.



On-farm Recharge Pilot Projects Case Study

Grower: Christine and Erich Gemperle

Crop: Almonds

Location: Ceres, Stanislaus County



Site Conditions



- Acreage = 36.5 acres for recharge in a 40-acre field
- Crop type = Almonds
- 20 acres, crop age = 5 years
- 20 acres, crop age = 21 years
- Land IQ rating = Moderately good
- Soil Agricultural Groundwater Banking Index rating = Excellent

Water Supply

- Gravity flow water was supplied free of charge from Turlock Irrigation District (TID) as part of their flood risk reduction efforts. TID notifies grower when water is available for delivery.

Soil Health

- Cover cropping for 10 years, mix of clover and broadleaf mustards.

On-Farm Recharge Logistics

Labor needed:

- One person to monitor recharge events day and night. No tractor work was involved.
- 4 days at 18 hours per day = 72 hours
- \$20/hour labor = \$1,440

Field infrastructure:

- Fields are set up with 1 turnout per 5 acres for gravity flood irrigation.
- TID installed Rubicon Flume meters to measure water use

Field preparation and management:

- Very little preparation was needed because the farm maintained the flood irrigation system even after converting to dripline and micro sprinkler irrigation.
- Gate valves require lubrication.

Recharge Events

Total applied water:

Water applied January 12-15, 2023.

- 27.5 acre-feet over 36.5 acres, about 0.8 foot per acre

Water applied February 1, 2023.

- 16.5 acre-feet over 36.5 acres, about 0.5 foot per acre

Total water recharged:

- 43.9 acre-feet over 36.5 acres, about 1.2 foot per acre

For more information, contact: Rogell Rogers, Agronomist, Sustainable Conservation, at rrogers@suscon.org or 209-576-7729 x346.

Grower: Eric Harcksen

Crop: Almonds

Location: Ballico, Merced County



Site Conditions



- Acreage = 18 acres for recharge (control field 20 acres)
- Crop type = Almonds
- Crop age = Mixture of 21 years and 28 years
- Land IQ rating = Good
- Soil Agricultural Groundwater Banking Index rating = Good

Water Supply

- Water was supplied free of charge from Turlock Irrigation District (TID) as part of their flood risk reduction efforts. TID notifies grower when water is available for delivery.
- TID covered the electrical cost of \$66.20 for pumping.

Soil Health

- Cover cropping mix of clover and broadleaf mustards.
- Shredded tree clippings spread across topsoil in the fall.

On-Farm Recharge Logistics

Labor needed:

- One person to monitor recharge events.
- 5 days at 12 hours/day = 60 hours
- \$20/hour labor = \$1,200

Field infrastructure:

- Water was pumped into the grower's existing underground flood system, which has valve gates every other tree row in the field.
- TID installed Rubicon Flume meters to measure water use.

Field preparation and management:

- Every 4 tree lines use 8- to 10-inch-high berms to enclose or hold water until water rose 6–8 inches.
- After water rose 6–8 inches, the valve was shut off and the next valve turned on to allow water to flow into the next set of four tree lines.

Recharge Events

Total applied water:

- Five applications were made during December 2022.
- 21.08 acre-feet over 18 acres, about 1.17 feet per acre

Total water recharged:

- 20.95 acre-feet over 18 acres, about 1.16 feet per acre (1.27 feet per acre with rain)

For more information, contact: Rogell Rogers, Agronomist, Sustainable Conservation, at rrogers@suscon.org or 209-576-7729 x346.

Grower: Eric Spycher

Crop: Almonds

Location: Bellico, Merced County



Site Conditions



- Acreage = 13 acres for on-farm recharge
- Crop type = Almonds
- Crop age = 7 years
- Land IQ rating = Excellent
- Soil Agricultural Groundwater Banking Index rating = Excellent

Water Supply

- Water was supplied free of charge from Turlock Irrigation District (TID) as part of their flood risk reduction efforts. TID notifies grower when water is available for delivery.

Soil Health

- Soil was amended with a cover crop and composting during the first three years of growth.

On-Farm Recharge Logistics

Labor needed:

- Three people to monitor recharge events (10 hours each person per day for 2 days = 60 hours) plus 1 person for 10 hours tractor work.
- \$20/hour for 70 hours = \$1,400

Field infrastructure:

- The original gravity flood system was divided into one underground water valve for every 8 plant lines.
- TID installed Rubicon Flume meters to measure water use.

Field preparation and management:

- Berms were installed to a height of 1.5 feet to flood 4 plant lines at one time.
- After reaching a head height of 7-8 inches, the berms were breached to direct water to move to the next set of 4 plant lines.
- 5-6 hours after the water was shut off, the water had completely infiltrated into the soil.

Recharge Events

Total applied water:

Water applied December 14-15, 2022.

- 16 acre-feet over 13 acres, about 1.2 feet per acre

Total water recharged:

- 15.99 acre-feet over 13 acres, about 1.2 feet per acre

For more information, contact: Rogell Rogers, Agronomist, Sustainable Conservation, at rrogers@suscon.org or 209-576-7729 x346.

Grower: Karun Samran

Crop: Almonds

Location: Chowchilla, Madera County



Site Conditions



- Acreage = 5 fields (total 165 acres)
- Crop type = Almonds
- Fields 1 and 2 = 12 years old
- Fields 3, 4, and 5 = 6 years old
- Land IQ rating = Moderately good
- Soil Agricultural Groundwater Banking Index rating = Good to moderately good

Water Supply

- Chowchilla Water District (CWD) provided water at \$10 per acre foot.
- CWD notified grower when water was available for recharge.

Soil Health

- Spread compost on berms post-harvest, 3 tons per acre.
- Applied shredded pruning brush in between plant lines.
- Cover cropping mix of clover and broadleaf mustards grown winter through spring.

On-Farm Recharge Logistics

Labor needed:

- One person to monitor recharge events.

Field infrastructure:

- The original gravity flood irrigation infrastructure was still intact, so no prep work was required.
- CWD metered turnouts.

Field preparation and management:

- Flood 10 rows at a time using one underground water valve.
- Upon filling the rows with 3-4 inches of water, shut off the valve and rotate to the next 10 plant rows.
- Repeated this process until the entire field has been flooded.

Recharge Events

Total applied water:

Water applied at various times from 1/13/2023 through 2/6/2013.

- 175 acre-feet over 165 acres, about 1.1 feet per acre

Total water recharged:

- 172.6 acre-feet over 165 acres, about 1 foot per acre

For more information, contact: Rogell Rogers, Agronomist, Sustainable Conservation, at rrogers@suscon.org or 209-576-7729 x346.



On-farm Recharge Pilot Projects Case Study

Grower: Al Costa

Crop: Wine Grapes

Location: Acampo, San Joaquin County



Project Description

Al Costa is a wine grape grower in the San Joaquin County who has participated in on-farm recharge since 2018. His 13.7-acre recharge site is very sandy, allowing the application of large volumes of water without harm to his crops (see tables below for details). The grower also has the benefit of working with an irrigation district that is very supportive of recharge efforts.

The on-farm recharge effort at the vineyard is a prime example of what can be achieved when different entities, such as farm communities, local irrigation districts, and groundwater sustainability agencies, collaborate with the common goal of replenishing groundwater.

The accomplishments of the grower and the recharge benefits observed at his farm are an important reminder that grower participation is critical to achieving Sustainable Groundwater Management Act goals. Incentivized on-farm recharge programs encourage grower participation, because many growers need financial support to cover the cost of infrastructure and electricity required to conduct on-farm recharge. Growers would like to see an expansion of similar programs in the San Joaquin and Sacramento valleys.

Field Description

Category	Details
Acres	13.7 acres (recharge site) 9.1 acres (control site)
Type of crop	Zinfandel grapes
Age of crop	Planted in 1992
Average root depth	6–7 feet
Irrigation infrastructure	Irrigation is applied using a single dripline tape per plant row.
Soil amendment	Periodically, based on need, the grower applies gypsum at a rate of approximately 20 pounds per acre.

Hydrogeology

Category	Details
Soil texture	- Sandy. - Mr. Costa notes it was extremely hard to get irrigation water across the field. Grape vines tended to be less developed at the end of furrows because of low soil moisture retention in sandy soil texture. There are some extremely sandy streaks in the recharge and control sites.
Land IQ rating	Moderately good
Soil Agricultural Groundwater Banking Index rating	Good to excellent
Restrictive layers	None
Depth to groundwater	75–80 feet

On-Farm Recharge Logistics

Category	Details
Source of water	Water for groundwater recharge was provided by North San Joaquin Water Conservation District (NSJWCD).
Maximum diversion rate	10 cubic feet per second
Method of diversion	Water was pumped from the Mokelumne River into an underground conveyance pipe that leads to the vineyard.
Cost of water	• NSJWCD did not charge the grower for the recharge water. • NSJWCD paid for the electricity to pump the water from the Mokelumne River and for the infrastructure to convey the water to the vineyard recharge pilot site. • The grower provided the labor and equipment to prepare the site and manage the applied water.
Field preparation and management during recharge	• A 6-inch berm was installed at the outer perimeter of the recharge field site, and an inflatable gated pipeline was placed on the west side of the field for flooding each row. • Water was conveyed through an underground pipe for approximately 1,500 feet before entering a flood-pipe riser at the head of the multiple rows on the field's west side where the inflatable, gated flood pipe was connected. • The water that was pumped into the rows rapidly infiltrated before reaching the end of the field, which was approximately 1,000 feet from west to east.
Nutrient management	Fertilizer was not applied during the dormancy period from late November to early April.
Average inundation height	The maximum depth of water in the field was 3–4 inches.
Duration of inundation	The infiltration rate was excellent. The water could be turned on continuously for 24 hours without overflowing the field.
Time to dry down	It took 1 day to dry down soil was required after turning off applied water.

Recharge Events

Year 2018

Dates of recharge	Duration (days)	Field size (acres)	Water applied (total acre-feet)	Water applied (feet per acre)	ETc (feet)	Net water recharged (total acre-feet)	Net water recharged (feet per acre)
Oct. 5– Nov. 5	32	13.7	237	17.30	0.26	232.73	16.99

Table notes: Dates of recharge, field size, and water applied sourced from the grower. Crop evapotranspiration (ETc) value sourced from California Irrigation Management Information System station #71C.

Net water recharged = water applied – (1.2 x ETc x acres).

Year 2019

Dates of recharge	Duration (days)	Field size (acres)	Water applied (total acre-feet)	Water applied (feet per acre)	ETc (feet)	Net water recharged (total acre-feet)	Net water recharged (feet per acre)
Oct. 4– Oct. 17	14	23	125.87	5.47	0.07	123.94	5.39
Oct. 21–Oct. 27	7	23	53.76	2.34	0.04	52.66	2.29
Nov. 16– Nov. 30	15	23	115.76	5.03	0.03	114.93	5.00
Rain							0.20
Total	36		295.39	12.84	0.14	291.53	12.88

Table notes: Dates of recharge, field size, and water applied sourced from the grower. ETc value sourced from California Irrigation Management Information System station #71C.

Net water recharged = water applied – (1.2 x ETc x acres).

Year 2022

Dates of recharge	Duration (days)	Field size (acres)	Water applied (total acre-feet)	Water applied (feet per acre)	Etc (feet)	Net water recharged (total acre-feet)	Net water recharged (feet per acre)
Dec. 9– Dec. 31	23	23	223.47	9.72	0.01	223.15	9.70
Rain							0.49
Total							10.19

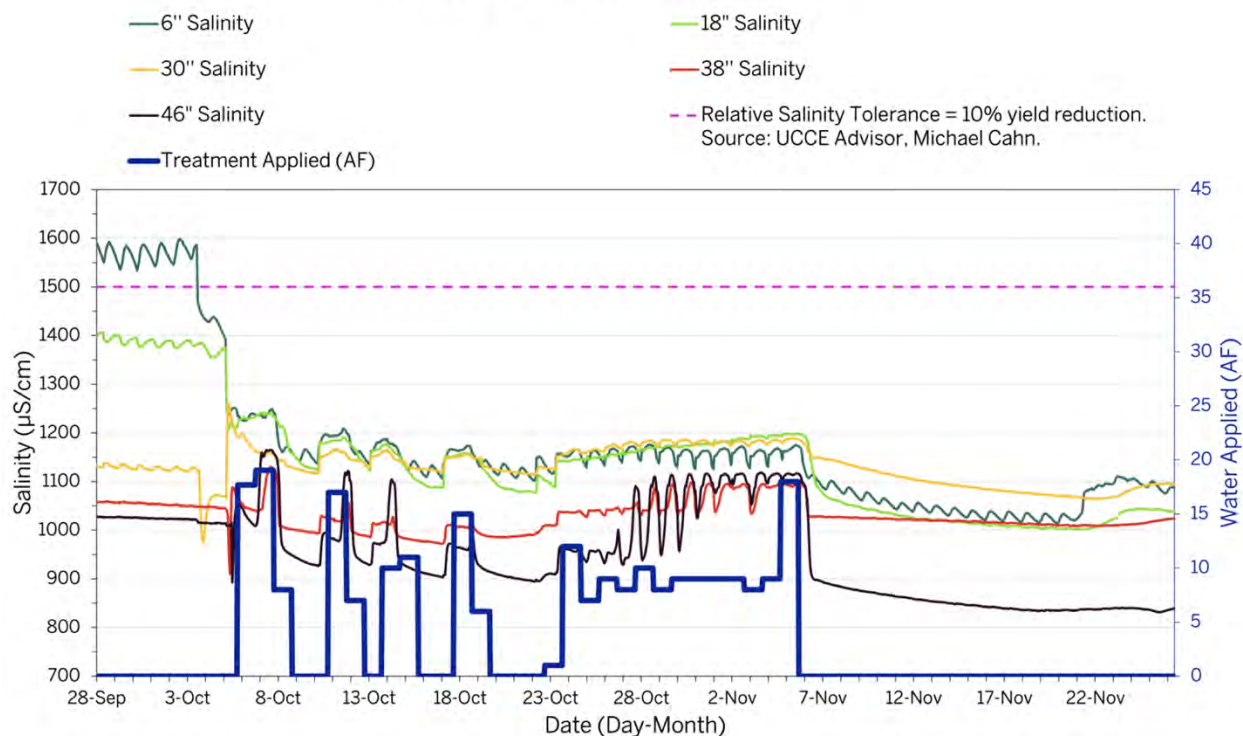
Table notes: Dates of recharge, field size, and water applied sourced from the grower. ETc value sourced from California Irrigation Management Information System station #71C.

Net water recharged = water applied – (1.2 x ETc x acres).

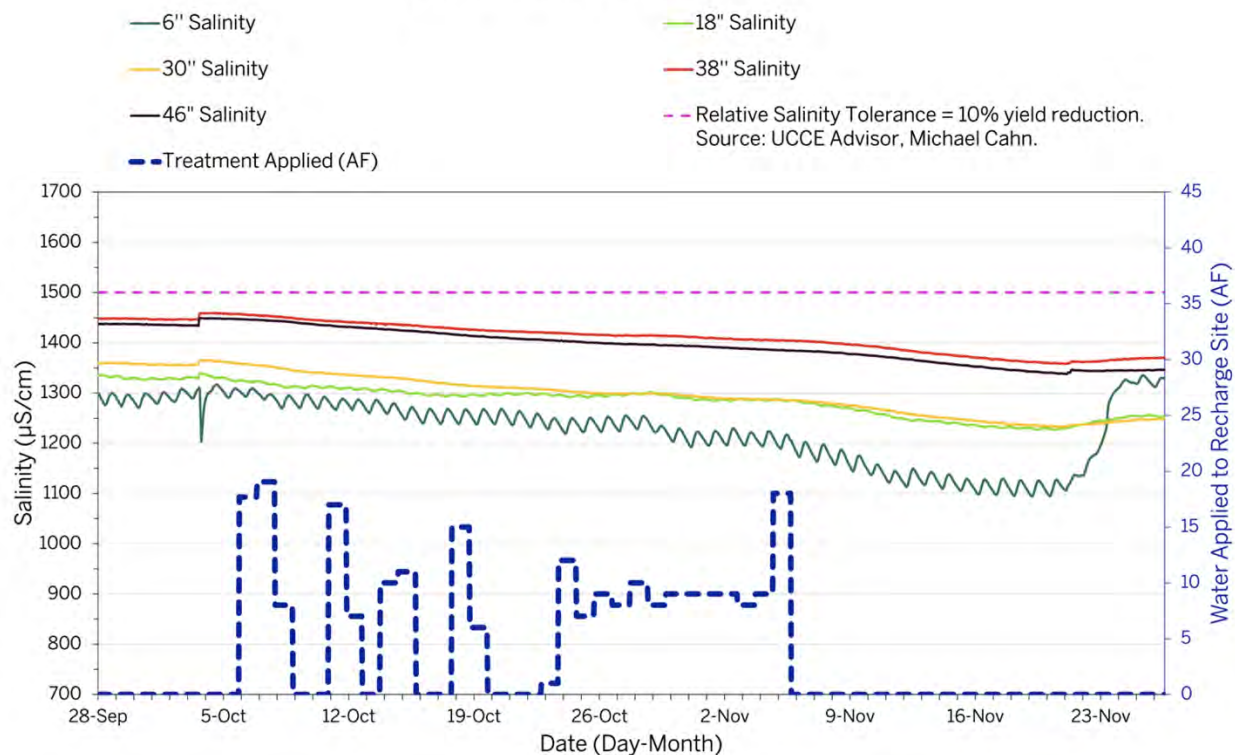
Changes in Field Conditions

Category	2018	2019
Diseases and weeds	The grower did not notice any increase in disease activity over the standard practice of routine powdery mildew and bunch rot prevention sprays that were also used on the control plot.	The grower did not notice any increase in disease activity of powdery mildew and bunch rot in the grapevines.
Yields	The recharged field yielded 2.29 tons per acre. The control field produced no significant difference in yield compared to the recharged field. Year 2018 was an off-year of production. In normal years, production is twice the tonnage per acre.	Not known.
Salinity	In the charts below, see an example of salinity dilution occurring during the application of recharge water within the first 46 inches of soil. Many growers refer to this as an immediate benefit from on-farm recharge to their crop growth and development. Growers throughout the Central Valley have commented on the excess salt buildup in the soil because of drought in California which has been compounded by drip irrigation in reducing yields and quality of crops.	Soil salinity levels were ideal, between 800–1,143 microSiemens per centimeter ($\mu\text{S}/\text{cm}$) in the first 46 inches of soil. These levels were well below the grapevine's tolerance level of 1,500 $\mu\text{S}/\text{cm}$.
Changes to field practices	The grower did not notice any increase in disease activity over the standard practice of routine powdery mildew and bunch rot prevention sprays that were also used on the control plot.	The grower did not notice any increase in disease activity of powdery mildew and bunch rot in the grapevines.

2018 - Salinity at Recharge Site



2018 - Salinity at Control Site



Grower's Experience

Category	Details
Grower observations	Mr. Costa believes his field could receive a lot more water if it is available and if he has continued access to local incentive assistance funding to help offset electrical bills for pumping.
Grower motivations	• Mr. Costa wants to recharge for replenishing overdrafted aquifers in order to meet Sustainable Groundwater Management Act goals. Also, he wants to help ensure the production of agriculture for future generations. • Mr. Costa thinks the immediate benefit of on-farm recharge is reduction in soil salinity, which promotes a healthier plant.

Groundwater Fate

The farm is located near the Mokelumne River, prompting interest in determining if recharged water flowed toward or away from the river. The North San Joaquin Water Conservation District funded a groundwater fate engineering study to understand where recharged water was going. According to their data, all monitoring wells confirmed increases in groundwater levels following the 2018 and 2019 recharge events. In both years, the most significant changes in water levels occurred at wells farther from the river relative to the recharge field indicating that the bulk of the recharge water was moving away from the river. This farm is somewhat unique because the soil is so sandy, but these results counter the commonly held belief that applying water on farms near rivers or streams does not contribute to aquifer recharge.

Position of monitoring well relative to recharge field	Approximate distance to the Mokelumne River	Increase in water levels from 2018 recharge (approximately 3 months after recharge commenced)	Increase in water levels from 2019 recharge (approximately 4 months after recharge commenced)
North of recharge field, away from river	2,600 feet	9.6 feet	1.5 feet
North of recharge field, away from river	2,550 feet	4.8 feet	5.3 feet
West of recharge field, parallel to river	2,160 feet	5.4 feet	4.9 feet
Recharge field	1,750 feet	4.0 feet	4.0 feet
South of recharge field, next to river	500 feet	0.8 feet	0.4 feet

On-farm Recharge Pilot Projects Case Study



LEFT Photograph: On-farm recharge in mid-January 2022. The water head height is 3–5 inches.

RIGHT Photograph: Jose Luis, the field manager, is standing on the west side of the Costa vineyard where the recharge water is pumped into the field from about 1,500 feet of underground pipe using a lay-flat perforated temporary conveyance pipe, which is connected to risers at the head of the plant line. The field manager handles all of the logistics for successful on-farm recharge without unintended consequences. This picture was taken on January 25, 2023, about two weeks following a flood overflow breach from the Mokelumne River after on-farm recharge efforts in December 2022.



The Mokelumne River is the water supply for the Costa vineyard. But as of early January 2023, all on-farm recharge efforts ceased because of river overflow and flood conditions in Acampo, CA.

For more information: contact Rogell Rogers, Agronomist, Sustainable Conservation, at rrogers@suscon.org or 209-576-7729 x346.

Grower: Arlan Thomas

Crop: Almonds

Location: Chowchilla, Madera County



Project Description

Arlan Thomas is an organic almond grower who was motivated to replenish the overdrafted aquifer below his farm to save his well from drying up and to prevent land subsidence. The organic farm used vegetative cover crops in alternate rows to help increase the water infiltration rate on the orchard floor. This farm has desirable Soil Agricultural Groundwater Banking Index (SAGBI) and Land IQ ratings that prioritized the site for on-farm recharge.

Mr. Thomas was willing to apply higher rates as one of the initial on-farm recharge pilot sites in the San Joaquin Valley because the almond trees were very old and the risk was lower as he planned to remove the almond trees in the near future. Yields were already low as a result of crop age.

This farm was the subject of an in-depth study, [*On-Farm Flood Capture and Recharge at an Organic Almond Orchard, Recharge Rates and Soil Profile Responses*](#) by Phil Bachand & Associates, Davis, California, and Tetra Tech, Rancho Cordova, California (April 2017). The information in this case study is largely based on the Bachand/Tetra Tech report, which focuses on salinity, soil moisture, and other aspects of the effects of on-farm recharge on tree crops.

Field Description

Category	Details
Acres	13.5 acres high recharge (targeted 2 feet of water per recharge event). 13.75 acres medium recharge (targeted 1 foot of water per recharge event). 26.25 acres control (no on-farm recharge).
Type of crop	Organic almonds since 2014.
Age of crop	- Planted 1976 (40 years old at time of recharge). - Well past prime (usually 25–30 years old).
Average root depth	4–5 feet.
Irrigation infrastructure	Flood infrastructure using district turnouts.
Soil amendment	- Mr. Thomas relied on cow manure compost inputs every other row at 5 tons per acre to fertilize the almond trees (equivalent to 225 pounds per acre of nitrogen). - Mr. Thomas grew cover crops on the plant rows where manure was not applied. He mowed the cover crop to a height of 2 inches and spread the plant residues on the topsoil in the late fall.

Hydrogeology

Category	Details
Soil texture	Loamy sand.
Land IQ rating	- Moderately good. - The grower's field observation experience leads him to think infiltration is very high.
SAGBI rating	Good to excellent.
Restrictive layers	Corcoran clay layer about 180 feet below ground surface
Depth to groundwater	160–170 feet

On-Farm Recharge Logistics

Category	Details
Source of water	Chowchilla Water District (CWD).
Maximum diversion rate	3–6 cubic feet per second.
Method of diversion	CWD canal turnout with gravity flow to the field.
Cost of water	CWD delivered surface water at \$118 per acre-foot to customers who were able and willing to participate in on-farm recharge.
Field preparation and management during recharge	• Before recharging, the grower mowed the cover crop to approximately 4–5 inches. • Trees are planted on raised plant lines, so no further preparation was needed to manage water in the field.
Nutrient management	No additional fertilizer inputs were made in-season besides the manure compost prior to the dormant season.
Average inundation height	3–4 inches.
Duration of inundation	• The fields were inundated for two days, then rotated back through the field for additional water applications. • Actual infiltration of water applied was within 24 hours.
Time to dry down	3–4 days.

Recharge Events

High Recharge Site

Dates of recharge (2016)	Duration (days)	Field size (acres)	Water applied (total acre-feet)	Water applied (feet per acre)	ETc (feet)	Net water recharge (total acre-feet)	Net water recharge (feet per acre)
June 4–June 13	10	13.5	92.9	6.88	1.76	64.39	4.77
June 28–July 3	6	13.5	92.9	6.88	1.76	64.39	4.77
July 20–July 26	7	13.5	92.9	6.88	1.76	64.39	4.77

Table notes: Dates of recharge, field size, and water applied sourced from grower. Crop evapotranspiration (ETc) value sourced from California Irrigation Management Information System station #71C.

Net water recharged = water applied – (1.2 x ETc x acres).

Medium Recharge Site

Dates of Recharge (2016)	Duration (days)	Field size (acres)	Water applied (total acre-feet)	Water applied (feet per acre)	ETc (feet)	Net water recharge (total acre-feet)	Net water recharge (feet per acre)
June 1–June4	4	13.75	42.25	3.07	1.76	13.21	0.96
June 25–June28	4	13.75	42.25	3.07	1.76	13.21	0.96
July 18–July 20	4	13.75	42.25	3.07	1.76	13.21	0.96

Table notes: Dates of recharge, field size, and water applied sourced from the grower. ETc value sourced from California Irrigation Management Information System station #71C.

Net water recharged = water applied – (1.2 x ETc x acres).

Control Site (Irrigation)

Dates of Recharge (2016)	Duration (days)	Field size (acres)	Water applied (total acre-feet)	Water applied (feet per acre)	ETc (feet)	Net water recharge (total acre-feet)	Net water recharge (feet per acre)
May 13–June 16	4	26.25	43.19	1.65	1.75	-11.94	-0.45
June 23–June 25	3	26.25	43.19	1.65	1.75	-11.94	-0.45
July 18	1	26.25	43.19	1.65	1.75	-11.94	-0.45

Table notes: Dates of recharge, field size and water applied sourced from the grower. ETc value sourced from California Irrigation Management Information System station #71C.

Net water recharged = water applied – (1.2 x ETc x acres).

Changes in Field Conditions

Category	Details
Diseases and weeds	No evidence of disease was found.
Yields	Yields were approximately 1,500–1,600 pounds per acre in 2010. Six years later, yield was down to a low of 400–600 pounds per acre in 2016. The grower expected the decline in yield because the crop was 40 years old at the time of this recharge event and well past its prime growing years.
Salinity	For information on salinity dilution impacts resulting from recharge, see the Bachand report .
Changes to field practices	None.

The following information on tree fall is sourced directly from the [Bachand report](#), Table 5: Tree Fall Observations, June 22, 2016.

Treatment	Number of Trees down	Area (acres)	Number of Trees down per acre
Control	5	26.25	0.2
Medium	5	13.75	0.4
High	8	13.5	0.6
Total	18	53.5	0.3

Note: According to the grower, the number of trees felled is normal for this orchard. Differences between treatments are within the range of variability that he has observed in the past, with trees less healthy on the west side (high treatment) than on the east side (control treatment) of the orchard.

Grower's Experience

Category	Details
Grower observations	The grower was surprised at how easy it was to apply a large amount of water to recharge. He would not be surprised if 10–15 feet of water can be recharged on the same field.
Grower motivations	Mr. Thomas wants to promote the future of recharge collaboration for the benefit of the farm community. He thinks that all growers should get involved in on-farm recharge for the benefit of the community.
Monitoring systems	For information on various monitoring methods to measure effects of recharge, see the Bachand report .

For more information: contact Rogell Rogers, Agronomist, Sustainable Conservation, at rrogers@suscon.org or 209-576-7729 x346.

Grower: Russel and Matt Efird

Crop: Raisin grapes

Location: Fresno County



Project Description

Russel and Matt Efird grow raisins, almonds, walnuts, pistachios, and canning peaches in Fresno County, California. Groundwater levels on their farm have decreased 50 feet from 1992 through 2022. On-farm recharge can help to reverse groundwater overdrafting and cease land subsidence occurring in the subbasin.

This farm can be a good measure of raisin grape tolerance to recharge timing and how much flood water can be applied without increased fungal disease, such as bunch rot, compared to the growers' standard practice. One of the most commonly asked questions about on-farm recharge is, "How much water can be applied and when should recharge be ceased to protect crop health?" Research continues to determine basic recharge guidelines on the timing of and how much recharge water is optimum for a given crop and soil type.



Field Description

Category	Details
Acres (recharge site)	12 acres
Acres (control site)	13 acres
Type of crop	Fiesta raisin grapes
Age of crop	Planted in 1993 (25 years old at time of recharge)
Average root depth	7–8 feet
Irrigation infrastructure	• The vineyard was irrigated by flood valves, double drip lines, and micro sprinklers. • Drip or micro sprinklers were the standard irrigation during the irrigation season. • The flood system was used to conduct on-farm recharge.
Soil amendment	Dairy compost was incorporated into every other row (6 tons/acre) in the late fall after the growing season.

Hydrogeology

Category	Details
Soil texture	Sandy Loam
Land IQ rating	Moderately Good to Excellent
Soil Agricultural Groundwater Banking Index rating	Good
Restrictive layers	- Both the recharge field and the control field were deeply ripped prior to planting in 1993. - Every other row was chiseled (14–16 inches depth) in 2014 for one row and in 2016 for the other row.
Depth to groundwater	1992: 100 feet 2009: 120 feet 2018: 142 feet 2022: 150 feet

On-Farm Recharge Logistics

Category	Details
Source of water	Kings River water was delivered from Consolidated Irrigation District (CID) canal system.
Maximum diversion rate	Turnouts have a capacity of 1,012 cubic feet per second.
Method of diversion	Gravity-fed district water canal turnout at the farm.
Cost of water	The CID charges growers an annual \$50 per acre surface water delivery fee. No additional fee was charged to growers who elected to divert water for on-farm recharge during this time.
Field preparation and management during recharge	The field was already set up for flood irrigation. The only preparation needed was placement of some strategic berms.
Nutrient management	The Efirds applied recharge water only on rows where the manure compost was not applied in order to avoid nutrient leaching.
Average inundation height	5 inches
Duration of inundation	Less than four hours

Category	Details
Time to dry down	After turning the water off, the field required a dry time of one day to be able to walk on firm ground without muddy conditions. In order to minimize soil compaction, tractor work started 10 to 14 days after shutting off water.

Recharge Events

Recharge Site

Dates of recharge (2018)	Duration (days)	Field size (acres)	Water applied (total acre-feet)	Water applied (feet per acre)	ETc (feet)	Net water recharged (total acre-feet)	Net water recharged (feet per acre)
April 28–May 5	6	12	25.84	2.15	0.12	24.11	2.01
May 6–May 9	4	12	25.84	2.15	0.12	24.11	2.01

Table notes: Dates of recharge, field size, and water applied sourced from the grower. Crop evapotranspiration (ETc) value sourced from California Irrigation Management Information System station #71C.

Net water recharged = water applied – (1.2 x ETc x acres).

Control Site (Irrigation Only)

Dates of recharge (2018)	Duration (days)	Field size (acres)	Water applied (total acre-feet)	Water applied (feet per acre)	ETc (feet)	Net water recharged (total acre-feet)	Net water recharged (feet per acre)
May 4–May 5	2	13	5.19	0.40	0.02	4.88	0.38

Table notes: Dates of recharge, field size and water applied sourced from the grower. Crop evapotranspiration (ETc) value sourced from California Irrigation Management Information System station #71C.

Net water recharged = water applied – (1.2 x ETc x acres).

Changes in Field Conditions

Category	Details
Diseases and weeds	- Some limited bunch rot in the control field and the treated field was seen by the growers. Powdery mildew and bunch rot are typical occurrences of leaf, stem, and fruit disease. Aerial fungicide applications are routinely included in cultural practices, according to the growers, who also notes that it is typical to see bunch rot in areas closer to irrigation valves. Although the Efirds were concerned about promoting powdery mildew under flood conditions, they could not confirm additional mildew resulted from recharging. - The growers think they needed more weed control spray across the treated field and the untreated field. They said they cannot determine if the need was because of the flooding, which would take several replications of recharge at this farm site.
Yields	Both the recharge field and the control field yielded 3.29 tons of raisin grapes per acre.
Salinity	Salinity levels in the recharge area and the control area were generally lower than the soil salinity threshold level (1,500 miliSeimens per centimeter or mS/cm) that can cause growth reduction and yield problems. The salinity levels were monitored from 2 inches to 46 inches of soil depth.
Changes to field practices	The Efirds noted that they needed one more fungicide application and one extra herbicide application before harvest, and more labor hours were required. But they also said that this should be expected when extra water is applied to fields.

Growers' Experience

Category	Details
Grower observations	• In the future, the growers are reluctant to put on extra water after March and would instead focus on recharging when vines are dormant. This is due to potential disease issues that could adversely affect yield and quality. • The Efirds saw that the Fiesta raisin variety has heavier foliage than others, which could potentially make it more susceptible to Bunch Rot because of higher canopy humidity. However, the growers also noted that the raisins were rained on multiple times close to harvest, which may have also contributed to Bunch Rot. • The Efirds think that many growers will focus on the benefits of using surface water for on-farm recharge in order to help reduce the build-up of salts in the field and groundwater.
Grower motivations	• The growers believe that recharge is beneficial for replenishing groundwater but want to see more support from state and federal agencies for individual growers doing on-farm recharge. • On-farm recharge can help replenish several wells on their property that are used for pumping groundwater.

For more information: contact Rogell Rogers, Agronomist, Sustainable Conservation, at rrogers@suscon.org or 209-576-7729 x346.

Grower: Don Cameron, Terranova Ranch

Crop: Almonds

Location: Helm, Fresno County



Project Description

This case study site is a great example of how on-farm recharge on young almond trees during the first years of production on suitable soils can be implemented without affecting yield and crop health. Don Cameron, general manager of Terranova Ranches Inc., had a goal in 2011 to determine how much water can be applied as on-farm recharge without crop damage or yield losses. He decided to start on very small plots of transitional fallow land. In 2017, the ranch expanded recharge efforts to a young almond orchard. Recharge occurred in this orchard for more than two weeks in spring 2017. The almond trees have been growing vigorously since then without any adverse effects on production yields. In 2023, the ranch reported the 10-year-old almond orchard as being a superior producer in yield and quality, averaging more than 2,000 pounds per acre.



Field Description

Category	Details
Acres	76
Type of crop	Almonds (25% Monterey scion, 25% Woody colony scion, 50% Nonpareil scion on the Rootstock Nemaguard).
Age of crop	Planted 2013 (4 years old at time of recharge in 2017).
Average root depth	3–4 feet deep.
Irrigation infrastructure	• Drip irrigation system and original flood irrigation infrastructure was in place. • On-farm recharge water was pumped from district canals, using flow metered pipe, into the field.
Soil amendment	Pre-season poultry compost was applied in the fall and incorporated into the soil in years not receiving floodwater.

Hydrogeology

Category	Details
Soil texture	• Loamy sand on field. • Infiltration rate is about 2.5–3 inches per day.
Land IQ rating	Moderately poor (north field is sandier).
SAGBI rating	Moderately poor.
Restrictive layers	N/A.
Depth to groundwater	230–250 feet below ground surface.

On-Farm Recharge Logistics

Category	Details
Source of water	Liberty Mill Race Ditch Company.
Maximum diversion rate	4–5 cubic feet per second.
Method of diversion	Pumped from Kings River North Fork into Terranova's on-farm canal ditch.
Cost of water	\$4 per acre-foot for flood water.
Field preparation and management during recharge	Place berms intermittently in the field every 5–10 rows until entire length of row is inundated up to 12 inches at the end of row, then breach the berm to allow the flood flow to the next 5–10 rows.
Nutrient management	- In order to avoid aggressive spring fertilizer application being delayed by flood conditions, the grower used a fall liquid application of UN 32 at 80–85 pounds per acre of nitrogen through the drip irrigation system at the end of year 2, prior to tree dormancy. - The grower followed his normal nitrogen management plan by applying sequential applications of 30–35 pounds of nitrogen per acre via drip tape from March through June.
Average inundation height	12 inches of water depth.
Duration of inundation	The field was inundated for approximately 1–2 weeks.
Time to dry down	3–4 days after turning off water.

Recharge Events

Dates of recharge (2017)	Duration (days)	Field size (acres)	Water applied (total acre-feet)	Water applied (feet per acre)	ETc (feet)	Net water recharged (total acre-feet)	Net water recharged (feet per acre)
April 2–April 15	15	76	52.96	0.70	0.09	44.75	0.59
May 28–June 17	21	76	98.78	1.30	0.21	79.63	1.05
Total			151.74	2.00	0.30	124.38	1.64

Table notes: Dates of recharge, field size, and water applied sourced from grower. Crop evapotranspiration (ETc) value sourced from California Irrigation Management Information System station #71C.

Net water recharged = water applied – (1.2 x ETc x acres).

Changes in Field Conditions

Category	Details
Diseases and weeds	No abnormal disease occurrence was noticed by the grower during or after on-farm recharge.
Yields	Almond yields for the recharge field were 2,296 pounds per acre of almond nuts compared to 2,094 pounds per acre of almond nuts for a control plot.
Salinity	No data
Changes to field practices	None.

Grower's Experience

Category	Details
Grower observations	- Mr. Cameron notes that it is important for growers who are planning to plant a new almond orchard to select rootstocks and scions that have low susceptibility to fungal diseases such as <i>phytophthora</i> ssp. - Mr. Cameron believes that the oxygen content in saturated soils is related to the water temperature. The warmer the water, the less oxygen that is contained, and the sooner there may be problems with ponding water in fields. He stopped recharging when the water and air temperature became too hot (90 degrees) for the trees and vines to survive. - Being able to move water through the soil quickly is an advantage. Mr. Cameron believes that not all soils are capable of recharging groundwater, and that growers should stick to the lighter, sandier soils.
Grower motivations	- Mr. Cameron is interested in replenishing overdrafted aquifers under his land in compliance with the Sustainable Groundwater Management Act. Also, he wants to prove that on-farm recharge is more cost-effective than irrigation district recharge basin efforts and that collective grower-led on-farm recharge can be more effective at achieving aquifer recharge. - Mr. Cameron believes that it is important to document practical lessons learned to complement scientific research. He encourages more growers to participate in the Kings River basin groundwater recharge efforts to improve the knowledge of field characteristics for recharge suitability.

For more information: contact Rogell Rogers, Agronomist, Sustainable Conservation, at rrogers@suscon.org or 209-576-7729 x346.

Grower: Don Cameron, Terranova Ranch

Crop: Wine Grapes

Location: Helm, Fresno County



Project Description

This case study site provided the opportunity to test on-farm recharge on wine grapes planted in moderately poor soil and subsurface conditions as rated by Soil agricultural Groundwater Banking Index (SAGBI) and the Land IQ soil suitability index. It also demonstrated the feasibility of applying recharge water during the wine grapes growing season, thereby increasing the total possible volume of annual on-farm recharge when excess surface water is not available until springtime, as occurred in 2017 and 2023.

The farm began experimenting with on-farm recharge in 2011. This was one of the pioneering recharge test plots to begin establishing guidelines for on-farm recharge in the San Joaquin Valley. In 2016, Mr. Cameron added his perennial crops such as almonds, olives, pistachios, grapes, and walnuts to the targeted list of crops for on-farm recharge.



Field Description

Category	Details
Acres	77.5 acres
Type of crop	Ruby red wine grapes.
Age of crop	Planted in 1998.
Average root depth	6–7 feet.
Irrigation infrastructure	• Flood with single check at end of plant row and intermittent berms between plant lines as needed. • Flow meters at turnouts.
Soil amendment	Periodic gypsum applications and light soil tillage done based on need.

Hydrogeology

Category	Details
Soil texture	Sandy-silt loam.
Land IQ rating	• Moderately poor. • Grower did not agree with the rating. He believes the soil has a higher rating because of long-term application of soil amendments which will increase infiltration over time.
SAGBI rating	Moderately poor.
Restrictive layers	N/A
Depth to groundwater	Unknown.

On-Farm Recharge Logistics

Category	Details
Source of water	Liberty Mill Race Ditch Company
Maximum diversion rate	4–5 cubic feet per second.
Method of diversion	Pumped into the Terranova canal ditch from the 4-gate turnout at the Kings River North Fork.
Cost of water	\$4 per acre-foot of surface water.
Field preparation and management during recharge	Berm the field every 10 rows at a time until the entire field is inundated 8–12 inches. This resulted in an enclosure that was about 100 feet wide and 0.25 mile long.
Nutrient management	The grower applies nitrogen (UN 32) in the fall prior to dormancy to promote higher nitrogen carryover into the spring. This enables him to avoid the need for initial fertilizer applications (or allow for lower inputs) in anticipation of potential recharge opportunities that typically occur in the spring in the Tulare Basin.
Average inundation height	6–8 inches.
Duration of inundation	Duration of flood condition was approximately 1 week.
Time to dry down	7–10 days

Recharge Events

Dates of recharge (2017)	Duration (days)	Field size (acres)	Water applied (total acre-feet)	Water applied (feet per acre)	ETc (feet)	Net water recharged (total acre-feet)	Net water recharged (feet per acre)
March 30–April 8	10	77.5	92.4	1.19	0.05	87.75	1.13

Table notes: Dates of recharge, field size, and water applied sourced from grower. Crop evapotranspiration (ETc) value sourced from California Irrigation Management Information System station #71C.

Net water recharged = water applied - $1.2 \times \text{ETc} \times \text{acres}$.

Changes in Field Conditions

Category	Details
Diseases and weeds	The grower made an aerial fungicide prevention application on the grapes because of his concerns of contracting bunch rot from the extra moisture. The grower was also concerned about latent Fusarium root rot because of the flooded conditions. After the fungicide application, no disease was seen.
Yields	10.31 tons per acre.
Salinity	The grower said the on-farm recharge helps dilute the salinity in the soil profile. The plants appear to respond with vigorous growth during the spring
Changes to field practices	The grower delayed in-season applications of fertilizer because of on-farm recharge or intentional flooded conditions. Some fertilizer was applied just prior to dormancy in anticipation of springtime recharge and to avoid the need for an aggressive fertilizer program during the growing season while conducting recharge events.

Grower's Experience

Category	Details
Grower observations	- The grower believes that the oxygen content in saturated soils is related to the water temperature. The warmer the water, the less oxygen that is contained, and the sooner there may be problems with ponding water in fields. He stopped recharging when the water and air temperature became too hot (90 degrees) for the trees and vines to survive. - Being able to move water through the soil quickly is an advantage. Mr. Cameron believes that not all soils are capable of recharging groundwater, and that growers should restrict on-farm recharge to the lighter, sandier soils.
Grower motivations	- Mr. Cameron is interested in replenishing overdrafted aquifers under his land in compliance with Sustainable Groundwater Management Act. He also wants to prove that on-farm recharge is more cost-effective than irrigation district recharge basin efforts and that on-farm recharge can be more effective at achieving aquifer recharge. - Mr. Cameron believes that it is important to document practical lessons learned to complement scientific research. He encourages more growers to participate in the Kings River basin groundwater recharge efforts in order to improve the knowledge of field characteristics for recharge suitability.

Year 2023 On-Farm Recharge Photographs



Above photo note: Mr. Cameron started recharging this field in late-March 2023 and has included it in his goal to recharge 30,000 acre-feet at Terranova Ranch. Ruby red wine grapes seen here on April 21, 2023.

On-farm Recharge Pilot Projects Case Study



Above photo note: Ruby red wine grapes on-farm recharge in mid-April 2023 with a 3-foot berm on the outer perimeter of the orchard to ensure water stays in the targeted field. The water has a head height of approximately 1 foot.

For more information: contact Rogell Rogers, Agronomist, Sustainable Conservation, at rrogers@suscon.org or 209-576-7729 x346.

Grower: Don Cameron, Terranova Ranch

Crop: On-Farm Recharge Basin System

Location: Helm, Fresno County

Project Description

Don Cameron, general manager of Terranova Ranch Inc., has been planning and building an on-farm recharge basin storage system for more than five years. Despite the long planning and construction phase, he is beginning to see promising results because of the massive amounts of rainfall and snowmelt in 2023 that have sparked a flooding emergency in the area.

The system comprises three on-farm recharge basins, each having a capacity of 50–60 acre-feet of water storage. These basins are unlined, which allow them to function as recharge basins while also serving as storage sites from which to convey on-farm recharge water to surrounding fields. He is offering the stored basin water to his farm neighbors at cost. Mr. Cameron spoke of his desire to divert enough water during high rainfall years such as 2023 to recharge Terranova Ranch and neighboring farms in the Kings subbasin. His goal in 2023 is to recharge 30,000 acre-feet, which he thinks he will reach.

The following pictures were taken during a recent tour of Terranova Ranch in April 2023. They document the water infrastructure work involved in the construction of this unique on-farm recharge basin system. Operations require considerable work in the field to strategically coordinate water conveyance across the farm. Staff required training in the coordination of opening and closing valves and gates as water pumps were turned on and off. Mr. Cameron spoke about the many adjustments for labor required for this system, and he stated, “The rewards are worth it.”

On-farm Recharge Pilot Projects Case Study



Pump used to divert water from the Kings River at peak flow levels. Maximum pump capacity of 12.5 acre-feet per hour (151 cubic feet per second).



Two of three on-farm recharge unlined recharge basins, each with storage capacity of 50–60 acre-feet. Mr. Cameron has observed a significant increase in shorebird activity in and around the recharge basins.



Water in an unlined canal conveyance system with pistachios orchards on either side.



The diversion point of water on the Kings River North Fork canal into the Terranova Ranch.

On-farm Recharge Pilot Projects Case Study



Four turnout gates on the Kings River diverting water into the Terranova Ranch canal system.



Mr. Cameron, using his computer telemetry to control the height of the turnout flood gates.



Pumping water from internal canal into a pistachio orchard through an intricate conveyance system.



Water metered and pumped from internal canal into a pistachio orchard.

On-farm Recharge Pilot Projects Case Study



Water is being pumped using diesel power take-off (PTO) motors from the basins into the pistachio orchards and wine-grape vineyards using thousands of feet of pipe across the entire ranch to convey water to different plantings for on-farm recharge.



Long length of pipe used to convey water from internal unlined canal ditches with water pumps into a pistachio orchard.



On-farm recharge in pistachio orchard (April 26, 2023) showing complete spring leaf out and trees already in full bloom.



Recharge on this pistachio orchard is the result of a well-planned and well-constructed farm infrastructure for an on-farm basin storage and water conveyance delivery system.