Groundwater Pumping Reduction Workplan: Napa Valley Subbasin

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GROUNDWATER PUMPING REDUCTION WORKPLAN: NAPA VALLEY SUBBASIN

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The Napa County Groundwater Sustainability Technical Advisory Group (TAG) is made up of five experts who provide guidance on the implementation of the Groundwater Sustainability Plan. The TAG has provided input on the direction, scope, and breadth of this Workplan. The Napa County Groundwater Sustainability Agency appreciates the contributions of the five members listed below:

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ORGANIZATIONS

During GSP implementation and throughout the development of multiple Workplans (including this Workplan), many organizations and individuals provided valuable input. The Napa County Groundwater Sustainability Agency appreciates the contributions of the organizations listed below:

California Department of Fish and Wildlife (CDFW)
California Sustainable Winegrowing Alliance
Napa County Farm Bureau
Napa County Resource Conservation District
Napa County Flood Control District
Napa Green
Napa Valley Grapegrowers Association
Napa Valley Vintners Association
National Marine Fisheries Service (NMFS)
Save Napa Valley Foundation
University of California Davis – Center for Watershed Sciences
University of California Berkley Extension
Winegrowers of Napa County

On behalf of the Napa County Groundwater Sustainability Agency, thank you to all of the community members who participated in public meetings, information sessions, and various outreach events. Your input was vital to shaping this Workplan.

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Acronym	Meaning
$/AFY	dollars per acre-foot per year
3SEB	three-source energy balance
AF	acre-feet
AFY	acre-feet per year
API	Application Programming Interface
ARS	USDA Agricultural Research Service
AVA	American Viticulture Area
BOD	biochemical oxygen demand
BOS	County Board of Supervisors
C&E	communications and engagement
CSWA	California Sustainable Winegrowing Alliance
DU	distribution uniformity
EO	Executive Order
EQIP	Environmental Quality Incentives Program
EQIP-CIC	Environmental Quality Incentives Program Conservation Incentives Contracts
ET	Evapotranspiration
FARMS	Farm and Ranch Management Support
FFF	Fish Friendly Farming
GDE	Groundwater Dependent Ecosystem
GPR Workplan	Groundwater Pumping Reduction Workplan: Napa Valley Subbasin
GRAPEX	Grape Remote Sensing Atmospheric Profile and Evapotranspiration eXperiment
GSP	Groundwater Sustainability Plan state
GSPAC	Groundwater Sustainability Plan Advisory Committee
HSP	Healthy Soils Program
ISW	Interconnected Surface Water
MO	Measurable Objective
MT	Minimum Threshold
NapaSan	Napa Sanitation District
NCGSA	Napa County Groundwater Sustainability Agency
NDPES	National Pollutant Discharge Elimination System
NDVI	Normalized Difference Vegetation Index
NRCS	Natural Resources Conservation Service
NVIHM	Napa Valley Integrated Hydrologic Model
O&M	operation and maintenance
PBES	Building and Environmental Services
PMA	Projects and Management Action
RCD	Resource Conservation District
RDI	regulated deficit irrigation

Acronym	Meaning
RMS	Representative Monitoring Site
SB	Senate Bill
SGMA	Sustainable Groundwater Management Act
SMC	sustainable management criteria
Subbasin	Napa Valley Groundwater Subbasin
SWEEP	State Water Efficiency and Enhancement Program
SWRCB	California State Water Resources Control Board
TAG	Technical Advisory Group
TDR	temperature domain reflectometry
TSEB	two-source energy balance
UCCE	University of California Cooperative Extension
UR	Undesirable Result
USDA	United States Department of Agriculture
USEPA	US Environmental Protection Agency
UV	Ultraviolet
WAA	Water Availability Analysis
WC Workplan	Napa County Water Conservation Workplan
WY	water year

EXECUTIVE SUMMARY

The Napa Valley Subbasin Groundwater Sustainability Plan (GSP) was submitted on January 31, 2022, and approved on January 26, 2023, by the California Department of Water Resources. The Napa County Groundwater Sustainability Agency (NCGSA) is now implementing the GSP to ensure that the Napa Valley Subbasin (Subbasin) achieves and maintains sustainable groundwater conditions. The Napa Valley Subbasin GSP includes Projects and Management Actions for achieving the sustainability goal as required by GSP Regulations. Following adoption of the GSP, initial GSP implementation for Management Action #2: Groundwater Pumping Reductions (GPR) has involved development of the GPR Workplan as specified in the GSP. This includes developing a series of Projects and Management Actions for implementation within the Subbasin to achieve the sustainability goal:

- *To protect and enhance groundwater quantity and quality for all beneficial uses and users of groundwater and interconnected surface water in the Napa Valley Subbasin both now and in the future.*
- *The NCGSA will implement sustainable management criteria and an adaptive management approach supported by the best available information and best available science, resulting in the absence of undesirable results within 20 years from GSP adoption.*

The GSP specified Management Action #2, the development of a Groundwater Pumping Reduction Workplan, to provide a direct means for reducing the impacts of groundwater pumping on interconnected surface and groundwater resources in the Subbasin. The GSP section on the GPR management action contains all the information required by 23 CCR 354.44, including the Measurable Objective expected to benefit from the management action, which is the sustainability indicator for depletions of interconnected surface water. The GSP specified that this management action would be triggered if Minimum Thresholds were exceeded at any Representative Monitoring Site (RMS) wells or at either of the two RMS stream gages for streamflow depletion volumes for the interconnected surface water sustainability indicator. However, even absent Minimum Threshold exceedances, the Groundwater Sustainability Plan Advisory Committee (GSPAC) indicated its support for achieving a 10 percent reduction in pumping, planned to begin following NCGSA adoption of the GSP. Largely due to severe drought conditions, the Subbasin exceeded Minimum Thresholds in Water Years 2021 and 2022 for two sustainability Indicators: (i) Reduction in Groundwater Storage and (ii) Interconnected Surface Water (ISW).

This Groundwater Pumping Reduction Workplan: Napa Valley Subbasin (GPR Workplan) summarizes the actions, opportunities, and implementation plan for achieving water conservation that result in a reduction in total groundwater pumping and a reduction in net depletion from the Subbasin aquifer system. The specific objectives of the GPR Workplan are:

- Provide technical data, analysis, and a roadmap for implementing measures to reduce groundwater pumping in the Napa Valley Subbasin.
- Improve the understanding of groundwater use in the Subbasin and evaluate the effectiveness of pumping reduction measures for improving groundwater conditions and sustainability.
- Develop an adaptive management process, including implementing mandatory measures if voluntary measures are insufficient to achieve groundwater sustainability.
- Develop strategies that can achieve pumping reductions while supporting the Napa Valley community and regional economy.

This Workplan is a companion document to the Napa County Water Conservation Workplan (WC Workplan). The WC Workplan describes water conservation measures to reduce water use or groundwater pumping in the Subbasin. In contrast to this Workplan, the WC Workplan is developed as a resource for water users that are interested in implementing water conservation practices. This GPR Workplan builds on the WC Workplan by developing a technical analysis of the costs, benefits, and potential for adopting measures to reduce groundwater pumping.

ES-1. Napa Valley Subbasin Groundwater Pumping Reduction Goal

The goal of the GPR Workplan is to develop an implementation plan for a suite of actions that would result in a Subbasin-wide groundwater pumping reduction to reduce streamflow depletion and achieve groundwater sustainability. The reduction in groundwater pumping necessary to reduce streamflow depletion to levels consistent with the sustainability goal is estimated to be a 10 percent reduction in pumping from the average annual historical (2005 to 2014) pumping in the Subbasin of about 15,000 acre-feet. A 10 percent reduction in Subbasin-wide pumping was incorporated in the GSP as an interim Measurable Objective for the sustainability indicator for depletions of interconnected surface water. Accordingly, the goal of the GPR Workplan is to reduce pumping in aggregate throughout the Subbasin to achieve groundwater sustainability during the GSP implementation horizon through reducing average annual groundwater pumping to approximately 13,500 acre-feet to improve interconnected surface water conditions, especially during the summer to fall period at the end of the irrigation/dry season. Although this is a Subbasin-wide goal of the GPR Workplan, it may also be achieved through site-specific, focused efforts, particularly those that reduce depletion of interconnected surface water. This may be accomplished by combining reductions in pumping with other demand management and/or supply augmentation approaches. In coordination with stakeholder and public input during GPR Workplan development, the Workplan focuses first on voluntary implementation steps and indicates that mandatory measures may be necessary in the future should voluntary measures be insufficient to achieve the Subbasin sustainability goal.

Importantly, the GPR Workplan focuses on reducing groundwater pumping for human-related needs. Environmental uses of groundwater are intentionally excluded from this GPR Workplan as there are no expectations to reduce environmental uses of groundwater.

Table ES.1 summarizes the baseline (historical 2005-2014 period) and recent (2015-2022) groundwater pumping in the Subbasin by major water use sector. These values represent groundwater pumping by sector; they do not include any surface water deliveries or separately show consumptive water use. Total average annual pumping is approximately 15,000 acre-feet per year (2005-2014) and 18,150 acre-feet per year (2015-2022).

Table ES-1. Groundwater Pumping Summary

Groundwater Use Sector	Average Annual Groundwater Pumping (AFY) (2005-2014)	Average Annual Groundwater Pumping (AFY) (2015-2022)
Domestic and Other Small Water Systems	2,680	3,230
Wineries	820	790
Municipal	390	350
Agriculture & Vineyards	11,110	13,780
Total Groundwater Use[1]	**15,000**	**18,150**

[1]The total groundwater use is only for groundwater pumpers and does not include native vegetation, such as riparian or wetlands, which are also a beneficial user of groundwater.

Note: AFY = acre-feet

ES-2. Reducing Groundwater Use in the Napa Valley Subbasin

The Subbasin includes a mix of rural residential, municipal, commercial and industrial (e.g., wineries), and agricultural water users, as well as environmental uses for instream flow and habitat. These businesses and individuals rely on the Subbasin water resources, including groundwater, to generate economic value, jobs, income, support the standard of living in the Subbasin, and improve riparian and aquatic habitat. In addition to managing groundwater for environmental needs, it is important to manage groundwater resources to support the current and future needs of all users in the Subbasin and broader Napa County. Reducing groundwater pumping should be done in a thoughtful way that balances the needs of the diverse users of water in the Subbasin, including residents, businesses, and the environment.

All water users can and should take various actions to conserve water. Water conservation actions can result in two types of groundwater savings: a reduction in total groundwater pumping and/or a reduction in net depletion of the groundwater (total groundwater pumping less useable groundwater that returns to the aquifer, e.g., through incidental recharge). It is important to evaluate how different water conservation practices result in a reduction in total groundwater pumping, net groundwater depletion, or both. Each water conservation practice will affect groundwater sustainability indicators in different ways.

Actions to reduce groundwater pumping described in this Workplan include both voluntary and potential mandatory measures. Voluntary measures include actions that all water users—residential, commercial, industrial, and agriculture—can take to conserve water if properly incentivized to do so. Incentives can include anything from education and outreach to financial incentives to encourage changes in behavior and the adoption of new technologies. Mandatory measures could be implemented to reduce pumping if voluntary measures are insufficient to achieve groundwater sustainability.

Voluntary water conservation actions were identified through an extensive stakeholder outreach process, review of technical studies, and input from the NCGSA Technical Advisory Group (TAG). Each practice was evaluated to quantify its implementation costs, groundwater benefits (total pumping or net depletion), and ability to increase the adoption of the practice in the Subbasin. This information was used to calculate potential groundwater savings across the entire Subbasin. The following voluntary actions are included in the Workplan:

- **Water measurement**. Measuring and tracking water use (using meters or other methods) provides new information (for those that do not currently measure or meter) to water users that allows them to take actions to reduce water use.
- **Recycled water**. Recycled water is treated wastewater that is then delivered for other uses, typically landscape irrigation and agriculture.
- **Benchmarking**. Benchmarking programs provide water users with an anonymous summary of how their water use compares to a group of similar (anonymous) peers to encourage water savings.
- **Irrigation system efficiency improvements**. This includes a range of actions, from fixing leaks to improving irrigation system management.
- **Distribution uniformity testing**. Testing irrigation systems to evaluate how evenly water is distributed to the field helps identify leaks and prevent over or under-irrigation.
- **Plant and soil moisture monitoring**. There are multiple technologies available to vineyards to monitor plant and soil moisture to precisely schedule crop irrigation and protect productivity and fruit quality.
- **Soil management**. Managing soil health with cover crops, mulching, and other practices can provide water benefits by improving infiltration and soil retention.
- **Canopy management**. Vineyard canopies are carefully managed for productivity and fruit quality; specific actions can be taken to reduce crop consumptive water use and save water.
- **Row orientation**. At planting or replanting, the orientation of the rows affects sun and wind exposure, which affects crop consumptive water use.
- **Rootstock selection**. Vineyard rootstocks are selected for pest and disease resistance, and some varieties provide drought tolerance that can help manage water during times of shortage.
- **Waterless barrel sanitation**. Wineries must use water to clean barrels and other activities at the winery, and new technologies are available to reduce (or eliminate) water use in this process.
- **Processing water reuse**. Winery wastewater must currently be treated and managed; additional treatment can make the water usable for landscaping or vineyard irrigation purposes.
- **WaterSense devices.** “WaterSense” devices are products certified by the US Environmental Protection Agency that are at least 20 percent more water efficient than other products on the market. Installation of these in homes and businesses can generate substantial water savings.

- **Other Urban Water Conservation Opportunities**. Other water conservation opportunities for urban (M&I) water users include planting drought-tolerant or native landscaping for residential and commercial buildings, additional outreach and education efforts to landscape design professionals, use of reclaimed water for outdoor irrigation, use of mulches to reduce outdoor irrigation demand, and general improvements in outdoor irrigation scheduling and management.

Table ES-2 summarizes the voluntary water conservation practices. It shows the annualized cost per acre-foot of water conserved, the potential Subbasin-wide benefits, the estimated timeline for adoption, and a qualitative assessment of the overall feasibility of implementing the practice in the Subbasin. **Section 3** of the main report provides a detailed analysis of each conservation practice.

Table ES-2. Decision Matrix for Adoption of Water Conservation Practices

Practice	Estimated Annualized Cost per AF Conserved	Estimated Potential Water Savings (Subbasin-Wide)	Adoption Timeline[1]	Overall Feasibility
Unit	$/AFY	AFY	Years	Ranking
Water Practices for All Water Users				
Recycled Water	$362 - $720	200 - 300	Medium-Term	High
Benchmarking	$100 - $350	300 - 1,100	Medium-Term	High
Vineyard-Specific Water Practices (Established)				
Water Measurement/Metering[3]	$250 - $375	250 - 400	Medium-Term	High
Irrigation System Efficiency[2,3]	$2,800 - $9,200	75 - 250	Near-Term	Medium
Distribution Uniformity1	$175 - $450	500 - 2,100	Near-Term	High
Plant and Soil Moisture Monitoring[2,3]	$155 - $3,340	1,000 - 2,000	Near-Term	High
High Tech, Low Labor (Time Temperature Domain Reflectometry)	$350 - $1,450			
Medium Tech and Labor (Neutron Probe)	$740 - $3,340			
Low Tech, High Labor (Tensiometers)	$155 - $1,170			
Soil Management (Cover Crop) [3,4]	$5,000 - $18,000	50 - 550	Medium-Term	Low
Canopy Management	$3,500 - $5,000	200 - 300	Near-Term	Medium
Vineyard-Specific Water Practices (New Plantings)				
Row Orientation	No additional cost	200 - 325	Long-Term	High
Rootstock Selection	No additional cost	Data Gaps	Long-Term	Data Gaps

[1] Timelines for adoption are categorized as follows: (1) Near-term practices can be implemented and accrue water savings potential within one year; (2) Medium-term practices can be implemented and accrue water savings in a 2–5-year time frame; (3) Long-term practices can be implemented and accrue water savings in 5 or more years.

Table ES-2. Decision Matrix for Adoption of Water Conservation Practices				
Practice	Estimated Annualized Cost per AF Conserved	Estimated Potential Water Savings (Subbasin-Wide)	Adoption Timeline[1]	Overall Feasibility
Unit	$/AFY	AFY	Years	Ranking
Winery-Specific Water Practices				
Water Metering	$150 - $250	5 - 15	Medium-Term	High
Waterless Sanitation	$1,900 - $2,800	100 - 165	Near-Term	Low
Processing Water Treatment and Reuse	Data Gaps	275 - 450	Long-Term	Medium
Municipal, Industrial, and Residential				
Water Metering	$950 - $2,500	100 - 130	Medium-Term	Low
WaterSense Devices[5]	$775 - $1,200	500 - 575	Near-Term	High
Other Urban Water Conservation[6]	Data Gaps	Data Gaps	Near-Term	Data Gaps

1 Eligible for cost-share funding or other technical support through the Napa Resource Conservation District (RCD).
2 Eligible for cost-share funding through the State Water Efficiency and Enhancement Program (SWEEP).
3 Eligible for cost-share funding through the Environmental Quality Incentives Program Conservation Incentives Contracts (EQIP-CIC).
4 Eligible for cost-share funding through the Healthy Soils Program (HSP).
5 Eligible for financial assistance programs in select municipalities in Napa County.
6 Example opportunities include improved outdoor irrigation management, low water use landscaping, and use of reclaimed water for outdoor irrigation. Detailed cost and scalability data were not available for initial workplan development. Additional information will be provided as part of education and outreach for Workplan implementation.
NOTE: $/AF = cost per acre-foot per year

Water conservation practices can be interrelated or influenced by one another, so the potential water savings cannot be added across all practices. For example, measuring water use allows users to identify options for adjusting water use patterns, such as implementing soil moisture monitoring. As such, water measurement and soil moisture measurement benefits are not additive.

If voluntary actions are not successful in achieving sustainability, then mandatory measures would be considered by the NCGSA. Mandatory measures are already widely implemented across the state, and in limited circumstances, in Napa County. For example, Napa County (outside of this GPR Workplan) has implemented mandatory measurement and reporting, limits on pumping, and other ordinances for new well permits. Potential mandatory measures include:

- **Mandatory measurement.** Measurement and reporting could be mandated, which would allow water users to better monitor and make changes in water use.
- **Pumping allocations**. Allocations that define the amount of groundwater that can be extracted by well or area are in place in several areas across the state.

- **Mandatory certification.** Mandatory certification and water use efficiency standards could be enforced, encouraging efficient practices for vineyards and wineries.
- **Other local ordinances**. Other local ordinances range from mandating changes in landscaping for new development to requiring new development to adopt efficient water technologies.

The analysis in this Workplan suggests that there is potential to achieve groundwater sustainability in the nearer term and the groundwater pumping reduction target during the GSP implementation horizon (before 2042) through voluntary measures, without the need for mandatory measures.

This GPR Workplan focuses on opportunities to reduce groundwater demand (conserve water). Supply augmentation options may include increased stormwater capture for commercial, winery and residential (water catchment systems) and for municipal and agriculture (increased reservoir and pond storage capacity). These and other supply augmentation opportunities will be assessed for technical, economic, and financial feasibility in parallel with GPR Workplan implementation. Supply augmentation opportunities must be consistent with Subbasin hydrogeologic conditions.

ES-3. Incentivizing Voluntary Actions

There is potential to achieve the Subbasin groundwater pumping reduction target through voluntary measures, and this can be achieved through appropriate incentives that encourage water users to adopt new technologies or change behavior. **Section 3** of this Workplan describes options for incentivizing adoption, which include:

- **Certification programs**. Certification programs require producers to meet specified standards to become certified. In exchange, certified businesses are able to meet regulatory standards, label their product in a certain way, and have access to new markets and value. Examples of existing programs in the Subbasin include Napa Green, California Sustainable Winegrowing Alliance (CSWA), and Fish Friendly Farming (FFF). These could be expanded to include additional water conservation practices for the benefit of the Subbasin. In exchange, the NCGSA could include funding to pay individuals to become certified since certified businesses save the NCGSA costs by being good stewards of groundwater resources. For example, certified businesses may help reduce the need for projects or other management actions, such as recharge. Another option is for the NCGSA to provide a pool of funds annually that could be distributed to designated programs for implementing water conservation practices.
- **Benchmarking programs**. Benchmarking programs provide water users with an anonymous summary of how their water use compares to a group of similar (anonymous) peers to encourage water savings. A conceptual program is developed in this Workplan that would provide anonymous data on crop evapotranspiration to show how an individual operation compares to a group of its peers. The intent is to incentivize behavioral changes. It has been demonstrated to be effective in the energy sector.
- **Other financial incentives**. Adopting water conservation practices can be costly. The Workplan includes a range of potential funding opportunities and resources for landowners who wish to implement certain practices. These could be expanded to encourage further adoption.

Effective incentives can encourage the adoption of water conservation practices and prevent the need for more strict, mandatory measures.

ES-4. Groundwater Pumping Reduction Implementation

This Workplan includes a multi-component approach to implementing groundwater pumping reduction in the Subbasin. This emphasizes a process that leverages current water conservation opportunities, recognizes individuals for previous investments in such practices, focuses on cost-effective voluntary actions, and includes an adaptive management process. Adaptive management allows for continuous improvement in water use and management strategies, programmatic adjustments for higher impact, tracking and evaluating Subbasin conditions relative to GSP sustainable management criteria, assessment of progress towards achieving groundwater sustainability and the groundwater pumping reduction goal, and recommended actions as needed to adjust approaches to achieve the pumping reduction goal.

The general implementation components include:

- **Component 1: Education and Outreach; Feasibility Planning**. This component focuses on improving outreach and education, including working with local entities, such as the Napa County Resource Conservation District, University of California Cooperative Extension, Napa Green, Napa Valley Grapegrowers Association, and Napa County Farm Bureau that already provide education and outreach services to agricultural water users in the Subbasin. This component also includes outreach to urban/rural residential and commercial and industrial water users to increase water conservation practices. It also incorporates the development of a feasibility plan to compare GSP projects and management actions on a consistent basis.
- **Component 2: Voluntary Adoption**. Encourage voluntary adoption of water conservation practices through appropriate financial and other incentives. This component includes the development of data and monitoring to track program goals and report on water savings.
- **Component 3: Voluntary Certification**. This component focuses specifically on certification. This is a mechanism to encourage additional adoption by working with existing certification programs to understand current water conservation practices and how those can be expanded under the program.
- **Component 4: Program Performance and Potential Mandatory Measure**s. This component includes updates and assessments of program performance and water conservation achievements. If voluntary measures are insufficient to achieve groundwater sustainability and the longer-term groundwater pumping reduction goal, then mandatory measures would be considered. The implementation plan would be recommended by the TAG and adopted by the NCGSA through an appropriate public process. This would include adaptive management as described in the GSP and supplemented with additional strategies and actions as new data are available and the performance of the program is monitored.

ES-5. Monitoring and Measuring Water Conservation Practices

The Napa Valley Subbasin GSP requires the implementation of water conservation practices and a quantifiable reduction in groundwater pumping in the Napa Valley Subbasin as needed to achieve sustainability. This requires (i) measuring water use and (ii) quantifying and defining real groundwater savings as water conservation practices are implemented.

Measuring water use. Water use can be defined as gross applied (delivered) water or consumptive water use. It is important to measure both applied water and consumptive water use for calculating groundwater savings attributable to a program.

Options for measuring water use include:

- Well meters. Meters on wells measure the amount of water pumped and applied to the crop, used at the home, used at the winery, or applied to landscaping. Managing well meter data can be burdensome, but new software and technologies offer the potential to reduce the costs of managing these data for businesses and individuals.
- Remote sensing data. Satellite data can be used to estimate evapotranspiration from the landscape. This is particularly useful for measuring water use in agricultural areas. New technologies allow growers to measure evapotranspiration within vineyard blocks, which can help managers with irrigation practices. This technology also informs native vegetation and non-native crop total water consumption (including precipitation, applied water, and indirect groundwater use) across the Subbasin and the watershed.
- Other evapotranspiration data. This can include land-based sensors that track evapotranspiration. Land based sensors can also be combined with satellite data to improve the accuracy of evapotranspiration estimates.

Quantifying real groundwater savings. Water conservation broadly includes a range of activities that aim to reduce the amount of water required and extracted from aquifers. To effectively reduce groundwater pumping for Subbasin sustainability benefits, the water conservation practice must result in a reduction in net depletion (pumping net of recharge). Some water conservation activities, such as improving irrigation efficiency, may decrease the quantity of water applied, but they also reduce recharge to the same groundwater aquifer (and may also result in an increase in crop consumptive use), and so do not reduce net depletion from the aquifer. Therefore, actions to reduce groundwater pumping outlined in this GPR Workplan and its companion document, the WC Workplan, include all potential actions but identify their effects both on total groundwater pumped and on net depletion. Reducing total groundwater applied can reduce pumping energy use, provide water quality benefits, avoid subsidence, and provide temporal benefits for interconnected surface water and groundwater dependent ecosystems (GDEs). But to achieve meaningful and lasting benefits to increase the volume of groundwater in storage and reduce the potential for undesirable results, the actions must reduce net depletion.

ES-6. Data Gaps

The GPR Workplan is based on the best available data. However, there are some data gaps in what different water conservation practices would cost, potential benefits, and opportunities for increasing adoption. Data gaps are noted throughout the Workplan. As part of the GPR implementation plan, these data gaps would be addressed and used to improve outcomes for businesses and communities.

ES-7. Next Steps

The next steps of the GPR Workplan include the development of several programs and activities in the multi-component implementation plan. The timelines reflect the initial development of each component. Implementation will continue and will be adaptively managed in response to stakeholder feedback. These next steps include:

- **Component 1: Develop educational materials.** Craft educational materials for specific users, including vineyard managers and farmworkers, wineries, residents, and tourists/hospitality. Materials for vineyards would be developed in English and Spanish. Expected timeline: 3 months.
- **Component 1: Build partnerships with local organizations.** Recognizing the wealth of relationships that various organizations have with the public and/or their membership, the NCGSA will work to build relationships and partnerships with organizations that are promoting water stewardship. Expected timeline: 1 year.
- **Component 1: Perform feasibility analysis.** Evaluate the costs and benefits of best management practices and projects included in the GSP and compare them on a consistent basis with the water conservation activities. This would result in a comprehensive analysis that establishes the most cost-effective GSP implementation plan for both projects and management actions. Expected timeline: 6 months.
- **Component 1: Develop an automated messaging system.** Develop a messaging system (e.g., texts or other medium) that would inform water users of relevant information for water conservation, such as seminars and workshops, other events, financial assistance programs, and public meetings. Expected timeline: 6 months.
- **Component 2: Develop incentive program for the adoption of High-Priority Water Conservation Practices.** Develop incentives for the adoption of high-priority water conservation practices and technologies. This will include evaluating the list of potential incentives and determining the levels of funding NCGSA will contribute for adoption. Expected timeline: 6 months.
- **Component 2: Develop pilot benchmarking tool starting with agricultural use.** Identify growers who would be interested in participating in the pilot benchmarking program. Develop the appropriate parameters for creating comparable peer groups against which to benchmark irrigation performance. Expected timeline: 1 year.
- **Component 2: Develop a voluntary meter data and reporting program.** Develop a program for groundwater users to voluntarily report their meter data, incorporating incentives. Expected timeline: 1 year.

- **Develop incentives for participation in a qualifying certification program.** Outline the minimum criteria for a certification program to incorporate key water conservation practices of relevance to the Napa Valley Subbasin and groundwater sustainability issues (i.e., define which practices would need to be incorporated in the program). This is an important component of certification program design. Under existing certification programs specific practices could be required (e.g., Tier 3 or 4 level water efficiency/conservation practices under CWSA) or water conservation practices would need to be included (e.g., Fish Friendly Farming does not currently include water efficiency practices). Describe the process for NCGSA to approve existing certification programs as meeting the criteria. Develop incentives to reward vineyards and wineries becoming and remaining certified by qualifying certification programs. Expected timeline: 1 year.

1 INTRODUCTION

The Napa Valley Subbasin Groundwater Sustainability Plan (GSP) characterizes baseline conditions and lays out a path for sustainable management of groundwater resources in the Napa Valley Subbasin (Subbasin). The Napa Valley Subbasin GSP includes projects and management actions for achieving the sustainability goal as required by GSP Regulations. It defines Undesirable Results (URs) associated with overuse of the groundwater resource, sets targets for managing groundwater levels, and defines a series of projects and management actions that will be implemented to maintain sustainable groundwater conditions in the Subbasin.

Following adoption of the GSP, initial GSP implementation for Management Action #2: Groundwater Pumping Reductions (GPR) has involved development of the GPR Workplan as specified in the GSP. The GSP section on the GPR management action contains all the information required by 23 CCR 354.44, including the Measurable Objective expected to benefit from the management action, which is the sustainability indicator for depletions of interconnected surface water. Management Action #2: GPR is intended to provide a direct means for reducing the impacts of groundwater pumping on interconnected surface and groundwater resources in the Subbasin. The Groundwater Pumping Reduction Workplan was conceptually defined during the GSP development process with input from stakeholders and the Groundwater Sustainability Plan Advisory Committee (GSPAC) and a Workgroup. The GSP specified that this management action would be triggered if Minimum Thresholds (MT) were exceeded at any Representative Monitoring Site (RMS) wells for the depletions of interconnected surface water sustainability indicators[2].

The Napa Valley Subbasin exceeded MT in Water Years 2021 and 2022 and caused URs for two sustainability Indicators: (i) Reduction in Groundwater Storage and (ii) Interconnected Surface Water (ISW). For ISW, the Yountville site showed one out of five RMS wells with three consecutive Fall readings below the MT, which was defined as a UR[3]. For Reduction in Groundwater Storage, the seven-year average annual net groundwater extraction in the Subbasin exceeds the sustainable yield, which was defined as a UR. GSPAC's direction to initiate a reduction in groundwater pumping, regardless of MTs and URs, led to the development of this Groundwater Pumping Reduction Workplan. Proactive measures are necessary to counter and mitigate the impacts of immediate and prolonged effects of drought conditions and prepare for the uncertain conditions resulting from climate change.

[2] In addition, on October 14, 2021, the GSPAC indicated its support for achieving a 10% reduction in average annual historical (2005-2014) pumping even if minimum thresholds are not exceeded at RMS wells. The GSP further specified that efforts to initiate a reduction in pumping would begin following NCGSA adoption of the GSP. This document summarizes the results of this effort.

[3] The GSP defines 20% of RMS well levels falling below the MT in fall (October) for 3 consecutive years as a UR. One out of five RMS wells met the 20% threshold for this indicator.

The Groundwater Pumping Reduction Workplan (GPR Workplan) is one of several projects and management actions described in the GSP to achieve sustainable groundwater management. The GPR Workplan addresses, directly and indirectly, all groundwater pumping sectors, including agriculture, wineries and other industrial users, and domestic users. Environmental users of groundwater, such as wetlands or riparian areas, are not expected to reduce groundwater use and are not addressed in this Workplan. An additional ISW and Groundwater Dependent Ecosystem (GDE) Workplan is being developed in parallel, which takes into consideration environmental users and their associated data gaps. Groundwater pumping reductions can be achieved through voluntary or mandatory measures. The GPR Workplan defines both voluntary and mandatory measures that may be implemented in the Subbasin.

The purpose of this GPR Reduction Workplan is to:

- **Provide technical data, analysis, and a roadmap for implementing measures to reduce groundwater pumping in the Napa Valley Subbasin**. This includes an assessment of the potential benefits of adopting practices to reduce groundwater pumping, implementation costs, and potential for adoption. This information will help identify voluntary actions that provide groundwater benefits for the Subbasin, are most cost-effective, leverage existing programs, and can generate value for participants.
- **Improve the understanding of groundwater use in the Subbasin and evaluate the effectiveness of pumping reduction measures for improving groundwater conditions and sustainability**. The technical data and analysis developed in the GPR Workplan may be integrated into GSP annual reports and 5-year GSP updates to improve Subbasin management.
- **Develop an adaptive management process, including implementing mandatory measures if voluntary measures are insufficient to achieve groundwater sustainability**. As part of the implementation plan, define an adaptive management process to adjust the program as data and sustainability indicators evolve.
- **Develop strategies that can achieve pumping reductions while supporting the Napa Valley community and regional economy.** This may include the development of programs and services that improve users' water use efficiency and provide appropriate financial incentives.

This GPR Workplan is a companion document to the related document, the Napa County Water Conservation Workplan (WC Workplan). The WC Workplan describes water conservation measures that will be implemented to save water in the Subbasin. In contrast to this GPR Workplan, the WC Workplan is developed as a resource for water users that are interested in implementing water conservation practices. This GPR Workplan builds on the WC Workplan by developing a technical analysis of the costs, benefits, and potential for adoption of measures to reduce groundwater pumping. It defines voluntary measures as well as mandatory measures and provides the Napa County Groundwater Sustainability Agency (NCGSA) with a draft implementation plan and adaptive management process for implementing the plan. Lastly, the GPR Workplan describes options for monitoring, tracking, and refining the understanding of groundwater use and the effect of that use on groundwater conditions and sustainability.

Other water management documents to support GSP implementation are being developed in parallel with the GPR and WC Workplans. The NCGSA is continually updating its website, informational emails, Technical Advisory Group presentations, NCGSA Board presentations, and other public workshops to provide current information to the public. This includes improving mapping resources and providing technical information about groundwater modeling efforts to support GSP implementation. Interested stakeholders are encouraged to subscribe to NCGSA notifications and participate in all opportunities to provide input on workplan implementation.

1.1 Groundwater Pumping Reduction Goal

Regulations require a GSP to include a description of projects and management actions (PMAs) necessary to achieve the basin sustainability goal. The Napa Valley Subbasin PMAs were identified by the GSPAC through a several-month process involving the NCGSA, a GSPAC Workgroup, and the general public. The GSPAC considered demand management programs, which refers to any water management activity that reduces the consumptive use of water. Groundwater pumping reductions provide a direct means of reducing the impacts of groundwater pumping on interconnected surface water and avoiding URs.

An ISW Workgroup was formed and met several times to discuss integrated hydrologic modeling results and streamflow depletion volumes occurring in response to groundwater pumping. The second highest rate of streamflow depletion (seasonal volume during June-October for 2005-2014) at two US Geological Survey stream gages (Pope Street and Oak Knoll) became the proposed interim MT. On October 14, 2021 the ISW Workgroup reported that previous discussions among GSPAC members indicated ”there is also broad support for initiating management actions now to reduce groundwater pumping by 10 percent.”

On October 14, 2021, the GSPAC also discussed and approved the sustainable management criteria (SMC) for the sustainability indicator for depletions of interconnected surface water. The interim Measurable Objective (MO) for ISW was set at the volume of streamflow depletion that corresponds to a 10 percent reduction of the recent historical average annual pumping (2005-2014) of about 15,000 acre-feet (AF) (which is also comparable to the estimated sustainable yield). Successful attainment of the MO (a reduction in Subbasin annual pumping by approximately 10 percent to about 13,500 acre-feet per year (AFY)) would increase the volume of groundwater in storage and reduce the potential for URs to interconnected surface water.

Importantly, the GPR Workplan focuses on reducing groundwater pumping for human-related needs. Environmental uses of groundwater are intentionally excluded from this GPR Workplan as there are no expectations to reduce environmental uses of groundwater. The ISW and GDE Workplan is being developed in parallel, which takes into consideration environmental users and their associated data gaps.

The GPR Workplan is one of several PMAs described in the GSP to achieve sustainable groundwater management. As defined by the GSPAC, and to avoid occurrences of URs in the Subbasin, the GPR Workplan includes voluntary measures to achieve a Subbasin-wide groundwater pumping reduction of 10 percent over recent historical average annual conditions. Additional information on historical to current groundwater pumping in the Subbasin is provided in **Section 2.1**.

1.2 Structure of the GPR Workplan

The GPR Workplan is structured as follows.

- **Section 2** provides an overview of water use in the Napa Valley Subbasin to provide context for the need for measures to reduce groundwater pumping. This includes a definition of water conservation, methods to measure it, and methods to monitor outcomes.
- **Section 3** describes costs, benefits, and adoption potential for voluntary actions to reduce groundwater pumping for urban, commercial, industrial, and agricultural water users.
- **Section 4** provides a summary of methods to measure water conservation.
- **Section 5** provides an economic analysis of potential actions to reduce groundwater pumping, then screens and ranks alternatives using a matrix format.
- **Section 6** summarizes stakeholder outreach conducted to support the GPR Workplan.
- **Section 7** presents an implementation plan and description of potential mandatory water conservation measures.
- **Section 8** summarizes key elements of the Workplan.

2 BACKGROUND

To help maintain groundwater quantity and quality throughout Napa County, the County has taken progressive actions to protect and manage groundwater since the mid-1960s through careful land use zoning policies, attention to groundwater monitoring, and permitting processes. Since 2008, Napa County has been implementing a groundwater management program to better understand groundwater conditions. The program includes monitoring to track conditions, education and outreach activities, and programs to assess and maintain groundwater sustainability.

2.1 Subbasin Groundwater Pumping Profile

Analysis of historical and current groundwater pumping for the Subbasin serves as the foundation for quantifying and evaluating groundwater pumping reductions. Per Section 11.5.2 of the GSP, the historical period from water year (WY) 2005 through 2014 serves as a baseline period used to quantify relative differences in groundwater pumping in the Subbasin (LSCE, 2022). This period is compared to estimates of current (WY 2015–2022) groundwater pumping to examine recent shifts in groundwater extraction. **Table 2-1** summarizes the total groundwater pumping for both periods. The following sections provide a description of methods used to quantify pumping and estimates of groundwater extraction. A summary of projected changes in future groundwater demand are also provided.

Table 2-1. Groundwater Pumping Summary

Groundwater Use Sector	Average Annual Groundwater Pumping (AFY) (2005-2014)	Average Annual Groundwater Pumping (AFY) (2015-2022)
Domestic and Other Small Water Systems	2,680	3,230
Wineries	820	790
Municipal	390	350
Agriculture & Vineyards	11,110	13,780
Total Groundwater Use[1]	**15,000**	**18,150**

[1] The total groundwater use is only for groundwater pumpers and does not include native vegetation, such as riparian or wetlands, which are also a beneficial user of groundwater.

2.1.1 Quantification of Groundwater Pumping

Groundwater pumping occurs in four primary groundwater water use sectors[4] in the Subbasin. These include agricultural water users, municipalities and non-municipal small public water systems, self-supplied rural residential users, and wineries. The volume of groundwater extraction for each sector is either directly measured or estimated using the Napa Valley Integrated Hydrologic Model (NVIHM)

[4] The Napa GSP and Annual Reports further describe the environmental users as an additional sector of beneficial users of groundwater.

developed to support the preparation and annual reporting for the Napa Valley GSP. The NVIHM is further described in **Section 4.1.4**. A description of each water use sector and methods used to estimate respective groundwater extraction are described below:

- **Agricultural** pumping represents groundwater extraction required for irrigation (or frost protection) of wine grapes and other crops in the Subbasin. Since groundwater pumping for irrigation is not reported, estimates are derived from a landscape water balance using NVIHM. The model relies on a supply-constrained demand framework where the portion of crop evapotranspiration not met by precipitation, groundwater uptake or surface water (either imported, diverted from streams or stored in on-farm ponds) is assumed to be met by groundwater pumping. Groundwater pumping demand is dynamically calculated and summarized for the Subbasin.
- **Rural Residential** includes groundwater extraction for self-supplied residential, commercial, and industrial water users. Typical self-supplied users in the Napa Valley Subbasin are private residences supplied by domestic wells or are part of small public water systems. Total estimates of groundwater demand for domestic users are calculated differently for indoor use versus landscaping. Groundwater use for indoor domestic demands is calculated based on population estimates and a daily per-capita daily indoor water usage of 60 gallons per day per person estimated in Sonoma County (Aquacraft, 2011). Monthly landscape irrigation is calculated using landscape evapotranspiration within the supply-constrained demand framework in NVIHM. Small public water systems are defined by the California State Water Resources Control Board (SWRCB) as water purveyors that supply water to between five and fourteen service connections. Since 2013, small public water system groundwater extraction is measured and reported monthly to the SWRCB.
- **Municipal** use groundwater extraction for water users connected to municipal water supply. Municipal groundwater extraction occurs from three supply wells operated by the City of St. Helena to supplement surface water supply. Municipal groundwater extraction is measured and reported monthly to the SWRCB and available directly from the City of St Helena.
- **Winery** groundwater extraction occurs to meet the water demand used in the production of wine for wineries where surface water is not available. In some instances, wineries meet the criteria of small public water systems and self-report groundwater extraction to the SWRCB. Groundwater extraction for wineries that do not report groundwater extraction was estimated based on the current permitted maximum volumes of wine production, assuming approximately seven gallons of water required to produce one gallon of wine.

It is recognized that ongoing updates and refinements to NVIHM may result in differences in estimates of Subbasin pumping. NVIHM updates are anticipated in response to changes in data availability, the development of novel tools or methods to quantify water use and groundwater extraction, and the continued study of Subbasin hydrology. It is expected that groundwater pumping estimated for the historical period from 2005-2014, which serves as the baseline for evaluating SMCs (including the interim MO for ISW), may be updated in the future. Accordingly, NVIHM is intended to quantify relative (e.g., fractional or percent-based) reductions in future pumping relative to the baseline period.

2.1.2 Historical Groundwater Use

Groundwater extraction within the Subbasin is summarized by water year for the four groundwater use sectors for the historical (2005-2014) period. During this period, total estimated groundwater extraction averaged 15,000 AFY and ranged from 10,290 to 18,960 AFY (**Figure 2-1**). The historical and current pumping averages (horizontal dashed lines) are shown over the period over which these averages were calculated. Groundwater shows variability from year to year, with less use in wet years when late spring precipitation provides sufficient soil moisture to sustain crops and landscaping for a longer period into the growing season before irrigation is necessary.

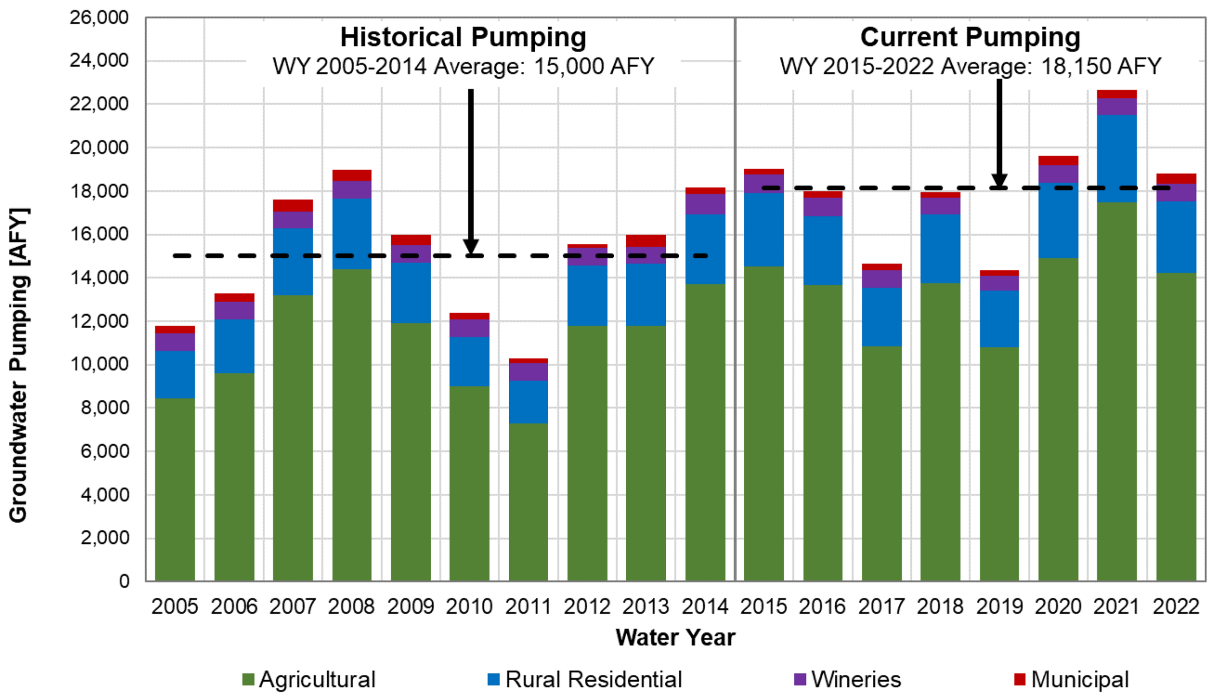

Figure 2-1. Estimated Groundwater Pumping (Water Years 2005-2022)

- **Agricultural** pumping accounts for approximately 74 percent of total groundwater extraction in the Subbasin (**Figure 2-2**). Agricultural groundwater pumping averages 11,110 AFY and ranges from 7,280 to 14,400 AFY from 2005-2014 (**Figure 2-1**). Pumping for irrigation varies considerably between wet and dry years. In wetter years, irrigation is reduced due to increased precipitation.
- **Rural Residential** groundwater extraction accounts for about 18 percent of all groundwater pumping in the Subbasin (**Figure 2-2**). Groundwater pumping from this sector averages 2,680 AFY and ranges from 1,970 to 3,270 AFY from 2005-2014 (**Figure 2-1**). Outdoor water use for landscape irrigation is estimated to account for nearly 90 percent of the groundwater pumped for rural residential use. Accordingly, total groundwater use varies between wet and dry years, similar to the agricultural groundwater sector. Reported water use from small public water systems is only available electronically from the SWRCB beginning in 2013. As a result, groundwater pumping for

this sub-sector from 2005 through 2014 is estimated from the available data. In total, small public water supply pumping accounts for about 10 percent of rural residential groundwater pumping.

- **Municipal** pumping accounts for approximately 3 percent of total groundwater extraction in the Subbasin (**Figure 2-2**). Municipal and small public water supply pumping averages 390 AFY and ranges from 180 to 530 AFY from 2005 through 2014 (**Figure 2-1**).

- **Winery** pumping accounts for approximately 5 percent of total groundwater extraction in the Subbasin (**Figure 3-2**). Winery pumping averaged 820 AFY from 2005-2014 (**Figure 2-1**). Winery pumping is largely estimated from maximum wine production in 2021. As a result, inter-annual variation is generally not accounted for, and estimates may over-account for winery pumping.

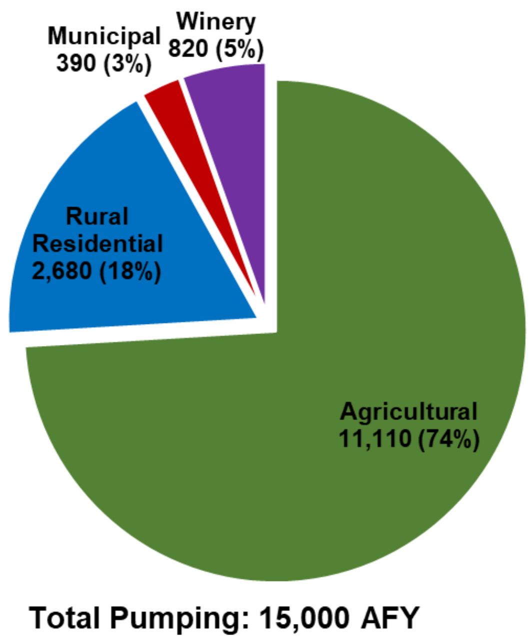

Figure 2-2. Average Estimated Groundwater Pumping by Sector (Water Years 2005-2014)

2.1.3 Current Groundwater Use

Groundwater extraction within the Subbasin is summarized by water year for the four groundwater use sectors for the current (2015-2022) period (**Figure 2-1**; LSCE, 2023). Average groundwater use increased from 14,960 to 18,050 AFY from the historic (2005-2014) to the current pumping period (2015-2022) in response to the drier climate during the current period. This is primarily driven by the agricultural and rural residential water use sectors where generally lower precipitation during recent years resulted in a relative increase in pumping required for irrigation of vineyards and landscaping. Total estimated groundwater pumping ranged from 14,340 to 22,840 AFY.

- **Agricultural** pumping accounts for approximately 76 percent of total groundwater extraction in the Subbasin between 2015 and 2022 (**Figure 2-3**). Agricultural groundwater pumping averages 13,780 AFY and ranges from 10,790 to 17,400 AFY (**Figure 2-1**). This represents an approximately 24 percent increase in average pumping over the historical (2005-2014) period.
- **Rural Residential** groundwater extraction accounts for about 18 percent of all groundwater pumping in the Subbasin between 2015 and 2022 (**Figure 2-3**). Domestic pumping averages 3,230 AFY and ranges from 2,620 to 4,030 AFY from 2015-2022 (**Figure 2-1**). Outdoor water use for landscape irrigation is estimated to account for over 90 percent of the groundwater pumped for rural residential use. Groundwater extraction is estimated to have increased by nearly 21 percent compared to the historical period (2005-2014). Groundwater use for small public water systems accounts for about 8% of all rural domestic pumping.
- **Municipal** pumping accounts for approximately 2 percent of total groundwater extraction in the Subbasin (**Figure 2-3**). Municipal pumping averages 350 AFY and ranges from 240 to 860 AFY from 2015-2022 (**Figure 2-1**). Municipal pumping decreased by about 10 percent compared to the historical period (2005-2014).
- **Winery** pumping accounts for approximately 4 percent of total groundwater extraction in the Subbasin during the recent period (**Figure 2-3**). Winery pumping averages 790 AFY from 2015-2022 (**Figure 2-1**). Since winery pumping is based on maximum permitted wine production, groundwater extraction for wine production may be overestimated. The 20 AFY decrease in winery groundwater pumping is a result of measured amounts reported to the SWRCB from a relatively small fraction of wineries in the Subbasin.

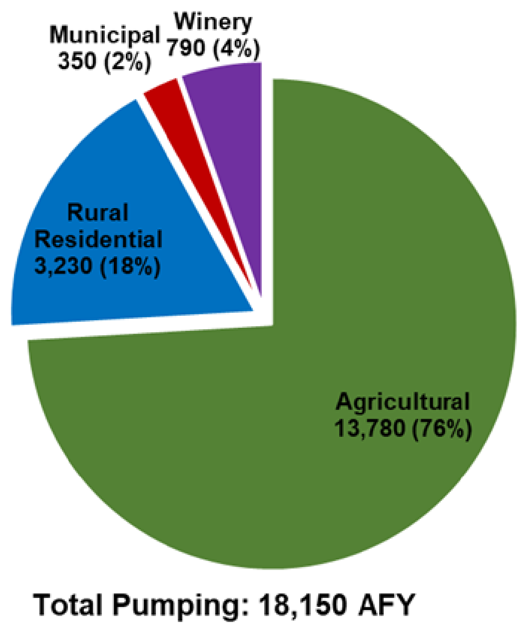

Figure 2-3. Average Estimated Groundwater Pumping by Sector (Water Years 2015-2022)

2.1.4 Groundwater Demand Forecast

Projected Subbasin water supplies are likely to be affected by climate change over the 50-year GSP planning and implementation horizon. Although there is considerable uncertainty in climate forecasting, projections utilized for the GSP reflect average reductions in supplies from local reservoirs averaging 2 percent and reductions in State Water Project supplies averaging 8 percent relative to historical water supplies. Projected water demands vary based on land use and population changes, as well as climate change, with the use of groundwater increasing under future conditions of a climate change scenario involving drier and warmer future conditions. Increases in groundwater use are projected for the agricultural sector (Association of Bay Area Governments, 2021). Depending on the future climate, groundwater use by agriculture is projected to increase by up to 8 percent (900 AFY) relative to historical agricultural groundwater uses, while groundwater uses by self-supplied users to meet outdoor irrigation demands is projected to increase up to 13 percent (310 AFY). Based on the historical rate of new and modified use permits in the Subbasin, winery demands are projected to increase by 7 AFY annually into the future. It is important to note that long-term climate projections are very uncertain. Climate projections are improving with better understanding and modeling. Ongoing work is being done to evaluate and incorporate the best available science for long-term climate planning.

Climate science is a quickly evolving field of study, and climate projections are being refined with new methodologies and models. While the demand forecast provides useful context to what may happen over the next 50 years, this Workplan does not incorporate possible increases in pumping due to a changing climate.

2.2 Napa County Groundwater Management

Napa County has taken an active role in understanding groundwater resources and has participated in and directed studies to help understand groundwater resources by analyzing safe yield and sustainable yield in the Subbasin since the mid-1960s. Involvement increased when the County's Planning Commission adopted the first Water Availability Analysis (WAA) procedure in February 1991. The WAA has been continuously updated and is discussed in more detail in **Section 2.2.2**. Napa County's involvement continued with the adoption of Ordinance No. 1162 (Groundwater Ordinance) in August 1999, with the intent to regulate the extraction and use and promote the preservation of the County's groundwater resources. On November 4, 2003, The County Board of Supervisors (BOS) adopted Ordinance No. 1230 and declared, "The groundwater basins of Napa County form significant water resources that must be managed in trust and must be conserved so that they may be placed to the reasonable and beneficial use of all potential users, while avoiding the waste and unreasonable use of these resources." The BOS also found that "Napa County has a right and duty to govern the management and extraction of resources within its jurisdiction" and "conserving the water resources in the groundwater basins of Napa County to avoid overdrafts and maximize the long-term beneficial use of groundwater resources, best serves the health, safety and welfare of residents of Napa County."

Napa County groundwater management has continued with the passing of Sustainable Groundwater Management Act (SGMA) and the formation of the NCGSA. The NCGSA adopted the GSP on January 11, 2022. To aid in the implementation of the Napa Valley Subbasin GSP, the NCGSA formed the Technical

Advisory Group (TAG). The TAG is an apolitical group of technical experts that provide context and local knowledge to the implementation process.

On March 28, 2022, the Governor issued Emergency Executive Order (EO) N-7-22 to address worsening drought conditions in California. The EO N-7-22 included mandates for water conservation, permit streamlining, and modifications to current regulations to address the drought. The EO N-7-22 also required additional review of well permits by local jurisdictions and groundwater sustainability agencies.

To comply with EO N-7-22, the Napa Valley Subbasin GSP implementation, and recent court decisions including public trust considerations, Napa County Planning, Building and Environmental Services (PBES) has required well permit applications throughout the County to include the information necessary to implement EO N-7-22 paragraph 9, including additional information regarding onsite water uses, total estimated annual water use, and other provisions.

2.2.1 Groundwater Ordinance and Well Permit Requirements

The County periodically updates its well permitting standards, even outside of GSP implementation. Well permitting is a process that must be undertaken for new or replacement wells. The County and NCGSA will regularly review well permitting requirements to ensure groundwater sustainability in the Subbasin and countywide. Well permitting standards can offer a useful regulatory framework to advance groundwater sustainability. Well permitting standards are revised as necessary to address issues such as well siting and design, measurement and reporting use, limiting new uses, mitigation, incorporating best practices, technical review, and public notice.

2.2.2 Water Availability Analysis

A WAA is required for any discretionary project that may utilize groundwater or will increase the intensity of groundwater use of any parcel through an existing, improved, or new water supply system (Napa County, 2015). As such, it will most commonly be used for discretionary development applications using groundwater, such as wineries and commercial uses. The WAA also provides procedures for further analysis when screening criteria are exceeded. An important sidelight to the process is public education and awareness. The WAA is based on an application that requires the applicant to gather information about existing non-project groundwater wells, and water uses at the applicant’s site, describe planned project well operations, document existing uses of groundwater on the property, and estimate future water demands associated with the proposed project. In addition, other information relating to the geology, proximity to surface water bodies (e.g., rivers, creeks, etc.), and the location and construction of existing non-project wells located near the applicant’s property or project well(s) are important to evaluate, as warranted, for the potential for well interference and effects on surface water. County staff can aid the applicant in obtaining and reviewing the latter information as part of the application data collection process.

During the development of the GSP, including the development of the sustainable yield estimate of 15,000 acre-feet per year, the NCGSA and the Napa County BOS recognized the need to revise the County’s Groundwater Ordinance and the WAA. In February 2022, the County BOS acknowledged this need and expressed support for revising the Groundwater Ordinance and WAA. While revisions are being made to the Groundwater Ordinance and the WAA, and in consideration of EO N-7-22, GSP implementation, and recent court decisions, including public trust considerations, the Department of Planning, PBES Director's requested approval by the County BOS on June 7, 2022 of procedural changes to the County's well permitting process (County of Napa, 2022). Based on the total Subbasin area of 45,900 acres and the estimated sustainable yield of 15,000 acre-feet per year, the interim water use criterion for the Subbasin is 0.3 acre-feet per acre per year. The County has applied the reduced water use criterion (or a no net increase in use where applicable) to new permits for wells in the Napa Valley Subbasin. These changes and other updates consistent with the GSP and other considerations will be incorporated in an update to the WAA and revisions to the Groundwater Ordinance, which are in progress.

The Napa River and its tributaries are an integral part of the Napa Valley Subbasin, where groundwater conditions and interconnected surface water are highly sensitive to wetter and drier hydrologic water years and are susceptible to drought effects. Prudent water resources management is necessary regardless of water year type. Although EO N-7-22 prompted revisions to the County's well permitting requirements, other factors, including the Napa Valley Subbasin GSP and public trust considerations (including the County's adoption of Resolution No. 2022-178 on December 6, 2022; see Appendix A) along with significant effects on water resources conditions in response to successive drought years, support the County's revised well permitting requirements.

On February 13, 2023, the Governor issued EO N-3-23 due to drought conditions that continue to affect groundwater basins, local water supplies, and ecosystems. EO N-3-23 contained some new orders and provisions; it also withdrew EO N-7-22 and replaced prior paragraph 9 with new paragraph 4. Even if the new EO N-3-23 is lifted in the future, the County's revised well permitting requirements are justified to remain in place for the County's duty to manage groundwater resources and implement policies and regulations affecting water supply reliability, water resources sustainability, protection of domestic wells and water systems, and protection of the environment consistent with public trust principles, as well as potential future threats due to drought. Water conservation from new wells may be modest because relatively few new well permits are issued annually, and thus conservation will need to consider existing wells and users in addition to new well permitting standards.

2.2.3 SB 552 Drought Resilience Planning

Senate Bill 552 (SB 552) was passed and signed by Governor Newsom in September 2021. It mandates that State and local governments prepare plans to manage water supplies in the case of drought conditions (water shortages). The intent of the law is to require local governments to proactively prepare for future droughts, improve management, and mitigate impacts on drinking water supplies for communities, including economically disadvantaged areas. The frequency and duration of drought and water shortage events are likely to increase in the future due to climate change, increasing demand and competition for water, and sustainability limits on groundwater use. Under SB 552 drought plans, governments will be more proactive in drought planning (DWR, 2022). For example, counties are required to create a standing County Drought and Water Shortage Task Force and develop a County Drought Plan that includes a water risk assessment for small systems and domestic wells in the county.

In response, the Napa County BOS established a Drought and Water Shortage Task Force on December 13, 2021. The Task Force meets periodically, most recently in July 2023. The Task Force is overseeing the development of a Drought Resilience Plan. The plan is being developed concurrent to this GPR Workplan and the companion WC Workplan, and it will address water management actions, including small system and domestic well drought resilience and risk.

The GPR Workplan and companion WC Workplan help the County achieve its requirements and broader water management goals under SB 552. Napa County's water supply comes from a mix of surface supplies, groundwater, and recycled water. Drought resilience in Napa County is improved when groundwater resources are sustainably managed. This GPR Workplan identifies data needs, implementation approaches, and a list of best practices to reduce groundwater use in the county. This results in improved drought resilience for small systems and domestic wells in the future. As additional information from the Task Force becomes available, both documents could be updated to better integrate across these related planning efforts.

2.3 Reducing Groundwater Pumping

Groundwater pumping reduction is alternatively referred to in other GSPs and water management documents as water conservation, demand management, or water use reduction. Reducing groundwater use broadly refers to any water management activity that reduces the use of groundwater. To achieve groundwater sustainability, it must result in a reduction in net groundwater pumping (pumping net of recharge that returns to the same aquifer). Net groundwater pumping is alternatively called net depletion. Some water conservation activities, such as improving irrigation efficiency, may decrease the quantity of water applied, but they also reduce recharge to the same groundwater aquifer (and may also result in an increase in crop consumptive use), and so do not reduce net depletion from the aquifer. Therefore, actions to reduce groundwater pumping outlined in this GPR Workplan and its companion document include all potential actions but identify their effects both on total groundwater pumped and on net depletion. Reducing total groundwater applied can reduce pumping energy use, provide water quality benefits, avoid subsidence, and provide temporal benefits for interconnected surface water and GDEs. But to achieve meaningful and lasting benefits to avoid URs, the actions must reduce net depletion.

This GPR Workplan characterizes actions to reduce groundwater pumping (water conservation) in the Subbasin (or other defined area) based on their potential to reduce total groundwater pumped and their potential to reduce net depletion. These amounts are defined as follows:

- **Total groundwater pumping** – the total amount of groundwater pumped for a particular use or for all uses, usually expressed as an annual amount in AF or AFY.
- **Net groundwater depletion** – the total amount of groundwater pumped adjusted for (i.e., subtracting) the portion that returns to the same usable aquifer. In most cases, net depletion represents the portion of total pumping that is consumptively used by crops, landscapes, industrial processes, etc., or is otherwise consumed.

Reducing net depletion generally requires reducing the consumptive use of groundwater, either by reducing total consumptive use or by replacing some groundwater use with another water source, such as recycled water. Reducing total groundwater pumping can also be achieved by reducing consumptive use or by improving water use efficiency and implementing water conservation measures. Water conservation can be achieved by implementing new technology, changing water use and management behavior, or by a combination of technology and management. All water users—including agricultural, urban/residential, and commercial/industrial—can potentially conserve water in the Subbasin. The following are some examples of measures that can reduce total pumping and/or net depletion for the three major water use categories.

- **Agriculture**. Reducing net depletion can be achieved by changing to less water intensive crops or grape varieties, idling land, and reducing non-productive[5] evapotranspiration (ET). Reducing total pumping can be achieved by increasing irrigation efficiency through improved irrigation system technology and management. It is important to note that some irrigation efficiency improvements can lead to an increase in ET of applied water by the crop and, therefore, an increase in total water use. That is, by applying water more efficiently to the crop, the crop can use more of the applied water, and therefore can have a greater total ET for the season.
- **Urban/residential**. Activities to reduce net depletion or total pumping can include stakeholder outreach and education programs to affect water use behavior, delivering recycled water, installing efficient fixtures and appliances, reducing landscaped area and water use, and reducing delivery system losses.
- **Commercial/industrial**. Activities to reduce net depletion or total pumping include adopting equipment and processes that use less water and increasing on-site treatment and reuse of water. Activities that reduce evaporative losses and discharges to unrecycled wastewater also reduce net depletion.

Programs to reduce groundwater pumping require careful accounting and data to identify savings in total pumping and net depletion. This typically requires water balance calculations to compare the changes with and without a reduction in pumping and the fate of the water that is no longer being extracted. Such calculations are required to monitor and assess the benefits of each practice to reduce groundwater pumping. This GPR Workplan includes a summary of implementation approaches, data needs, and monitoring.

Water conservation practices fall under the following general categories:

- **Measurement and tracking.** These strategies apply broadly across residential, industrial, and agricultural sectors. They refer to the quantification and monitoring of water use over time. Strategies include metering, other forms of measurement, and benchmarking.

[5] Non-productive ET is considered any component of ET that doesn't measurably improve the quality or quantity of the harvest. This can include the bare ground evaporation which occurs during over irrigation or increased transpiration from full canopies that are not actively managed. It is further noted that Napa is predominately planted to high-value grapes and opportunities to idle land or switch crops may not be cost-effective or have limited options under current market conditions.

- **Residential and business water conservation practices**. These include improving landscape water management, installing low-flow appliances and equipment, and other adjustments at residences and businesses.
- **On-farm irrigation system management**. This includes irrigation system maintenance, equipment upgrades, and other management practices that increase distribution uniformity. All practices under this general category are implemented by growers at the farm/field level.
- **On-farm technology for irrigation scheduling**. This includes technology and water management to improve irrigation scheduling. For example, sap-flow sensors and other technology can improve the timing and amount of water applied to crops. All practices under this general category are implemented by growers at the farm/field level.
- **On-farm land development practices**. This includes practices for new crop establishment, such as rootstock selection, land preparation, and row orientation. All practices under this general category are implemented by growers at the farm/field level.
- **In-lieu use strategies**. In-lieu water use strategies reduce groundwater pumping by switching to an alternative surface water source. In Napa County, the (Napa Sanitation District) NapaSan is building out its recycled water supply. For example, recycled water or winery process water that is treated and reused represent in-lieu sources. Recycled water is one example of an alternative to using groundwater for irrigation and landscaping. All practices under this general category require additional outside capital investments.

This GPR Workplan describes a range of practices to reduce groundwater pumping that could be implemented by landowners in agriculture, wineries, other businesses, and residential uses. No actions are mandated currently. Rather, this document describes options for voluntary adoption that would be up to the individuals/businesses in the county. Some practices have been implemented already, and others may be jointly implemented by landowners and businesses on a case-by-case basis. To support the adoption of groundwater pumping reduction practices, this document also lists and describes the cost of adoption, benefits from adoption, and state and federal grant funding support for the widespread adoption of each practice.

2.4 Current Water Conservation Practices

Many businesses and residents in Napa County have invested in water conservation practices. For example, low-flow appliances are commonly installed in homes, some wineries have implemented low-water use methods for tank cleaning, and most vineyards are irrigated with low-volume drip systems. It is important to understand current water conservation practices to evaluate the effect of additional water conservation measures.

2.4.1 Residential, Municipal, and Industrial

Napa County residents can contribute to surface water and groundwater conservation by adopting water-saving practices. Implementing water-saving practices saves water and reduces utility bills (energy and/or water). Outdoor water usage, particularly for landscaping, represents a substantial portion of household water consumption. For example, the City of Napa estimates that about half of its potable drinking water is used outdoors (City of Napa, 2023). Residents can minimize water use through water scheduling, adjusting irrigation based on weather conditions, and irrigating only during cooler hours to reduce evaporation. Upgrading irrigation systems with technologies like smart controllers, selecting drought-resistant plants, and using organic mulch can further reduce outdoor water use. Collecting rainwater and using it for landscaping also conserves water. Indoors, simple practices like washing produce in containers, running dishwashers and washing machines with full loads, taking shorter showers, and turning off faucets while brushing teeth can save water. Water-efficient fixtures such as low-flow toilets, aerated faucets, and efficient showerheads can contribute to substantial water and cost savings without compromising performance. Regularly checking for leaks in faucets, pipes, and irrigation systems is essential, with water meters assisting in leak detection. Consistent leak checks and timely repairs prevent water waste.

Drought-resistant landscaping and turf removal also reduce water demand. Outdoor landscaping is typically the greatest source of residential water use. Local programs that pay for turf removal have been implemented across the state. Turf removal and drought-tolerant landscaping reduce ET losses and therefore can result in a net depletion water savings.

The US Environmental Protection Agency (USEPA) has developed standards for water-efficient products; by meeting these standards, products earn the “WaterSense” label. These products must be at least 20 percent more water efficient than other products on the market. For comprehensive information on water-saving strategies, residents can explore the resources provided by Save Our Water, USEPA WaterSense, and Energy Star. A 2015 study found that an estimated 6 percent of residences and commercial buildings in California have high-efficiency toilets, 21 percent have high-efficiency bathroom faucets, and 24 percent have high-efficiency shower heads (GMP Research, 2015). This represents substantial room for improvement in the adoption rates of water-efficient devices.

2.4.2 Wineries

Wineries are an important industry in the Subbasin. Wineries and other self-supplied users are estimated to pump approximately 16 percent of total groundwater pumped in the Subbasin. Wineries use water for a variety of essential purposes throughout the winemaking process, including cleaning and sanitizing equipment, facilities, bottling lines, and tanks, which ensure the quality and safety of the wine. It is also required during the crushing and pressing stages, as well as for fermentation and aging processes.

Water use by the winemaking stage varies by winery. Implementing the means to measure and monitor total amounts in each stage of the process is an emerging trend that allows a winery to identify where efficiency improvements will have the largest impact. For example, if a winery finds that one-fifth of its water use is for tank cleaning, it may investigate waterless sanitation methods. Overall, water is a fundamental resource that supports the hygiene, sanitation, and production needs of wineries.

Water is also used for landscaping, which may represent a substantial amount of the winery’s total water use. To reduce pressure on groundwater resources, many wineries are using or blending treated winery wastewater for landscape irrigation. Other wineries are connecting to recycled water programs to reduce pumping demands.

Wineries certified by the California Sustainable Winegrowing Alliance (CSWA) have demonstrated the adoption of several winery best management practices, signaling the winemaking community's interest in sustainable practices. Napa Green Certified wineries must implement over 120 sustainability practices, including a minimum of 23 Water Efficiency best management practices. (Napa Green, 2023). Examples of practice-specific adoption rates are shown in **Table 2-2**, which shows the range of adoption for different practices. Importantly, there is room for improvement in many of these areas, even for certified sustainable wineries (California Sustainable Winegrowing Alliance, 2020). Napa Green includes required and recommended practices for wineries under its verification and certification program. Examples of required practices under Napa Green include water metering/monitoring; tank, and hose cleaning; low-flow nozzles; and separate landscape metering. Examples of Napa Green recommended practices include steam for barrel cleaning and using cleaning products that significantly increases water use efficiency for tank cleaning process. Workplan implementation may explore expanding these practices and ensuring verification.

Table 2-2. Water Conservation Practice Adoption by Wineries

Winery Practice	Adoption Rate in CSWA Certification Program (2020)
Water Metering	84% use meters 42% monitor use as part of a conservation program 21% installed a separate meter for landscaping/irrigation
Process Water Reuse	48% use some process water for irrigation
Tank Cleaning	86% use high-pressure, low-volume nozzles 38% use temperature-controlled hot water 7% use an alternative sanitation technology

2.4.3 Agriculture

Napa vineyards have made significant strides in the adoption of various water conservation technologies and practices, showcasing a strong commitment to sustainable viticulture. These efforts have led to tangible water savings and improved resource management within the region. However, despite these commendable advancements, there remains an untapped potential for further adoption of innovative water conservation approaches. As the viticulture community continues to prioritize environmental stewardship and climate resilience, the implementation of additional water conservation strategies stands to fortify Napa's position as a global leader in sustainable winegrowing.

The California Code of Sustainable Winegrowing, developed by the California Sustainable Winegrowing Alliance, provides a list of vineyard water management criteria in its workbook (California Sustainable Winegrowing Alliance et al., 2020). Practices range from creating a basic irrigation management plan to technology, including soil and plant moisture monitoring methods. Irrigation system efficiency and uniformity are stressed to maintain optimal water use. A 2020 survey of 2,402 certified vineyards suggests that a vast majority of vineyards are implementing some of these practices (California Sustainable Winegrowing Alliance, 2020). Note that this survey was conducted across their entire certification program and is not specific to Napa. The survey shows high adoption rates of certain practices, but room for improvement exists for others (see **Table 2-3**). For example, while 100 percent of certified vineyards have a water management strategy, only one-third monitor soil moisture and plant water status.

Table 2-3. Water Conservation Practice Adoption

Vineyard Practice	Adoption Rate in CSWA Certification Program (2020)
Water Management Strategy	100%
Metering	36%
Measuring Water Use via Other Methods	52%
Distribution Uniformity	43% tested in last 5 years 93% tested in last 7 years
Plant Water or Soil Moisture Monitoring	32%

Source: California Sustainable Winegrowing Alliance, 2020.

Napa vineyards have adopted water conservation practices over time, and there is potential for wider adoption of adaptive irrigation management that could provide substantial water savings. For example, a 2021 study of irrigation efficiency practices in Paso Robles found only a 43 percent adoption rate of adaptive management (Babin et al., 2022). This means that even if a vast majority of vineyards measure (or have the capabilities to measure) water use, soil moisture and vine moisture, less than half alter their irrigation patterns during a season based on the readings. Furthermore, recent research on the effects of deficit irrigation tied to adaptive management techniques (e.g., Torres et al., 2021) suggests that substantial water can be saved with no loss in fruit yield or quality. Combined with an efficient and uniform irrigation system, adaptive management techniques utilizing plant water and soil moisture sensing could allow for additional savings in the total groundwater pumped and/or net depletion.

Napa Valley Grapegrowers developed a set of actionable water conservation practices (Napa Valley Grapegrowers, 2023). Practices include canopy management through regular hedging and early leaf area removal to curtail vine water consumption. Additionally, techniques such as extending typical irrigation intervals, implementing foliar nutrition for stress reduction, and utilizing measures like shade cloth to diminish vine evapotranspiration are emphasized. Longer-term water reduction strategies include selecting drought-tolerant rootstocks, embracing soft row orientation for natural shade, and deepening ground preparation to foster greater rooting depths. Finally, the integration of onsite water storage systems, such as on-farm ponds, is a recommended measure. This could be done to capture excess stormwater flows and conjunctively manage water or to store recycled water for later use. By prioritizing these practices, Napa Valley growers can proactively contribute to both immediate and lasting water conservation efforts, reinforcing the region's commitment to responsible resource management.

Numerous local agencies, including Napa County Resource Conservation District (RCD), Napa Green, and others, work with growers to implement strategies to use water more efficiently. For example, many growers use soil moisture probes to track water availability, pressure bombs to monitor plant leaf water potential to track water stress, land-based systems to track plant water use and to predict future water needs, and Normalized Difference Vegetation Index (NDVI) to track plant health at the vineyard scale. However, interviews with the Napa County RCD and other industry experts conducted for this GPR Workplan found that technologies and practices could be better utilized by improving the understanding and interpretation of the data they produce and that this improved understanding will enable more adaptive irrigation management.

2.5 Measuring Water Use and Water Conservation

Implementing water conservation practices must result in a quantifiable reduction in groundwater pumping in the Napa Valley Subbasin. This requires (i) measuring water use and (ii) quantifying and defining real groundwater savings as water conservation practices are implemented.

- **Measuring water use**. Water use can be defined as gross applied (delivered) water or consumptive water use. For example, gross applied water is water that is pumped and applied as irrigation water to the crop. Crop consumptive use is the water that evaporates or is transpired by the crop and does not include water that percolates back into the ground or runs off fields into other water ways. It is important to measure both applied water and consumptive water use for calculating groundwater savings attributable to a program. The following subsections describe different techniques to measure gross and consumptive water use.
- **Quantifying real groundwater savings**. Water conservation broadly includes a range of activities that aim to reduce the amount of water required and extracted from aquifers. To effectively reduce groundwater pumping for Subbasin sustainability benefits, the water conservation practice must result in a reduction in net depletion (pumping net of recharge). Activities that, for example, apply water more efficiently to the crop may reduce the amount of groundwater pumped but also reduce deep percolation and recharge to usable groundwater, and so do not reduce net depletion of the aquifer. In some cases, improving irrigation water application efficiency and uniformity can result in a net increase in crop water consumptive use.

The water conservation practices described in **Section 3** include activities that may reduce total groundwater pumping, net groundwater depletion, or some combination of the two. The GPR Workplan attempts to make it clear where a conservation practice would reduce groundwater pumping, net groundwater depletion, or both.

2.5.1 Remote Sensing

Remote sensing has emerged as a cost-effective and scalable tool to estimate consumptive water use. Remote sensing uses technologies such as satellites, drones, and sensors to collect data remotely, enabling the assessment of various water-related parameters without direct contact. Remote sensing is particularly valuable for monitoring water consumption on regional and global scales, aiding in water resource management in water-scarce regions.

The development of OpenET, an open-source platform for field-level agricultural ET data, has made this data particularly accessible and low-cost. OpenET uses a combination of satellite data, crop type data, weather station data, and an ensemble of models to calculate ET.

Remote sensing has several known challenges, including a potentially wide error range for estimates of crop consumptive water use. It also cannot distinguish between sources of water. If an agricultural field uses more than one source of water, such as groundwater, surface water, recycled water and/or precipitation, remote sensing estimations are unable to detect what portion of the crop's ET comes from which source. This can be a challenge for management and quantifying one source of water use or savings, such as groundwater.

Remote sensing provides some advantages over other water measurement approaches, such as meters. For instance, the monitoring and enforcement costs are generally low as the data are collected via satellites rather than collected via individual metered sites, for which there are 993 irrigation, both landscaping and agricultural, well sites in the Napa Valley Subbasin (County of Napa, 2023a). They can also help detect meter bypassing or other non-compliance issues. Further, remote sensing can estimate the ET of dry-farmed vineyards. Even though these vineyards are not using applied groundwater, they still use groundwater through deep rooting systems. These groundwater use amounts could not be estimated through a metered system since no groundwater is applied.

As remote sensing technologies advance, they provide practical and affordable means to estimate water use and water savings. These data should be used cautiously given the limitations noted above, but the data still offer a range of benefits related to monitoring that are difficult to achieve at scale with other methods.

2.5.2 Water Meters

Installing water meters is another method to quantify water pumped or delivered. Meters are typically installed at each well, or at a home or business service connection and quantify the total amount of water that flows through the meter. Meters offer a high degree of accuracy when properly maintained and can quantify the water applied from that single source (e.g., a groundwater well).

The drawbacks of meters, particularly for vineyards, include potentially high monitoring costs as metering sites are dispersed over larger areas, which typically average about 15 acres but can cover much larger areas. These data are not centrally collected or reported, meaning that collecting the necessary data to quantify use and savings could become expensive. Volunteered and self-reported data, particularly combined with verification (e.g., an accompanying photo), may be enough to overcome this challenge.

Another drawback is that groundwater meter data do not capture the groundwater use by deep-rooted vineyards that uptake groundwater through their rooting systems instead of from applied irrigation water. This represents a potential gap in data to quantify groundwater use or potential savings on such fields.

2.5.3 Estimating Conserved Water

As described earlier in this section, it is critical to differentiate between reducing total groundwater pumping and reducing net depletion. This is the key for successfully measuring water savings attributable to a conservation practice.

Steps to measure and estimate water conservation include:

1. Define, quantify, and refine the baseline applied water and water use data in the absence of water conservation practices. This should include a mix of meter data to track water applied, as well as remote sensing and other methods to track consumptive water use. This establishes the reference point for calculating savings in net depletion and/or total pumping.
2. Document the time and location of adoption of the water conservation practice, verify it is used and managed properly, and monitor how the volumes of water applied and consumptively used change relative to the baseline. This typically requires working with selected individuals who are willing to share data or implementing appropriate data reporting systems.
3. Quantify water savings in terms of total pumping or net depletion and, if necessary, extrapolate results from a subset of available data to quantify Subbasin-wide water savings. Quantified savings must also account for weather-related or other differences between the baseline water use and the with-conservation water use.

Estimated savings in total pumping and net depletion can then be applied to support GSP updates and groundwater management in the Subbasin. This may include evaluating the effectiveness of the water conservation practices on sustainability indicators and using the available monitoring data and quantified water savings to update the water conservation practices over time.

3 VOLUNTARY APPROACHES TO REDUCE GROUNDWATER PUMPING

This section describes voluntary water conservation actions that may reduce total groundwater pumping, net depletion, or both. Actions include the adoption of technologies and practices, training and educational programs, data-driven performance and benchmarking, and certification programs. The water conservation technologies, practices, and programs advance water conservation in ways that derive benefits to the users. Benefits may include reduced energy or water costs, increased marketing potential through certification labeling, or intrinsic value for conservation efforts and a commitment to sustainability.

This GPR Workplan focuses on opportunities to reduce groundwater demand (conserve water). Supply augmentation options may include increased stormwater capture for commercial, winery and residential (water catchment systems) and for municipal and agriculture (increased reservoir and pond storage capacity). These and other supply augmentation opportunities will be assessed for technical, economic, and financial feasibility in parallel with GPR Workplan implementation. Supply augmentation opportunities must be consistent with Subbasin hydrogeologic conditions.

The following sections describe user-specific water conservation practices that are summarized in the WC Workplan. Each water conservation practice includes a description of the practice, its scaling opportunity, and estimated standardized cost:

Practice Description: This is a description of the technology or practice and how it may result in water savings. This also states whether the practice would result in a reduction in total pumping, net depletion, or both.

Scaling Opportunity (AFY): The scaling opportunity is defined as the potential water conservation (total pumping or net depletion) that each practice could achieve if applied over an entire water use sector. The potential water savings is expressed as a percent of savings from the baseline. This is based on industry interviews and a literature review of available data, scientific literature, or other industry publications. Next, the share of individuals and businesses that have not yet adopted the practice was estimated based on the best available data. The total potential water conservation across the Subbasin in AFY is calculated as:

> Scaling Opportunity (AFY) = (1 – Adoption Rate of Practice (%)) * (Water Savings Potential of Practice (%)) * (Total Water Use of Sector (AFY))

The adoption rate is measured as a percent of total sector water use (not percent of water users). The baseline water use by sector in the GPR Workplan is annual total groundwater pumping by sector. **Table 3-1** summarizes baseline groundwater use from WY 2005 through 2014, which is applied in all subsequent calculations (see also **Section 2** of this Workplan and Section 2 of the companion WC Workplan). These values represent groundwater use by sector in the Napa Valley Subbasin, do not include any surface water deliveries, and are interpreted as gross groundwater pumped (e.g., applied water for agriculture), not consumptive water use. Note that the “Domestic and Other Small Water Systems” category includes rural residential use and other small private water systems.

Table 3-1. Groundwater Use Summary	
Industry Sector	**Average Annual Pumped Groundwater Water Use (AFY)**
Domestic and Other Small Water Systems	2,680
Wineries	820
Municipal	390
Agriculture & Vineyards	11,110
Total Groundwater Use	**15,000**

Standardized Cost ($/AFY): The capital cost of each water conservation practice was estimated based on industry interviews, available data, and review of published reports. The annual operating, maintenance, and, if available, replacement costs were also estimated. Capital costs were amortized over the expected useful life of the conservation practice and added to the operation and maintenance (O&M) costs to estimate the total annual cost of each water conservation practice. The total cost was divided by the estimated water conservation to estimate the dollars per acre-foot per year ($/AFY) of water conservation.

3.1 Best Management Practices for Water Conservation

Water users may consider a variety of best management practices that best fit their conservation and household or business goals. While some of the practices included in the GPR Workplan are specific to the user type, others are generally applicable to all water users. For example, water meters are a fundamental and effective tool to manage water. The act of metering both creates a sense of accountability and helps detect leaks and other system malfunctions. This can be broadly applied for any user type, whether it's for vineyards, wineries, or rural domestic users. Using recycled water for irrigation is another strategy that can be broadly applied across users, such as vineyard irrigation or landscape irrigation at a winery or household.

The following sections describe water conservation practices that apply to all water users - agriculture, commercial and industrial (e.g., wineries), and residential.

3.1.1 Practices for All Water Users

All water using sectors in the Subbasin have opportunities to implement practices to reduce groundwater pumping. As described in the companion WC Workplan and subsequent sections of this Workplan, there is no single practice that, if implemented, would achieve the targeted reduction in groundwater pumping in the Subbasin. Rather, a combination of practices collectively could help the Subbasin meet its sustainability objectives. The following subsections describe the costs, benefits, and scaling opportunities for practices that potentially apply to all water using sectors in the Subbasin.

3.1.2 Water Measurement / Metering

Measuring water use is necessary for quantifying the water savings that a water conservation practice achieves across the Subbasin. It also allows individual water users to understand how much water they are currently using and how that use changes as they implement water conservation practices. In addition, simply measuring water use can provide water users with new information that allows them to make changes that reduce water use, even without investing in additional water conservation technology or equipment.

Practice Description: Achieving a reduction in groundwater pumping by expanding water measurement in the Subbasin includes two components: (i) expanding the adoption of water measurement technologies and (ii) making that information easily available to water users to induce changes in water use behavior/practices. Improving water measurement can result in savings in total pumping, net depletion, or both.

Water measurement involves quantifying the amount of water applied or consumed by residential, commercial and industrial, and agricultural users. Methods for different water use sectors (see also **Section 3**) broadly include:

- **Agriculture**. Typical water measurement practices include metering, crop coefficients (an indirect water measurement strategy), and more recently, remote sensing of ET using satellite data. The installation of water meters on wells records the volume of water passing through the meter in units such as acre-feet, cubic meters, or gallons. Crop coefficients are used for irrigation scheduling purposes by applying the coefficient for the crop to a reference crop (used to estimate reference ET) to determine seasonal crop irrigation needs. Remote sensing data provide a more precise measurement of field ET that can be used both for irrigation scheduling and for tracking crop water use.
- **Commercial and industria**l. Indoor and outdoor (e.g., landscaping) water uses for commercial and industrial businesses connected to a municipal supply system are typically accomplished through meters. These data form the basis for volumetric billing. For businesses that have a private well, the well may have a meter to track water use.
- **Residential**. Similar to commercial and industrial water users, residential customers that are connected to a municipal water supply system are typically metered. Rural residential users typically rely on a domestic well that can be metered to track water use.

Water measurement can provide accurate and reliable data on water use, enabling users to monitor their usage patterns and make informed decisions about conservation. By tracking water use, individuals and businesses can identify areas where water is being used inefficiently and implement measures to conserve water. However, measurement data must be accessible to the water user so that the user can easily interpret the data and make corresponding changes to their use habits. Access to water use data and new technology has been demonstrated to result in reductions in water use:

- **Agriculture**. Remote sensing of ET using satellite data or in-field sensors is now available to growers on a weekly and daily basis. For example, technologies available in California include Tule Technologies, IrriWatch, and ET data developed by Land IQ, which can provide daily and monthly ET information to growers (IrriWatch, 2023, Land IQ, 2023, and Tule Technologies, 2023). Outside of California, for example, in Kansas, growers must meter and report water use to the state. Grower tools (including TAPP H2O) allow growers to have information about metered water usage (Mammoth Water, 2023).
- **Residential**. Tracking residential water use helps residents detect leaks and make other adjustments at the home to reduce use. For example, smart meter technology for residential users can collect and synthesize water consumption data through an automated system that can also detect waste or inefficiencies and trigger alerts. Automated outdoor irrigation systems, such as those offered by Rachio, provide use data and can automatically adjust applied water based on weather conditions (Rachio, 2023). Recent studies indicate that providing residential users with information on their water use results in durable conservation behavior (Cominola et al., 2021).
- **Commercial and industria**l. Commercial and industrial approaches to water measurement vary by industry. Water measurement technologies include traditional meters and smart meters to track water use. Commercial and industrial water users generally respond the same way as residential water users to additional measurement/metering data.

Scaling Opportunity (AFY): The amount of water conservation depends on the current water use for each sector, the current adoption of measurement practices, and how water users would change water use in response to implementing water measurement.

An average water savings was applied to estimate Subbasin-wide potential savings from adopting water measurement. Studies have found the potential for residents to reduce water use by 15 - 20 percent by using metering and price structures (Pacific Institute, 2014). Cominola et al. (2021) observed an 8 percent long-term reduction in residential water use after receiving metered usage data. A conservative 5 percent potential water savings was applied to agriculture (vineyards), wineries and other industrial, and municipal and rural domestic water users.

The share of water users that measure water use in the Subbasin is not currently known. Water measurement practices in Napa and other regions of the state were reviewed. The California Sustainable Winegrowing Alliance (2020) estimated that between 70 and 91 percent of wineries meter or otherwise measure water use. Between 36 and 55 percent of irrigated vineyard acreage in California measures water use (California Sustainable Winegrowing Alliance, 2020 and Babin et al., 2022). Most municipal and public water systems measure water use, between 70 - 90 percent (Pacific Institute, 2014; Kaser, F. et al., 2013). Rural residential wells typically do not have meters; it is estimated that less than 10 percent have meters in the Subbasin.

The scaling potential for each sector is, therefore, 45 - 64 percent for agriculture, 9 - 30 percent for wineries, 10 - 30 percent for municipal and industrial, and 90 - 100 percent for rural domestic and other small water users. Multiplying each of these rates by the water savings of 5 percent and the water use of each sector yields the water savings potential of metering for each. The potential reduction in total pumping is approximately 350 - 550 AFY in the Subbasin.

Standardized Cost ($/AFY): The cost of implementing water measurement and taking actions in response to water measurement data to reduce groundwater use are highly dependent on the industry and practices. For example, implementing a system of distributed flow meters at a large industrial site would be costly and difficult to manage, whereas installing a smart home irrigation system controller can be done cheaply and quickly.

Adding a flow meter to an agricultural or domestic well was selected as a representative cost because it represents the main potential for groundwater savings under this practice and can be implemented by some well owners. The capital cost of a flowmeter, with installation, ranges from $600 to $2,500 per meter, which typically has a 20-year life (Irrigation King, 2023). The user can expect annual maintenance, periodic calibration, and general operating costs of around $100. The resulting annual cost is approximately $140 - $250 per meter.

The total annual cost per AF saved to achieve a groundwater pumping reduction benefit depends on the volume of water savings per meter and the number of meters that must be purchased. This varies substantially by user type. For example, a vineyard may only need to purchase one meter for its single well that irrigates several blocks. A rural household would also have to purchase just one meter, but it pumps substantially less water. As a result, the annualized cost per AF of water conservation for a meter varies by user type: $150 - $250 per AFY for wineries, $250 - $375 per AFY for agriculture, and $950 to $2,500 per AFY for municipal and rural domestic.

Table 3.2 summarizes potential water savings from expanding water measurement in the Subbasin. The potential savings in total pumping is between 350 - 550 AFY in the Subbasin. The cost per acre-foot saved is between $150 and $2,500. All savings are per AF of total pumping reduced. Savings in net depletion are unclear and depend on the use of the water pumped and what kind of changes in technology or use patterns the users make to reduce total pumping.

Table 3-2. Water Measurement

Practice	Scaling Opportunity, %	Scaling Opportunity, AFY*	Standardized Cost, $/AFY*
Metering for Agriculture	45 - 64%	250 - 400	$250 - $375
Metering for Wineries	9 - 30%	5 - 15	$150 - $250
Metering for Municipal & Industrial	10 - 30%	< 10	$950 to $2,500
Metering for Rural Domestic and Other Small Water Users	90 - 100%	100 - 130	$950 to $2,500

***Savings are based on the potential reduction in total groundwater pumped.**

Other Limits to Adoption: Some rural domestic groundwater users may not have the financial means to purchase, install, and manage a flowmeter on a well. Even if funding is provided, the water user needs to use the data to make changes to water use. Similarly, vineyards that do not have metered wells may rely on other irrigation management practices, such as crop coefficients and remote sensing, and therefore would have little incentive to install meters and use those meters to adjust water use. Other limitations may include resistance from water users to measure data because of fear that sharing this data might cause them harm in the long run.

3.1.2.1 Recycled Water

Recycled water, also known as reclaimed water or treated wastewater, is wastewater that has undergone treatment and disinfection to remove impurities and contaminants. Recycled water is suitable for various non-potable purposes, such as landscapes, golf courses, agricultural irrigation, firefighting, and some industrial processes. Recycled water, as an in-lieu use strategy, helps conserve other freshwater, including groundwater, by providing an alternative or replacement source of water to meet various non-potable needs.

In the Subbasin, recycled water is produced by NapaSan, City of American Canyon, City of Calistoga, and Town of Yountville. If water was not treated to this tertiary level and reused, wastewater from these municipalities would be treated to a secondary level and be discharged. NapaSan, for example, treats slightly more than half of its wastewater annually for recycled water purposes and discharges the rest to the Napa River (A. Damron, personal communication, 2023). This wastewater is discharged under NapaSan's National Pollutant Discharge Elimination System (NPDES) permit primarily during the months of November through April, as there is considerably less demand for recycled water during the winter months (A. Damron, personal communication, 2023). While most of these programs offset surface water use rather than groundwater use, it still derives a benefit to the Subbasin by less diversion of surface water, resulting in more water being left in storage or in streams. In agricultural uses, such as the Carneros area (which is outside of the Napa Valley Subbasin boundary) recycled water deliveries can offset groundwater pumping.

Expanding recycled water requires infrastructure to process water and infrastructure to deliver recycled water to customers. NapaSan published its Wastewater Treatment Plant Master Plan in October 2022. It reviews the existing infrastructure, evaluates facilities, and assesses capacity and capacity constraints. Demands for some customers can be met with expanded water treatment and recycled water delivery.

Napa Sanitation District (NapaSan)

The NapaSan recycled water facility was originally designed to deliver 2,000 AFY but was enhanced to reach its existing total capacity of 3,400 AFY. NapaSan's distribution network consists of two main pipelines heading southeast and north of the Soscol Water Recycling Facility, a six-mile Milliken-Sarco-Tulucay pipeline that can deliver up to 700 AFY during summer, and a nine-mile Los Carneros Water District pipeline that contractually delivers up to 450 AFY during summer but can deliver up to 1,500 AFY (Carollo, 2022). For new customers to receive recycled water, they must be located within the "water benefit zone," or region that has access to the distribution network.

The NapaSan service area overlaps with a portion of the Napa Valley Subbasin. As such, opportunities for expanding recycled water deliveries would need to be targeted to existing service areas in the short-term and could be expanded to other areas.

Demand for recycled water peaks in the summer months and is substantially less in the winter months. According to NapaSan, around 10 percent of recycled water use in 2021 was in Quarter 1 (in the winter months).

NapaSan incentivizes use during the off-peak season. Through 2021, it set an off-peak rate that was 25 percent lower than the peak rate (Carollo, 2022). NapaSan subsequently eliminated the off-peak and peak rates. It now charges a flat rate and a storage rate. The storage rate is for customers to receive, and store recycled water in their own storage facility in the months of February and March. Customers can purchase storage water at approximately 50 percent of the current flat (standard) rate. Increasing off-peak recycled water deliveries and storage may be an option for further reducing total pumping in the Subbasin.

NapaSan recycled water is used for various non-drinking purposes in Napa County, including irrigation of golf courses, pasturelands, public parks and playing fields, lawns and landscaping, commercial developments, cemeteries, and vineyards (NapaSan, 2023). Currently, NapaSan distributes approximately 3,200 AF per year of recycled water, with a maximum production capacity of up to 3,400 AF during the months of May through October (NapaSan, 2022). **Table 3-3** summarizes water deliveries by user category. Currently, 101 vineyards[6] totaling more than 2,200 acres receive recycled water, using about 1,200 AF in 2022.

Table 3-3. Summary of NapaSan Recycled Water Distribution

Type of Use	Number of Sites	Amount Distributed (AF)	% of Total Reuse Flow
Landscape Irrigation			
Parks	1	16	1%
Golf Courses	4	1,264	40%
Schools	2	50	2%
Commercial Developments	11	375	12%
Cemeteries	2	119	4%
Napa Sanitation District	3	133	4%
Agriculture			
Vineyards	101	1,173	37%
Industrial			
Cooling			

[6] Studies such as Weber et al (2006) have evaluated and demonstrated that recycled water of suitable quality can be used on vineyards.

Table 3-3. Summary of NapaSan Recycled Water Distribution			
Type of Use	Number of Sites	Amount Distributed (AF)	% of Total Reuse Flow
Trucked		74	2%
Fire Suppression	2	0	
Compost	1	0	
Structural Fire Fighting	1	0	
Total	**128**	**3,205**	**100%**

Practice Description: Recycled water can be used in lieu of other potable water sources, including groundwater. If a groundwater user switches to recycled water (and does not otherwise change water use), it provides a full (100 percent) savings in total pumping. It also eliminates the net depletion associated with the pumping it replaces.

Scaling Opportunity (AFY): The primary limit to adopting recycled water is the capacity of the recycled water facilities. NapaSan reports that its total capacity is 3,400 AFY (NapaSan Board of Directors, 2022). It delivers approximately 3,200 AFY currently (NapaSan, 2023). Therefore, approximately 200-300 AFY of recycled water could be expanded, approximately 6 percent more than the current levels. Importantly, these customers would have to be located within the service area of the distribution system. NapaSan describes these infill or future customers as:

> *Generally the infill (future) customers are located in the airport area industrial parks, the Napa County Airport, North Kelly Road area (west of North Kelly Road), Devlin Road area, parcels between State Route 29 and South Kelly Road and north of Fagan Creek, areas within the City of Napa City limits near NapaSan's recycled water pipelines describes in the agreement between NapaSan and the City of Napa (dated 1998, amended 2018), including Napa Pipe, Napa Valley Commons, and South Napa Marketplace.*

Standardized Cost ($/AFY): Using NapaSan's 2023 standard rate structure of $2.21 per 1,000 gallons, this translates to a cost of approximately $720 per AF (Carollo, 2022). Storage rates, which are available in February and March, are $1.11 per 1,000 gallons or $362 per AF. **Table 3.4** summarizes potential water savings from expanding recycled water in the Subbasin. The potential savings in total pumping is between 200 - 300 AFY in the Subbasin. The cost per acre-foot is between $362 and $720.

Table 3-4. Recycled Water Expansion			
Practice	Scaling Opportunity, %	Scaling Opportunity, AFY	Standardized Cost, $/AFY
Recycled Water	6%	200 - 300	
Standard Rates (April through January)			$720
Storage Rates (February and March)			$362

Other Limits to Adoption: NapaSan's facility has largely been fully built out, meaning that there are few untapped opportunities to expand the recycled water program without new infrastructure during peak months. However, there is more water supply available than demand in the winter, and NapaSan has incentivized the use of taking and storing recycled water for use in the spring and summer. While there is little demand during this period, it represents a scaling opportunity at a low cost. The future scaling potential for storage is unknown at this time, as it depends on site-specific factors related to storage capacity for potential infill customers (those that are within the distribution network).

Other Recycled Water Programs: City of American Canyon, City of Calistoga, and Town of Yountville

1. Other recycled water programs are in operation in the City of American Canyon, City of Calistoga, and Town of Yountville. Like the City of Napa, these municipalities draw from surface water sources and may have little potential to offset groundwater pumping unless the recycled water offsets groundwater pumping by self-supplied users such as vineyards, wineries, or rural domestic. This may be a limited opportunity since recycled water may largely offset potable surface water use within municipal boundaries rather than groundwater pumping outside of municipal boundaries. For example, the City of Calistoga supplies recycled water for irrigation on City-owned and privately owned land, including fairgrounds, schools, parks, churches, resorts, and hotels (City of Calistoga, 2016). Recycled water accounts for approximately 250 to 300 AFY of Calistoga's water supply. While there are currently no plans to expand recycled water, it is identified as a potential source of water supply in the Municipal Service Review and Sphere of Influence Update (City of Calistoga, 2016). On the other hand, Yountville services recycled water to a golf course within the town boundary and also to six vineyards outside of it (Town of Yountville, 2017). Yountville delivered approximately 400 AF in 2015, comprising nearly 90 percent of its total wastewater. By comparison, American Canyon has recycled and reused approximately 40 percent of its wastewater, Calistoga 80 percent, and NapaSan 30 percent (Napa Local Agency Formation Commission, 2020). In the past three years, NapaSan has increased this figure to 54 percent of its wastewater (A. Damron, personal communication, 2023). The City of St. Helena is actively working towards the expansion of its wastewater treatment infrastructure to generate and deliver recycled water (City of St. Helena, 2023).

3.1.2.2 Benchmarking

Benchmarking stimulates changes in practices by showing individuals (e.g., water users) how their performance over time compares to an anonymous peer group. Benchmarking programs have been effectively applied in energy and residential water usage. A water benchmarking program establishes a structured framework for tracking and assessing water use, defines comparable anonymous water user types, and provides this information to water users. Then, each water user can make changes to reduce water use.

There is currently no benchmarking program for water use in Napa County. A benchmarking program could be developed and tailored for water usage in Napa's vineyards, wineries, and potentially other water using sectors. The program could result in savings in total pumping, net depletion, or both.

An important obstacle to implementing benchmarking is that it relies on measurement data, specifically meter data, to benchmark use. Should meter data become available, for example, through voluntary reporting, benchmarking could be a viable program. Users could be benchmarked in appropriate peer groups within residential/domestic, winery, or vineyard settings.

In the absence of meter data, a pilot benchmarking program could be developed using OpenET data, open-source and satellite-based data that estimate the ET of native and non-native vegetation (OpenET, 2023). Because OpenET can only estimate vegetation-related ET and not municipal, industrial, or domestic uses, the pilot program would necessarily focus primarily on agricultural benchmarking. As described above, ET measures crop water use and evaporation and cannot distinguish between sources of water. However, it could be a starting point for evaluating water use performance in the absence of meter data.

A hypothetical example was developed using OpenET data. Vineyard ET was analyzed to determine representative groups that typically show similar ET. Vineyard characteristics that were analyzed include soil drainage, slope, elevation, precipitation, temperature, grape variety (grouped as either red or white), location within the GSP model water balance region, and Napa Valley American Viticulture Area (AVA). The most promising of these were AVAs and variety to represent peer groups for ET[7]. A box plot of the variability of ET by AVA (generally presented from north to south) for red winegrapes is shown in **Figure 3-1**. A hypothetical benchmarking program could provide reports to vineyard managers to show how each vineyard compares to the average of other vineyards in its peer group. All data would be fully anonymous.

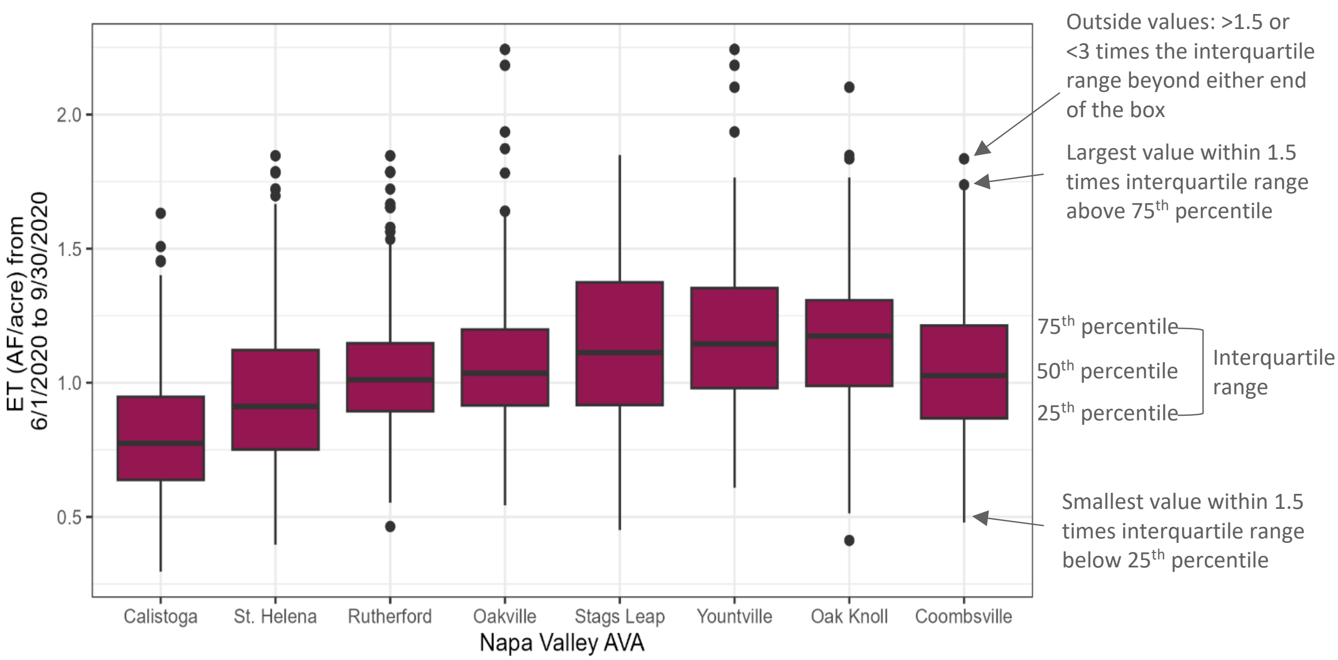

Figure 3-1. Box Plot Demonstrating ET Variability by AVA for Red Winegrapes

[7] It is unclear why AVAs appears to be related to ET differences. It could be standing in for other unmeasured variables such as, perhaps, wind exposure or specific grape varieties.

While important differences exist across vineyards, an initial pilot program could provide vineyard managers with new information that could encourage them to evaluate irrigation performance. Benchmarking has the potential to create behavioral changes among participants, reduce Subbasin water use, and potentially inform system-wide improvements over time.

Practice Description: A pilot benchmarking program for Subbasin vineyards could use representative peer groups (e.g., based on vineyard-related characteristics by water balance region and/or AVA) and estimate the range of water use for each group. Vineyards could be provided with reports summarizing ET use during the irrigation season. The report could compare (or benchmark) the ET use on each vineyard relative to other vineyards in the anonymized peer group.

Scaling Opportunity (AFY): Benchmarking in the energy sector has been proven to generate year-over-year energy savings of 2.4 percent (Energy Star, 2012), amounting to 30 percent savings in the past decade (USEPA, 2022). A 10 percent reduction in pumping is applied for an estimate of agricultural water conservation potential using benchmarking. The target for groundwater pumping reductions, however, may be specified by the variation observed within the peer group. For example, some peer groups may have wide variations in pumping and, therefore, a more aggressive water savings target compared to other peer groups with smaller variations in pumping (an overall more efficient peer group, e.g., one that is certified sustainable). The specific pumping reduction targets of peer groups would have to be developed as part of the program set-up and maintenance.

For a pilot benchmarking program that uses OpenET data, which would focus on agricultural water use, the total water savings potential could be as much as 1,100 AFY (approximately 10 percent of baseline agricultural pumping). However, it would take time for water users to receive reports and make changes in water use. A more conservative estimate may be that one-quarter of participants use and act on the benchmarking reports, in line with the participation rate of commercial floorspace participating in the Energy Star Portfolio Manager benchmarking program (USEPA, 2022). This would result in a water savings potential of around 300 AFY of total pumping. In the long-term, this practice could be scaled up to 100 percent of all agricultural fields, for a potential water savings of approximately 1,100 AFY.

Standardized Cost ($/AFY): The benefit of a benchmarking program is that it can be developed at a relatively low cost. It is estimated that the initial startup cost of the program would include technical studies, data development, analysis, and preparing a standardized method for sending benchmarking reports to water users. This is estimated at $100,000. The annual costs of the program would include sending annual reports, managing data, updating the program, and general program administration. These costs are estimated to equal an additional $100,000 per year. Therefore, the annual cost to develop and operate a benchmarking program per AF of water savings is estimated to equal $100 - $350 per AFY of total pumping reduction (300 - 1,100 AFY; **Table 3-5**). The corresponding volume of ET reduction (net depletion) would be somewhat smaller, and therefore, the unit cost would be somewhat higher.

Table 3-5. Benchmarking			
Practice	**Scaling Opportunity, %**	**Scaling Opportunity, AFY**	**Standardized Cost, $/AFY**
Benchmarking	25 - 100%	300 - 1,100	$100 - $350

Other Limits to Adoption: One challenge with a water benchmarking program is accounting for the differences in water consumption influenced by varying field attributes and microclimates. Vineyards differ in attributes, and water use will be impacted by soil type, microclimate, and other attributes not captured by OpenET estimates. It may also be difficult to extend the program to domestic users or wineries. For residents, the costs of meters may be cost-prohibitive. For wineries, each winery's operation differs, and its intensity of water use will be impacted by size, bottling frequency, wine type (e.g., type of barrel, aging, grape variety, etc.), onsite versus off-site crush, and more. At a given winery, each vintage is different, with changes resulting from available fruit sources, business demands, labor availability, and other factors. This limitation can be overcome by carefully evaluating anonymized peer groups as part of the program design. Educating water users about the basis for benchmarking will also be important to encourage participation.

Another potential challenge is that benchmarking requires measurement data to make comparisons and track performance over space and time. Groundwater meter data are not widely available in the Subbasin. These data would need to be available (e.g., volunteered by water users), particularly for a winery benchmarking program or rural domestic benchmarking program. For vineyards, using OpenET, an open-source tool for estimating field-level ET, may be a viable way to start a benchmarking program for agricultural uses. While OpenET data are an imperfect proxy for applied water, these data could still generate value to show agricultural producers how their ET data vary over space and time.

3.1.3 Practices for Vineyards and Other Crops

Subbasin agricultural water use is predominately for premium wine grapes. Vineyards account for 91 percent of the total acreage, with idle cropland and wetlands making up another 8 percent and a small amount of grass, pasture, and other crops accounting for less than 2 percent. Because agricultural water use is dominated by vineyards, most of the practices analyzed in the GPR Workplan apply to vineyards.

Napa County vineyards carefully manage irrigation for productivity and fruit quality. Therefore, groundwater conservation and stewardship and strategies to use groundwater efficiently are commonly applied for vineyard management. However, there are opportunities for expanding the adoption of water conservation practices on vineyards. Examples of water conservation practices include irrigation system maintenance and upgrades, distribution uniformity testing, irrigation scheduling, soil moisture monitoring, canopy management, row orientation, and plant stress monitoring. The following section describes example practices that could be more widely adopted to conserve water on vineyards.

3.1.3.1 Irrigation System Efficiency

The Napa Valley produces some of the highest value winegrapes in the world. Vineyard irrigation is carefully managed during the various stages of plant growth and fruit development to maximize productivity and manage fruit quality. Most Napa Valley vineyards are irrigated with low-volume precision pressurized systems that can include buried or (typically) above ground drip systems. These typically include one or two emitters per vine that target irrigation to the vine's root system. However, depending on factors, including grape variety, soil, vineyard location and effective rainfall, some vineyards are dry farmed—meaning no supplemental irrigation water is applied—in all or some years.

The University of California Cooperative Extension (UCCE) representative crop production budget for Cabernet Sauvignon variety grapes estimates irrigation during the first two years of vineyard establishment is approximately two irrigations per week at around 2.5 gallons per vine per irrigation (Kurtural et al., 2020). The typical irrigation season is between May and early October (approximately 20 weeks), with the specific irrigation period dependent on variety, annual rainfall, weather conditions, and grower experience. Starting in the third year, applied water is around five gallons per vine per irrigation. Cabernet Sauvignon planting density is around 1,555 vines per acre. Therefore, typical applied water requirements equal about 3 acre-inches in the first two years and 6 acre-inches in the third year and all subsequent years (Kurtural et al., 2020).

Irrigation system capital components include the well, any booster pump and filtration, system pipe mainlines and sub-mains (installed prior to trellising), drip lines, drip wire, and drip emitters. System operating costs include general maintenance and repairs, labor, energy, and any additional water (e.g., for recycled water instead of well water).

Vineyard irrigation is carefully tailored to the variety to manage crop quality. Vines are purposefully stressed (deficit irrigated) later in the growing season to reduce canopy growth and allow more sunlight to reach fruit clusters during fruit ripening. This is generally referred to as the practice of regulated deficit irrigation (RDI) (Prichard, 2015 and Chalmers et al., 1986). RDI is part of standard vineyard irrigation management practices, with appropriate RDI during fruit ripening causing an increase in the rate of sugar accumulation in the fruit. However, RDI is carefully managed as too much or too little water during different stages of plant growth can have a detrimental effect on crop quality and/or productivity. The irrigation strategy varies by variety, location, and grower preferences and experience.

In summary, Napa Valley wine grape irrigation systems and irrigation management practices are tailored to the variety and growing conditions of the vineyard. There are modest opportunities for improving irrigation system efficiency that would result in less applied water and, potentially, less consumptive water use.

Practice Description: Improving irrigation system efficiency is a broad term that encompasses a range of irrigation scheduling, management actions, and system improvements to deliver applied irrigation water more effectively to the crop. Drip irrigation is used here as an example practice[8]. A substantial share of

[8] Other practices, such as soil moisture monitoring, canopy management, etc. are described separately in subsequent subsections.

irrigated vineyards use pressurized on-farm irrigation systems that allow for smaller, more precise, and steadier flow rates at more frequent intervals and for longer durations relative to gravity-fed systems. There is some potential for expanding the adoption of drip systems and, more importantly, maintaining existing drip systems.

Improving irrigation system efficiency can result in savings in total pumping. It typically does not reduce net depletion because deep percolation of applied water is reduced, and crop ET is largely unchanged.

Scaling Opportunity (AFY): Statewide, approximately 80 percent of vineyards have drip irrigation systems (Zellman, 2016). The share of vineyards on drip systems in Napa is likely higher, estimated near 90 percent. The high rates of adoption for drip irrigation can be attributed largely to the high degree of control to produce high-quality winegrapes (Ohmart, 2000, Sanden, 2008, and LCWC, 2014).

The adoption of drip irrigation yields an estimated reduction in total pumping of 6 to 20 percent, assuming it is replacing typical sprinkler irrigation systems (eVineyard, 2023). Multiplying the total vineyard water use by the scaling potential of 10 percent and the estimated water savings of 6 - 20 percent yields potential savings in total pumping of 75 - 250 AFY across the Subbasin.

Standardized Cost ($/AFY): The amortized cost of irrigation system equipment is $165/acre, the cost to install the drip line to drip wire on the trellis is $250/acre, and the O&M cost to check, repair, and maintain the efficiency of the irrigation system is $125/acre, according to UCCE budgets (Kurtural et al., 2020). The irrigation system is considered part of the establishment costs, as it will be removed when the vineyard is removed. Therefore, the irrigation system has a life of about 27 years. With amortized establishment costs to purchase and install a drip irrigation system of $415 per acre, O&M of $125 per acre, and a water savings potential of 75 - 250 AFY, the annualized cost of total pumping reduction is estimated between $2,800 and $9,200 per AFY.

Table 3.6 summarizes the estimated capital costs, operating and maintenance costs, total annualized costs, and potential Subbasin-wide benefits of increased adoption of irrigation system efficiency improvements.

Table 3-6. Drip Irrigation System

Practice	Scaling Opportunity, %	Scaling Opportunity, AFY	Capital Cost, $	Annualized Cost, $/AFY
Drip Irrigation System	20%	75 - 250	$6,250	$2,800 to $9,200

Other Limits to Adoption: Irrigation system improvements are typically done at vineyard establishment or replanting. This limits the ability to rapidly expand the adoption of practices. However, when systems are being used beyond their lifetime, they may become inefficient and require repair or replacement before the vines' end-of-life. Repairing and replacing old drip systems can improve irrigation efficiency.

Most vineyards in the Subbasin are already on low-volume irrigation systems. However, there are opportunities for improving how irrigation systems are managed, maintained, and how and when water is delivered to the plant. These also fall under the category of "irrigation efficiency improvements" and are described in subsequent sections.

3.1.3.2 Distribution Uniformity Tests

Distribution uniformity (DU) measures how uniformly irrigation water is applied across a vineyard within an irrigation block (Zellman, 2016). Perfectly uniform application means the same amount of water would be applied to each vine. In practice, emitters become clogged over time, or there are other system leaks that cause differences in the amount of water that is applied to different areas of a vineyard. Other causes for uneven irrigation application include pressure variations due to elevation changes or improperly set regulating valves.

Poor DU means that some vines receive more water, and other vines receive less. If a grower is irrigating for the vines that receive the least amount of water, the other vines are receiving too much, resulting in higher levels of applied water than necessary. Some of this water may percolate back into the ground, but some of it may be lost to evaporation, unproductive transpiration, or runoff. In addition, over-irrigation can degrade winegrape quality. On the other hand, if a grower is irrigating for the vine that receives the most water, other vines are not receiving enough. In this case, addressing DU could lead to an increase in applied water and ET since more water would go to the vines that previously did not receive enough. While this result depends on irrigation management decisions, evidence suggests that most growers do not under-irrigate their vineyards but over-irrigate parts of the vineyard to accommodate the vines receiving the least amount of water (Zellman, 2016).

A DU test can be a helpful diagnostic tool for growers. DU tests are conducted after an irrigation system is established to create a baseline to compare to in subsequent tests. DU is measured by calculating the uniformity of water distribution across emitters, measured as a percentage. The target for vineyards is greater than 95 percent (Burt, 2004). When DU is low (below 85 percent), parts of the vineyard tend to be overwatered. According to industry standards, DU tests should be performed a minimum of once every three to five years to identify and remedy inefficiencies. For example, Napa Green requires DU tests every five years. They also conduct tests for growers and require an Action Plan for implementation of any significant recommendations.

DU issues can be addressed by performing appropriate maintenance, including backwashing and filter cleaning, flushing of lines, and monitoring pump pressures. Zellman (2016) describes these and other maintenance for improving drip irrigation system DU:

- Using pressure-compensating emitters to compensate for elevation change;
- Using flow meters for scheduling and monitoring system and pump performance;
- Backwashing filters, and installing an automatic backwash system;
- Upgrading filters or injecting appropriate chemicals to control for clogged emitters or algae;
- Flushing mainlines and lateral lines; and
- Testing and addressing pump efficiency.

Details on these maintenance operations can be found in Zellman, 2016.

Practice Description: Distribution uniformity tests are conducted by measuring the outputs across all the drip emitters in an irrigation block over a constant period. The test captures and measures the total flow from each emitter in a fixed period, such as 3 to 5 minutes. The results are ranked from lowest to highest flow, and the lowest one-quarter of the results are averaged. The average over all measured emitter flow is also calculated, and the equation below determines the system's DU (Zellman, 2016; **Table 3-7**).

DU = (Average of the Lowest Quarter of Emitter Flows) / (Average of All Emitter Flows) * 100

Table 3-7. Distribution Uniformity

DU Result	Performance
Above 95%	Ideal; system is uniformly irrigated
85 - 95%	Sufficient; system is mostly uniformly irrigated
75 - 85%	Inefficient; system should receive maintenance and improvements
Below 75%	Poor; system needs maintenance and improvements

Source: Adapted from Zellman, 2016

Expanding DU testing would allow growers to identify fields with poor DU and make adjustments to the irrigation system. This would result in savings of total pumping and could potentially affect net depletion as well.

Scaling Opportunity (AFY): Based on recent academic studies, an estimated 53 percent of vineyards test for DU to assess the operational efficiencies of their irrigation systems (Babin et al., 2022). However, according to Zellman (2016), only 18 percent of certified vineyards in the California Sustainable Winegrowing Program have tested for DU in the last three years, with a majority having tested in the last seven years. Therefore, between 47 - 82 percent of vineyards could test for DU to be in line with industry standards.

Zellman (2016) also estimated that increasing DU to 95 percent could reduce vineyard applied water by up to 18 percent for those with a current DU of 90 percent and reduce applied water by 46 percent for those with a current DU of 70 percent (Zellman, 2016). For purposes of this document, a more conservative water savings potential of 9 - 23 percent is applied. While the water savings vary greatly by vineyard and DU result, this potentially represents a substantial opportunity to reduce applied water in vineyards.

It is not currently known what the distribution of DU is across Subbasin vineyards. Data exists on the rate of DU testing, but the data describing the results of those tests are not available. The Napa Resource Conservation District (RCD) reports that over the past 5 years, the RCD has evaluated approximately 97 vineyards with an average DU score of 79 percent.

Using the range of scaling potential above (47 - 82 percent), the range of reductions of applied water by improving DU (9 - 23 percent), and the total vineyard water use, the water savings by testing and improving DU are estimated between 500 - 2,100 AFY across the Subbasin.

Standardized Cost ($/AFY): Distribution uniformity tests range in cost from $1,200 - $2,000 per field (JAIN by Rivulis, 2020; M. Garcia, personal communication, 2023). These tests should be completed every three to five years. In addition to the cost of DU testing, a grower would need to take additional actions and incur additional costs to correct irrigation system deficiencies that are leading to poor DU. These costs will vary by operation and, therefore, are not included at this time. To get a complete picture of the cost and benefit of DU testing, costs to correct the nonuniformity must be included. Therefore, the cost estimates here are a lower bound.

Table 3.8 summarizes the estimated testing costs, total annualized costs, and potential Subbasin-wide benefits of increased adoption of DU testing. The cost per AF of total pumping reduction is estimated between $175 - $450 per AFY.

Table 3-8. Distribution Uniformity				
Practice	Scaling Opportunity, %	Scaling Opportunity, AFY	Capital Cost, $	Annualized Cost, $/AFY
Distribution Uniformity	47 - 82%	500 - 2,100	$1,200 - $2,000 per field	$175 - $450

Other Limits to Adoption: Experience from the Napa County RCD has shown that testing for DU does not necessarily result in corrective actions. Merely testing DU may not lead to improvements in efficiency, particularly if corrective actions are expensive. Therefore, expanding DU testing may result in additional savings in total pumping if it is coupled with funding opportunities for growers to take action to improve DU.

Plant Water and Soil Moisture Monitoring

Ongoing monitoring of available water for vine consumption is a key component in an efficient irrigation management plan. Several options exist for monitoring available and consumed water and can be grouped into two categories: monitoring water available for vine use via soil moisture monitoring techniques and monitoring water uptake and use by plant moisture monitoring techniques. Both methods are important irrigation scheduling technologies that provide information that can be used to adjust applied water during the irrigation phase of vine growth (adaptive irrigation management).

Soil moisture monitoring shows available water for vine use and can be accomplished by either measuring volumetric water content or by measuring soil water tension. Both methods rely on probes or sensors that can either be stationary with central recording devices or handheld. Generally, soil moisture monitoring sensors can be affected by soil type and condition and operate in a small range such that the appropriate method should be determined based on the vineyard soil composition and deployed in several locations throughout the vineyard. Experience and familiarity with the vineyard help determine appropriate locations.

Vine water use and stress are other options for measuring irrigation effectiveness. Measurement methods such as leaf pressure bombs, sap flow monitors, and ET monitors allow for precision adaptive irrigation management but tend to come at a higher cost than soil moisture monitoring methods. As with the soil moisture monitoring techniques, vine water use, and monitoring techniques can either use stationary sensors that need to be placed throughout the vineyard or handheld sensors that can be used in multiple locations. There are tradeoffs between the two types of vine monitoring techniques. Stationary sensors will provide constant real-time data but in specific locations. Mobile sensors are more flexible and can be used throughout but require operators to walk the vineyard. Pressure bombs can be taken on individual leaves to measure vine stress but only offer a single observation; ET can be continuously monitored by sensor and data logging systems such as Tule Technologies. Vine sap flow monitors can be permanently affixed to vines to measure continuous water flow. An industry white paper by Fruition Sciences (2023) and a project report by the California Energy Commission (2021) assert that there is a substantial opportunity to reduce vineyard water use.

Soil moisture and vine moisture monitoring techniques enable adaptive irrigation management such that the least amount of water can be applied to achieve the grape quality and quantity objectives of the vineyard. However, it takes additional time and effort to translate this information into actions (e.g., changing irrigation scheduling). Annual irrigation schedules are typically determined by the vineyard manager based on winter/spring conditions. Often, irrigation scheduling is only adjusted with weather events (rain, extreme heat, etc.) regardless of soil moisture or vine stress.

Scaling Opportunity (AFY): No data are available on how many soil and vine moisture monitors are used in Napa County. Conversations with the Napa County RCD indicated that it varies widely across the valley. Babin et al. (2022) found that approximately 41 percent of Central Coast vineyards apply one or both technologies (Babin et al., 2022). For purposes of estimating the potential, this value is applied to the Subbasin.

The GSP estimates that the average Napa vineyard historical water use is approximately 6.78 inches per acre. The UCCE estimates that applied water requirements are around 5.72 inches per acre or about 16 percent less than the current application rate. To represent a range of potential water savings, 5 - 16 percent water savings is applied.

Applying the estimated rate of adoption (41 percent) to the potential applied water (total pumping) savings of 5 - 16 percent, the potential pumped groundwater savings is 1,000 - 2,000 AFY in the Subbasin.

There are several uncertainties in the scaling potential. First, the adoption rate of vine and soil moisture sensors may be larger or smaller than the survey results from Central Coast vineyards. The irrigation application rates were based on modeling results for the GSP and have a level of uncertainty since these are not metered quantities. In addition, the UCCE application rate is a representative amount but does not consider the variety of field-level characteristics across the Subbasin. Lastly, it may be optimistic to presume that vine and soil moisture monitoring could lead to fully optimized water use. As a result, a range of potential water savings (1,000 - 2,000 AFY) is presented to capture the range of uncertainties. It is unclear what portion of this applied water savings would translate to a reduction in net depletion.

Standardized Cost ($/AFY): Costs depend on the technology that is adopted. These have been grouped into three categories: (1) high tech, low labor, such as a time temperature domain reflectometry (TDR); (2) medium tech, medium labor, such as a neutron probe; and (3) low tech, high labor, such as tensiometers.

High Tech, Low Labor (Time Temperature Domain Reflectometry)

One of the available high-tech options for monitoring soil/vine moisture is TDR for soil moisture monitoring (Acclima, 2023). With TDR, sensors are placed semi-permanently in the ground, which then send soil moisture readings electronically to the logger that can be downloaded or stored in a cloud service. Most data loggers have output that needs to be periodically downloaded. Monitoring soil moisture allows farmers to apply the appropriate amount of water to their vines and avoid over or under irrigation. Continuous monitoring will show available moisture for plant uptake and help schedule irrigation for when the vine needs it most.

Handheld TDR meters are also available that technicians can use to take several readings throughout a field. These applications are mostly used in turf fields such as golf courses but could be adapted to other situations. The moisture data can be combined with other soil variable attributes such as temperature. Services are also offered by some manufacturers in conjunction with the soil moisture meters that would allow for vineyard mapping integration and data storage for additional fees.

High Tech, Low Labor Standardized Cost ($/AFY): For a typical field size of 25 acres, approximately four sensors and a data logger would be used at a capital cost of $3,500, or $140 per acre for the example field size. Annual costs include vineyard manager time to monitor the system and implement changes in response to information. In addition, there may be additional costs for cloud storage and other add-on services of approximately $300 per year. Scaled to the potential adoption rate across the Valley and range of water savings, this equals an approximate total cost of $350 - $1,100 per AFY.

As an alternative, handheld TDR meters are approximately $1,500 each but require additional rods of varying lengths that are placed in the soil. Rods cost approximately $70 each. For two rods and a handheld TDR, this totals $1,640 in capital costs. With the addition of labor to walk the field of $32 per acre per year and the range of water savings of 5 - 16 percent, the cost of a handheld TDR is $450 - $1,450 per AFY. Specific costs depend on field size and number of sensors.

Medium Tech, Medium Labor (neutron probe)

Medium technology options that also require some labor include neutron probes. Neutron probes are accurate over all soil types and come in a portable carrying case. They are heavy, very expensive, and use radioactive materials that require training and licensing to use. The readings cover a wide area, and the neutron probe is not affected by environmental factors such as temperature or barometric pressure. Therefore, it is good for use in most soil conditions.

Once in place in the soil, the probe emits neutrons in all directions that collide with hydrogen atoms in water. This creates a readable signal that is translated into a number, such as inches of water per foot of soil, which is displayed on the device or stored in onboard memory that can be accessed by the user. While this type of sensor can be highly accurate, it is substantially more costly than most other methods.

Standardized Cost ($/AFY): The capital cost of a neutron probe ranges from $5,000 to $10,000 per unit. In addition, because the probe includes radioactive material, the user must be certified and trained to handle the probe, creating additional costs over standard irrigation labor, for an estimated labor cost of $40 per acre per year. For a typical field size of 25 acres and the range of potential water savings, this translates to a cost of $740 to $3,340 per AFY. These costs vary based on field size.

Low Tech, High Labor (tensiometers)

Lower technology solutions are also available that typically require more labor and management. Tensiometers measure how tightly water is held in the soil and, therefore, the level of energy needed for the plant to draw moisture out of the soil. Tensiometers have been commercially in use for several decades, with the first proposed use in the early 1900s. They provide a simple way to measure soil moisture. The meters need to be chosen specific to the type of soil in the vineyard and the depth of vine roots.

The meters only read soil tension in a small area, so they need to be placed in multiples throughout a vineyard to get an accurate representation of soil moisture. They either come with a gauge attached to the meter or can be hardwired to data collection devices with cloud-based software systems for continuous reading at an additional cost.

Standardized Cost ($/AFY): Tensiometers with single gauges cost between $100 and $200 per unit. Operational costs are approximately $32 per acre to cover manual labor. Two sensors are recommended per 20-acre field placed side-by-side at different depths (Peacock et al., 1998). For the range of potential water savings, this translates to an annualized cost of $360 - $1,170 per AFY.

Tensiometers supported by central data gathering units and continuous readout software cost between $400 - $600 per unit pair. They do not require additional labor time (walking the field) like their low-tech counterparts but would require a software subscription of approximately $300 per year. For the range of potential water savings, this translates to an annualized cost of $155 - $500 per AFY.

Table 3.9 summarizes the estimated testing costs, total annualized costs, and potential Subbasin-wide benefits of integrating water and soil moisture monitoring. These costs would vary based upon field size and the number of sensors.

Table 3-9. Water and Soil Moisture Monitoring				
Practice	**Scaling Opportunity, %**	**Scaling Opportunity, AFY**	**Capital Cost, $**	**Annualized Cost, $/AFY**
Water and Soil Moisture Monitoring	59%	1,000 - 2,000		$155 - $3,340
High Tech, Low Labor			$1,640 - $3,500	$350 - $1,450
Med Tech, Med Labor			$5,000 - $10,000	$740 - $3,340
Low Tech, High Labor			$100 - $600	$155 - $1,170

Other Limits to Adoption: A limit to broader adoption of soil moisture monitoring is understanding and incorporating the acquired data with the vineyard irrigation schedule. Typical irrigation scheduling is determined by winter/spring moisture levels and the general vineyard yield/and fruit quality objectives. Schedules are set early in the season and are occasionally adapted based on weather events (rain) during the irrigated portion of the growing season.

Adding adaptive management to the irrigation schedule based on soil moisture readings requires additional irrigation labor time that may not be available. If the vineyard employs a vineyard management company, they may have irrigators scheduled and available on a limited basis, restricting the option of weekly adjustments to irrigation times and duration. The incorporation of “smart systems” in the irrigation system that allows for remote control via web-based apps could allow for more adaptive irrigation management, but these systems are not widely adopted and require added remote data transfer systems that can be costly. The current estimated adoption rate for any soil moisture monitoring is around 40 percent of vineyards, but information by type and location in Napa is a data gap.

3.1.3.3 Soil Management via Cover Cropping

Healthy soils are the foundation of productive, sustainable agricultural systems. Healthy soils can allow water to infiltrate and retain water more efficiently. Example practices to improve soil health (increase soil organic matter[9]) include cover crops, applying compost, and limiting tillage operations. These enhance soil health by improving soil structure through the formation of stable aggregates. This can increase the soil water holding capacity. Cover cropping may include annual cover crops with cultivation or perennial cover crops with no tilling. Other opportunities include soil compaction and benefits of within row deep ripping on a multi-year program. Specific opportunities will vary by operation and field conditions.

The USDA estimates that increasing soil organic matter content by 1 percent has the potential to increase soil water holding capacity by an additional 0.08 acre-feet per acre (Rust, 2015). Maintaining soil cover year-round with the use of cover crops or mulching can regulate soil temperature and substantially reduce evaporative losses. It is common to have extreme wet events in between dry years (as Napa County

[9] Healthy soils have 5 - 15% organic matter, while unhealthy soils have less than 5% (Bricault, 2014).

experienced in Fall 2021 and Winter 2022/23) and maintaining soil health prevents erosion and increases water infiltration during such events.

Cover crops offer a range of benefits that contribute to improved soil health, water retention, and overall ecosystem balance. Cover crops prevent erosion by shielding the soil from rainfall and runoff, reducing the loss of topsoil and associated sediment runoff. This stabilization is important in riparian areas and sloped vineyards. Cover crops also promote better water infiltration and retention by enhancing soil porosity and creating pores and channels in the soil through their root systems. Cover crops contribute organic matter to the soil through their decaying plant material. This organic matter improves soil structure, promotes microbial activity, and enhances water-holding capacity. Healthy soils with good structure are better equipped to absorb and retain water, reducing the risk of soil compaction. Note that cover crops transpire water, so that must be taken into account when estimating water savings.

Recent investigations into the combination of biochar[10] and composting applications to vineyards, among other crops, have shown promise for increasing soil fertility. A recent pilot project in vineyards showed improved yields with applications of biochar and compost for the same amount of water applied, indicating the potential for water savings (Sonoma Ecology Center, 2021). Further research is needed to confirm potential benefits.

Practice Description: Cover cropping was selected as a representative soil management practice that conserves water by creating more soil water holding capacity. Cover crops are intentionally grown plants that cover and protect the soil surface between rows of main crops, such as vineyards. The root systems and ground cover significantly reduce erosion and also improve infiltration rates. Typical cover crops include annual and perennial grasses, which are highly effective at improving water infiltration, and legumes, which add nitrogen to the soil (UCCE Amador County, 1999).

Cover crops can potentially save total pumping. The overall effect on ET (and therefore net depletion) is complicated because the cover crop increases ET relative to bare ground, but the cover crop also cools the ground surface, which can reduce ET from the vineyard.

Scaling Opportunity (AFY): Most Subbasin vineyards have cover crops. Adoption rates of cover cropping are estimated between 70 and 90 percent (California Sustainable Winegrowing Alliance, 2020). Cover cropping is estimated to result in applied water (total pumping) savings of 4 - 14 percent based on aggregate USDA data not specific to Napa County (Jerkins, 2012). Additional data for Napa County can be developed as part of the GPR Workplan implementation. Applying this best available data, across the 10 - 30 percent of vineyards that have not adopted cover cropping, these water savings amount to approximately 50 - 550 AFY in the Subbasin.

[10] Biochar is a highly porous, stable form of charcoal. It is used as a soil amendment to improve soil structure, moisture retention, and nutrient availability in agricultural and gardening practices.

Several uncertainties may affect the results of the potential water savings. The adoption rate of cover cropping may be different from Central Coast adoption rates. The estimated water savings for cover cropping also includes uncertainties. As a result, there is a wider range of potential water savings.

Standardized Cost ($/AFY): Costs to develop a cover crop include soil preparation, seed and seeding, fertilizer and fertilizing, and mowing. Costs to plant a cover crop are estimated at $154 per acre, with annual mowing (two times) and discing (one time) costs totaling $260 per acre (Kurtural et al., 2020). This translates to a total cost of $414 per acre. Given that cover crops generate between 4 to 14 percent water savings, or approximately 0.02 to 0.08 AF/acre, the annualized per-AF cost translates to approximately $5,000 - $18,000 per AFY.

Table 3.10 summarizes the estimated capital costs, annualized costs per AF of water savings, and the potential Subbasin-wide benefits of increased adoption of cover cropping.

Table 3-10. Soil Management via Cover Cropping				
Practice	Scaling Opportunity, %	Scaling Opportunity, AFY	Capital Cost, $	Annualized Cost, $/AFY
Soil Management	10%	50 - 550	$154/acre	$5,000 - $18,000

Other Limits to Adoption: Key limits to the adoption of cover cropping include the additional time and costs to establish and manage a cover crop. The establishment and maintenance of a cover crop includes planting, irrigating, discing, mowing, and weed control. Other limitations include a lack of awareness or knowledge or perceived risks of the cover crop competing with the grapes for water or nutrients. The high cost per AFY saved indicates that cover cropping is not adopted primarily as a way to reduce pumping. Other benefits, such as soil health and erosion control, are discussed above.

3.1.3.4 Vine Canopy Management to Reduce Water Use

The grapevine canopy includes all the components of the plant above the roots, such as the leaves, flowers, shoots, trunk, and fruit. Managing the vineyard canopy is an important component of effective grape growing that affects fruit ripening, quality, yield, and overall plant vigor. Canopy management practices are implemented from fruit set through harvest. These practices typically include winter pruning of the vines, shoot thinning (suckering) and positioning to remove excess shoots and leaves throughout the growing season, and fruit cluster thinning in mid to late summer.

Canopy management is critical for positioning and thinning shoots to allow vines to develop good fruit clusters, allow air movement through the vines and around the clusters, and manage fruit quality. The UCCE estimates that annual cash costs (excluding equipment and other capital) are around $3,600 annually for the main canopy management activities. For farms that are more labor intensive (less mechanized canopy management), these costs can be substantially greater.

Practice Description: Canopy management is part of standard vineyard management practices in the Subbasin. The process of reducing biomass on the plant naturally reduces consumptive water use through ET. To achieve additional water conservation in the Subbasin would require an expansion of canopy management practices and changes in those practices to specifically focus on those that can reduce water use.

Scaling Opportunity (AFY): The ability to increase (scale) canopy management depends on current canopy management practices and the ability to expand specific, lower water use practices. A review of industry data and interviews with industry experts found that virtually all vineyards are carefully managed in the Subbasin. Fruit quality depends critically on how the canopy is managed; thus, this is a practice that is consistently implemented. Available data sources show that approximately 85 to 90 percent (or more) of Napa vineyards manage canopies to reduce consumptive water use and manage fruit quality, in line with statewide totals for certified sustainable vineyards (California Sustainable Winegrowing Alliance, 2020).

Rieger (2011) evaluated alternative canopy management systems and found that improving canopy management can achieve up to a 15 percent reduction in applied water in vineyards (Rieger, 2011). Therefore, improving canopy management may provide a total pumping benefit to the Subbasin.

Applying current vineyard water use, the potential to scale canopy management that focuses on reducing water use, and a potential water savings of 15 percent, the total pumping savings potential equals around 200 - 300 AFY in the Subbasin.

Standardized Cost ($/AFY): The cost to improve canopy management is in training, management, and additional field labor time. There is no additional capital investment in new equipment or machinery. As summarized above, annual costs for canopy management total around $3,600 per acre (Kurtural et al., 2020). Based on interviews with industry experts, it was estimated that vineyards that are implementing insufficient canopy management practices likely incur lower costs because they are utilizing less labor and materials for these practices. It was estimated that optimal canopy management practices would be about 10 percent of the full budget cost of $3,600 per acre. Therefore, the estimated cost of improving canopy management equals approximately $360 per acre per year.

Across the Subbasin, an estimated 10 to 15 percent of vineyards could improve canopy management to reduce groundwater use (California Sustainable Winegrowing Alliance, 2020). For the cost of $360 per acre per year and a 15 percent water savings, this yields an annualized cost of $4,250 per AFY. A range of $3,500 - $5,000 per AFY is presented to capture uncertainties in the data and analysis.

Table 3.11 summarizes the estimated cost for improving canopy management, total annualized costs, and potential Subbasin-wide benefits of increasing canopy management to achieve water saving benefits.

Table 3-11. Canopy Management

Practice	Scaling Opportunity, %	Scaling Opportunity, AFY	Capital Cost, $	Annualized Cost, $/AFY
Canopy Management	10 - 15%	200 - 300	$0	$3,500 - $5,000

Other Limits to Adoption: The primary limit to expanding canopy management is that most vineyards already implement appropriate management practices. A second constraint is additional outreach and education to help vineyard managers understand practices and how to implement them. Lastly, additional research is needed to evaluate what practices can result in quantifiable water savings and maintain or improve crop quality.

3.1.3.5 Row Orientation

To establish a new vineyard, the old vineyard must first be removed and cleaned up, disposing of the old grapevines and trellis systems. The field has an opportunity for redesign, including new spacing and orientation of the vine rows. The field can be surveyed, and the optimal design determined for the new vineyard. Cover crops can be planted in the row middles, and the trellis system reinstalled. The redesign period may also provide an opportunity for irrigation and drainage infrastructure improvements. This redesign process typically occurs in the fall/winter of the year prior to replanting. As this is done in the establishment phase, row orientation is a land development activity that can contribute to groundwater savings.

Selecting the optimal orientation of vineyard rows can reduce ET by reducing the amount of sun exposure of the vines. This is a long-term strategy since re-orienting rows can only be adopted at replanting, which typically occurs every twenty years. Other benefits can be obtained from correctly orienting rows when replanting a vineyard. In addition to optimizing sun exposure, proper row orientation can minimize erosion potential.

Practice Description: Balancing sun exposure, erosion control, and other environmental factors that may influence row orientation is a complex decision process.

Row orientation and canopy management are related. The ability to reduce consumptive water use through canopy management may be constrained by the vineyard's row orientation.

Row orientation has the potential to reduce ET and, therefore, provide net depletion savings for the Subbasin.

Scaling Opportunity (AFY): Academic research is beginning to look at the interaction of row orientation, canopy management, and other water saving techniques (Mirás-Avalos and Araujo, 2021). However, the scalability of the water savings potential for row orientation for Napa Valley is unknown. Given that row orientation for erosion control, grape sun exposure, and operational savings is standard practice, there is unlikely to be a large potential for immediate adjustments to reduce consumptive water use.

Recent research has demonstrated an 18 percent reduction in vine transpiration for an optimized row orientation under controlled conditions (Buesa et al., 2020). Anecdotal evidence from local sources also provides promising insights. The Napa Valley Grapegrowers, for instance, have reported water savings of around 30 percent through strategic row orientation. Although specific results may vary depending on factors like climate, soil type, and grape variety, these observations underscore the potential of this approach to contribute to water conservation efforts in the Napa Valley Subbasin.

The best estimate for assessing the potential scalability is to combine row orientation with canopy management, where there is a potential scaling opportunity of 10 percent (California Sustainable Winegrowing Alliance, 2020). With a potential water savings of 18 - 30 percent, this equals a modest potential savings of 200 - 325 AFY with the potential for increased erosion control depending on where the vineyard is located.

Standardized Cost ($/AFY): There may be minimal additional capital investment for selecting row orientation as it may require shorter as opposed to longer rows. However, the marginal cost depends on the vineyard and is estimated to be relatively small regardless. Similarly, there are no additional annual management costs for adoption. However, there may be modest costs for additional labor associated with canopy management and vineyard manager time to select row orientation.

Table 3-12. Row Orientation

Practice	Scaling Opportunity, %	Scaling Opportunity, AFY	Capital Cost, $	Annualized Cost, $/AFY
Row Orientation	10%	200 - 325	No additional cost	$0

Note: no additional cost over standard vineyard replanting costs.

Other Limits to Adoption: Optimal row orientation for reducing consumptive water use should be a part of the vineyard plan when establishing a new or replanting an existing vineyard. It is directly tied to operational costs associated with canopy management and environmental conservation controls. Row orientation is not a consideration for immediate adoption since it can only be changed during vineyard establishment or replants. However, it has the potential to decrease overall consumptive water use (albeit modestly) in the long run with potentially little cost.

3.1.3.6 Rootstock Selection

Rootstock selection and grafting is a fundamental process of vineyard establishment or replants. Different rootstocks have been developed over time to resist various pests, diseases, and external stressors like drought. As the increased frequency of drought is forecasted and may be exacerbated by limited access to groundwater, rootstock drought resistance will become an integral part of vineyard adaptability and sustainability.

The practice of selecting drought-tolerant rootstocks represents a prudent investment in vineyard resilience against water and heat stresses. While its direct impact on water savings may not be extensively quantified, the broader benefits of reduced vine damage and improved vigor mean that rootstock selection may be a valuable component of water-efficient vineyard management. This approach, undertaken during the replanting process, offers vineyards a low to no-cost avenue for enhancing the vines' adaptive capacity. As rootstock selection happens during the vineyard establishment phase, it is considered a land development strategy.

Practice Description: Selecting rootstocks that are drought tolerant can help the vineyards withstand heat and water stresses. Furthermore, drought tolerance in rootstock selection can be achieved in a variety of ways (Marín et al., 2021). Rootstocks differ in their ability to take up and transfer water and can affect transpiration rates in the rest of the vine. Across all types of drought tolerant rootstock, the balance between vine production during drought and wet conditions and its ability to ward off other pathogens is integral in its cost effectiveness and scalability.

Scaling Opportunity (AFY): Academic research has focused primarily on rootstock selection's impact under drought conditions. There is limited information on quantified water savings. Most research has focused on how rootstock selection may reduce overall damage to the vines resulting from water and heat stress (Williams, 2010). Rootstock selection is most important for addressing pathogens and other stressors.

Standardized Cost ($/AFY): Selecting drought-tolerant rootstocks is only done at replanting, and most vines are grafted to rootstock for pathogen protection; therefore, there is no marginal capital investment, nor is there additional O&M for adoption of drought tolerant varieties. As a result, rootstock selection is a low to no-cost water management practice that vineyards should consider at the time of replanting.

Table 3-13. Rootstock Selection

Practice	Scaling Opportunity, %	Scaling Opportunity, AFY	Capital Cost, $	Annualized Cost, $/AFY
Rootstock Selection	Data Gaps	Data Gaps	No additional cost	$0

Note: no additional cost over standard vineyard replanting costs.

Other Limits to Adoption: Given the increased stressors on vineyards worldwide, there is a large effort to breed more drought tolerant and resilient rootstock. Careful consideration should be given when choosing rootstock and how it will affect vineyard vigor and water use in both wet and dry seasons. Scalability will continue to evolve as new varieties are produced; however, rootstock selection will continue to be an integral part of vineyard sustainability and resilience.

3.1.4 Practices for Wineries

Napa's wineries play a key role in groundwater conservation, with opportunities to incorporate various strategies across their operations. Example practices that can provide opportunities for water conservation include:

- Crush operations. Using indoor or shaded settings prevents excessive heat and the resulting "baking" of waste materials on surface equipment. Pre-cleaning surfaces with brushes, using a high pressure/low volume nozzle with a shut-off valve, and using tools like brooms and squeegees also reduce water use (California Sustainable Winegrowing Alliance).

- Cellar operations. Practices include tank and line cleaning, reusing tank rinse water, and using high-pressure/low-volume equipment for cleaning. Best management practices for tank washing include temperature-controlled hot water with shut-off nozzles and alternative technologies for efficient cleaning, such as waterless tank sanitation.
- Landscaping at a winery. Practices include using drought-tolerant plants, mulching, and recycled water. Treating and reusing winery wastewater for irrigation is a viable option to reduce water consumption and reliance on groundwater.

Throughout the winemaking process, water measurement and monitoring can improve understanding of water use patterns and help detect any issues, such as leaks. Certification programs such as Napa Green work with wineries to monitor water use and implement best practices.

3.1.4.1 Waterless Sanitation

Tank sanitation involves cleaning and sterilizing tanks. Proper sanitation is essential to prevent spoilage, off-flavors, and microbial contamination in the wine. The process can require a substantial amount of water.

Waterless sanitation has emerged as a method to clean and sterilize without the use of water. In waterless sanitation, the goal is to achieve the same level of cleanliness and microbial control as traditional methods while conserving water resources. Waterless sanitation has gained some popularity in the wine industry due to its water-saving benefits.

Practice Description: Ultraviolet (UV) sanitation methods are used as an example of waterless sanitation practice. UV sanitation does not use water, steam, chemicals, or ozone to sanitize, representing a substantial savings in materials (water, energy, and chemicals), and other related costs. UV sanitation is used by several larger wineries in the Subbasin (G3 Enterprises, 2023).

Waterless sanitation saves applied water and, therefore, is a potential saving in total pumping, as well as net depletion, for wineries that depend on pumped groundwater for sanitation practices.

Scaling Opportunity (AFY): There are substantial data gaps on adoption rates of this practice in the Subbasin and no consistent inventory of winery sanitation practices. Interviews with industry experts indicated that fewer than 10 percent of wineries have adopted waterless sanitation (perhaps as low as 1 percent).

Subbasin wineries collectively use around 820 AF of groundwater per year (winery water use also includes surface water from municipal deliveries). Sanitation accounts for an estimated 15 - 25 percent of winery water use, or 125 - 205 AFY (based on example water balances from California Sustainable Winegrowing Alliance, 2014). Waterless sanitation by UV light may reduce water use by up to 80 percent (BlueMorph UV, 2023). Therefore, the adoption of waterless sanitation would result in water savings of 100 - 165 AFY across the Subbasin. However, there are substantial data gaps in adoption rates and the fraction of winery water used for sanitation.

Standardized Cost ($/AFY): The cost of switching to waterless sanitation depends on the size of the winery. Quackenbush (2015) estimates that the initial investment cost is around $50,000. This includes the UV sanitation device, the rolling cart, and necessary probe and power hookups (Quackenbush, 2015). Annual operating costs are reported to be lower than standard water-based sanitation practices; Jackson Family Wines estimated a 60 percent reduction in labor and a 50 percent reduction in energy costs (Quackenbush, 2015), though the baseline of these costs is unknown. The estimated water savings is around 250,000 gallons (0.77 AF). The annualized cost is approximately $2,500 per AF.

Table 3.14 summarizes the estimated cost of adopting waterless sanitation, total annualized costs, and potential Subbasin-wide benefits. The cost of total pumping reduction is estimated between $1,900 and $2,800 per AFY.

Table 3-14. Waterless Sanitation

Practice	Scaling Opportunity, %	Scaling Opportunity, AFY	Capital Cost, $	Annualized Cost, $/AFY
Waterless Sanitation	More than 90%	100 – 165	$50,000	$1,900 - $2,800 AFY

Other Limits to Adoption: A substantial barrier to adoption is the up-front capital cost. This may be particularly problematic for smaller wineries. Other barriers include technical expertise on the use of the equipment and other perceived risks to wine quality in transitioning from existing practices.

3.1.4.2 Processing Water and Reuse

Wastewater is a byproduct of the winemaking process, from grape processing to cleaning and bottling. The ratio of wastewater to wine produced is 6:1 for typical wineries but ranges from 12:1 to 3:1 (Ochs, 2023). This waste can be turned into a resource by treating and reusing processing water for landscaping or vineyard irrigation. Given the potentially large volumes of wastewater produced, this is a substantial opportunity to replace groundwater with processing water and reduce groundwater use.

Reusing winery process water for vineyard irrigation is occurring by some wineries to reduce water use. Approximately 50 percent of wineries certified by the California Sustainable Winegrowing Alliance already reuse some amount of winery process water for purposes such as irrigation (California Sustainable Winegrowing Alliance, 2020).

Wineries must already treat their process water to comply with applicable regulations under the Statewide General Waste Discharge Requirements (WDRs) for Wineries (State Water Resources Control Board, 2021). However, wineries may incur additional costs to treat it to the quality necessary for irrigation. In particular, treated winery process water may still contain contaminants such as nitrogen, salinity, and biochemical oxygen demand (BOD) that could harm vineyards, grasses, or other plants. Depending on the cleaning chemicals used in the winery, salinity may pose an issue when reusing winery process water.

Implementation of this workplan may include additional evaluation of the Regional Water Board's Winery Waste Discharge Requirements and how these requirements affect cost and incentives for using treated process wastewater for irrigation.

Practice Description: If winery process water is treated to an adequate level, it can be used for vineyard irrigation, landscaping, or aquifer recharge. Additional treatment would require removing salts and other contaminants that pose risks to crops.

Scaling Opportunity (AFY): Rather than winery process water being viewed as waste, this water can be used for vineyard or landscape irrigation. Therefore, this is a replacement source of water that can reduce groundwater pumping by the same amount.

Since the California Sustainable Winegrowing Alliance (2020) estimates that around half of certified wineries reuse some (not all) portion of processing water, this practice has the potential to be scaled by about 50 percent in the Subbasin.

Wineries pump an estimated 820 AFY of groundwater in the Subbasin, which is used for a range of purposes, including some consumptive uses such as landscaping and irrigation, which are estimated at one-third of total water use (California Sustainable Winegrowing Alliance, 2014). The remaining two-thirds are not consumptively used, used for purposes such as cleaning, and represent process water that could be treated and reused, totaling about 550 AFY. Given the potential to scale this practice in the Subbasin and the uncertainties related to how much winery process water is currently reused, a range of 275 to 450 AFY is presented.

Several uncertainties may affect the total water savings potential. Existing adoption rates may be higher or lower in Napa. Further, the amount of process water already reused varies by winery and is unknown, as is the total amount of consumptive use, such as for landscape irrigation or evaporation. The total amount of process water may vary based on annual production amounts and winery efficiency.

Standardized Cost ($/AFY): Wineries must currently treat process water. Wineries would incur additional costs to treat it to the standard necessary for irrigation. In particular, treated winery process water may still contain contaminants such as nitrogen, salinity, and BOD that could harm vineyards, grasses, or other plants.

The marginal cost to treat this process water to a sufficient quality for irrigation purposes is not known currently. This is a data gap that will be addressed in the future.

Table 3.15 summarizes the estimated cost for expanding process water reuse, total annualized costs, and potential Subbasin-wide benefits. The cost per AF of total pumping reduction is not known currently.

Table 3-15. Winery Wastewater Treatment and Reuse

Practice	Scaling Opportunity, %	Scaling Opportunity, AFY	Capital Cost, $	Annualized Cost, $/AFY
Winery Wastewater Treatment and Reuse	50%	275 - 450	Data Gap	Data Gap

Other Limits to Adoption: Several barriers to adoption exist for the reuse of treated winery process water. First, there may be a timing element related to when the process water is generated (mostly during crush, in the fall) and when it is needed for application on vineyards for landscape irrigation (mostly during summer). Other limitations include the infrastructure to connect wastewater sources with irrigation piping; this may represent an additional cost for some wineries. Finally, the volume of process water may exceed the amount of water needed for irrigation or other purposes.

3.1.5 Practices for Urban (Municipal and Industrial) and Rural Domestic Users

Municipal, industrial, and rural residential users account for approximately 20 percent of the Subbasin's annual groundwater use (**Table 2.1**). Residents and other urban users can implement conservation and water-saving practices as a way of life (Napa County Board of Supervisors Meeting; March 28, 2023). Household and industrial water conservation also provide benefits, including lower utility bills (energy and/or water). Outdoor water usage, particularly for landscaping, represents a substantial portion of household water use and consumption. For example, the City of Napa estimates that about half of its potable drinking water is used outdoors (City of Napa, 2023), which is in line with statewide estimates (Department of Water Resources, 2023). Indoor water use accounts for a substantial share of delivered water but less consumptive water use. Water-efficient fixtures such as low-flow toilets, aerated faucets, and efficient showerheads can contribute to substantial water and cost savings without compromising performance.

The EPA has developed standards for water-efficient products; by meeting these standards, products earn the "WaterSense" label. These products must be at least 20 percent more water efficient than the other products on the market.

Practice Description: Residents and businesses can implement water conservation practices and install low water using products (e.g., WaterSense-labeled products). These products include water-efficient toilets and urinals, showerheads, faucets, sprinklers, and irrigation controllers.

Indoor water conservation practices typically reduce water use, including total pumping. Outdoor water conservation practices can reduce total pumping and net depletion where applicable.

Scaling Opportunity (AFY): WaterSense-labeled products must be at least 20 percent more water efficient than the other products on the market. The statewide average is that approximately 6 - 20 percent of households have water-efficient products (WaterSense) installed (GMP Research, 2015).

Given the scaling potential of 80 - 94 percent, the water savings of 20 percent, and the total water used by urban and rural residential users, the total groundwater savings opportunity is approximately 500 - 575 AFY.

Standardized Cost ($/AFY): Costs of urban water conservation measures vary widely, depending on the particular measure and the conditions under which it is implemented. The California Urban Water Conservation Council (now the California Water Efficiency Partnership) commissioned a study in 2005 and updated it in 2016, estimating costs and potential savings of a range of water management practices for both residential and commercial users. A more recent analysis by Cooley et al. (2019) provides a range of costs and potential water savings for a list of residential and non-residential water conservation measures.

To estimate the costs of adoption for a two-bath house, hardware and installation costs were compiled for the devices in **Table 3.16**. Total hardware costs are $920, and total installation costs are $1,790, totaling $2,710. Most of the products have a lifetime of 10 - 15 years.

Table 3-16. WaterSense-Labeled Products

Practice	Hardware Cost	Installation Cost
Irrigation Controller	$200	$125
Irrigation Sprinkler Heads – 10	$60	$415
Kitchen Faucet – 1	$80	$125
Bathroom Faucet – 2	$120	$250
Toilet – 2	$400	$750
Shower Head – 2	$60	$125
Totals, per Household	$920	$1,790

Given the total water savings potential of 500 - 575 AFY, the annualized cost of adoption for WaterSense devices for a two-bath home is $775 - $1,200/AFY (**Table 3-17**). These costs may be lower for residents or businesses of municipalities that offer cost-share or other financial assistance programs.

Table 3-17. WaterSense-Labeled Products Cost Summary

Practice	Scaling Opportunity, %	Scaling Opportunity, AFY	Capital Cost, $	Annualized Cost, $/AFY
WaterSense Labeled Products & Cash-for-Grass	Data Gaps	500 - 575	$920	$775 - $1,200

Other Limits to Adoption: While several municipalities offer financial assistance programs to incentivize the adoption of water-efficient devices, these are limited to within the municipal boundaries, which primarily use surface water. Because the adoption of these can be cost-prohibitive, this has been identified as an opportunity for NCGSA to fill a funding gap for residents and businesses outside of municipal boundaries but within the County or NCGSA, who predominantly rely on groundwater. Other barriers to adoption may include awareness of the financial assistance programs or lacking expertise on installation.

Other water conservation opportunities for urban (M&I) water users include planting drought-tolerant or native landscaping for residential and commercial buildings, additional outreach and education efforts to landscape design professionals, use of reclaimed water for outdoor irrigation, use of mulches to reduce outdoor irrigation demand, and general improvements in outdoor irrigation scheduling and management.

3.2 Training and Education

Training and education are powerful and low-cost opportunities to scale conservation. A number of local organizations have active education programs that are targeted to agriculture and vineyards, wineries, or residential/commercial water users. A key guiding principle of the GPR Workplan is to leverage existing programs and relationships to scale conservation impact.

3.2.1 Educational Programs for Vineyards

There are a variety of local organizations that provide training and educational programming targeted at vineyards. These activities are operated by groups including:

- **Napa County Resource Conservation District (RCD):** Napa County RCD works to empower agricultural users and the community at large to protect natural resources, including water. Napa County RCD offers a range of services, events, workshops, and field days. It further offers assessments to evaluate irrigation efficiency and soil health. The RCD further supports the development of habitat projects and carbon farm plans.
- **Napa Valley Grapegrowers:** Napa Valley Grapegrowers is a membership association devoted to viticultural excellence and environmental stewardship in the Napa Valley. It supports its membership through educational tools and programming, including seminars, events, and website resources.
- **Napa County Farm Bureau:** Napa County Farm Bureau advocates for the Napa Valley's agricultural community at local, state, and federal levels. Among its services to members, education, information, and networking opportunities are available.
- **University of California Cooperative Extension (UCCE) – Napa County:** The Napa County UCCE is a bridge from academic research to the field, helping to apply new, science-based information to agricultural settings. They offer publications, workshops and seminars, volunteer programs, training, and other one-on-one consultations.
- **Third-Party Certifications:** Other educational opportunities include certification programs such as Napa Green and the California Sustainable Winegrowing Alliance, which are active in the Napa Valley and actively promote water sustainability in grapegrowing and winemaking businesses. Napa Green hosts education and training workshops and thought leadership events throughout the year, and biennially organizes the six-event RISE Climate & Wine Symposium.

3.2.2 Educational Programs for Wineries

There are a variety of local organizations that provide training and educational programming targeted to wineries. These activities are operated by groups including:

- **Winegrowers of Napa County:** Winegrowers of Napa County is engaged with the winemaking community and represents membership on a variety of issues facing winemakers. Interested parties may join their newsletter.
- **Napa County Farm Bureau:** Napa County Farm Bureau advocates for the Napa Valley's agricultural community at local, state, and federal levels. Among its services to members, education, information, and networking opportunities are available.
- **Third-Party Certifications:** Other educational opportunities include certification programs such as Napa Green and the California Sustainable Winegrowing Alliance, which are active in the Napa Valley and actively promote water sustainability in grapegrowing and winemaking businesses. Napa Green hosts education and training workshops and thought leadership events throughout the year, and biennially organizes the six-event RISE Climate & Wine Symposium.

3.2.3 Educational Programs for Urban and Rural Domestic Users

Several educational programs and resources are available to residential users across Napa County, including the Napa County Water Conservation webpage. There are websites dedicated to water-efficient landscaping, including Water-Wise Gardening in the Napa Valley, UC Master Gardeners, and California Native Plant Society – Napa Chapter. Other education and outreach opportunities include signs that indicate lawns irrigated using specific water conservation practices and other community awareness.

In addition, several cities offer home water use calculators/do-it-yourself (DIY) audits on their websites, as well as resources to learn about water-efficient landscaping and tools. Many cities also offer free conservation kits, rebates for upgrading to water-efficient devices, and cash-for-grass programs. The City of Napa also has a variety of events to engage with customers and the public, including having a booth at the Napa Farmers Market and tools for educators to bring into their classrooms or schedule field trips.

3.3 A Pilot Benchmarking Program

A concept for a pilot benchmarking program was explored to enhance water conservation efforts. A pilot benchmarking program could leverage the publicly available OpenET data for vineyards. The program's objectives would center on developing data and metrics that inform field-level decision-making, including the implementation of water conservation practices. The data would allow individual groundwater users to compare their usage with that of similar users, with an emphasis on preserving anonymity and confidentiality. Any peer data for comparison purposes would be aggregated and anonymized.

To begin the pilot program, NCGSA would solicit growers who are interested in participating in the initial development of the program. This small, focused group of growers would provide feedback on how "peer groups" or field characteristics could be further refined to capture important field variability that would affect water use. These characteristics, as described earlier, may include temperature, soil type, or grape type (red vs. white), among others. This group would help refine the peer group development and overall approach of the program. The pilot program would also seek to understand what types of data growers would be interested in self-reporting to refine the results of the benchmarked water use, which could include meter data, row orientation, grape variety, or other management actions.

The benchmarking initiative could establish linkages with the implementation of water conservation practices, as well as certification programs, and could create a robust framework for quantifying water-saving measures. For example, if users indicate field-level adoption of practices or their participation in a certification program, the pilot program may be able to quantify the water savings effects of those actions. As the program transitions to implementation, initial results would be closely monitored and evaluated. This iterative process could refine baseline data, further improve the benchmarking framework, and ultimately inform how the NCGSA could make the best investments in voluntary water conservation. Benchmarking stands to catalyze insights and practice adoption and encourage stakeholders to actively engage, compare, and adopt measures that ensure the sustainable future of the Subbasin's vital water resources.

To further illustrate the program's impact, case studies would spotlight volunteers who contribute data for spatial distribution analysis. These would be developed in consultation with interested stakeholders.

3.4 Certification Programs for Vineyards and Wineries

Certification requires businesses to follow standardized practices. This can allow businesses to meet regulatory requirements, demonstrate environmental responsibility, and meet consumer demand for sustainably produced goods. Several certification programs exist for vineyards and wineries, including:

- **Napa Green**, a local program with 92 Napa Green Certified wineries and 70 growers certified or in the process of becoming certified, representing over 7,000 vineyard acres in Napa County.
- **California Sustainable Winegrowing Alliance (CSWA)**, a program that operates statewide and has approximately 33 wineries and 259 vineyards on 15,000 acres certified in Napa County. Some CSWA certified wineries are also certified by other programs, such as Napa Green.
- **SIP Certified**, a program focused on vineyards and wineries on the Central Coast of California but with some small additional certifications in other parts of California, Oregon, and Michigan.
- **Lodi Rules**, a program focused on vineyards in Lodi (Central Valley) of California but also certifying across California, Washington, and Israel. Lodi Rules does not have a winery certification program.
- **Fish Friendly Farming**, a vineyard/agricultural program that serves 10 California counties to support regulatory compliance with water quality regulations.

Certification programs can provide additional value to vineyards and wineries committed to sustainability. By obtaining third-party verification through annual audits, they receive external credit and recognition for their efforts and can credibly communicate their commitment to consumers, the trade, and peers using various logos and claims. Certification helps businesses continually improve by organizing goals and providing access to free educational tools and resources. Implementing best practices can allow businesses to save money by lowering resource costs and realize additional revenues by marketing to specific consumers. Furthermore, businesses that are certified are expected to have less impact on natural resources use, such as groundwater, which could reduce costs for GSP implementation.

Certification can encourage water users to adopt water conservation practices, such as those outlined in this GPR Workplan and the WC Workplan. Incentivizing vineyards and wineries to get certified, particularly with organizations that are active in Napa and emphasize water conservation, such as Napa Green and

California Sustainable Winegrowing Alliance, may increase the adoption of water conservation practices and help the Subbasin achieve its sustainability goal.

Given the positive impact that certification may have on water management and other goals, the NCGSA may consider incentivizing participation in certification. Incentives can take a variety of forms, including different financial arrangements.

Examples of potential incentives for certification include but are not limited to:

- **Reimbursement of certification fees.** Lowering the cost of certification is an important financial incentive. The NCGSA may consider reimbursement of certification fees. This would also lower the financial barrier to entry for smaller operations. Reimbursement could be a one-time reimbursement and/or could apply annually. The one-time reimbursement would help new businesses and operations get certified, increasing the total number of certified businesses. The annual reimbursement would help with ongoing annual costs to maintain certification, which would help existing certified businesses as well. Given the cost and regulatory pressures that exist in the winemaking business, it may be preferrable to offer both reimbursement pathways to encourage businesses to maintain their certification rather than letting it lapse.
- **Cost-share or reimbursement for required practices or technologies.** For some operations, certification may require substantial changes with respect to practices or technology adoption, which could represent a financial barrier. The NCGSA could provide cost-share funding for the required practices and technology changes needed, which would effectively reduce the cost to get certified.
- **Availability of in-kind services.** The NCGSA could also offer in-kind services, such as technical support related to permitting. Typically, a new or replacement well permit would require the landowner to invest in a hydrologic analysis at their own expense. If their vineyard or winery is certified, the NCGSA could offer in-kind services to conduct the analysis itself.
- **Reduced GSP fees.** Given that certified businesses could have less impact on groundwater resources than non-certified businesses, their participation in certification could lower costs to implement the GSP. This may be an important consideration in the development of the GSP fees and any potential tiering for certified versus non-certified businesses.

Importantly, the certification programs incentivized by the NCGSA would need to incorporate water management criteria and, potentially, data reporting. It would not be prudent for the NCGSA to incentivize participation in a program that did not emphasize water use efficiency and measurement, as a primary goal of the GPR Workplan is to reduce pumping and achieve groundwater sustainability. The NCGSA would need to review each certification program's criteria and pre-approve the programs for which it would incentivize participation.

Programs like Napa Green already include substantial water management requirements for certification. The NCGSA could work with these certification programs to ensure that certification results in groundwater pumping reduction benefits for the Subbasin. Examples include, but are not limited to:

- **Vineyards/Agriculture**: Must adopt metering and report water use annually, test for distribution uniformity every 3-5 years, use drip irrigation, and use soil moisture/plant water monitoring.
- **Wineries**: Must adopt metering and report water use annually, use high-pressure, low-flow nozzles throughout operations, and use some process water for irrigation, if allowed.
- **Commercial/Industrial**: Must adopt metering and report water use annually, adopt WaterSense devices, and participate in Energy Star Portfolio Manager.

The development of any NCGSA-specific certification should be informed by the economic analysis of cost-effective ways to generate quantifiable water savings from each of the required practices. The practices required of the NCGSA-specific certification program may change over time to reflect any refinements in water savings potential, costs, or new practices or technologies that emerge.

4 DATA NEEDS AND MEASURING WATER USE

Measuring water use is critical for helping water users reduce consumption in addition to quantifying program-level water savings. Municipal water uses and wineries are generally metered. The main data gap exists for water use in vineyards. Estimating and measuring water conservation efforts requires a deep understanding of how water moves through a vineyard. It is necessary to characterize various vineyard management styles, tools, and techniques, including groundwater and surface water use, drainage, soil types, row orientation, land-based sensors, soil moisture monitoring, plant measurements, etc. The establishment of 'Pilot Sites' was proposed and well received by the TAG during the development of this Workplan. The goal of establishing Pilot Sites is two-fold:

1. The establishment of Pilot Sites would provide the technical team access to data to better understand how water moves through vineyards in accordance with different characteristics, which would help estimate total water use throughout the Subbasin, and
2. Pilot Sites would provide a way to document and disseminate any new practices or vineyard characteristics, how they impacted and/or improved grape quality, as well as lessons learned during implementation.

Some data of interest in the Napa Valley have been volunteered. Recently acquired data have been received through publicly developed or available data, data collected by Napa County, or data volunteered by the Napa Valley community. These data include but are not limited to, remotely sensed ET measurements, soil characteristics, field-based ET measurements, grape variety as either red or white, and vine density. Additional data from Pilot Sites would include soil pit evaluation, soil moisture, soil heat flux, field-based ET measurements, sap-flow measurements, soil organic carbon data, irrigation timing, irrigation duration, irrigation volume, other changes in management practices, and impacts and/or improvements to vineyard yield or quality. Specific information on the Pilot Site data request is outlined in **Section 4.3**.

4.1 Available Information

The Napa Valley can be subdivided into the eight American Viticultural Areas (AVAs) located within the Napa Valley/NCGSA area. The eight AVAs include Calistoga, Coombsville, Oak Knoll District of Napa Valley (Oak Knoll), Oakville, Rutherford, St. Helena, Yountville, and Stags Leap District (**Figure 4-1**).

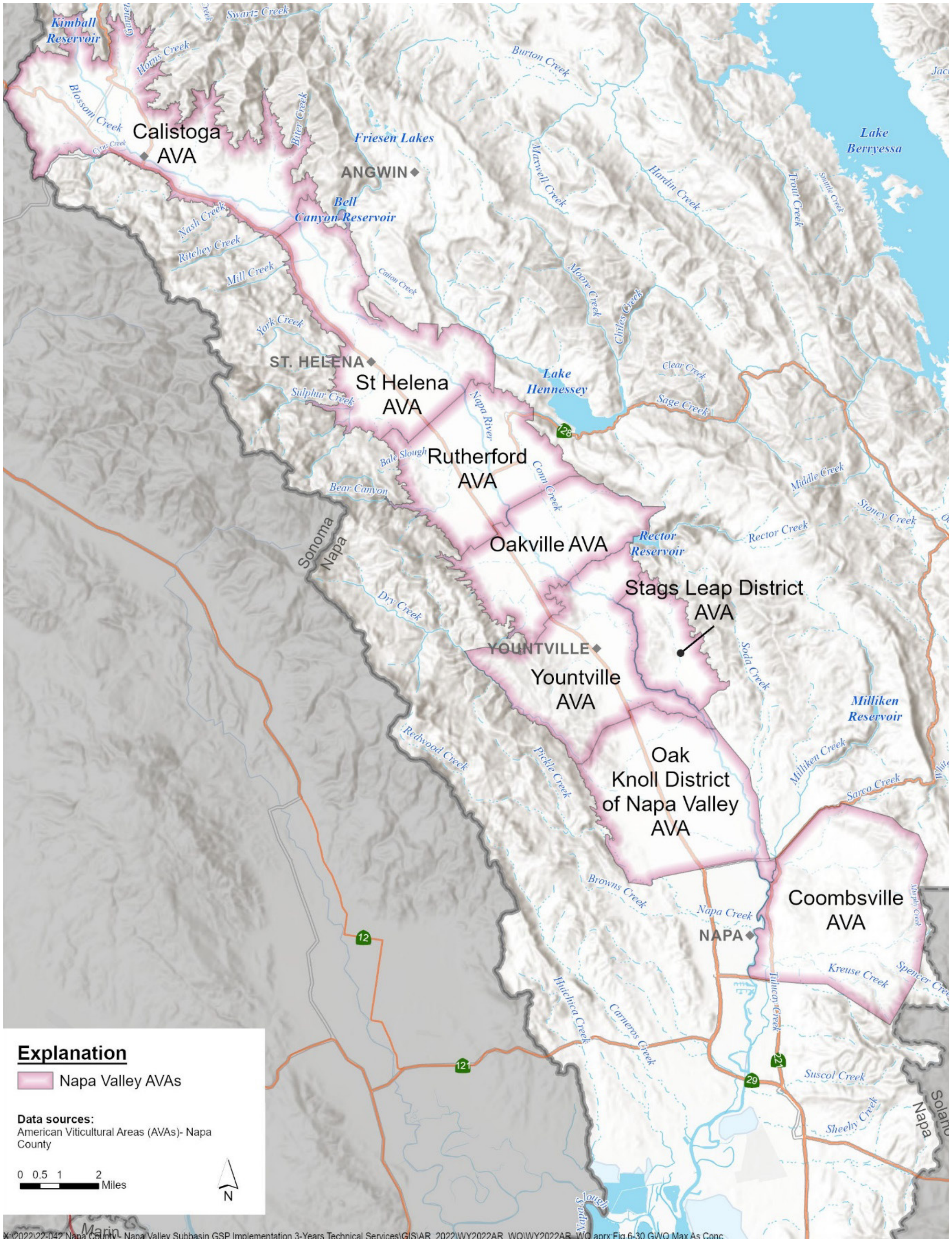

Figure 4-1. Napa Valley AVAs

4.1.1 Remote Sensing Measurements

The development of satellite-based methods to estimate ET data holds substantial promise to lower the costs of applied water metering. These methods use satellite images to capture visible and near-infrared light, as well as thermal sensors to measure temperature, from which information about the plant health, stress levels, soil moisture levels, and ET estimates can be derived. Satellites can also detect changes in landscape management, including land cover and irrigation patterns. While these data have been historically difficult to access, a number of public and private solutions have emerged to make these data more accessible.

- **OpenET** is an open-source platform for field-level agricultural ET data that has made satellite-based ET data particularly accessible and low-cost. OpenET uses a combination of satellite data, crop type data, weather station data, and models to calculate ET (OpenET, 2023). OpenET uses six different algorithms to estimate ET, as well as creating its own "ensemble" that averages the estimates. Daily, monthly, and yearly data are available publicly on their website and cover the entire western United States. Its spatial resolution is 30m x 30m.
- **Land IQ** is a private solution to estimating agricultural ET data. Land IQ differs from OpenET in that they maintain multiple ground stations and use the data to calibrate and interpret ET data. Land IQ covers more than 3 million acres in the California Southern San Joaquin Valley and supports more than 35 crop types. Its data are available monthly or annually. Its spatial resolution is 10m x 10m.
- **IrriWatch** is another private solution for estimating agricultural ET data using the SEBAL method. The data are focused on irrigation, crop production, soil health, and climate. It supports approximately 120 crop types, 12 soil types, and nine irrigation types that the user can specify. Its coverage spans the US as well as many other countries. Its spatial resolution is 10m x 10m.

While many of the satellite-based ET products include publicly available satellite imagery, there is a growing demand and supply of commercial imagery that provides data at a finer spatial and temporal resolution. Multiple companies now provide satellite imagery at resolutions over one hundred times more refined than that used in OpenET.

4.1.1.1 OpenET

The use of OpenET has been identified as the preferred venue for remotely sensed ET estimation at this time. Ongoing work in evaluating OpenET compared to other measurements in consumptive use in vineyards is ongoing, and these developments are expected to be implemented in the algorithms on an ongoing basis. Due to the OpenET framework incorporating reference ET, it can also provide crop coefficients (Kc) to show the variation of consumptive use while correcting for any climate factors, such as temperature gradients.

OpenET recently released the next generation of their application programming interface (API) (October 3, 2023), which allows data to be more easily retrieved and integrated into water management applications. The next phase of work is to create a graphical user interface, formally titled the OpenET

Farm and Ranch Management Support (FARMS) tool. This tool will allow for queries and recurring reports for management areas or individual stakeholders. A prototype of this tool may be available in early 2024.

4.1.2 Grape Remote Sensing Atmospheric Profile Evapotranspiration eXperiment

The Grape Remote Sensing Atmospheric Profile and Evapotranspiration eXperiment (GRAPEX; Kustas et al., 2022) is a program housed in the USDA Agricultural Research Service (ARS). The mission of GRAPEX is to "refine and apply a multi-scale remote sensing … ET toolkit for mapping crop water use and crop stress for improved irrigation scheduling and water management in vineyards …" To date, there have been two special issues in the scientific journal *Irrigation Science*. There are a total of 20 journal articles outlining advances in cutting edge energy balance modeling, uncertainty in measurements, and machine learning in vineyards, to name a few. Advances provided by the GRAPEX program are being reviewed and assessed for inclusion in how Napa County can measure water use and provide additional data to stakeholders.

GRAPEX began in 2013 with support from nine vineyards located in the Central Valley and Sonoma County. These vineyards were instrumented and monitored to compare against remotely sensed data to improve ET estimates. Multiple developments of refined surface energy balances to estimate ET have been developed within the GRAPEX program. Multiple refinements to two-source energy balance (TSEB) methodologies were made; these separate evaporation from the ground surface and the transpiration of the vines. Development of three-source energy balance (3SEB) techniques for vineyards were developed to include evaporation from the ground surface, transpiration of a cover crop, and transpiration of vines.

The micrometeorological data collected from the GRAPEX program continue to play a large role in the remote sensing community with the development of new remote sensing techniques (Knipper et al., 2023) and assessing uncertainty in other ET estimation techniques (Bambach et al., 2022).

4.1.2.1 Incorporating Remote Sensing

Advancements from the GRAPEX program are expected to be incorporated into OpenET algorithms over time. Advancements of energy balance estimates from researchers could be incorporated into Napa Valley for locally derived ET estimates in conjunction with the development of Pilot Sites.

4.1.3 Collected Vineyard Data

4.1.3.1 Cropping Density

While the Subbasin's total vineyard acreage has changed relatively little, the cropping density has increased since the 1960s throughout the Napa Valley. Based on local crop statistics data, the average density of vines has approximately doubled from 600 to 1200 vines per acre (**Figure 4-2**) for vineyard replants. The vine density in 2020 ranged from approximately 250 to more than 3,000 vines per acre.

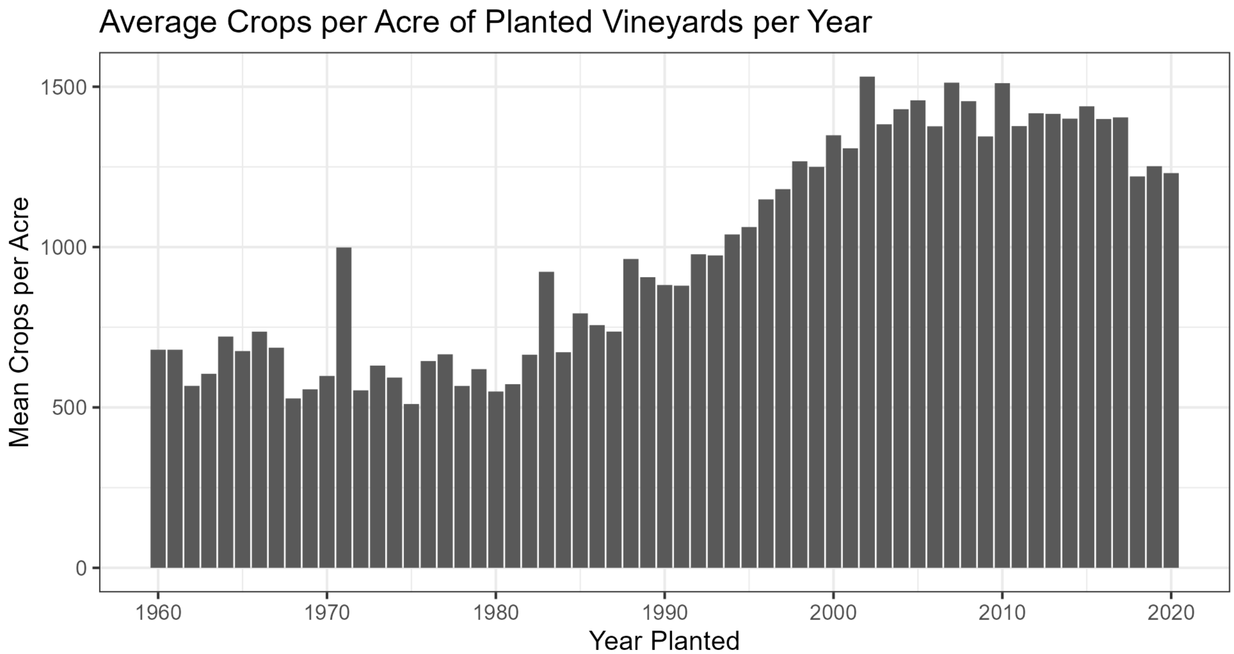

Figure 4-2. Vineyard Planting Density per Year in Napa Valley

4.1.4 NVIHM Data

NVIHM was developed to simulate surface and near-surface farm-related processes and groundwater movement in the Napa Valley Groundwater Subbasin. The development of a calibrated model is intended to support water resources management and GSP development and implementation for the Subbasin. NVIHM has been developed to be used as a platform to evaluate historic hydrologic conditions and develop predictive modeling scenarios aimed at evaluating the impact of future management actions, projects, and adaptive management strategies.

NVIHM incorporates many types of data, including climate, surface water and recycled water supply, crop properties, soil type, surface water, and subsurface geology. The NVIHM also relies on estimates of ET to calculate irrigation demand based on consumptive use for agriculture and landscaping. Since NVIHM accounts for interdependencies between landscape, climate, surface water, and groundwater, it is capable of partitioning different water sources (precipitation, groundwater uptake, and applied water) required to meet water demand. As a result, NVIHM can be leveraged to estimate the amount of water applied as irrigation from estimates of ET. To that end, NVIHM can serve as a valuable tool in bridging the gap between ET and water conservation measures aimed at reducing irrigation demand.

4.1.5 Volunteered Local ET Data

In-field sensors measure crop water use and ET with a higher degree of accuracy. Daily water uses and stresses can be monitored, which can inform irrigation scheduling decisions. The sensors outlined below provide important information to understand how water use moves through a vineyard and the Subbasin.

Field Based Methodology. On a field scale, ET can be estimated in two ways: eddy covariance and surface renewal. Eddy covariance estimates ET continuously at a single point by using high-frequency measurements of wind speed and water vapor concentration. Using these measurements in addition to other site-specific information, the total ET can be continuously measured. Typically, the cost of installation, maintenance, and data processing make eddy covariance a research tool and not a management tool. Eddy covariance is regarded as the 'gold standard' of ET measurements and is used to validate and calibrate other ET estimation methods. Surface renewal uses high-frequency air temperature measurements to estimate the heat fluxes within a field. The estimated heat flux is used within an energy balance equation to estimate the ET of a field. The application of surface renewal methods has been compared to various other water use estimation methods, including eddy covariance, and found to be comparable (Parry and Shapland et al., 2019). Surface renewal has become available for commercial use.

It is important to note that all ET "measurements" result from models designed to simulate the physical processes around ET. Additional methodologies to estimate total ET and consumptive use measure gas exchange at the leaf level or measure sap-flow measurements and scale these up to the field scale.

Volunteer Sites Instrumented by Tule Technologies. Land-based sensor companies, such as CropX (formerly Tule Technologies), measure key parameters such as air temperature, humidity, wind speed, and solar radiation to accurately measure ET via the surface renewal methodology. During the development of this Workplan, data have been volunteered by vineyards that use Tule Technologies' surface renewal sensors. As of September 2023, 18 sites have volunteered their information to help understand the range of values that are measured. These 18 sites include a total of more than 20,000 days of local ET data. Of the 18 sites that have volunteered data, 12 are located within the Napa Valley Subbasin. Of the 12 located within the Subbasin, sensors are in the Rutherford, St. Helena, Yountville, Calistoga, Oak Knoll, and Coombsville AVAs. Vine densities in the volunteered sites range from 900 to 4,000 vines per acre.

4.2 Data Comparison

Below (**Figure 4-3**) is the comparison of a surface renewal station and all 6 algorithms, and ensemble value, of the ET estimates from OpenET. The algorithms from OpenET show a wide range of estimates, some of which capture the magnitude and trend of surface renewal (disalexi, ssebop), others provide much higher overall estimates (ptjpl), and some algorithms fluctuate around the surface renewal estimates (geesebal). Due to the disalexi algorithm's continued development through GRAPEX and other vineyards (Parry et al., 2019; Knipper et al., 2023), the data presented below for **Figures 4-4** through **4-7** rely on the disalexi algorithm ET estimates.

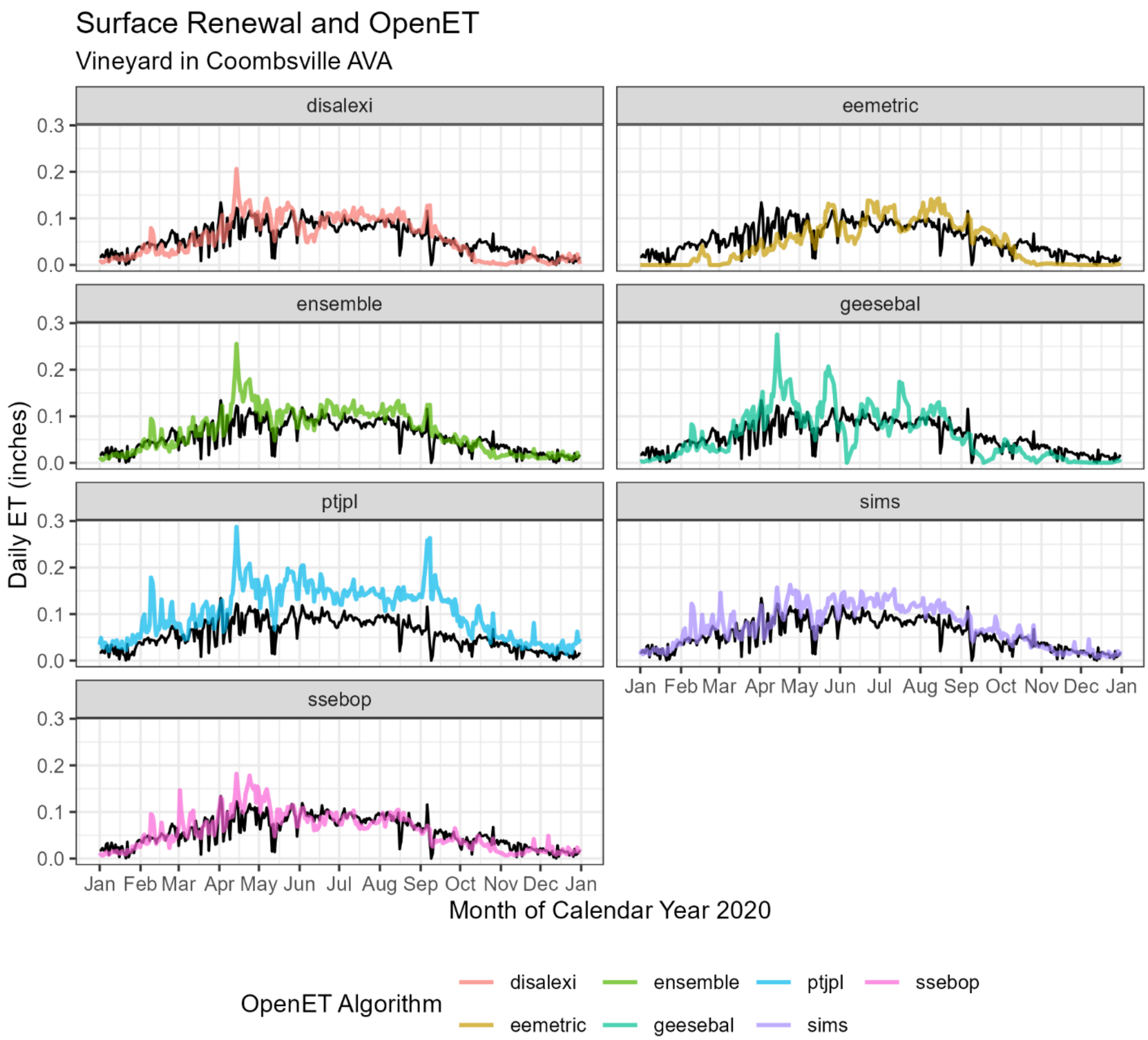

Figure 4-3. OpenET and Surface Renewal Comparison in Calendar Year 2020

4.2.1 OpenET in Napa Valley

To evaluate the consumptive use, as reported by OpenET, the total ET from June 1st to September 30th, or growing season ET, in 2020 is plotted (**Figure 4-4**). The lack of precipitation during the June 1st - September 30th growing season allows for a better estimate of consumptive use of groundwater uptake and applied water. In this section, OpenET data will be shown by AVA, grape variety, and by planting density to show the range and differences in remotely sensed ET across Napa Valley. The figures show box and whisker plots, which indicate the variability (typically in quartiles) around the average in graphical form. See **Figure 3-1** for an explanation of information presented on box plots.

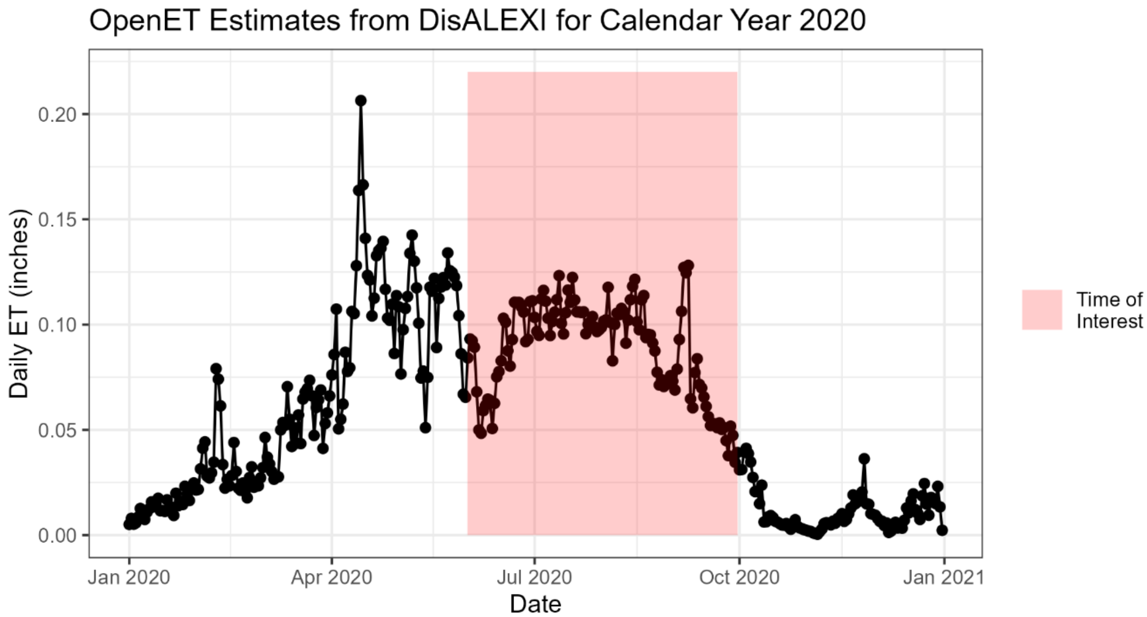

Figure 4-4. OpenET and Surface Renewal Comparison in Calendar Year 2020

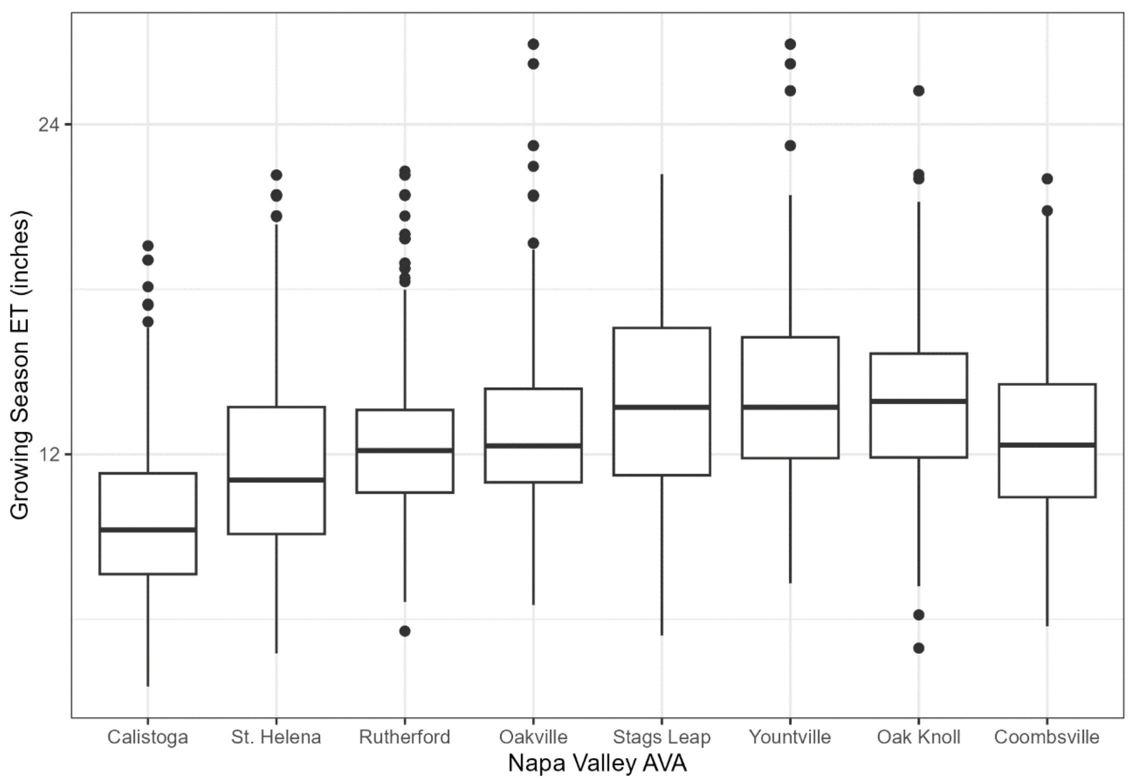

Figure 4-5. OpenET by AVA Region in 2020

The Napa AVA regions shown in **Figure 4-5** are, in general, presented north on the left and south on the right of the plot. The mean ET for the growing season in 2020 was smallest in Calistoga, with an average of 9.7 inches of ET, and greatest in Yountville AVA, with an average of 14.3 inches. In general, the mean ET for each AVA is significantly different than other AVAs.

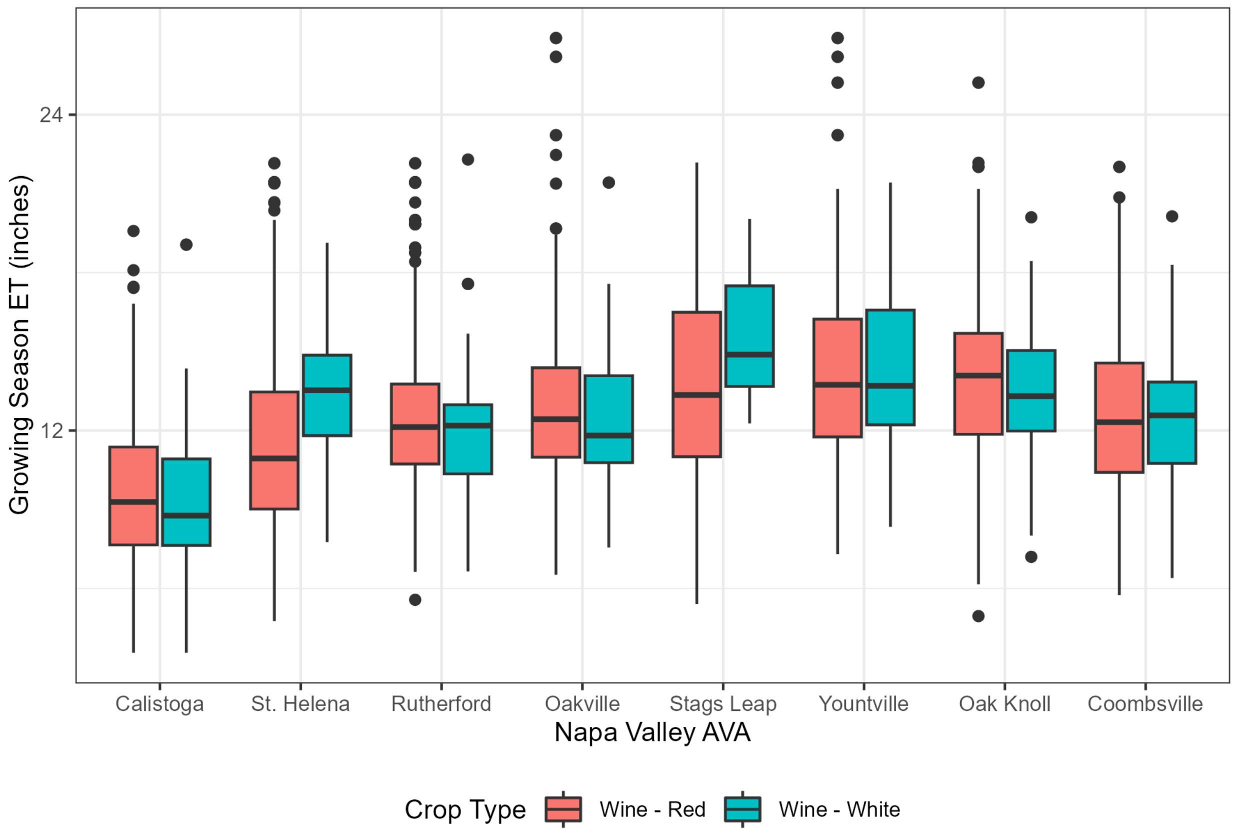

Figure 4-6. OpenET by AVA and Crop Type in 2020

Within each AVA, total ET can vary by grape variety, with white grapes using less (Calistoga, Oakville, Oak Knoll, Coombsville), using the same (Rutherford, Yountville), or using more (St. Helena, Stags Leap). In general, grape variety does not influence the measured ET as much as the location within the Napa Valley. A partial explanation of this is explored in **Figure 4-7**, which splits estimation out further by examining the vine density in relation to all other variables. In general, white wine grapes are planted at lower densities than red wine grapes within the same AVA.

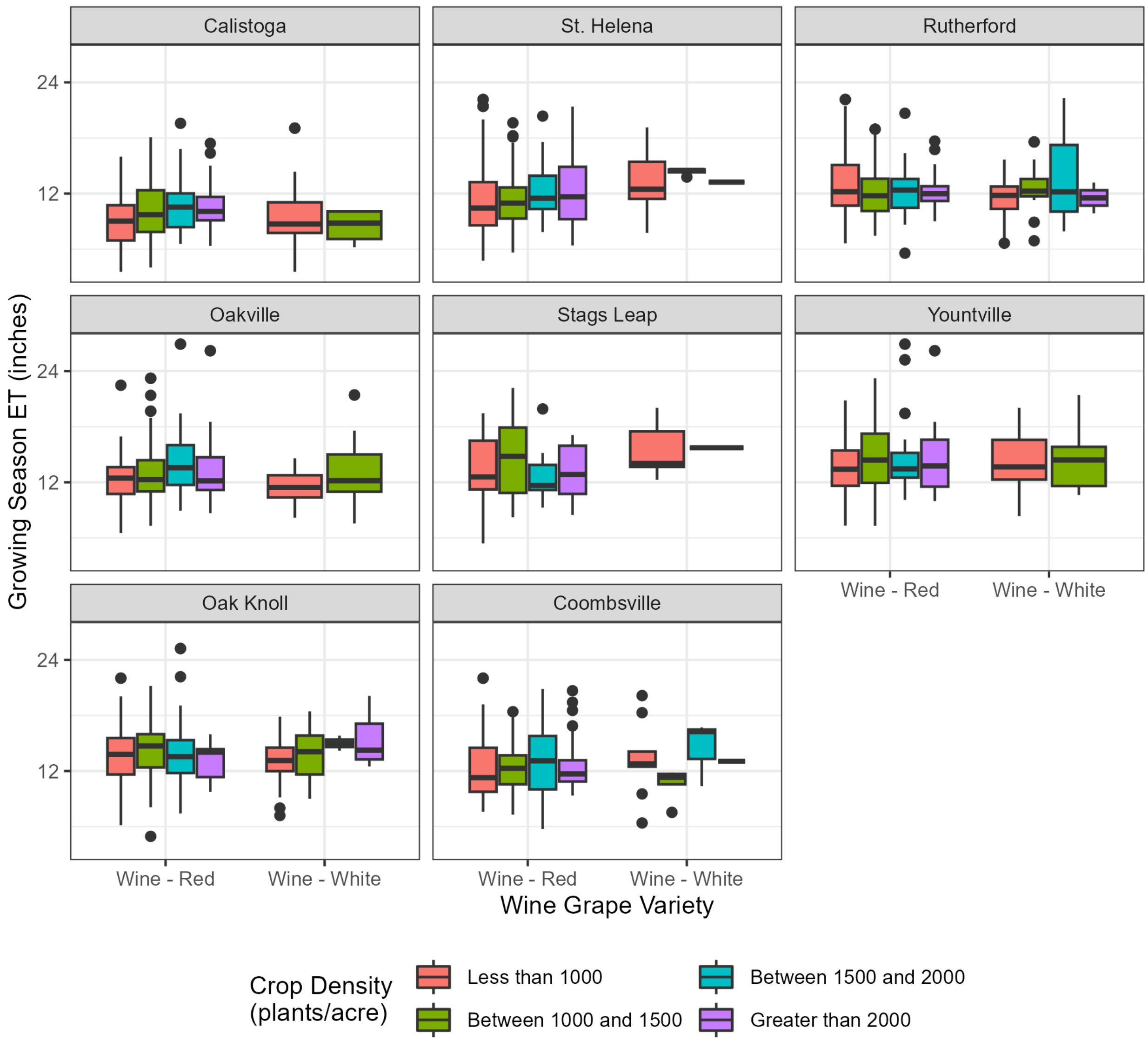

Figure 4-7. OpenET by Crop Type, AVA, and Planting Density in 2020

By including planting density (**Figure 4-7**), some AVAs show increasing ET with increasing planting density, such as Calistoga and Oakville red grapes. At planting densities greater than 2,000 plants per acre, there is generally less total ET. Vineyard management at higher density vineyards may play a role in this trend. Planting density for white grape varieties is typically less than 1,500 plants per acre in northern AVA, such as Calistoga, St. Helena, Oakville, Stags Leap, and Yountville.

By grouping vineyards throughout Napa Valley, trends from different management styles can be explored for a better understanding of how different decisions may impact total consumptive use. ET estimates from OpenET will be coupled within the NVIHM to begin investigating the impact of groundwater levels and vicinity to streams to better estimate the amount of applied water within a vineyard.

4.3 Pilot Site Data Request

The goal of establishing Pilot Sites in Napa Valley is to provide an outlet for vineyards to document and disseminate any influential practices, impacts and/or improvements to grape quality and lessons learned. These sites would be data driven and provide measurements to illustrate what was done and how, in addition to providing data that could help speed up the adoption of water conservation and sustainability in the Napa Valley. Information gathered for the Pilot Sites seeks to describe historical, current, and planned vineyard management practices, including drivers for changes in practices, the benefits realized, and the objectives for future changes (such as building climate resiliency). In addition, these sites would be used to evaluate different remotely sensed ET products, such as OpenET.

Volunteered Pilot Sites are important for developing additional data to support the GPR Workplan and the GSP implementation and updates. There are no predetermined requirements for a vineyard to become a Pilot Site, only a willingness to share data. Some potential Pilot Site monitoring frameworks are shared below, with potential ways data sharing could help the technical team and other growers. Participation as a Pilot Site may be further rewarded by providing in-kind services or payments for monitoring technologies.

- **Metered Groundwater Extraction and/or Surface Water Diversion Data (Metered Applied Water).** Develop a framework to see when irrigation first starts, the total daily or weekly volume of irrigation, and how regulated deficit irrigation is expressed in applied water measurements.
- **Plant Water Use, Metered Applied Water, and Co-Located with ET Sensor Data for Cross Correlation with OpenET Data.** Develop a better understanding of how variation in vine water use is estimated by remote sensing algorithms. Potential value to vineyard water management who do not meter applied water to better inform decisions based on remotely sensed data.
- **Soil Moisture Data and/or Shallow Monitoring Wells Co-Located with Sensor Data (especially where Dry-Land Vineyard Management).** Understanding the interaction of groundwater with available soil water would help refine groundwater estimates, especially in areas with high groundwater levels.
- **Shallow Monitoring Wells near Instrumented Tile Drain Systems.** Understanding the volume of water removed from the soil zone would begin the process of increasing conjunctive use or additional recharge projects.

Pilot Site implementation will be guided by interest from landowners/businesses that are willing to participate in the program and share data. During the development of this Workplan, several businesses have expressed interest in participating as a Pilot Site. The potential benefits to participants include but are not limited to data and information regarding water use and conservation practices, reputation as an industry leader in water conservation, and other potential incentives (e.g., cost savings) to be defined as part of workplan implementation.

4.3.1 Well Meters

Recognizing the importance of field-level data, it may be beneficial to develop a self-reported groundwater metering and reporting program. The objective of this program is to improve the understanding of the Subbasin's groundwater use patterns, refine baseline data, and facilitate informed decision-making.

This program would establish a collaborative relationship with groundwater users and provide a range of benefits to participants. Meter data would be self-reported by the water user using a website or other centralized system to reduce data collection costs. In return, the participants would receive reports to monitor and visualize their water use data, helping them gain valuable insights on temporal and spatial patterns of use.

The program could also be adapted to provide additional benefits, such as systems diagnostics or rapidly detecting leaks or other inefficiencies. The program could also create an alert or notification system for upcoming weather events, such as storms or heat waves, to remind participants to shut off or adjust any irrigation. The notifications could also inform participants of other upcoming water conservation forums and educational opportunities. Participation may be further rewarded by providing incentives for meter data.

The data made available through this reporting initiative would help refine estimates of groundwater use across vineyards, wineries, domestic, and other groundwater users. To the extent possible, these data could be linked with practice adoption, which can help inform which practices generate the most water conservation. The data could also inform modeling updates and implementation progress of the GSP.

Financial incentives to participate in this program could include covering services to improve irrigation efficiency, including unlocking cost-share funding for High Priority Water Conservation Practices (see **Section 5**), funding for professional services such as the Napa County RCD's irrigation evaluation, payments for annual participation, or partial reimbursement for participating in an approved certification program.

5 ECONOMIC ANALYSIS OF WATER CONSERVATION PRACTICES

While it is important for the Napa Valley Subbasin to realize quantifiable reductions in groundwater pumping, it is important that the adoption of practices is cost-effective for the water user and for the NCGSA. To the extent possible, the practices described in this document have been quantified for their water savings potential and their adoption costs. These findings have been summarized and organized in a concise matrix format (**Table 5-1**), whereby practices are ranked by criteria including estimated costs, water savings benefits, implementation timeline, overall feasibility, and documenting where other required studies or data gaps exist. Practices have been ranked for overall cost-effectiveness and feasibility, highlighting top-priority practices for adoption and highlighting cost-share programs that would lower costs of adoption for applicable practices and technologies.

5.1 Methodology

An economic analysis was developed to prepare a consistent cost analysis of water conservation practices that allows for comparison and screening of alternatives. Consistency means that practices are compared using the same price levels (eliminating the effect of inflation), the same internal interest rate, and the same standards for consistent planning horizons and cost accounting (e.g., life of equipment).

Water conservation practice-specific data, such as water supply savings, scaling potential, costs, and other benefits, were collected from a variety of sources that are documented in this Workplan (see **Section 3**). Costs are representative of average conditions, and there are substantial data gaps that are noted throughout this Workplan. Actual costs vary based on factors that include location, management practices, and business-specific costs (e.g., prevailing labor rates). The costs and economic analysis presented in this Workplan are intended to be representative of average expected conditions.

The result of the analysis is a concise summary of potential water conservation practices and a comparison across alternatives of the cost per acre-foot water savings benefit. It is anticipated that it will be updated every five years, concurrently with the GSP Five-Year Update, to incorporate data refinements, new practices or technologies developed, or other information.

5.2 Benefit-Cost Analysis (Cost-Effectiveness)

Benefit-cost analysis is a standardized methodology for displaying and comparing a water conservation action's costs and benefits on a consistent, present value basis. It is commonly used to determine whether an action is economically feasible, which can be assessed using cost-effectiveness, benefit-cost ratio, or net benefit measures.

Water conservation practices included in the WC Workplan and this GPR Workplan show annualized water costs but do not include monetized economic benefits (benefits are reported in terms of physical water savings). Therefore, it is possible to compare water conservation practices by the metric of cost-effectiveness. This shows the lowest cost water conservation practices to achieve an acre-foot of water savings benefit.

Figure 5-1 illustrates the cost-effectiveness of the water conservation practices, ranked in order of cost per AFY. Costs are shown as a range (high to low). These costs are the incremental (additional) cost to implement a water conservation practice. Practices such as row orientation and rootstock selection have zero cost because it is assumed that these practices would only be implemented when a vineyard is being established or replanted. Therefore, there is no additional cost for these two practices. However, there would be some management costs to evaluating options and selecting root stock or row orientation that are not explicitly shown. In contrast, cover cropping is relatively expensive and results in only modest water savings, though it provides other important benefits, including soil health and erosion control. Therefore, the unit cost per AF saved can be substantial. There are several practices for which the cost of water conservation is less than $2,500 per AFY.

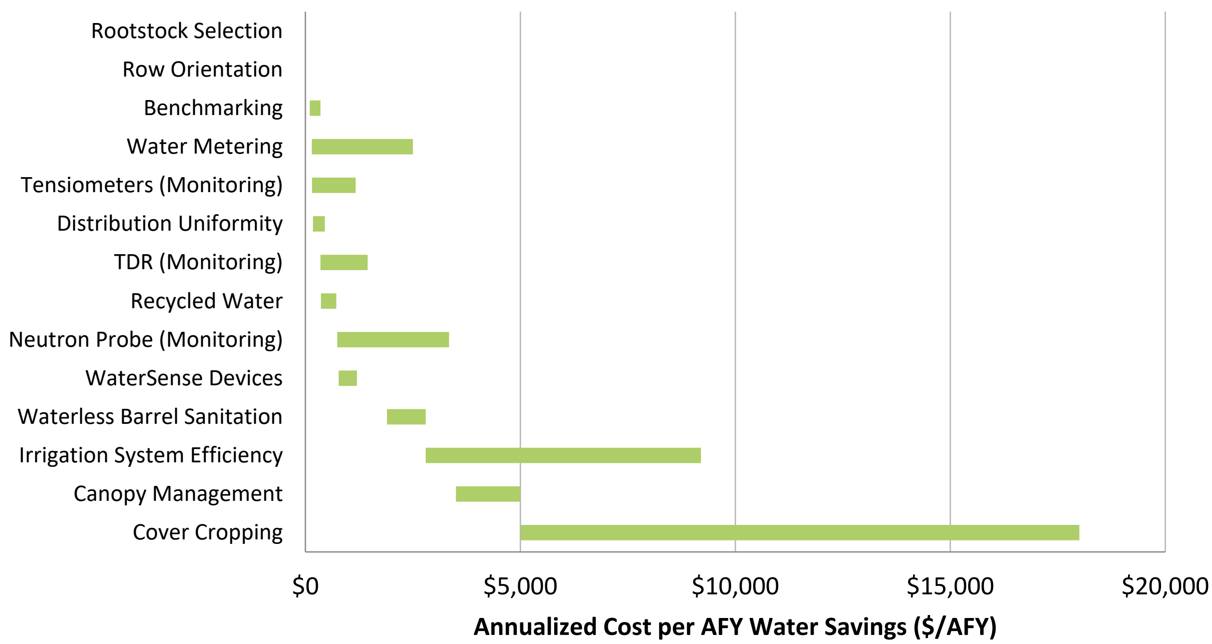

Figure 5-1. Range of Costs ($/AFY) of Alternative Water Conservation Practices

There are several practices with lower-bound cost estimates under $1,000 per AFY, as well as strategies with high-bound cost estimates under $2,500 per AFY. Water conservation practices with costs that are less than $2,500 per AFY include:

- Rootstock selection
- Row orientation
- Benchmarking
- Water metering
- Plant water or soil moisture monitoring (e.g., tensiometers or TDR)
- Distribution uniformity
- Recycled water
- WaterSense devices

It is important to emphasize that the benefits of water conservation practices are not additive. For example, the water savings benefits generated for distribution uniformity and soil moisture monitoring together would be less than the sum of the water savings individually. Still, the practices identified represent an opportunity to cost-effectively reduce groundwater pumping across sectors to achieve the goal of reducing groundwater pumping.

5.3 Other Considerations

Factors beyond cost-effectiveness are important considerations for implementation. For example, the scaling potential is a key aspect of how much a particular practice can be scaled. As discussed previously, most irrigation systems in Napa are already on drip irrigation. Therefore, the savings in applied water by switching from sprinkler to drip have already been largely realized in Napa, and the water savings potential for scaling this practice further is relatively small. By comparison, other practices and technologies have much more room for adoption, such as benchmarking, metering, and plant water and soil moisture monitoring. As a result, the total scaling potential is an important consideration beyond cost-effectiveness.

Another important consideration is the implementation timeline. Some practices will realize benefits nearly immediately, while others may take time to implement or realize the benefits. For example, plant water monitoring would help reduce applied water use in the same year it was implemented (assuming other factors allow for immediate action). On the other hand, expanding a recycled water program or benefitting from re-orientation of rows would be a long-term endeavor. Evidence from benchmarking programs has also shown that it may take time for users to understand, experiment with, and enact appropriate changes; this is a more medium-term project. Therefore, the implementation timelines are important considerations and factors, particularly as their impact is measured. For purposes of this GPR Workplan, the time horizons are categorized as follows:

- **Near-term**: Practices can be implemented and accrue water savings potential within one year
- **Medium-term**: Practices can be implemented and accrue water savings in a 2–5-year time frame.
- **Long-term**: Practices can be implemented and accrue water savings in 5 or more years.

Cost-share programs may further lower the costs of adoption for certain technologies and practices. Many programs have become available to remove turf grass, switch to low-flow appliances in residential settings, or support the adoption of several agricultural practices and technologies. These existing opportunities are also an important consideration for how practices should be prioritized and ranked.

Together with the cost-effectiveness, these additional factors contribute to determining a practice's overall feasibility for prioritization and implementation.

5.4 Summary Matrix

A qualitative scoring matrix was developed to compare and screen alternative water conservation practices. The matrix includes potential water conservation practices:

- **Costs**. The annualized cost of the water conservation practices, expressed as dollars per acre-foot of potential water conservation.
- **Benefits**. The physical benefits of the water conservation practices, expressed as the annual (potential) water conservation. Note that water conservation includes both gross applied water and net consumptive use for different projects.
- **Adoption timeline**. It takes time for the NCGSA to develop incentives and stakeholders to adopt new practices. Limits include access to funding, management time, labor, and difficulties with adopting new technologies. A qualitative assessment of the estimated timeline (years) to adopt each water conservation practice was developed.
- **Overall feasibility**. Overall feasibility is a subjective ranking of the water conservation practices based on cost, benefit, and adoption timeline parameters, in addition to feedback from industry experts and stakeholders. It is expressed on a high, medium, or low feasibility basis.

Table 5-1 summarizes the project matrix summarizing water conservation practices included in the GPR Workplan.

Table 5-1. Decision Matrix for Adoption of Groundwater Practices

Practice	Estimated Annualized Cost per AF Conserved	Estimated Potential Water Savings (Basin-Wide)	Adoption Timeline	Overall Feasibility
Unit	$/AF	AFY	Years	Ranking
Water Practices for All Water Users				
Recycled Water	$362 - $720	200 - 300	Medium-Term	High
Benchmarking	$100 - $350	300 - 1,100	Medium-Term	High
Vineyard-Specific Water Practices (Established)				
Water Measurement[3]	$250 - $375	250 - 400	Medium-Term	High
Irrigation System Efficiency[2,3]	$2,800 - $9,200	75 - 250	Near-Term	Medium
Distribution Uniformity[1]	$175 - $450	500 - 2,100	Near-Term	High
Plant and Soil Moisture Monitoring[2,3]	$155 - $3,340	1,000 - 2,000	Near-Term	High
High Tech, Low Labor (TDR)	$350 - $1,450			
Medium Tech and Labor (Neutron Probe)	$740 - $3,340			
Low Tech, High Labor (Tensiometers)	$155 - $1,170			
Soil Management (Cover Crop)[3,4]	$5,000 - $18,000	50 - 550	Medium-Term	Low
Canopy Management	$3,500 - $5,000	200 - 300	Near-Term	Medium

Table 5-1. Decision Matrix for Adoption of Groundwater Practices

Practice	Estimated Annualized Cost per AF Conserved	Estimated Potential Water Savings (Basin-Wide)	Adoption Timeline	Overall Feasibility
Unit	$/AF	AFY	Years	Ranking
Vineyard-Specific Water Practices (New Plantings)				
Row Orientation	No additional cost	200 - 325	Long-Term	High
Rootstock Selection	No additional cost	Data Gaps	Long-Term	Data Gaps
Winery-Specific Water Practices				
Water Metering	$150 - $250	5 - 15	Medium-Term	High
Waterless Sanitation	$1,900 - $2,800	100 - 165	Near-Term	Low
Processing Water Treatment and Reuse	Data Gaps	275 - 450	Long-Term	Medium
Municipal, Industrial, and Residential				
Water Metering	$950 - $2,500	100 - 130	Medium-Term	Low
WaterSense Devices[5]	$775 - $1,200	500 - 575	Near-Term	High
Other Urban Water Conservation[6]	Data Gaps	Data Gaps	Near-Term	Data Gaps

[1] Eligible for cost-share funding or other technical support through the Napa County RCD.

[2] Eligible for cost-share funding through the State Water Efficiency and Enhancement Program (SWEEP).

[3] Eligible for cost-share funding through the Environmental Quality Incentives Program Conservation Incentives Contracts (EQIP-CIC).

[4] Eligible for cost-share funding through the Healthy Soils Program (HSP).

[5] Eligible for financial assistance programs in select municipalities in Napa County.

[6] Example opportunities include improved outdoor irrigation management, low water use landscaping, and use of reclaimed water for outdoor irrigation. Detailed cost and scalability data were not available for initial workplan development. Additional information will be provided as part of education and outreach for Workplan implementation.

The analysis illustrates that several practices could generate substantial water savings cost-effectively. These practices, which are ranked as a high priority for scaling potential, include water measurement, benchmarking, distribution uniformity, plant water and soil moisture monitoring, and row orientation. These were ranked as high-priority due to their scaling potential and ability to generate water savings and due to relatively lower costs of adoption. Note that several of these practices are eligible for cost-share funding. Distribution uniformity tests are conducted free of charge by the Napa County RCD. The adoption of flow meters for agricultural water measurement is supported by the Natural Resources Conservation Service (NRCS) Environmental Quality Incentives Program (EQIP). Water and soil moisture monitoring are supported by multiple state and federal programs, such as the State Water Efficiency and Enhancement Program (SWEEP) and EQIP. The adoption of WaterSense (water-efficient) devices is supported by several programs in municipalities in Napa County; this presents an opportunity for the NCGSA to expand such programs for residents and businesses outside of municipal boundaries but within the County or NCGSA boundary.

Based on the analysis, water measurement (metering), benchmarking, recycled water, distribution uniformity, plant water and soil moisture monitoring, and row orientation were selected as High-Priority Water Conservation Practices for vineyards. These practices exhibited the highest potential to cost-effectively save substantial water. Several of these practices are also eligible for cost-share funding or other financial assistance programs through local, state, and federal programs.

The analysis is expected to be refined as the NCGSA collects and refines baseline data on adoption rates and water savings potential. Additional practices and technologies may be added periodically as the industry continues to evolve and innovate. To this end, the NCGSA will maintain open communication with wine and grape industry organizations on improvements and innovations.

6 COMMUNICATION AND ENGAGEMENT

Communications and engagement (C&E) are an essential element of the Workplan. The C&E strategies aim to achieve a broad understanding and acceptance of the Workplan's groundwater pumping reduction approach and to facilitate actions leading to successful plan implementation. While the companion WC Workplan focuses on water conservation in general, this Workplan targets outreach focused on groundwater pumping reduction.

6.1 Background

During the development of the GSP, a 25-member GSPAC for the Napa Valley Subbasin provided broad stakeholder representation for the NCGSA. The GSPAC was charged with advising the NCGSA on matters related to the preparation of the Napa Valley Subbasin GSP, including policies and recommendations for groundwater management. As part of their final deliberations, the GSPAC unanimously approved a recommendation for the formation of a TAG as a successor body to aid in the implementation of the Napa Valley Subbasin GSP.

The TAG's core charge is to provide well-informed, practical recommendations to the NCGSA as the NCGSA carries out GSP implementation, considering the best available scientific information and best practices in groundwater management. The TAG's charge includes consideration of groundwater conditions where some GSP representative monitoring sites are exhibiting exceedances of GSP-defined SMCs or triggers and invoking adaptive management approaches, including analyses and response actions to address SMC exceedances or triggers, and identifying potential projects and/or management actions to avoid undesirable results.

The TAG meetings have been the primary point of stakeholder engagement during the initial phases of GSP implementation and the development of the GPR Workplan. The TAG will continue to serve as an important source of guidance for the implementation of the Workplan and provide a standing, formal process for public input on the GPR Workplan implementation and performance.

6.2 C&E Strategies

C&E strategies permeate all four of the Workplan's general implementation components. This begins with education and outreach and continues with providing multiple options for achieving voluntary adoption and advancing certification. In the event voluntary efforts are not found sufficient, the NCGSA and its TAG may activate C&E to support the adoption of mandatory measures.

The tailoring of C&E for each Workplan component requires consideration of the target audiences and the appropriate level of engagement, relevant topics, and messages for each. This is paired with defining the best timing and methods for C&E delivery. Following are the primary C&E strategies for GPR Workplan implementation.

Macro, Overarching Communications - Macro, overarching communications refer to non-Workplan, general outreach, and messaging related to water sustainability and conservation generally and groundwater specifically. It refers to information deployed by the NCGSA and others (for different or related purposes) likely to drive public perception or actions benefiting groundwater reduction.

This approach, more fully explored in the NCGSA Communications Plan Update 2023, leverages outreach already being conducted by the County in its role as the NCGSA, land use authority, and water steward. It also operates in concert with other local, regional, state, tribal, and federal water conservation, and sustainability campaigns as well as integration with K-12 school-based science curriculum. Examples include recent statewide and western conservation campaigns initiated in response to severe drought and school-based programs that encouraged students to turn off the water while brushing their teeth.

Macro Messages. The Napa Valley Subbasin macro messaging may be tailored to feature the value of groundwater as an economic engine and the importance of sustainable use to Napa's quality of life. It would also include general messaging regarding Napa's dynamic (surface and groundwater) water system, groundwater sustainability, and what individuals and other entities can do to support sustainable use in their homes and businesses.

Additional macro messages may be developed for the wine-drinking public and larger tourism audiences. For example, messages will be developed on the importance of keeping Napa's groundwater sustainable, including how they can contribute to this by supporting businesses and entities committed to sustainable water management practices, as demonstrated through certifications or other similar validation programs.

Maro messages are continuous and utilize multiple delivery mechanisms, from the use of social media and public service announcements to utility bill inserts. National annual campaigns, such as the US Water Alliance's "Value of Water," and "Imagine a Day Without Water" offer event-based outreach opportunities.

6.3 Documentation

All forms of C&E will be documented. Documentation will include the date and type of C&E that occurred, the venues and participants involved, and any key outcomes.

6.4 Education and Outreach

The education and outreach component of the Workplan identifies options to accelerate and increase knowledge related to sustainable water use and the value and importance of sustainability to the community. Messages will focus on identifying the actions individuals, businesses, and other entities can take to advance sustainability. Audiences for this phase, which would continue throughout the life of the Workplan, include the public, partner organizations and businesses, groundwater users, and tourists.

Partner Approach. A key strategy includes partnering with organizations such as the Napa County RCD, certification organizations, and other industry organizations that promote sustainable water use and deliver quality education and training to target audiences. Collaboration with these entities will allow the NCGSA to benefit from and leverage their deep knowledge and well-developed community relationships. Further, because each of these entities is a trusted messenger for the communities they serve, their engagement enhances the legitimacy of the NCGSA's efforts.

Urban and Rural Domestic Water Users. The Workplan includes educational resources to support individuals who wish to implement water conservation and groundwater sustainability efforts in their homes, workplaces, and communities.

Vineyard and Winery Audiences. For those individuals able to effectively implement and use water conservation practices in vineyards and wineries, additional outreach is proposed. Workshops and seminars, field days, and literature in both English and Spanish will be used to gain support from vineyard and winery leadership. Training opportunities for skills building and the development of useful handouts and other media will help ensure on-site personnel can effectively implement the proposed conservation practices.

Outreach to vineyard and winery decision makers will be designed to encourage participation in educational programs. Key messages will describe the training being offered and how the use of new methods will impact the entities that adopt them, as well as the onsite personnel that will implement the change. It will also explain the benefits of adoption. Finally, this audience will be encouraged to suggest improvements and identify others who should be engaged.

See **Section 7.1.1** for more information on education, workshops, and resources.

6.5 Voluntary Adoption

A C&E campaign for voluntary adoption utilizes a layered approach. This includes outreach and education on the GSP approach to sustainability, what each sector is being asked to do, the implementation steps, and the feasibility and benefits of voluntary adoption.

General Information. General information on groundwater sustainability and the voluntary adoption campaign is suitable for a broader community audience. Providing a speaker to service clubs or information at highly attended farmer's markets and the County Fair or at events like Earth Day festivals are examples.

Targeted information: More specific messages will be designed for the audiences most impacted by the proposed changes. A multi-prong approach utilizing communications through partnerships, small group meetings, and individual on-site visits to high impact locations may be required. As with the educational outreach, it will be necessary to explain the changes being requested, how the audience will be impacted, the methods that will be used to implement the change, and the benefits of the change. The audience should also be asked about who else should be engaged and ways to improve the implementation.

Data Driven: Easily accessible, web-based tools such as dashboards, color coded maps, infographics, and other data visualizations will be used to illustrate the degree of progress being made through voluntary action. This will be paired with other feedback mechanisms, such as benchmarking (described in more detail in **Section 3-3**).

Evaluation: The TAG will provide feedback on messages developed for C&E prior to deployment. Once deployed, a variety of methods may be used to determine the degree of audience saturation (the extent to which messages are reaching intended audiences) and actions taken in response to messages. This may include tracking attendance at events, participation in surveys, visits to an informational website, and sign-ups for mailing lists or other forms of notifications. As voluntary actions are implemented, it will be useful to determine the primary factors, including the degree of influence C&E had, in motivating that led to implementation consistent with GPR Workplan goals.

Engagement: TAG meetings will provide opportunities for direct engagement; however, workshops and other venues for community input at locations and times convenient to the audience will also be provided. Additional outreach will include engagement to identify barriers to achieving compliance and collaboration with impacted users to determine ways to overcome those barriers. This type of engagement may occur in one-on-one or group settings.

Risks of Non-Action. Secondary messages on the risks of non-action will also be developed. This will include easily understood information about SGMA requirements and the elements of the GSP (undesirable results and minimum thresholds) driving the need for change. It will also explain the consequences of the Napa Valley Subbasin being out-of-compliance with state requirements, including loss of grant and other financial benefits, and the potential for the State Water Resources Control Board to assume management of the basin and impose mandatory management fees.

Celebration of Success: Napa County has an enviable quality of life and a thriving economy. Achieving groundwater sustainability voluntarily enhances the County's stature and should be celebrated along with all the participants that make it possible.

6.6 Mandatory Measures

Should it become necessary, communications and engagement for Mandatory Measures must be clear and direct. These messages will describe the change(s) that are required, how the change will impact affected groundwater sectors, and the methods to achieve compliance, including the types of assistance that may be available.

The C&E and evaluation processes developed for the voluntary action element of the Workplan should be revisited and updated to reflect the need for required actions. Collaboration to overcome barriers and the risks of non-action are particularly pertinent.

7 STEPS FOR IMPLEMENTATION

This section describes an implementation plan for achieving the groundwater pumping reduction targets. **Section 7.1** describes the implementation plan to scale the adoption of voluntary measures that generate water savings. **Section 7.2** describes the process for measuring progress, adaptive management framework, and integration with the GSP process. **Section 7.3** describes the potential mandatory measures that may be considered and adopted should the voluntary measures be found to be insufficient.

7.1 Implementation Plan for Voluntary Measures

To effectively implement the Workplan, a multi-component implementation approach was developed to scale the implementation of voluntary measures. The components detailed below provide a roadmap for gradual refinement and optimization, ensuring the Workplan's effectiveness in achieving its objectives to reduce groundwater pumping and achieve and maintain sustainability in the Subbasin. The components can also be implemented so they are not mutually exclusive, but they build upon one another. Components of the implementation plan may be implemented concurrently. Throughout implementation, the following activities would occur:

- **Improve Baseline and Subbasin Data.** The NCGSA would continue to study and quantify groundwater use and adoption of practices in the Subbasin. These data would help to refine baseline data and measure progress over time.
- **Quantify Water Savings:** The NCGSA would continue to invest in data and studies that quantify water savings resulting from voluntary practice adoption and refine the list of High-Priority Water Conservation Practices resulting from refinements in the data.
- **Refine Benchmarking Pilot Program.** The NCGSA would further develop and continue to refine its pilot benchmarking program.
- **Refine Volunteered Data Program.** The NCGSA's program for volunteered data would undergo review and refinements pending lessons learned.
- **Develop Feasibility Plan.** This GPR Workplan identifies voluntary demand management opportunities for reducing groundwater pumping in the Subbasin. In addition to understanding the range of opportunities and costs of alternative demand management projects, the NCGSA will evaluate opportunities to cost-effectively enhance supplies. The range of supply-side and demand-side projects and management actions will be outlined and developed in a feasibility plan.

Importantly, progress achieved during GPR program implementation would be assessed by the NCGSA annually and included in the GSP Annual Report and/or Five-Year Updates. This will provide opportunities to evaluate program effectiveness and whether additional actions are needed to achieve sustainability within the GSP implementation horizon.

Table 7-1. Expected Timeline of Development (D) and Implementation (I) of Plan Components

Component / Activity	Q1 24	Q2 24	Q3 24	Q4 24	Q1 25	Q2 25
Component 1: Education and Outreach; Feasibility Analysis						
Educational Materials	D	I	I	I	I	I
Partnership-Building	D	D	D	D	I	I
Automated Messaging System	D	D	I	I	I	I
Feasibility Analysis	D	D	I			
Component 2: Voluntary Adoption						
Incentive Program for Adoption	D	D	I	I	I	I
Benchmarking Program	D	D	D	D	I	I
Meter Data and Reporting Program	D	D	D	D	I	I
Component 3: Voluntary Certification						
Incentivize Certification	D	D	D	D	D	I

7.1.1 Component 1: Education and Outreach, Feasibility Analysis

As part of Component 1, the NCGSA would support, host, and develop educational programming targeted to specific user groups described below. These would include pamphlets and other materials that are easy to digest, as well as workshops and seminars. This would increase awareness about water conservation practices and encourage adoption. In addition, the NCGSA could also develop an automated system to remind or "nudge" subscribers about relevant water-savings information and encourage behavioral change. For vineyard or winery operators, this may include reminders of upcoming seminars or field days. It may also include reminders of cost-share programs that are available. For residents, these reminders may include information about where to learn about efficient appliances, water-efficient landscaping, or any incentive programs that are available. Nudge programs have proven effective in bringing water sustainability to the forefront of participants' minds.

Vineyards and Wineries. The NCGSA would partner with organizations such as the Napa County RCD, local certification organizations, and other industry organizations that promote sustainable water use. Educational programming includes workshops and seminars, field days, and literature. Field days and literature related to effectively using water conservation practices in vineyards would be developed in both English and Spanish to ensure that farmworkers also have access to this information.

Municipal and Industrial, Residential, and Hospitality. The NCGSA would also develop educational materials on the importance of sustainable water use and issues facing the Subbasin. The materials would be developed to inform residents about groundwater sustainability and what they can do about it in their homes and businesses. Hospitality/tourism materials would inform tourists, who, as consumers, can encourage wineries and vineyards to adopt more sustainable water conservation practices.

Feasibility Analysis. The GSP includes a range of projects and management actions, one of which is this GPR Workplan. Other example projects and management actions include expanding recycled water use, managed aquifer recharge, and in-lieu aquifer recharge (GSP, 2022). To comprehensively support GSP implementation, NCGSA will evaluate the costs of best management practices and alternative projects outlined in the GSP and compare them on a consistent basis. **Next Steps for Component 1 include:**

- **Develop educational materials.** Craft educational materials for specific users, including vineyard managers and farmworkers, wineries, residents, and tourists/hospitality. Materials for vineyards would be developed in English and Spanish. *Expected timeline: 3 months*.
- **Build partnerships with local organizations.** Recognizing the wealth of relationships that various organizations have with the public and/or their membership, the NCGSA will work to build relationships and partnerships with organizations that are promoting water stewardship. *Expected timeline: 1 year.*
- **Perform feasibility analysis.** Evaluate the costs and benefits of projects included in the GSP and compare them on a consistent basis with the water conservation activities. This would result in a comprehensive analysis that establishes the most cost-effective GSP implementation plan for both projects and management actions. *Expected timeline: 6 months.*
- **Develop an automated messaging system.** Develop a messaging system (e.g., texts or other medium) that would inform water users of relevant information for water conservation, such as seminars and workshops, other events, financial assistance programs, and public meetings. *Expected timeline: 6 months.*

Metrics for evaluating success are provided in Section 7.2.1.

7.1.2 Component 2: Voluntary Adoption

Component 2 incorporates education and outreach as a pillar of implementation. In Component 2, the NCGSA would leverage new and existing cost-share programs to incentivize adoption of water conservation practices. Examples of existing cost-share programs include but are not limited to, SWEEP, HSP, the NRCS EQIP, and the Napa County RCD Irrigation Evaluation. The NCGSA would also pursue additional funding opportunities, such as grants, to support technology adoption, incentive-based programs, and educational programming. This could include developing a cost-share program for High-Priority Water Conservation Practices (see **Table 7-2**). These practices may be subject to change should new data reveal more impactful practices or should new technologies and practices be analyzed and found to be impactful and, therefore, prioritized.

Table 7-2. High-Priority Water Conservation Practices

Practice	User Type
Water Measurement (Metering)	All
Recycled Water	All
WaterSense Devices	Urban (Municipal & Industrial) and Domestic
Benchmarking	Vineyards to start, with the potential to expand into wineries and rural domestic pending available data.
Distribution Uniformity	Vineyards
Plant Water and Soil Moisture Monitoring	Vineyards
Row Orientation	Vineyards, at replanting

These High-Priority Water Conservation Practices include measuring (metering) groundwater pumping, using recycled water, and installing WaterSense devices. Vineyard-specific practices further include conducting and addressing issues identified in a distribution uniformity test; adopting plant water or soil moisture monitoring technology; and establishing the most water-efficient row orientation during replanting. The practices were selected based on their potential to increase water savings cost-effectively.

The NCGSA would also make available a benchmarking tool (see earlier example based on OpenET). The benchmarking tool would allow users to learn about their water use performance. It would benchmark their water use against other comparable vineyards, controlling for selected factors.

Water conservation practices are most effective when coupled with water use measurement and tracking, as it helps the user quantify, monitor, and analyze their water use. Measurement data would also fill important data gaps that are critical to measuring the outcomes and progress towards the GSP goal. As these data are essential to both enabling water conservation and measuring the success of the programs, the NCGSA will develop a voluntary metering and reporting program for groundwater use data. The program would consider stakeholder needs and concerns, including the convenience of reporting, handling of private and potentially sensitive data, and the potential rewards and incentives that would encourage their participation.

Next steps for Component 2 include:

- **Develop an incentive program for the adoption of High-Priority Water Conservation Practices.** Develop incentives for the adoption of high-priority water conservation practices and technologies. This will include evaluating the list of potential incentives and determining the levels of funding NCGSA will contribute for adoption. *Expected timeline: 6 months.*
- **Develop pilot benchmarking tool.** Identify growers who would be interested in participating in the pilot benchmarking program. Develop the appropriate parameters for creating comparable peer groups against which to benchmark irrigation performance. *Expected timeline: 1 year*.
- **Develop a voluntary meter data and reporting program.** Develop a program for groundwater users to voluntarily report their meter data, incorporating incentives. *Expected timeline: 1 year.*

Incentives are expected to include a range of options from behavioral nudge programs (e.g., benchmarking) to financial (e.g., direct payments and cost-sharing). Any financial incentives would be tailored to conditions in the Subbasin to encourage adoption. This will include reviewing other programs with financial incentives for demand management, such as DWR's LandFlex program, the Department of Conservation's Multibenefit Land Repurposing program, and the National Oceanic and Atmospheric Administration (NOAA) Voluntary Drought Initiative (VDI) program. The NOAA VDI was available in both Sonoma and Napa Counties, but there was limited adoption of the program in Napa relative to Sonoma. Financial incentives will be structured in consideration of what will work for landowners in the Subbasin.

7.1.3 Component 3: Voluntary Certification

Component 3 builds upon the previous components, incorporating the educational programming and voluntary adoption in Components 1 and 2. In Component 3, the NCGSA would work with existing certification programs (e.g., Fish Friendly Farming, LandSmart, California Sustainable Winegrowing Alliance, Napa Green) to scale certification programs that provide water management benefits. The intent of this program would be to incentivize the vineyards and wineries to participate in existing certification programs that promote water quantity management, which would generate groundwater savings in the Subbasin.

Some certification programs' existing criteria may be found to be sufficient for these purposes. For example, programs such as Napa Green and CSWA include advanced water quantity management criteria. For others, an addendum may need to be developed to address water quantity needs. This addendum would go above and beyond existing criteria for some certification programs, such as Fish Friendly Farming (FFF) or LandSmart, which focus on management for water quality. NCGSA would need to set minimum criteria for a certification program to meet in order for the participating business to be eligible for an incentive or financial reward. Such criteria could include measuring and reporting water use to the certification organization and verification of specific water conservation practices. For verified participation, the NCGSA could provide cost-share funds or other financial incentives.

Next steps for Component 3 include:

- **Develop incentives for participation in a qualifying certification program.** Outline the minimum criteria for a certification program to incorporate key water conservation practices of relevance to the Napa Valley Subbasin and groundwater sustainability issues (i.e., define which practices would need to be incorporated in the program). Describe the process for NCGSA to approve existing certification programs as meeting the criteria. Develop incentives to reward vineyards and wineries becoming and remaining certified by qualifying certification programs. *Expected timeline: 15 months.*

7.2 Progress Reports, Adaptive Management, and GSP Integration

The purpose of reducing groundwater pumping is to ensure that the Subbasin achieves its sustainability objectives. The GSP will be updated and so will the GPR Workplan. The programs will be reviewed and improved annually, with a more comprehensive review and update every five years. Importantly, a comprehensive review would include coordinating groundwater pumping reduction assessment metrics with sustainable management criteria and triggers that lead to response actions. The Workplans will be integrated into the GSP process as follows:

- **Program Performance Review (Annually).** NCGSA will conduct annual assessments of its GPR Workplan programs. The review would assess program participation and opportunities to improve program performance. This review would happen in parallel with the GSP Annual Updates.
- **Program Outcomes Review (Every Five Years).** NCGSA will conduct five-year assessments of the programs' water savings outcomes to ascertain whether the GPR Workplan and its programs have been effective at achieving reductions in groundwater pumping. This will be conducted in parallel with the GSP Five-Year Updates. This review will also incorporate any refinements to baseline data and updates to the GPR Workplan and WC Workplan.

7.2.1 Program Performance Review

Annual assessments of the WC Workplan and GPR Workplan would be conducted to track participation levels, adoption rates, attendance, and other performance indicators. The assessment would track process-oriented goals around the NCGSA programs, including, for example, the participation levels in voluntary programming such as educational workshops and seminars, the reporting program, the benchmarking pilot program, and adoption rates for certification and/or cost-share technologies (see **Table 7.2**). The goal would be to determine the effectiveness and participation rates of these programs. If the programs see low participation rates, the program would be reviewed to determine what changes should be made to the program. Additional management goals related to groundwater pumping would be achieved through the GSP updates; those would also be reflected in updates to the GPR Workplan.

Table 7-2. Example Voluntary Program Metrics

Program	Metric
Educational Events	Total number of attendees.
Newsletter and Messaging Signups	Total number of subscribers to the newsletter and total number of subscribers to the automated messaging system.
Technology Adoption	Total cost-share funds dispersed, and total number of projects funded.
Reporting Program	Total number of participants and total meter readings.
Benchmarking Pilot Program	Total number of participants.
Certification by Third-Party	Total number of vineyard acres certified, and total number of wineries certified.

In addition to monitoring the GPR program metrics annually, data related to voluntary water conservation practices for vineyards, wineries, and rural domestic uses would be periodically updated and analyzed. This would be accomplished in part through a survey and incorporating other new data showing adoption rates in the Subbasin and potential water savings, which would help quantify the impact of adoption and any untapped potential for further scaling.

The GPR program progress reports would review the metrics described above, as well as develop estimates for the voluntary groundwater savings (in the past year, as well as in total). This would include recommendations of lessons learned from active programs, outline any changes to the program(s) to be made in the following year, and provide recommendations as needed to increase program effectiveness. These progress reports and recommendations would be reviewed annually by the TAG to determine if sufficient progress has been made and whether other management actions are necessary.

7.2.2 Program Outcomes Review

To determine whether the GPR programs are effective at improving Subbasin groundwater conditions, program-level and practice-specific metrics would be analyzed alongside the GSP Five-Year Updates. The GSP Five-Year Updates use modeling and the best available science and data to determine progress towards the GSP's outcome-oriented goals, including how the model results and best available data (including physical measurements) compare with the sustainable management criteria. With these metrics, alongside the data from the annual program performance reviews, it would be possible to determine whether the components are achieving the desired results for voluntary groundwater pumping reductions.

The GPR program implementation information would be used to refine baseline data and assess program effectiveness, which would be incorporated into the GSP adaptive management process. Adaptive management allows for continuous improvement, programmatic adjustments for higher impact, and overall updating of the management goals. Through this process, the WC Workplan and GPR Workplan would be updated every five years to reflect any key changes in findings or approach.

7.3 Potential Mandatory Measures

The fourth component of GPR program implementation includes mandatory measures. Mandatory measures may be considered if voluntary measures are insufficient to show progress towards achieving Subbasin sustainability. Mandatory measures can ensure consistency of program application, but such measures may also increase staff time and impose other costs to monitor and enforce new, mandatory requirements. For example, if a pumping limit is developed, there must be a way to measure and document use and the appropriate penalties in place for pumping overages, such as fines. The cost of non-compliance (e.g., penalties) must be sufficient to discourage non-compliance.

Pending the nature of the measures needed to achieve sustainability, mandatory measures can be strategically applied based on the specific needs and challenges related to groundwater management. This flexible approach aims to adaptively customize and design solutions to the broader context of groundwater sustainability. Additional mandatory measures may be considered by the NCGSA if and when it determines that voluntary efforts for conservation were insufficient to achieve sustainability.

A Subbasin-wide example of mandatory measures is provided:

Subbasin-Wide Application. If the groundwater conditions lead to undesirable results that persist across most or all the Subbasin, mandatory measures can be applied to ensure consistent management and conservation efforts that get the Subbasin back on track to achieve sustainability. Potential measures could include:

- **Measurement and Reporting**: Mandatory measuring and reporting of pumping data could be enforced to track groundwater withdrawals.
- **Water Use Restrictions (Allocations)**: Mandatory restrictions on groundwater pumping could be applied within a subregion or across the Subbasin, depending on the need, with specific targets for different user types.
- **Mandatory Certification Standards**: Mandatory certification and water use efficiency standards could be enforced, encouraging efficient practices for vineyards and wineries.
- **Other Ordinances and Land Use Restrictions**: Land use restrictions may alter or regulate how land and water can be used in a way that contributes to groundwater sustainability and other County goals.

The decision to apply mandatory measures involves stakeholder engagement, scientific assessments, and collaboration between local authorities and the affected communities. Balancing localized needs with the broader Subbasin-wide sustainability goal is crucial to ensuring effective and equitable groundwater management.

7.3.1 Mandatory Measurement and Reporting

Measurement and reporting of groundwater use is an important mandatory measure that can help stakeholders better monitor and improve water use while filling critical data gaps for groundwater management. Measurement could be conducted using remote sensing methods or metered data. Should meter data be required, it would necessitate that landowners have metered their wells, which represents a private cost of compliance to purchase and install new hardware. Meter readings can be reported through manual inspection by NCGSA staff, through automated updates by smart meters, or through self-reported meter readings. Each approach comes with tradeoffs related to the cost to the NCGSA (an indirect cost to landowners) or directly to the landowner. Note that NCGSA costs could be passed on to landowners, such as through the development of a NCGSA fee. Whether the costs are direct or indirect, reporting may represent a substantial cost to landowners to support the necessary combination of hardware, software, database management, labor, and equipment. The development of a measurement and reporting program for existing groundwater users in the Subbasin would need to consider stakeholder input and an analysis of the costs and benefits of alternative program designs.

7.3.2 Pumping Allocations

A common mandatory measure to reduce groundwater pumping is the development of pumping caps, called allocations. An allocation limits the volumetric amount of groundwater that can be extracted over some period, such as a one-year or multi-year period (Young et al., 2020).

Allocations can be designed with a range of temporal or spatial flexibility. For example, single-year allocations limit the total amount of pumping in any single year, whereas multi-year allocations limit the total amount of pumping over that multi-year period, such as three or five years. This temporal flexibility can be helpful to some groundwater users, such as farmers, who may use less water in wet years and more in dry years. On the other hand, this flexibility can also result in acute stream depletion, which can impair environmental habitat needs (Young et al., 2020). Spatial flexibility allows for reallocation across space. For example, if a landowner has multiple fields, an allocation policy might allow them to flexibly move some allocation from one parcel to another. This allows users to move water to parcels where there are higher water use needs based on the crop water needs or soil type. Groundwater allocations can be initially set with a variety of methods but should be designed in a way that conforms with groundwater rights and would withstand legal challenges. For example, an allocation that is based on historical use is closely linked with the prior appropriation doctrine, while a constant allocation per acre (e.g., aligned with Subbasin sustainable yield) is closely linked with the correlative rights doctrine. The development of allocations has important legal, economic, and environmental implications and should be designed in a way that is consistent with the goals of the Subbasin.

Should NCGSA consider the development of a groundwater pumping allocation, it will do so through a public process and in a way that considers the variety of environmental, socioeconomic, and legal constraints.

7.3.3 Mandatory Certification

Mandatory certification would build from the voluntary certification in Component 3, whereby instead of voluntary certification, NCGSA would require mandatory certification for vineyards and wineries in the Napa Valley Subbasin. This mandatory certification with an existing and qualifying certification program would be similar in concept to that of the Irrigated Lands Regulatory Program, for which certification with qualifying organizations is sufficient to meet regulatory standards for water quality.

NCGSA could explore requiring certification that would enhance water quantity management for the betterment of the Napa Valley Subbasin. NCGSA would work with existing certification programs, such as Napa County RCD LandSmart, Napa Green, FFF, and CSWA, on how vineyards and wineries could meet the requirements of its water management criteria. Working with existing certification programs would minimize impacts, as many vineyards and wineries in Napa are already certified by one or more programs.

7.3.4 Other Ordinances and Land Use Restrictions

Other land use restrictions that contribute to groundwater management and the sustainability goal could be considered by the NCGSA or by Napa County for broader land and resource use goals. Land use restrictions may alter or regulate how land and water can be used in a way that contributes to groundwater sustainability and other County goals. Furthermore, state-level requirements are also being implemented locally, such as the Model Water Efficient Landscape Ordinance, which requires local agencies to adopt landscaping ordinances that improve water efficiency and environmental conditions (Department of Water Resources, 2023). Other state-level initiatives include increased water quality standards for wineries (County of Napa, 2023b). Land use restrictions can prevent the development of high-intensity land or water uses.

Examples of such land use restrictions include but are not limited to:

- **Requiring new development of agricultural, commercial, industrial, or domestic uses to incorporate conservation practices.** For new development, the County could require the installation of a meter and annual reporting or require user-specific management practices that conserve groundwater. For example, new plantings or agricultural redevelopments may be required to meet minimum criteria, such as metering and reporting, installation of drip irrigation, and use of soil moisture monitoring. New or retrofitted domestic, commercial, and industrial uses may require the installation of meters.
- **Requiring new development to have efficient appliances.** New housing, commercial, or industrial permits could require the installation of low-flow and energy-efficient appliances. Such requirements are currently under consideration for the Napa County Climate Action Plan.
- **Requiring new development to use green infrastructure, such as stormwater scaping.** New housing, commercial, or industrial permits could require incorporating elements of green infrastructure, such as rain gardens, disconnected downspouts, or green roofs (University of Nebraska-Lincoln, 2023). These would help increase localized percolation and potential recharge.

These are a few of the many options available to guide responsible land development and advance groundwater sustainability. These and any mandatory measures would need to be evaluated by the County/NCGSA to understand the potential costs and benefits of enacting such measures as well as impacts on already existing permitting requirements.

8 SUMMARY

The goal of this GPR Workplan is to develop an implementation plan for a suite of actions that would result in Subbasin groundwater sustainability including:

1. nearer-term voluntary measures to reduce pumping, and
2. over a longer-period achieve the interconnected surface water Measurable Objective through a Subbasin-wide groundwater pumping reduction of 10 percent of the recent historical average pumping (2005-2014) of 15,000 AFY to maintain and improve interconnected surface water conditions.

Total Subbasin pumping during 2015-2022 averaged 18,150 AFY in response to very dry years. The nearer-term goal of the GPR Workplan is to reduce streamflow depletion through voluntary measures to reduce pumping to the estimated sustainable yield of 15,000 AFY. Although this is a Subbasin-wide goal, it may also be achieved through site-specific, focused efforts, particularly those that reduce depletion of interconnected surface water. This may be accomplished by combining reductions in pumping with other demand management and/or supply augmentation approaches. In coordination with stakeholder and public input during GPR Workplan development, the Workplan focuses first on voluntary implementation steps and indicates that mandatory measures may be necessary in the future should voluntary measures be insufficient to achieve the Subbasin sustainability goal.

The GPR Workplan includes the following:

- **Overview of groundwater use in the Subbasin**. Average annual pumping is around 15,000 AFY (2005-2014) and 18,150 AFY (2015-2022). The GPR Workplan development is a GSP implementation management action. GPR Workplan development is particularly important due to the occurrence of two URs in WYs 2021 and 2022.
- **Methods for measuring water savings**. This includes differentiating between total pumping savings and savings in net depletion. Data gaps are identified in the Workplan and will be addressed as part of the Workplan implementation.
- **Voluntary measures for water conservation**. All sectors can contribute to water conservation. Many potential practices are described. For each practice, the cost, benefits, and scaling potential were assessed.
- I**mplementation plan**. A multi-component plan for implementation was included in **Section 7**. This includes leveraging current conservation practices and an adaptive management process to update the GPR Workplan as additional data becomes available.

The analysis in this Workplan illustrates the potential groundwater pumping reduction that can be achieved through voluntary measures. Appropriate incentives can encourage water users to adopt new technologies or change existing behaviors. Incentives include outreach and education, benchmarking programs, certification, and financial incentives.

9 REFERENCES

Acclima. 2023. Available at: Digital TDR Soil Moisture Sensors.

Aquacraft. 2011. California Single-Family Water Use Efficiency Study. Available at: https://www.waterboards.ca.gov/waterrights/water_issues/programs/hearings/byron_bethany/docs/exhibits/pt/wr71.pdf.

Association of Bay Area Governments. 2021. Plan Bay Area 2050 Final Blueprint Growth Pattern. Available at: https://www.planbayarea.org/digital-library/plan-bay-area-2050-final-blueprint-growth-pattern.

Babin N., C. Klier, and A. Singh. 2022. Understanding and promoting adoption of irrigation efficiency practices in Paso Robles, California vineyards: The importance of farm typology and grower sustainability networks. *Current Research in Environmental Sustainability, Volume 4,* 100143. Available at: https://www.sciencedirect.com/science/article/pii/S2666049022000214.

BlueMorph UV. 2023. BlueMorph UV Home Page. Available at:https://bluemorphuv.com/.

Bricault B. 2014. Smart gardens begin with healthy soil. Michigan State University MSU Extension. Available at: https://www.canr.msu.edu/news/smart_gardens_begin_with_healthy_soil.

Buesa, I., J.M. Mirás-Avalos, and D.S. Intrigliolo. 2020. Row orientation effects on potted-vines performance and water-use efficiency. *Agricultural and Forest Meteorology, 294,* 108148.

Burt C.M. 2004. Rapid field evaluation of drip and microspray distribution uniformity. Irrig Drainage Syst 18, 275–297. Available at: https://doi.org/10.1007/s10795-004-2751-x.

California Energy Commission. 2021. Energy Efficiency and Water Savings in Agriculture by Innovative Plant-Aware Irrigation. Energy Research and Development Division Final Project Report. Available at: https://www.energy.ca.gov/sites/default/files/2021-05/CEC-500-2021-011.pdf

California Sustainable Winegrowing Alliance. 2014. Sustainable Water Management Handbook for Small Wineries. Available at: https://www.sustainablewinegrowing.org/docs/CSWA_Sustainable_Water_Management_Guide_for_Small_Wineries.pdf.

California Sustainable Winegrowing Alliance. 2020. Sustainability from Grapes to Glass: California Wine Community Sustainability Report 2020. Available at: https://library.sustainablewinegrowing.org/item/244/2020-california-wine-community-sustainability-report.

California Sustainable Winegrowing Alliance, Wine Institute, and California Association of Winegrape Growers. 2020. California Code of Sustainable Winegrowing, 4th Edition. Available at: https://www.sustainablewinegrowing.org/swpworkbook.php.

Carollo. 2022. Napa Sanitation District Cost of Service Recycled Water Rate Study: Rate Study Results and Recommendations. Available at: https://www.napasan.com/DocumentCenter/View/1142/Napa-Sanitation-District-Recycled-Water-Study-Final-Report?bidId=.

Chalmers D.J., G. Burge, P.H. Jerie, and P.D. Mitchell. 1986. The Mechanism of Regulation of 'Bartlett' Pear Fruit and Vegetative Growth by Irrigation Withholding and Regulated Deficit Irrigation. *Journal of the American Society for Horticultural Science*, *111*(6), 904-907. Retrieved September 7, 2023, from https://doi.org/10.21273/JASHS.111.6.904.

City of Calistoga. 2016. Final Municipal Service Review & Sphere of Influence Update. Napa LAFCO. December 5, 2015. Resolution No. 2016-14.

City of Napa. 2023. Water-Wise Landscaping, https://www.cityofnapa.org/600/Water-Wise-Landscaping. Accessed: October 11, 2023

City of St. Helena. 2023. PRESS RELEASE & VIDEO: City Plans "Big Pour" to Prepare for New Wastewater Treatment Plant Equipment. Available at: https://www.cityofsthelena.org/community/page/press-release-video-city-plans-%E2%80%9Cbig-pour%E2%80%9D-prepare-new-wastewater-treatment-plant.

Cominola A., M. Giuliani, A. Castelletti, P. Fraternali, S.L. Herrera Gonzalez, J.C. Guardiola Herrero, J. Novak, and A. Emilio Rizzoli. 2021. Long-term water conservation is fostered by smart meter-based feedback and digital user engagement. *npj Clean Water*, 4:29. Available at: https://doi.org/10.1038/s41545-021-00119-0.

County of Napa. 2023a. Napa County Well Inventory.

County of Napa. 2023b. Winery Waste Discharge Requirements (WDRs). Available at: https://www.countyofnapa.org/1918/Winery-Waste-Discharge-Requirements-WDRs.

County of Napa. 2015. Water Availability Analysis (WAA). Available at: https://www.countyofnapa.org/DocumentCenter/View/25903/Water-Availability-Analysis-Adopted-Policy---12-May-2015.

County of Napa. 2022. Napa County and GSA Response to the Governor's Emergency Executive Order N-7-22 – Draft. June.

Department of Water Resources. 2023. Model Water Efficient Landscape Ordinance. Available at: https://water.ca.gov/Programs/Water-Use-And-Efficiency/Urban-Water-Use-Efficiency/Model-Water-Efficient-Landscape-Ordinance.

Department of Water Resources and State Water Resources Control Board. 2022. Planning for Small Water Suppliers and Rural Communities (SB 552). Available at: https://water.ca.gov/Programs/Water-Use-And-Efficiency/SB-552.

Energy Star. 2012. Benchmarking and Energy Savings: Data Trends. Available at: https://www.energystar.gov/sites/default/files/buildings/tools/DataTrends_Savings_20121002.pdf.

eVineyard. 2023. How to schedule vineyard irrigation? Available at: https://www.evineyardapp.com/blog/2018/04/09/how-to-schedule-vineyard-irrigation/.

Fruition Sciences. 2023. Sap Flow Irrigation Sensors. Available at: https://fruitionsciences.com/en/sap-flow-irrigation-sensors.

G3 Enterprises. 2023. Tank Sanitation. Available at: https://www.g3enterprises.com/products/equipment/processing/tank-sanitization.

GMP Research. 2015. US Market Penetration of WaterSense Shower Heads, Lavatory Faucets And Toilets. Available at: https://www.safeplumbing.org/files/safeplumbing.org/documents/press_release_downloads/9-15-15-WaterSense-market-penetration-study.pdf.

Irrigation King. 2023. Flow Meters. Available at: https://www.irrigationking.com/flow-meters.html.

IrriWatch. 2023. IrriWatch Homepage. Available at: https://irriwatch.com/.

Jerkins, D. 2012. Cover Crops Reduce Crop Loss During Drought. US Department of Agriculture, National Institute of Food and Agriculture. Available at: https://www.usda.gov/media/blog/2012/09/20/cover-crops-reduce-crop-loss-during-drought.

JAIN by Rivulis. 2020. Performing A Distribution Uniformity Test For Irrigation And Identifying Areas For Improvement ITRC. Available at: https://www.youtube.com/watch?v=RzbRSAy_EIA

Kaser F., H. Hauenstein, T. Quinn, and E. Osann. 2013. Water Meters: Codes and Standards Enhancement (CASE) Initiative for PY 2012: Title 20 Standards Development. Analysis of Standards Proposal for Water Meters.

Kurtural S.K., D. Stewart, and D.A. Sumner. 2020. Sample Costs to Establish a Vineyard and Produce Winegrapes. Cabernet Sauvignon, North Coast Region, Napa County, Crush District 4. University of California Cooperative Extension. Available at: https://coststudyfiles.ucdavis.edu/uploads/cs_public/fe/24/fe24e27a-5c29-4cc3-a83c-63a31cd0c767/2020napawinegrape.pdf.

Lake County Winegrape Commission (LCWC). 2014. Winegrower Water Management and Irrigation Technology Survey.

Land IQ. 2023. Land IQ ET. Available at: https://www.landiq.com/land-iq-et.

Luhdorff & Scalmanini, Consulting Engineers (LSCE). 2022. Napa Valley Subbasin Groundwater Sustainability Plan. Prepared for Napa County Groundwater Sustainability Agency.

Luhdorff and Scalmanini Consulting Engineers (LSCE). 2023. Napa County Groundwater Sustainability: Annual Report – Water Year 2022. March 2023. Available at: https://www.countyofnapa.org/DocumentCenter/View/28114/2022-Napa-County-Groundwater-Monitoring-Annual-Report?bidId=.

Mammoth Water. 2023. TAPP H2O: Water Accounting for Growers. Available at: https://mammothwater.com/tapp/.

Marín, D., J. Armengol, P. Carbonell-Bejerano, J.M. Escalona, D. Gramaje, E. Hernández-Montes, and F. De Herralde. 2021. Challenges of viticulture adaptation to global change: Tackling the issue from the roots. Australian Journal of Grape and Wine Research, 27(1), 8-25.

Mirás-Avalos, J.M. and E.S. Araujo. 2021. Optimization of vineyard water management: Challenges, strategies, and perspectives. Water, 13(6), 746.

Napa County Board of Supervisors. 2023, March 28. Agenda – Final. Available at: https://napa.legistar1.com/napa/meetings/2023/3/1338_A_Board_of_Supervisors_23-03-28_Agenda.pdf.

Napa Green. 2023. Napa Green Certified Vineyard: Regenerating Carbon, Climate, and Community. Available at: https://napagreen.org/vineyard-certification/.

Napa Local Agency Formation Commission. 2020. Napa Countywide Water and Wastewater Municipal Service Review Final. Available at: https://bloximages.chicago2.vip.townnews.com/napavalleyregister.com/content/tncms/assets/v3/editorial/f/6d/f6d68165-aeab-592a-9a2e-19ac1b3a6007/615340f1a6ae4.pdf.pdf.

Napa Sanitation District (NapaSan). 2023. Annual Recycled Water Report for 2022. Available at: https://www.napasan.com/DocumentCenter/View/1222/Recycled-Water-Annual-Report-2022?bidId=.

Napa Sanitation District Board of Directors. 2022. Resolution No. 22-020: Resolution of the Board of Directors of the Napa Sanitation District Adopting a Policy Allocating Recycled Water Supply.

Napa Valley Grapegrowers. 2023. Groundwater Sustainability Plan. Available at: https://www.napagrowers.org/groundwater-sustainability-plan.html

Ochs, A.L. 2023. The Problem with Winery Wastewater & What to Do About It. *The Grapevine Magazine*.

Ohmart, C.P. and S. Matthiasson. 2000. Lodi Winegrower's Workbook: A Self-Assessment of Integrated Farming Practices, Chapter 5: Water Management. Prepared for Lodi-Woodbridge Winegrape Commission.

OpenET. 2023. OpenET: Filling the Biggest Data Gap in Water Management. Available at: https://openetdata.org/.

Pacific Institute. 2014. Metering in California. Available at: https://pacinst.org/wp-content/uploads/2014/09/pacinst-metering-in-california-1.pdf.

Peacock, B., L.E. Williams, and L.P. Christensen. 1998. Water management and irrigation scheduling. *Raisin Production Manual. ANR Pub*, *3393*, 127-33.

Pritchard, T. 2015. Irrigation Management of Winegrapes with Limited Water Supply. UC Davis Technical Paper. Available at: http://agwaterstewards.org/wp-content/uploads/2021/07/Prichard_Irrigation-Mgmt-Winegrapes.pdf.

Quackenbush, G. 2015. Jackson Family Wines shows off UV waterless tank cleaner. *North Bay Business Journal.* Available at: https://www.northbaybusinessjournal.com/article/industry-news/jackson-family-wines-shows-off-uv-waterless-tank-cleaner/.

Rachio. 2023. Weather Intelligence: How it Works. Available at: https://rachio.com/smart-watering/.

Rieger, T. 2011. Mechanized Canopy Management: Fresno State trials show yield, quality, cost benefits. Vineyard & Winery Management: Mar-Apr 2011.

Rust, B. 2015. Healthy Soils: The Promise for the Future. Soils Report: USDA Forest Service. Shasta-Trinity National Forest. Available at: https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprd3834308.pdf.

Sanden, B. 2008. Micro Irrigation Systems Tune-up for Kern County. Available for download at: https://ucanr.edu/sites/Kern22/files/98690.doc.

Sonoma Ecology Center. 2021. Benefits of Biochar. Available at: https://sonomaecologycenter.org/benefits-of-biochar/.

State Water Resources Control Board. 2021. State Water Resources Control Board Order WQ 2021-0002-DWQ: General Waste Discharge Requirements for Winery Process Water. Available at: https://www.waterboards.ca.gov/water_issues/programs/waste_discharge_requirements/docs/wqo2021-0002-dwq.pdf.

Torres N., Yu R., J. Martinez-Luscher, E. Kostaki and S.K. Kurtural. 2021. Effects of Irrigation at Different Fractions of Crop Evapotranspiration on Water Productivity and Flavonoid Composition of Cabernet Sauvignon Grapevine. *Frontiers in Plant Science, Volume 12.* Available at: https://doi.org/10.3389/fpls.2021.712622.

Town of Yountville. 2017. Revised Final Municipal Service Review & Sphere of Influence Update. Napa LAFCO. Available at: https://napa.lafco.ca.gov/files/e5564a257/Yountville_MSR-SOI_RevisedFinalReport_2017.pdf.

Tule Technologies. 2023. Sensors. Available at: https://tule.ag/sensors/. Accessed: October 11, 2023.

University of California Cooperative Extension (UCCE) Amador County. 1999. Cover Cropping in Vineyards: An Introduction to Vineyard Cover Crop Management.

University of Nebraska-Lincoln. 2023. Landscaping and Stormwater. UNL Water, Institute of Agriculture and Natural Resources. Available at: https://water.unl.edu/landscapes/landscape-design.

US Environmental Protection Agency. 2022. Two Decades of ENERGY STAR: A Retrospective Study of EPA's ENERGY STAR Office Buildings Score and Certification. Available at: https://www.energystar.gov/sites/default/files/tools/Two_Decades_Report_v7.pdf.

Williams, L.E. 2010. Interaction of rootstock and applied water amounts at various fractions of estimated evapotranspiration (ETc) on productivity of Cabernet Sauvignon. *Australian Journal of Grape and Wine Research*, 16(3), 434-444.

Young R., T. Foster, T. Mieno, A. V. Valocch, and N. Brozovic. 2020. Hydrologic-Economic Trade-offs in Groundwater Allocation Policy Design. Republished in *Water Resources Research, Volume 57, Issue 1*. Available at: https://doi.org/10.1029/2020WR027941.

Zellman P. 2016. Drip Irrigation System Evaluations: How to Measure & Use Distribution Uniformity Tests. Available at: https://www.sustainablewinegrowing.org/docs/DUArticle.pdf.

APPENDIX A

Napa County Resolution 2022-178: Human Right to Water Policy including Protection of Public Health, the Environment Consistent with Public Trust Principles, and All Beneficial Uses